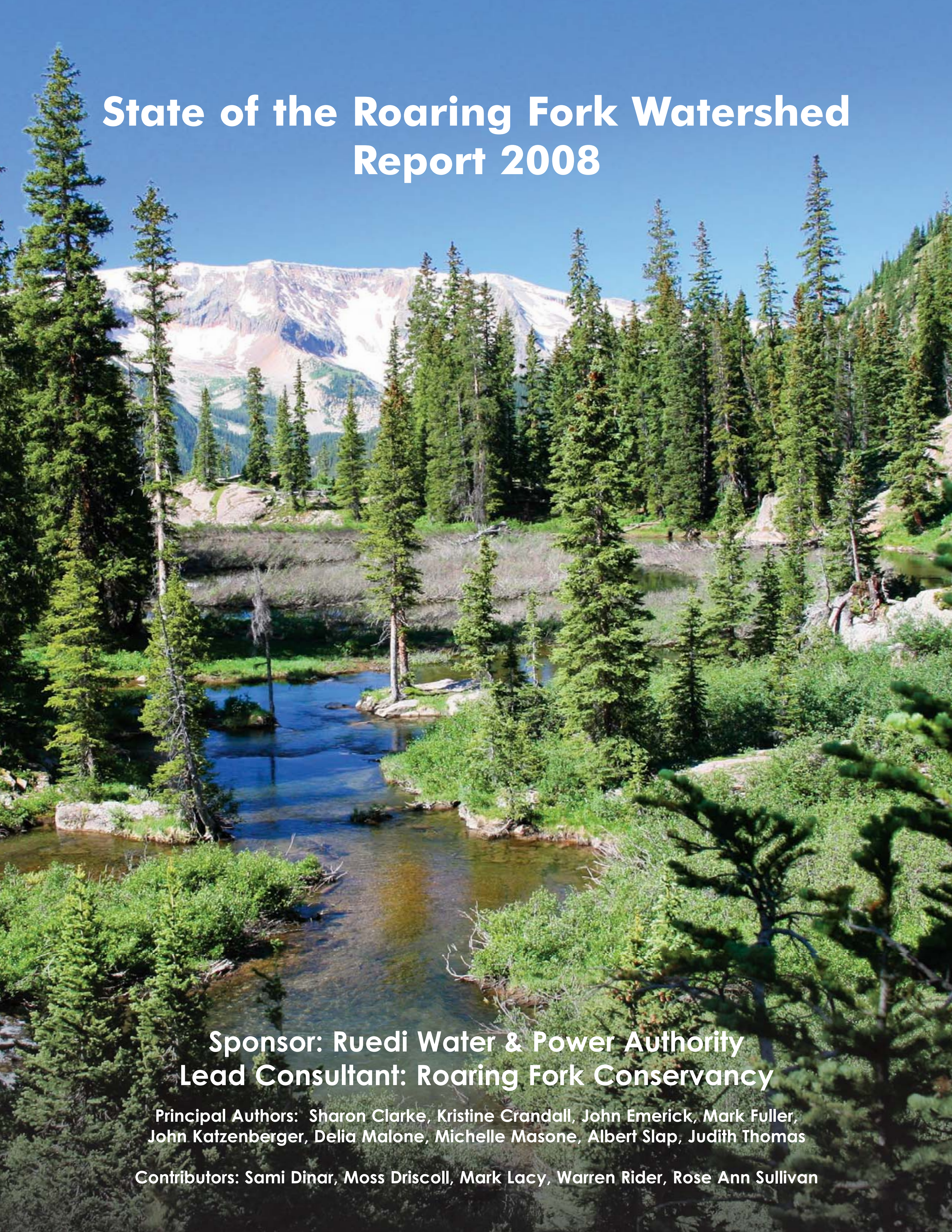
State of the Roaring Fork Watershed Report 2008



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Preface

This "State of the Watershed Report," which comprises Phase I of the Roaring Fork Watershed Plan, is the product of dedicated effort by a host of people including technical experts, government planners and administrators, conservation professionals, and water managers. Also included are residents of the Roaring Fork Watershed who care about issues of water quality and quantity and expressed that caring by participating in the public meetings, forums, and interviews that have been part of this project. A listing of the report's authors, contributors, and reviewers is provided in Appendix 1.1. We would like to thank all of these participants for their time, energy, and thoughtfulness and to invite them, along with all other readers of this report, to stay involved in the future phases of the Roaring Fork Watershed Plan.

The Watershed Plan had its origins in the Roaring Fork Watershed Collaborative, an informal group of planners, government officials, and interested citizens who began meeting several years ago to discuss issues of valley-wide interest including transportation, affordable housing, open space and trails, and, of course, water. That group eventually appointed a Water Subcommittee to focus on the need to address water concerns in the valley without regard to political or jurisdictional boundaries. When the Ruedi Water and Power Authority and the Roaring Fork Conservancy took on their respective roles of institutional overseer and principal author of the Watershed Plan, the project developed real momentum. All who will benefit from this plan owe gratitude towards the groups and individuals who had a role in this work and to the elected and appointed officials who encouraged them to think beyond their own bureaucratic boundaries.

Few question that healthy water resources, along with air, soil, wildlife, and vegetation, are critical to the maintenance of a healthy environment and to the outdoors-oriented lifestyle enjoyed by those of us who live in the Roaring Fork Watershed. Two things set water apart from these other basic resources. First, water is inherently scarce in some areas and becoming more so. Despite an occasional heavy snow year like 2007-08, ample evidence exists that the arid West is becoming more arid, and that increasing development and population will bring ever more pressure to bear on existing water resources. Second, water, at least in Colorado, is bought and sold in the open marketplace as a commodity, which means that water management is often subject to the ebbs and flows of the free market economy and also to the interests of those who own water rights. These two factors add unique challenges to any attempts at water resource planning. However, it has been clear from the beginning of this process that a Roaring Fork Watershed Plan is needed and welcomed both by those who are charged with managing local water resources and by the public at large.

The following report illustrates the current status of the Roaring Fork Watershed in terms of its water quality and quantity and its water-dependent ecosystems. It also points out areas where insufficient data prevents an accurate assessment of that status. Finally, the report identifies acute and immediate threats to local water resources from pollution, diversions, channel instability, and other sources.

The next step in the Roaring Fork Watershed Plan will be the development of a series of goals and objectives based on the findings of the State of the Watershed Report and aimed at preserving and improving local waters. Those goals and objectives then will be translated into action steps that can be taken by water managers, governments, and individual water users. This Phase II of the Plan will move forward through 2009 and will eventually be turned over to local governments and water management agencies to adopt and codify within their individual policy frameworks. As with Phase I, Phase II will feature many opportunities for public input, education, and discussion. We look forward to that process and to a healthy future for the waters of the Roaring Fork Valley.

Mark Fuller, Director, Ruedi Water and Power Authority

1. Introduction

The central purpose of this State of the Watershed Report is to summarize existing studies and information in order to present a comprehensive understanding of the Roaring Fork Watershed's natural and cultural attributes as well as issues and challenges that bear further scrutiny within Phase II of the Watershed Plan process. This Report is intended to present the most accurate and current information while recognizing that data on local water resources are subject to legal and scientific interpretation. The authors analyzed the most complete and current data, consulted with a wide range of experts, and requested comments from a large number of academic and institutional reviewers (see Appendix 1.1 and Acknowledgements). The authors also recognize that new data is constantly being generated and that it will be important to the credibility and usefulness of this Report to incorporate updated, corrected, and additional information as it becomes available. Phase II of the Watershed Plan will include opportunities for making corrections and additions to the State of the Watershed Report. Readers who find factual inaccuracies are urged to contact the authors with any comments or suggestions.

The report is organized to proceed from broader topical discussions at the watershed scale to more site-specific explorations of conditions by sub-regions within the watershed. The remainder of this chapter provides an overview of the environmental and socio-economic settings of the Roaring Fork Watershed. Chapter 2 presents the regional water management policies and activities that influence how the watershed's resources have been developed up to the present, and ongoing planning initiatives and potential issues that could impact the future. In Chapter 3, critical topical components of the watershed are described in detail, ranging from water quality and quantity to riparian, wetland, and instream habitats. Summaries by sub-watershed of the studies that have been done to evaluate environmental conditions comprise Chapter 4. The specific sub-watersheds that are covered in this more refined analysis include four separate segments of the Roaring Fork River mainstem corridor, plus the Maroon/Castle Creek, Snowmass/Capitol Creek, Fryingpan River, Crystal River, and Cattle Creek sub-watersheds. The next steps for Phase II are presented in Chapter 5. With the aim of affording the readers access to that level of information in which they are most interested, this main report is accompanied by a complement of appendices and references providing in-depth information on a particular topic and/or the original studies.

1.1 Environmental Setting

The context of this report is grounded in the philosophy of taking a "watershed" perspective. A watershed is defined as the landscape drained by a stream and its tributaries. Looking at the Roaring Fork River, the Roaring Fork Watershed extends from the river's headwaters near Independence Pass to its confluence with the Colorado River at Glenwood Springs, 70 miles downstream. The river flows through Aspen and is joined further downstream by two major tributaries: the Fryingpan River in Basalt and the Crystal River just downstream of Carbondale. The Roaring Fork Watershed (1,453 square miles) is located in west-central Colorado in Pitkin, Eagle, Garfield, and a small portion of Gunnison counties (see Figure 1.1). It comprises an area of high mountainous terrain and deep intervening valleys, with altitudes ranging from 5,717 to 14,235 feet. The Roaring Fork River is the second largest tributary of the Colorado River in the state, yielding an average of almost one million acre-feet per year.

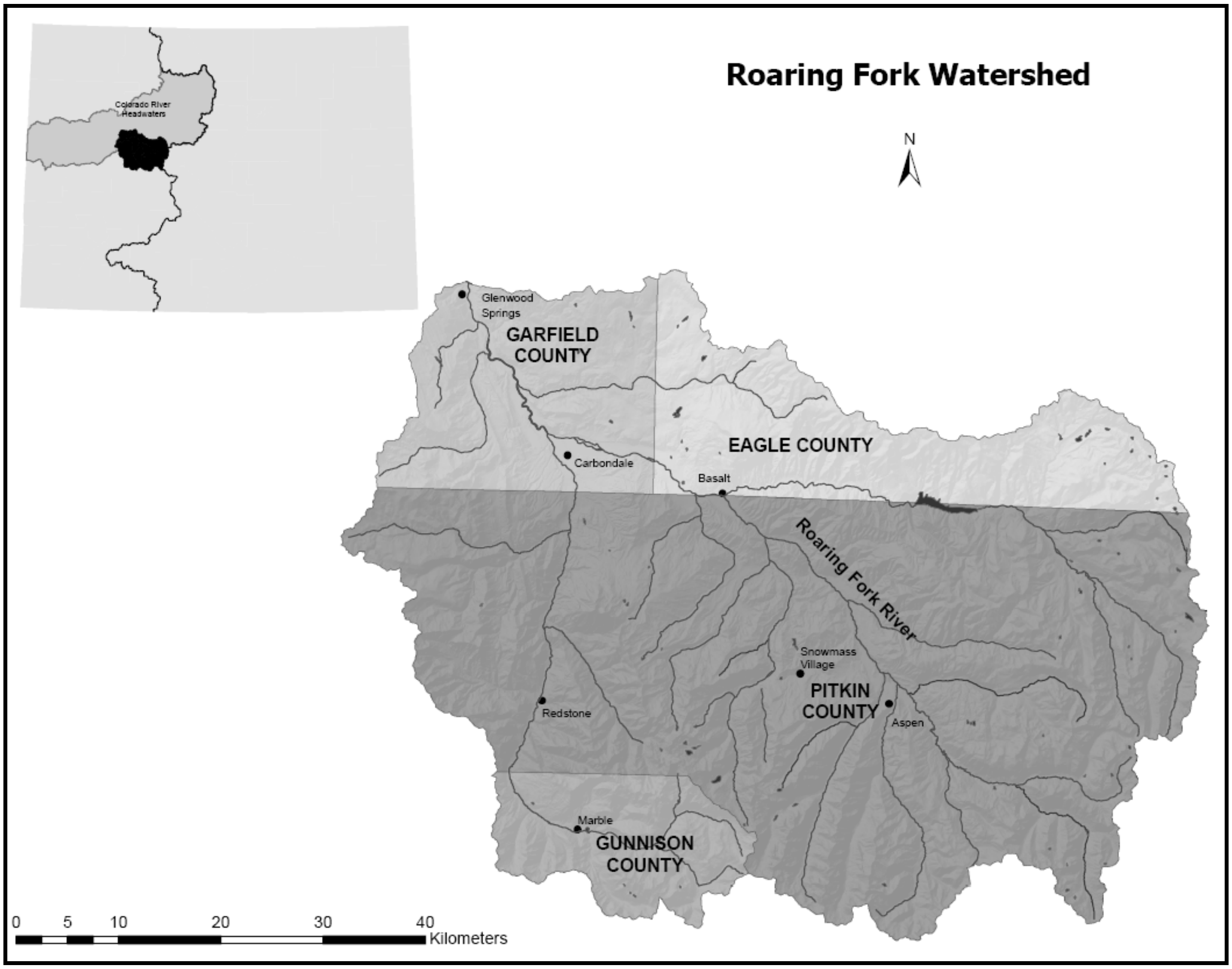


Figure 1.1. Overview map of the Roaring Fork Watershed.

Across the watershed, two controlling factors – geology and climate – determine the characteristics of three basic ecosystem components: soil, vegetation, and water. Because stream quality and stream flow are determined by the condition of these three components, land uses that alter them will affect watershed functions and health. The water cycle perhaps best encapsulates the complex interdependence of elements and functions that are integral to the watershed, including precipitation, snowpack and runoff, temperature, geology, rivers and lakes, vegetation, and evaporation. A schematic of the water cycle is shown in Figure 1.2.

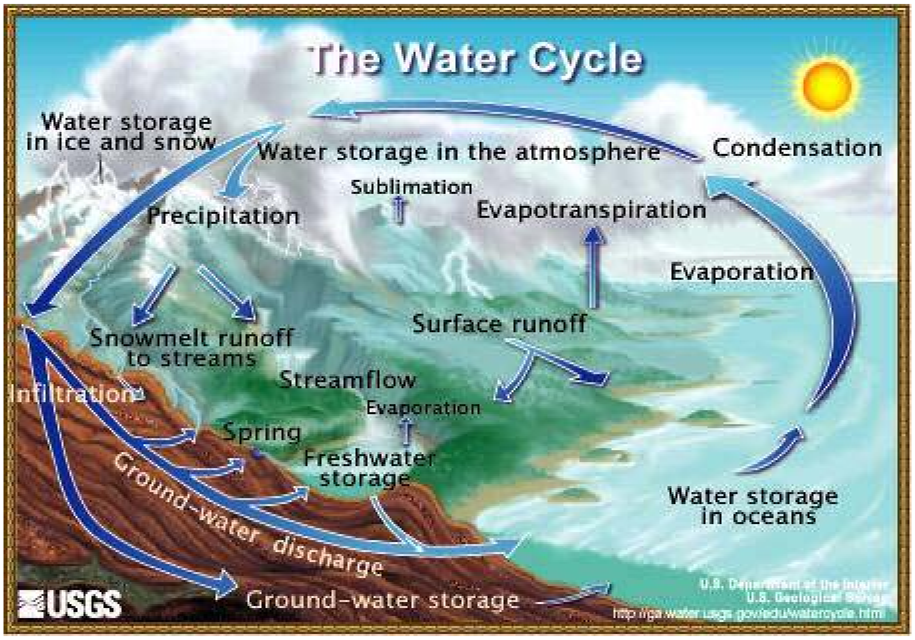


Figure 1.2. Diagram of the water cycle.

1.1.1Geology

Figure 1.3 shows a surface geology map of the watershed including a key for each geologic unit. Dr. John Emerick compiled this map, focusing on characteristics that could influence water quantity and quality. He relied on the following sources: Bryant, 1979; Freeman, 1971; Green, 1992; Tweto, 1979; and Olander et al., 1974. Various U.S. Geological Survey maps of the region were also consulted to get a better understanding of the regional geology. These sources used for the compilation of the geology map are listed in a separate geology sub-section within the references. Because slope strongly determines the interplay of geology and water resources, a map depicting steep slopes (those greater than 30 and 45 percent) is shown in Figure 1.4.

Following are the detailed geologic unit descriptions and color codes that correspond with Figure 1.3.

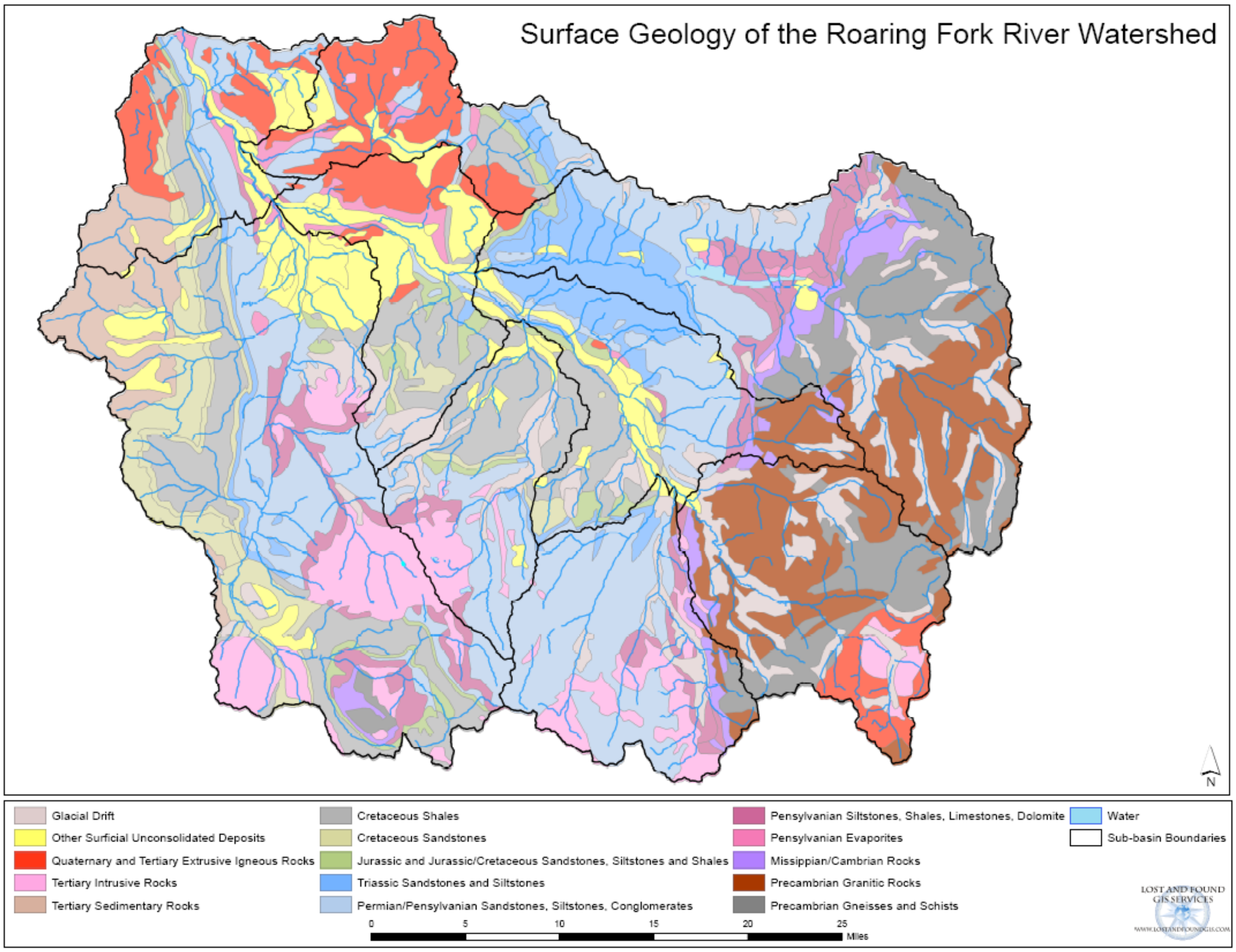


Figure 1.3. Surface geology of the Roaring Fork Watershed.

Glacial Drift

Moraines of Pleistocene glaciers up to 2 million years old. Moderately stable to relatively unstable in some locations; recent landslides in the Snowmass Creek Valley have occurred in these deposits. May yield construction aggregate in some areas. Represents approximately 8 percent of watershed's total land surface area.

Other Surficial Unconsolidated Deposits

Modern to ancient gravels and alluviums, landslide deposits, slumps, talus, and outwash terraces. Stable to relatively unstable in some areas. Thicker deposits provide important alluvial aquifers for many rural areas. Terrace deposits are important sources of construction aggregate in the Roaring Fork Valley. Approximately 8 percent of watershed's land surface area.

Quaternary and Tertiary Extrusive Igneous Rocks

Primarily basalt lava flows as well as tuff (volcanic ash). Produce geologic hazards in the northern part of the watershed where escarpments of these rocks are underlain by easily erodable evaporites, creating sporadic rockfall. Some deposits have been used for landscaping aggregate. Approximately 7 percent of watershed's land surface area.

Tertiary Intrusive Rocks

Formed during the last 65-70 million years when molten magma forced up into older rocks near the earth's surface, but failed to break the surface and thus never became volcanic. Mount Sopris is formed from one of the more prominent intrusive stocks in the watershed. These rocks are mostly dense, hard, and stable, and commonly associated with rugged terrain. Fracture and joint patterns weather and may produce hazardous rockfall. A possible source for quarry aggregate and riprap. Approximately 7 percent of land surface area in the watershed.

Tertiary Sedimentary Rocks

Primarily the Wasatch and Ohio Creek formations. Finer-grained parts of the Wasatch Formation tend to be soft and susceptible to erosion. Clay content of certain beds can cause building foundation problems and road bed failures. The conglomerates of the Ohio Creek Formation are more stable and locally may be an aquifer. Approximately 3 percent of watershed's land surface.

Cretaceous Shales

Primarily the Mancos Formation, consisting of a 4,000 to 6,000 foot-thick layer of shale. Predominately a dark olive gray. Very susceptible to erosion, leading to mudflows, landslides, and other slope instability problems. Swelling clays produce building foundation problems, and the impermeable nature of the shale may account for seasonal high water tables and flooding of various types. Water from the formation is notably brackish, malodorous, and often corrosive. Approximately 10 percent of watershed's land surface.

Cretaceous Sandstones

Principally the Mesaverde Group and Frontier and Dakota sandstones. Mostly stable, except locally where escarpments may produce rockfall. The Mesaverde Group also contains shale and carbonaceous shale, with economically significant coal beds found in the lower third of the formation, such as in the Coal Creek Valley near Redstone. Approximately 5 percent of watershed's surface area.

Jurassic and Jurassic/Cretaceous Sandstones, Siltstones and Shales

Mostly the Morrison Formation and Entrada Sandstone, with Ralston Creek, Burro Canyon, and Wanakah formations. Sandstone units are relatively stable, but Morrison shales can be unstable and prone to slide, and contain swelling clays that create engineering problems. The sandstone units may have aquifer potential in some areas. Approximately 2 percent of the watershed.

Triassic Sandstones and Siltstones

Mainly the Chinle and State Bridge formations. Siltstone and claystone units of the Chinle Formation susceptible to erosion, and local seasonal high water tables should be anticipated. The State Bridge Formation is relatively stable, though clay or carbonate cement might also be impermeable and cause drainage problems. Approximately 5 percent of the watershed.

Permian/Pennsylvanian Sandstones, Siltstones, and Conglomerates

Primarily the Maroon Formation with some Weber Sandstone. The Maroon Formation is found throughout the watershed, ranging in thickness from 2,500 to 12,000 feet. It makes up the Maroon peaks as well as the scenic red cliffs near Redstone. Generally hard and stable, though low permeability creates local water table problems. Frost heave in rock fractures occasionally produces large, isolated, rockfall blocks. Approximately 19 percent of watershed's land surface.

Pennsylvanian Siltstones, Shales, Limestones, Dolomite
Includes Minturn and Belden formations, Weber Sandstone, and non-evaporitic components of Eagle Valley Formation. Most of these rocks are stable with few adverse engineering characteristics. Much of the metal mining in Aspen area focused on the contact between the Weber Sandstone and underlying Leadville Formation. Approximately 5 percent of the watershed.

Pennsylvanian Evaporites
Mostly found in the evaporitic parts of the Eagle Valley Formation. Predominantly interbedded gypsum and dark grey shale beds of variable thickness, but believed to be around 3,000 feet thick at Cattle Creek. Has weak physical characteristics making it prone to unstable slopes; movement of surface or groundwater can produce serious subsidence problems; and the formation's minerals can contribute to chemical degradation or pollution of surface and groundwater. This formation presents serious problems and hazards to development. Approximately 1 percent of the land surface in the watershed.

Mississippian/Cambrian rocks
Primarily the Leadville Limestone, Chaffee Formation, Manitou Dolomite, Peerless Formation, and Sawatch Quartzite. Generally hard, stable rocks, within which fractures may produce local rockfall hazards. At Marble, strongly metamorphosed Leadville Limestone has been quarried for its white marble. These rocks are potential source for construction aggregate. Approximately 2 percent of the watershed.

Precambrian Granitic Rocks
Ancient granites up to 1.7 billion years old, forming the mountains in the southeastern part of watershed along with Precambrian gneisses and schists. Hard and stable rocks with the exception of areas that are intensely sheared or faulted. Approximately 9 percent of the watershed.

Precambrian Gneisses and Schists
Hard and stable ancient metamorphic rocks that, with Precambrian granitic rocks, make up Precambrian core of the mountains in the southeastern part of the watershed. Approximately 7 percent of the watershed.

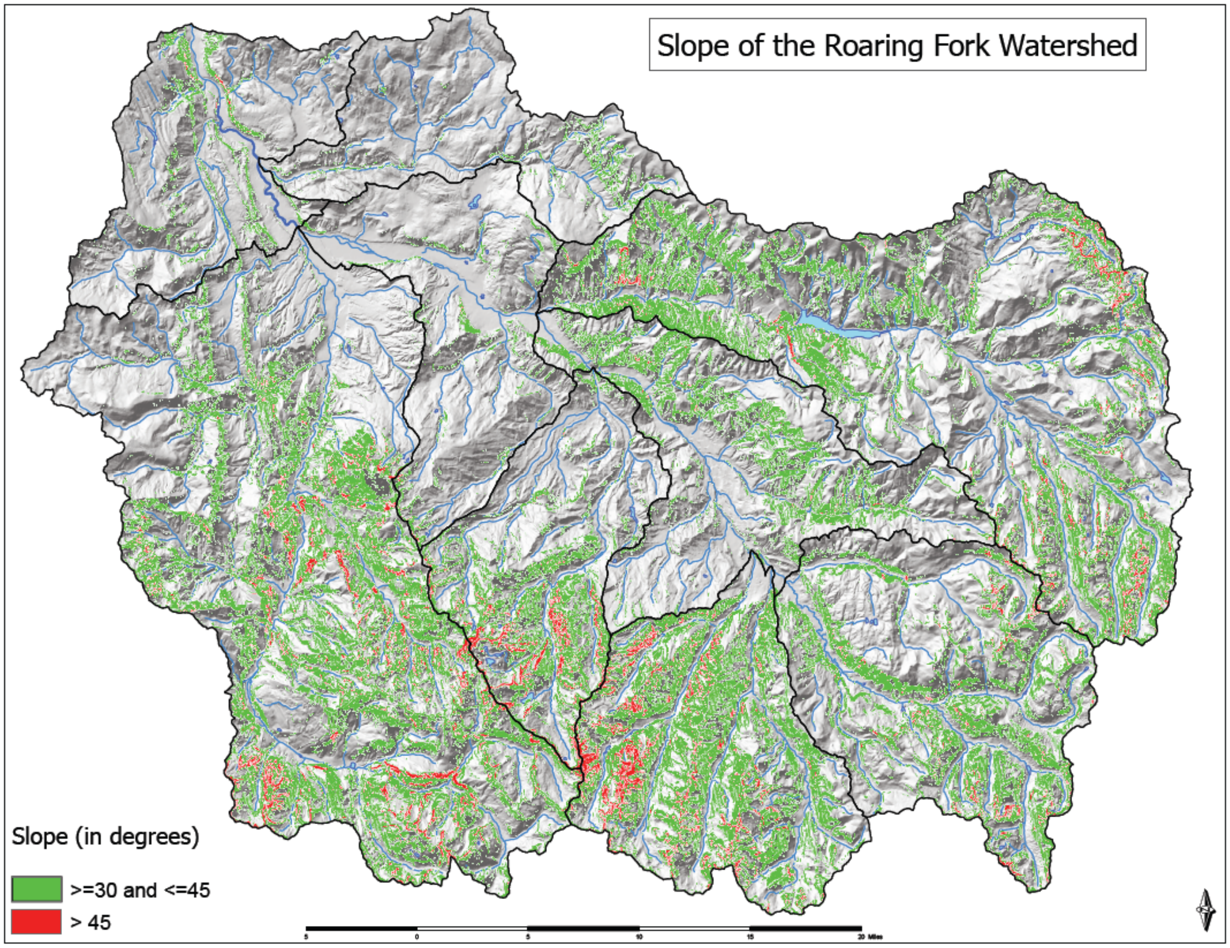


Figure 1.4. Steep slopes in the Roaring Fork Watershed.

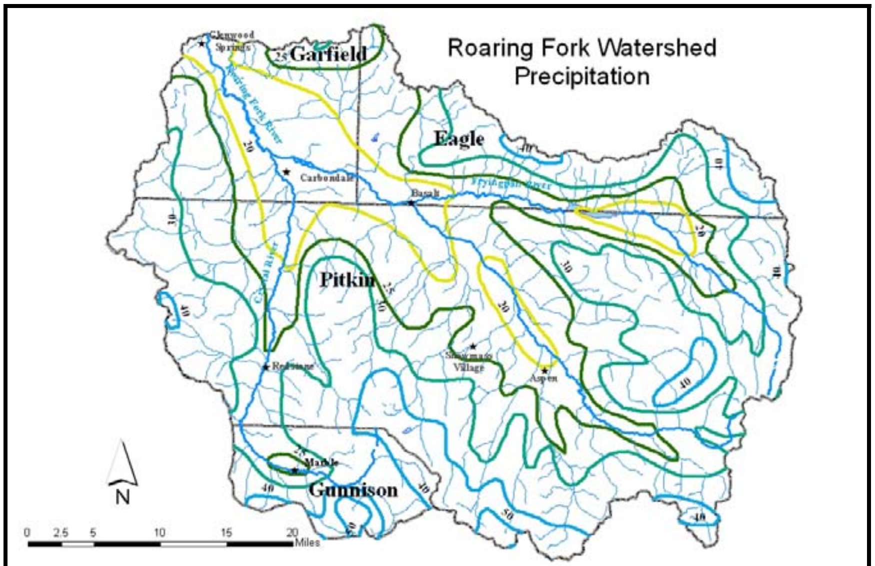
The oldest geologic rocks in the watershed, Precambrian gneisses, schists, and granitic rock, are exposed in the present-day Sawatch Range and in Glenwood Canyon. These rocks are hard and stable. The Pennsylvanian evaporites, which occur in a small percentage of the watershed, formed from the evaporation of shallow seawater. They are found in patches north of Ruedi Reservoir, on lower Thompson Creek, and in several strips along the lower Roaring Fork River and in the Cattle Creek Sub-watershed. The formation is prone to unstable slopes and subsidence problems, and the minerals in this formation can contribute to chemical degradation or pollution of surface water and groundwater.

Erosion of the Ancestral Rocky Mountains created the most extensive and distinctive formation in the watershed, the Maroon Formation. Although relatively stable, the low permeability of this formation can create local high water table problems, frost heaves, and large rockfalls. Both the State Bridge and Chinle formations are floodplain/tidal flat deposits. The more fine-grained Chinle Formation is prone to erosion and seasonal localized flooding. Both the Entrada Sandstone and Morrison Formation were deposited during a period of uplift and volcanism. The Mesaverde Group and the Frontier and Dakota sandstones were deposited in a broad marine trough (depression) as delta and beach features. The coal beds found in the Crystal River Valley are an example of the Mesaverde Group sandstones that were deposited in a warm and humid environment. Mancos Shale was deposited during this same time period, and represents the second largest unit in the watershed. Found in the Brush, Snowmass, and Sopris Creeks drainages, and the Crystal River Valley, Mancos Shale is very susceptible to erosion and its impermeability may account for seasonal high water tables and flooding. The Wasatch and Ohio Creek formations are found in the headwaters of Fourmile and Thompson creeks. The poorly cemented sandstone and shale of the Wasatch Formation makes it soft and susceptible to erosion.

Molten magma was intruded into these various rock formations to form such recognizable features as Mount Sopris and Capitol Peak. Large movement of the earth's crust shifted many of the watershed's rock formations, creating their present-day appearances (such as sedimentary rocks appearing at an angle). Glaciation sculpted the upper portions of the watershed and left behind distinctive landforms and deposits. Wind and water erosion, as well as heating and cooling, have acted upon the watershed's unique combinations of rock type, slope, and orientation – adding the final touches on the landscape you see today.

1.1.2 Climate

Wide variations in temperature and precipitation are found throughout the watershed. Average annual maximum and minimum temperatures, total precipitation, and snowfall recorded for four stations are shown in Table 1.1. Appendix 1.2 contains average monthly data for the climate stations in the watershed. More information on sources of climate data can be found in Section 3.1. Most of the developed area within the watershed (including municipalities and private lands) receives less than 25 inches of precipitation a year (Figure 1.5). Colder, north-facing slopes receive more snow and retain that snow well into the summer. Warmer south-facing slopes receive less snow and that melts off more quickly, leaving snow-free habitat even in winter. The watershed's north-facing Elk Mountains receive 40 to 50 inches of precipitation annually.



Source: CDSS data derived from Colorado State University, Dept. of Atmospheric Science, 1984, Climatological Report 84-4.
Values represent average annual precipitation in inches from 1951-1980.

Figure 1.5. Precipitation map of the Roaring Fork Watershed.

Table 1.1. Comparison of average annual climate information for the Roaring Fork Watershed. Data source: Western Regional Climate Center http://www.wrcc.dri.edu/ .

NAME	ID	BEGIN DATE	END DATE*	ELEV. (ft)	AVG. MAX. TEMP. (F)	AVG. MIN. TEMP. (F)	AVG. TOTAL PRECIP. (in.)	AVG. TOTAL SNOWFALL (in.)
Meredith	5507	1963	2007	7825	55.5	21.4	16.1	90.2
Basalt	514	1965	1971	6624	61.1	26.9	15.1	66.3
Aspen 1 SW	372	1980	2007	8163	55.5	27.8	24.3	172.6
Redstone 4W	6970	1980	1994	8065	53.3	26.0	27.7	169.4
Glenwood Spgs. #2	3359	1900	2007	5880	62.9	31.3	16.6	59.9

* Ending date of reported data

Climate data have been collected at the Aspen climate station since the 1890's, establishing normals for temperature and precipitation. In this same time period there has been a 30 percent increase in greenhouse gases in the atmosphere primarily due to the burning of fossil fuels (Neftel et al., 1994 and Solomon et al., 2007). While this change is a global phenomenon, it has a direct effect on the local and regional climate. Studies discussed in greater detail in Chapter 3.5 and Section 4.1 show that the future climate of the Roaring Fork Watershed is very likely to be warmer. There is greater uncertainty about annual precipitation change. It is likely, however, that more of the annual precipitation will fall as rain rather than snow, influencing the timing and amount of spring runoff. Global warming is projected to significantly alter the Upper Colorado River Basin (McCabe and Wolock, 2007) and will impact the Roaring Fork Watershed's ecosystems, agriculture, and the socioeconomic patterns related to outdoor recreation. As regional demand for water increases, it is probable that global warming will add additional stress to water availability in the Southern Rockies and the entire Southwest.

1.1.3 Biological Communities

Flatter benches and valley floor areas in the watershed are characterized by vegetation adapted to arid conditions, including dry grassland and sagebrush meadows. South-facing lower elevation hillsides are characterized by pinyon pine and juniper. North-facing slopes are dominated by moisture-loving plant communities such as spruce-fir forests and slope wetlands; south-facing slopes have more drought-tolerant plant communities such as lodgepole pine and oak shrublands. Aspen groves are found on each slope wherever appropriate soil moisture occurs. The higher elevations are mostly tundra with some low-lying shrubs. See Figure 1.6 for a map of the watershed's land cover.

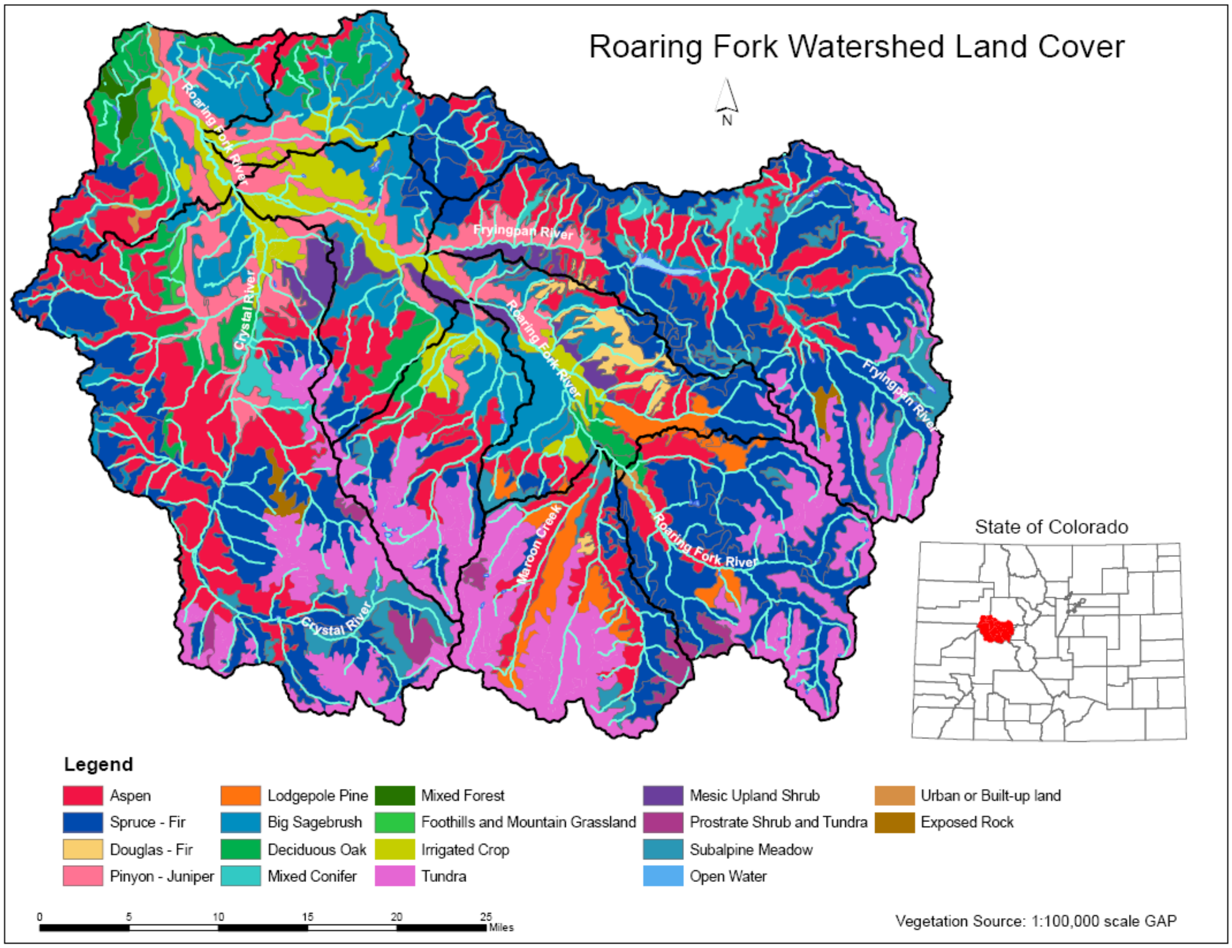


Figure 1.6. Land cover types in the Roaring Fork Watershed.

Along the watershed's rivers and streams, a favorable combination of soil, vegetation, and water have created extensive, relatively intact riparian forests, shrublands, and wetlands. The Colorado Natural Heritage Program (CNHP) and local biologists have identified numerous occurrences of rare plants and animals, and combinations of plants that occur in rare plant communities. Appendix 1.3 lists the riparian-related species of concern and their occurrence by sub-watershed based on listings and designations at the federal and state levels, and those made by CNHP and Audubon.

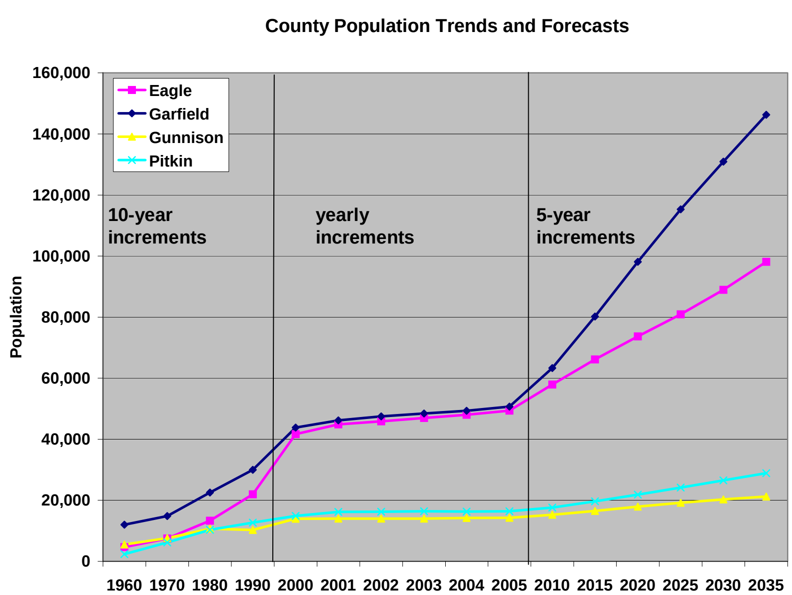
1.2 Socio-economic Setting

In addition to the vital life force that river systems provide for wildlife, they also support and sustain humans in many different ways. In the Roaring Fork Watershed, streams and rivers provide humans with water for drinking and other domestic uses, and for agricultural and industrial purposes. The aesthetic beauty of water attracts tourists as well as new residents. Water from the watershed's streams and rivers also is diverted for Front Range uses. Lakes and rivers provide recreational opportunities such as fishing, rafting, and kayaking, benefiting local economies. The following section looks at the watershed's socio-economic setting in relation to its environmental setting.

1.2.1 Population Growth

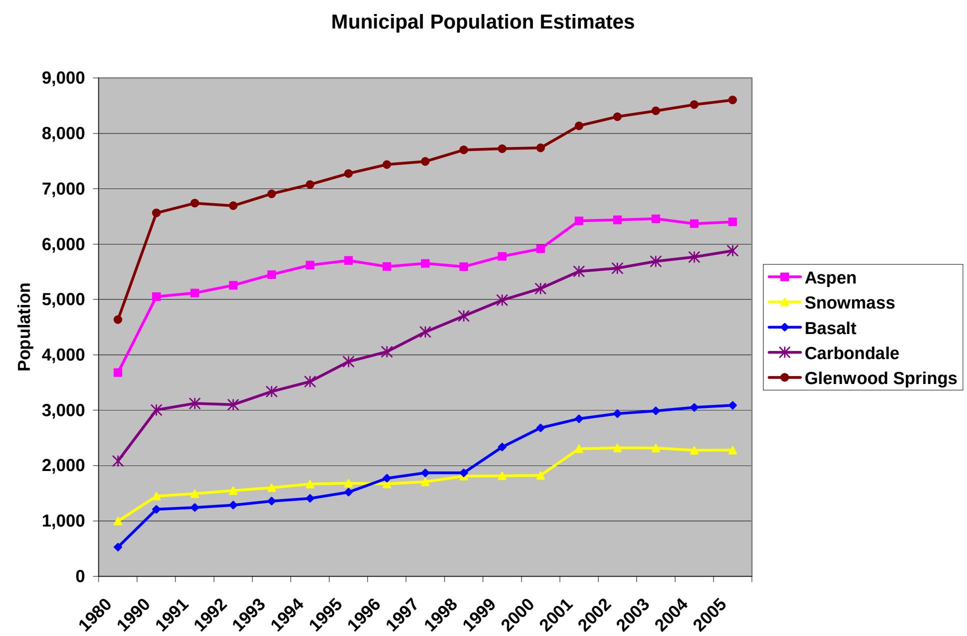
The Roaring Fork Watershed is witnessing a significant increase in population. Such a trend influences the watershed's environmental resources through increases in impervious surfaces, decreases in native vegetation as it is replaced by developed landscapes, a decline in open space, a shift in water use patterns, and impacts on water quality. Development tends to be concentrated along stream corridors and on former ranchlands due to easier access, flatter topography, milder climate, and private ownership patterns. The uplands also face increased development pressure as steeper slopes are converted to urban uses, a practice which can increase erosion and stream sedimentation. The conversion from agricultural to municipal uses alters the timing of stream flows and can have implications for water quality. Population growth outside of the watershed, with its attendant water demand, also can affect stream flows, especially through increased transmountain diversions and downstream demands.

The population in the Roaring Fork Valley is expected to increase by 24 percent between 2000 and 2010 (O'Keefe and Hoffman, 2005). The highest rates of increase are occurring and expected to continue in Garfield and Eagle counties. See Figure 1.7 for a view of county population trends and forecasts. Two of the watershed's municipalities, Snowmass Village and Aspen, along with a portion of Basalt (the other part of Basalt is in Eagle County), are in Pitkin County. Although only a small percentage of Garfield County is located within the watershed, it holds almost 40 percent of the watershed's urban population within Glenwood Springs and Carbondale. Gunnison County contains the small incorporated town of Marble (2005 population: 103). Specific population numbers by municipality for the past 25 years are provided in Figure 1.8. The county seats for Pitkin County (Aspen) and Garfield County (Glenwood Springs) are located within the watershed.



Source: Colorado Department of Local Affairs
Note differences in year spacing

Figure 1.7. County population trends and future estimates.



Source: Colorado Department of Local Affairs
Note break between 1980 and 1990

Figure 1.8. Population estimates for the watershed's various municipalities.

All five municipalities have seen steady population growth since 1980, with the greatest increase taking place in Carbondale during the 1990s (CDOLA, No date a). Indicators of growth include increasing traffic congestion, the need to expand schools, and decreases in open space. A major part of the upper watershed's residential growth has been driven by second homeowners. A study done by the Northwest Colorado Council of Governments reported that 51 percent and 46 percent of homes belonged to second homeowners in 2006 for Pitkin and Eagle counties, respectively (for Eagle County this percentage includes resort areas not in the Roaring Fork Watershed, such as Vail, Beaver Creek, Avon, and Eagle). Second homeowner data from the 2000 U.S. Census for municipalities in the watershed indicated that in the year 2000 Aspen had 26 percent second homeowners, Snowmass Village had 47 percent, Basalt had 7 percent, and El Jebel, Carbondale and Glenwood Springs had less than 2 percent (Figure 1.9).

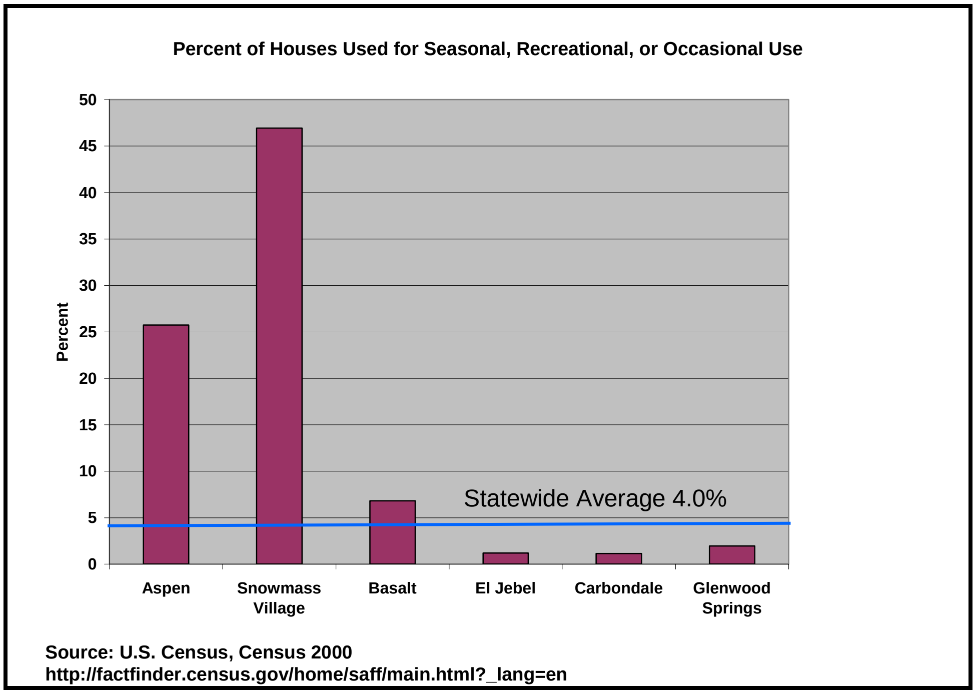


Figure 1.9. Percentage of houses classified as owned by second homeowners.

1.2.2 Recreation and Tourism

For the Colorado River Basin, the 2004 report produced by the Colorado Statewide Water Supply Initiative (CDM, 2004) recognized the issues of rapid growth and lack of available water supplies in headwater areas (e.g., Roaring Fork Watershed), stating that "recreation and the environment are key drivers for industries and economic health as well as important components to quality of life" in Colorado. Resort areas such as Aspen have become "growth poles" due primarily to the attraction of the region's environmental amenities (Travis et al., 2002).

Recreation is important to both the watershed's residents and visitors. Results from a 2007 survey done by Venturoni Surveys and Research, Inc. indicate that 96 percent of Pitkin County's registered voters live in Pitkin County for its recreational opportunities and more than 80 percent of second homeowners in Pitkin and Eagle counties listed recreational amenities as the main reason they purchased a home in those counties (NWCCOG, 2006). Second homeowners are attracted to both winter and summer recreational activities. On average, second homeowners spend slightly more than two months of the year at their properties. Pitkin County second homeowners spend the highest number of days in the summer (22 days in July and August) of all the resort communities in Summit, Grand, Eagle, and Pitkin counties and the City of Steamboat Springs (NWCCOG, 2006).

The quality and quantity of the watershed's water resources and their associated habitat is important for many recreational activities. The 2007 Pitkin County Community Survey (Venturoni Surveys and Research, Inc., 2007) revealed that 30 percent of total residents (full-time residents and second homeowners) participated in rafting/kayaking/boating activities and 33 percent in fishing activities. Table 1.2 lists participation rates across a comprehensive list of recreation activities.

Table 1.2. Results about outdoor recreation from Pitkin County Community Survey.

2007 Pitkin County Community Survey
Recreation

	Assessor				
	Full-time Resident	2nd Homeowner	ALL Homeowners	Business	Voter
	n=196	n=174	n=382	n=157	n=331
Hiking	87%	74%	81%	87%	86%
Alpine Skiing	86%	87%	86%	80%	80%
Walking/Jogging	72%	74%	73%	65%	71%
Bicycling	70%	55%	63%	73%	68%
Camping/Backpacking	55%	24%	41%	56%	57%
Nordic Skiing	52%	26%	39%	45%	52%
Wildlife viewing	54%	45%	49%	43%	47%
Mountain Biking	42%	24%	34%	52%	43%
Snow shoeing	33%	28%	31%	32%	39%
Rafting/Kayaking/Boating	29%	32%	30%	31%	33%
Picnic Areas	32%	29%	30%	35%	31%
Fishing	26%	40%	33%	28%	30%
Golf	30%	42%	35%	34%	25%
Climbing/Mountaineering	18%	18%	18%	22%	23%
Motorized sightseeing/jeeping	18%	20%	18%	18%	20%
Playgrounds	26%	18%	22%	19%	20%
Snowboarding	13%	17%	15%	22%	20%
Tennis	23%	25%	24%	23%	17%
Ice Skating	19%	12%	15%	16%	15%
Four-wheeling	9%	11%	10%	11%	12%
Hunting	13%	3%	9%	13%	12%
Other:	12%	9%	11%	11%	11%
In-line skating	8%	3%	5%	9%	7%
Dirt biking - motorized	7%	2%	4%	9%	6%
Skate boarding	5%	2%	4%	3%	2%

Numbers reflect frequency responses

Yellow	80-100%
Pink	50-79%
Light blue	30-49%

Looking at the economics of water-based recreation, a report for the Colorado Division of Wildlife (CDOW) (Pickton and Sikorowski, 2004) estimated the direct expenditures and total impact of fishing in 2002 by county. These numbers were conservatively adjusted for the three counties that extend past the watershed boundary (Jacob Bornstein, Executive Director, Colorado Watershed Network, personal communication, March 29, 2005) (Table 1.3). In 2002 fishing was estimated to bring in more than $17 million annually to the Roaring Fork Watershed. The 2002 economic study of the lower Fryingpan Valley (Crandall, 2002) estimated approximately 35,000 annual visitor days for the 7.5 miles of the lower Fryingpan River that is publicly accessible (Crandall, 2002).

Table 1.3. Estimated economic impacts of fishing in the Roaring Fork Watershed (in thousands of dollars).

COUNTY	DIRECT-IMPACT	TOTAL-IMPACT [1]
Pitkin	$6,140	$11,140
Eagle	$2,608 [2]	$3,721 [2]
Garfield	$1,589	$2,827
Gunnison	$0	$0
TOTAL	$10,337	$17,688

[1] Includes multiplier effect.

[2] Fryingpan Valley Economic Study (Crandall, 2002). This total is exclusive to the Fryingpan River and thus ignores the impact of fishing on the Roaring Fork River in Eagle County (from Basalt past El Jebel).

Some of the watershed's allure for fishing is the availability of "Gold Medal" water, a designation used by the CDOW to signify waters providing the greatest potential for trophy trout and angling success (at least 60 lbs/acre of trout and more than 12 trout greater than 14 inches per acre) (Kendall Ross, CDOW Aquatic Biologist, personal communication, June 9, 2008). The Roaring Fork Watershed has the longest contiguous section of Gold Medal water in the state, extending along 14 miles of the Fryingpan River and 28 miles of the Roaring Fork. Only 168 miles (approximately 2 percent) of Colorado's 9,000 miles of trout streams carry the Gold Medal signature.

Boating activities, particularly rafting and kayaking, generate another source of economic impact (Figure 1.10). The Roaring Fork River and its major tributaries are used by local commercial raft companies as well as by private boaters (Figure 1.11). The Colorado River Outfitters Association (CROA, 2007) reported the number of commercial river user days from 1988-2007 and the economic impact generated from commercial river use. Economic impact is derived by multiplying direct expenditures by an economic multiplier that estimates the number of times a dollar is spent in the local area before being spent outside of the area. Not surprisingly, the number of user days is partially related to river flows, as can be seen in Figure 1.12. In 2002, a drought year, no commercial user days were reported. The maximum usage was reported for two high water years: in 1997 for the upper Roaring Fork River (5,074 user days), and in 1995 for the lower Roaring Fork River (5,000 user days). The report estimated that $272.71 of economic impact was derived from each user in 2007. The average number of users from 1988 through 2007 was 4,087, ranging from 0 in 2002 to 9,000 in 1995. Using 2007 daily user economic impact numbers, this translates to an annual average economic impact of $1,114,566 with a range from $0 to $2,454,390.

Figure 1.10. Rafters enjoying the Roaring Fork River.

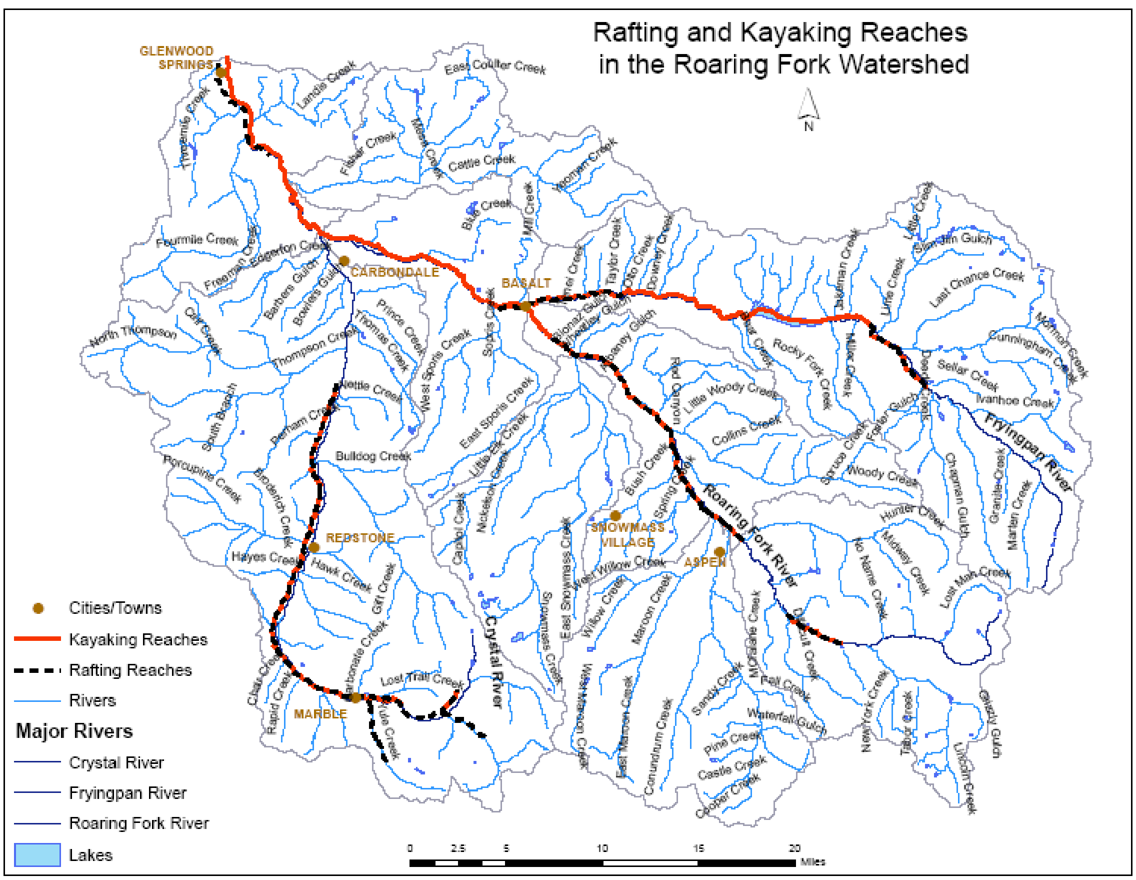


Figure 1.11. Rafting and kayaking reaches in the watershed (Data source: CDM, 2007a).

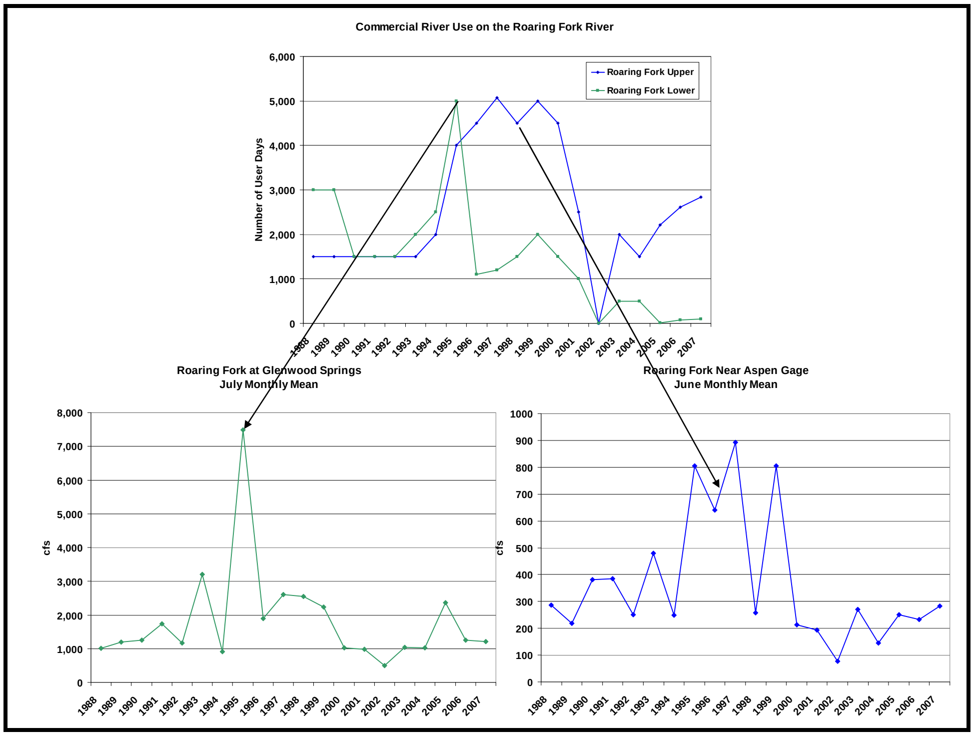


Figure 1.12. Comparison of commercial river use and June and July mean stream flows at the Roaring Fork at Glenwood Springs and Roaring Fork near Aspen gages. River Use Data Source: Colorado River Outfitters Association. 2007.

Although boating at Ruedi Reservoir contributes significantly less than angling and rafting to the local economy, generating an estimated annual total economic impact of just over $200,000 in 2001 (Crandall, 2002), the reservoir is a popular regional destination for motorboaters, sailors, and campers. It was estimated that Ruedi had more than 15,000 visitor days per year during the 2001 summer season (Crandall, 2002). The reservoir holds up to 102,360 acre-feet and the Ruedi Marina is operable when the reservoir is half full (52,000 acre-feet). Boat ramps for the Dearhamer and Aspen Yacht Club need the reservoir at least 83 percent full (85,000 acre feet) to operate.

In addition to supporting these direct water-based recreation activities, water indirectly contributes to hiking and backpacking, camping, golf, and the ski industry. Table 1.5, found later in this chapter, contains additional information regarding water use by the local ski industry.

1.2.3 Ecosystem Services

Taking a comprehensive view, watershed resources provide vital, difficult-to-quantify services that contribute to the local and regional economy. Known as “ecosystem services,” these include purification of water, mitigation of droughts and floods, cycling and movement of nutrients, detoxification and decomposition of waste, and maintenance of biodiversity (Ehrlich and Ehrlich, 1981). Healthy river ecosystems also support recreation activities and their economic benefits, as described above.

Although the Roaring Fork Watershed has not been studied from an ecosystem services perspective, studies have been done on other river systems in Colorado, including a 45-mile stretch of the South Platte River. Studies of the South Platte show that habitat degradation and depleted flows and groundwater have led to a loss in the economically and environmentally important functions performed by natural river systems. Results indicate a total economic cost between $19 and $70 million for restoration of the South Platte's ecosystems services of wastewater dilution, natural purification of water, erosion control, fish and wildlife habitat, and recreation (Loomis et al., 2000). One aim of the Roaring Fork Watershed Plan is to acknowledge, track, and, where needed, consider restoration of these valuable services. Chapter 4's sub-watershed summaries of key findings regarding stream flows, water quality, and riparian and instream areas all relate to the level of ecosystem services that can be provided.

1.3 Land Use

1.3.1 Ownership and Land Use

The activities and trends described in Section 1.2 provide an indication of how humans use the land and water resources within the watershed. It is important to understand these land uses, given their direct influence on the environmental variables and functions noted in Section 1.1. The following is a broad overview of land use patterns (see Chapter 4 for a detailed discussion of localized land uses by sub-watershed). For physical and spatial orientation, Figure 1.13 shows a combination of land uses and covers for the watershed. Figure 1.14 shows general land ownership in the watershed.

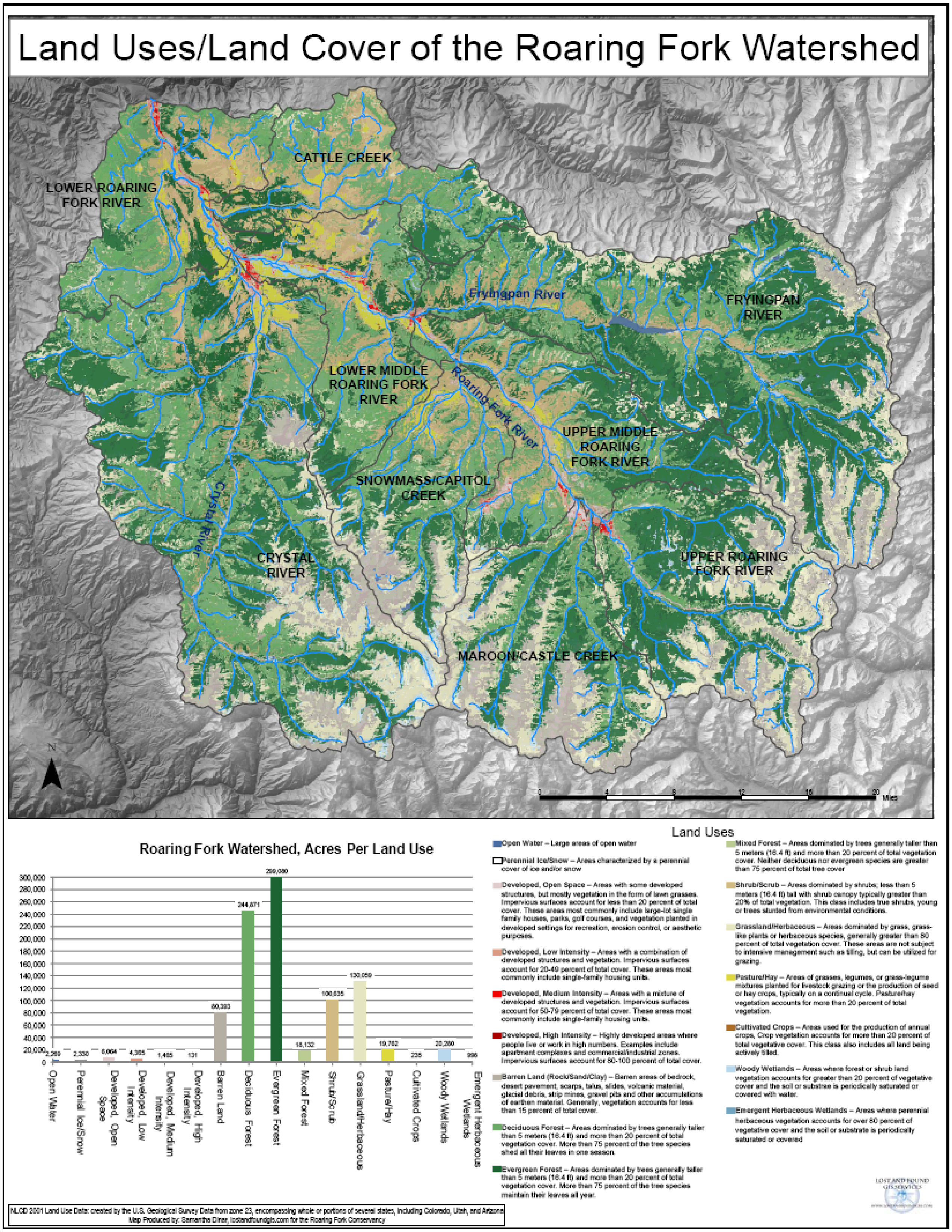


Figure 1.13. The watershed's land uses and covers.
Online Version: http://www.roaringfork.org/images/collaborative/2008sowr/1.13_LandUseLandCoverFINAL.pdf

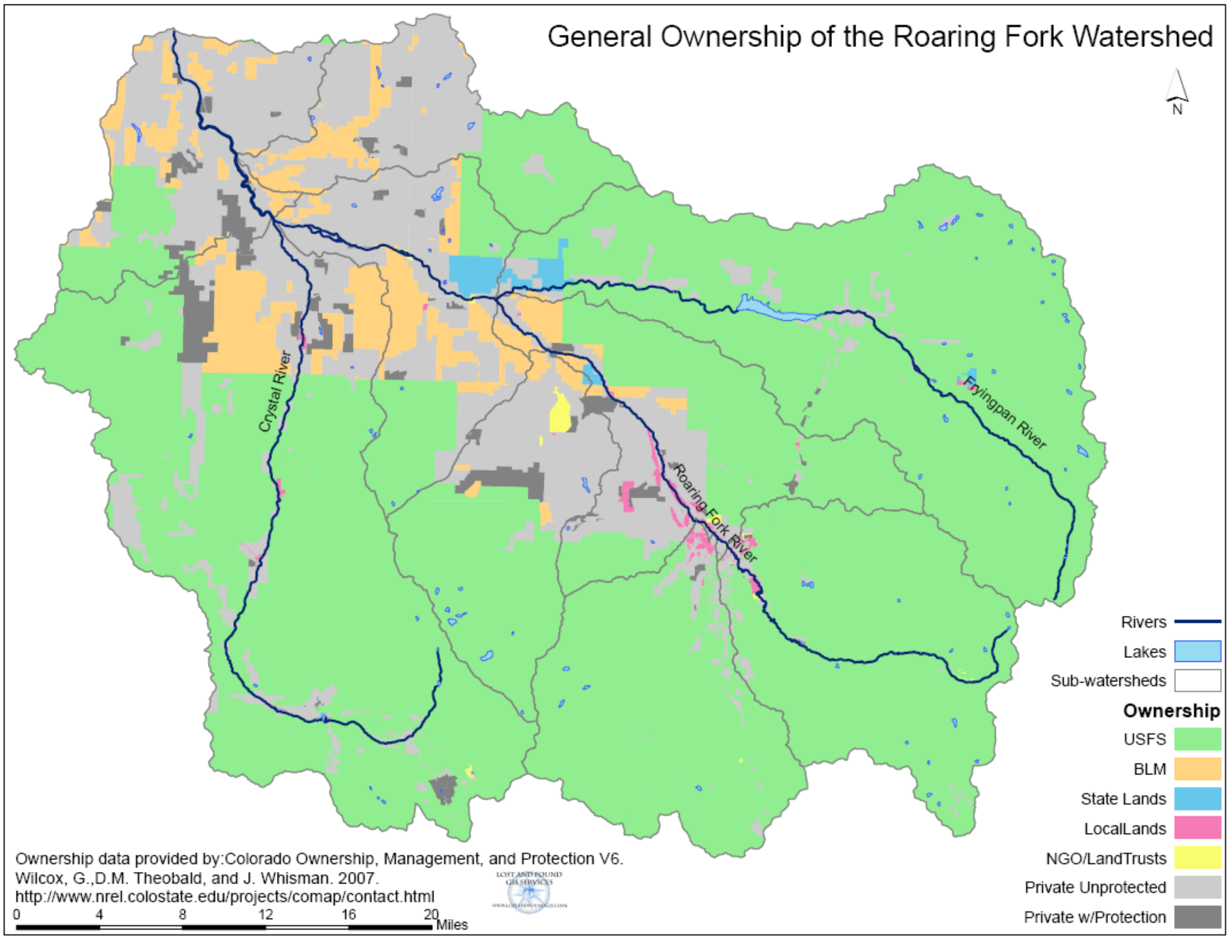


Figure 1.14. Land ownership within the watershed.

A majority of the watershed is made up of public lands. The White River National Forest, managed by the U. S. Forest Service (USFS), comprises 70 percent of the watershed's area, and 6 percent falls under the jurisdiction of the Bureau of Land Management (BLM). USFS lands are predominantly contiguous, higher-elevation forested lands with barren ground and perennial snowfields found at the highest elevations. These public lands tend to be relatively undisturbed, although there are examples of more developed activities and land uses, including ski area operations. BLM lands occur lower in the watershed and their interspersion with private lands results in smaller parcel sizes. The largest BLM parcel is about 14 square miles. The lands are predominantly shrub and brush rangelands and lower elevation forest types. The differences between these two types of public lands in landscape characteristics, relationship with private lands, and management philosophies contribute to their different management approaches (see Section 1.3.2 for further information about public land management).

According to Colorado Ownership, Management, and Protection (COMap) Project Version 6 data (http://www.nrel.colostate.edu/projects/comap/), 18,663 acres (8.5 percent) of the watershed's private lands are protected through conservation easements. Although the percentages of these lands across the counties making up the watershed are small (Figure 1.15), they are significant because they represent lands deemed valuable enough (e.g. for open space, wildlife habitat, scenic viewshed protection) to proactively protect.

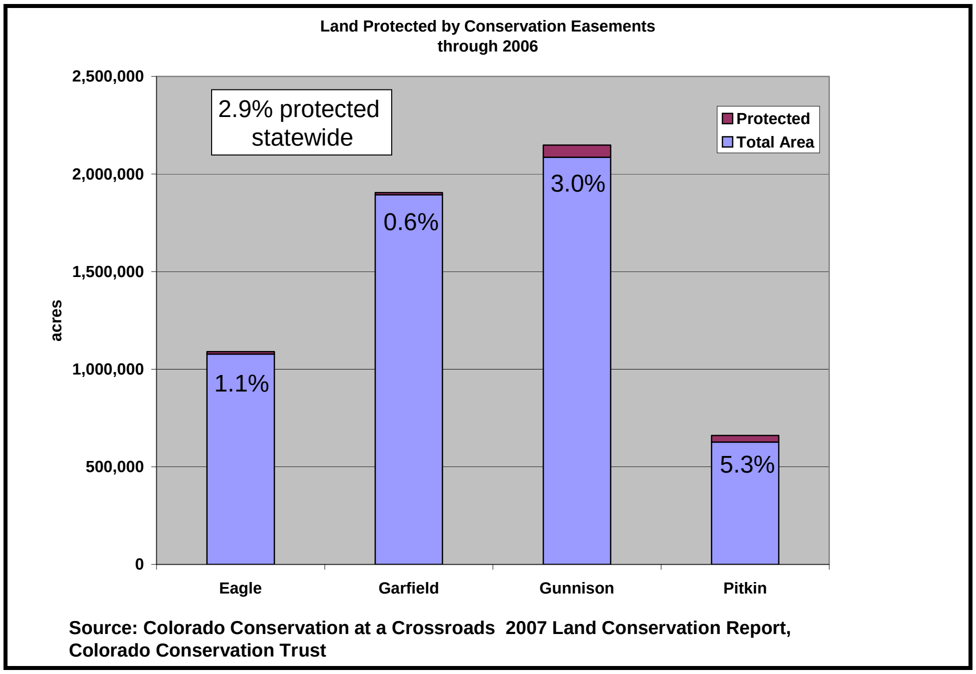


Figure 1.15. Land protected by conservation easements.

As mentioned earlier, most of the developed land uses (in the categories of developed open space; low, medium, and high intensity developed activities; pasture/hay production; and cultivated crops) are found along the major rivers.

The medium and high intensity land uses are associated with the five major municipalities. With the exception of Snowmass Village, all municipalities are located close to one or two of the watershed's major rivers. Snowmass Village is located along Brush Creek, a smaller tributary of the Roaring Fork River. Municipalities have the greatest amount of impervious surface, which causes increased flood potential and decreased natural water retention. In general, these areas have a greater concentration of stormwater runoff and wastewater infrastructure and runoff, higher intensity of riverfront development, and higher year-round water consumption. The relationship of each municipality to its proximal river(s) and streams is discussed further in Chapter 4.

Although irrigated agriculture occupies a small percentage of the watershed's total area, it is an important land use given its proximity to streams and rivers (Figure 1.16). Agricultural activities directly affect stream flows through water diversions and can affect riparian and instream habitat quality as well as stream water quality. In addition, these lands provide vital open space adjacent to stream corridors. Return flows from irrigated agriculture recharge the groundwater table, increasing summer and fall stream flows. Irrigated agriculture mainly occurs along the Roaring Fork and Crystal rivers; some of the major tributaries such as Woody, Snowmass, Brush, Owl, Capitol, Sopris, Cattle, Landis, and Fourmile creeks; and in the Missouri Heights area. This land use decreased by 11,390 acres between 1993 and 2000, changing from 3.6 percent of the watershed's area to 2.4 percent. However, based on preliminary Geographic Information Systems (GIS) data, irrigated agriculture increased by 3,270 acres from 2000 to 2005 (Carolyn Fritz, GIS Coordinator, CWCB, personal communication, May 14, 2008). There was very little change in flood irrigation (about 70 percent) versus sprinkler irrigation (about 25 percent) from 1993 to 2000. In 1993, 77 percent of the watershed's irrigated agriculture was grass and pasture and 21 percent was alfalfa, while by the year 2000, almost all of it was grass and pasture. The characteristics that make these lands desirable for agriculture such as proximity to roads and streams, flatter topography, and lower elevations, also make them desirable for housing developments and other municipal uses.

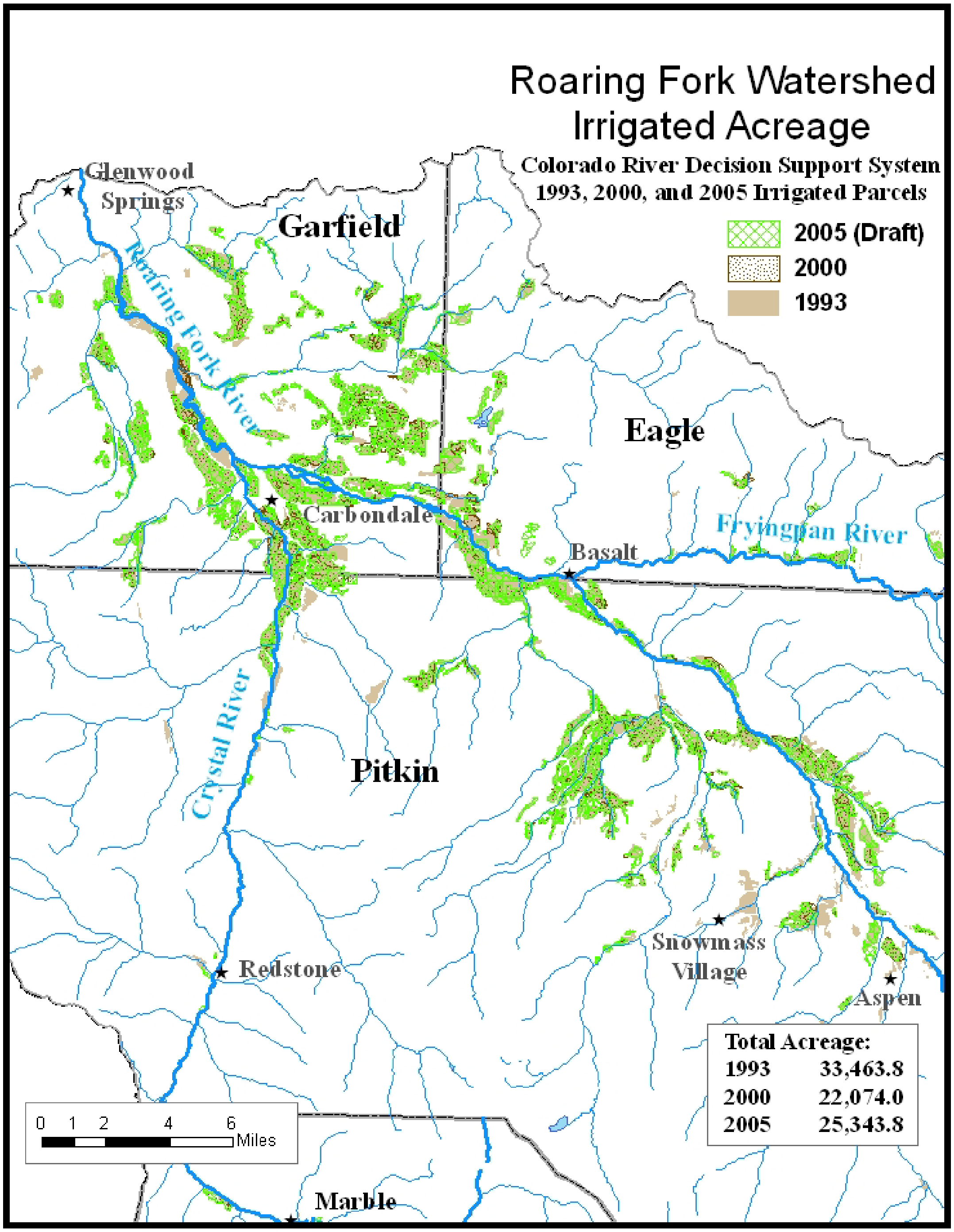


Figure 1.16. Roaring Fork Watershed irrigated acreage.
Online version: http://www.roaringfork.org/images/collaborative/2008sowr/1.16_irrigatedag_no_graphs.pdf

In higher-elevation, steeper areas, mining activities dominated historic human land use practices. Gravel is presently mined adjacent to stream areas. Sections 3.2, 3.3, and 3.4 provide a general discussion of the potential influence of mining on water quality and riparian and instream areas. Chapter 4 lists the mines located within each sub-watershed and discusses specific mining-related impacts. The information for the list of mines was obtained from the Colorado Division of Reclamation Mining and Safety website (http://mining.state.co.us/GIS%20Data.htm). The website has locational and ownership information and other data such as commodities mined, mine type, status, permit date, and acreage for each mapped site. This list of mines does not include historical mine sites. For a specific mine, locational information and site maps can be accessed through the Topozone website by selecting the appropriate county and feature type (mine) (http://www.topozone.com/states/Colorado.asp).

Both ski area and golf course activities fall under the land use category of developed open space. There are eight golf courses in the watershed covering 955 acres. Table 1.4 provides a listing of these golf courses and any available information. Golf courses use water for irrigation and can impact water quality through fertilizer and pesticide runoff, large scale soil disturbance during construction, and watering practices that increase surface water runoff (NWCCOG, 2002). In an effort to blend environmentally responsible maintenance practices into day-to-day golf course operations, the Audubon Cooperative Sanctuary Program for Golf Courses (ACSP) was set up in 1992. The ACSP focuses on environmental planning, wildlife and habitat management, chemical use reduction and safety, water conservation, water quality management, and outreach and education (ACSP, Environmental Practices for Golf Courses. http://www.audubonintl.org/e-Source/pdfs/Environmental%20Management%20Guidelines%20for%20Golf%20-%202006.pdf). See Table 1.4 for information on which local golf courses have been certified by the ACSP.

Table 1.4. Golf courses in the Roaring Fork Watershed.

GOLF COURSE	ACRES	WATER USE (acre-feet/year)	SOURCE	SUB-WATERSHED	CERTIFIED AUDUBON COOPERATIVE SANCTUARY
Aspen Glen Club	160	420	Glenwood Ditch Kaiser Sievers Ditch Crane and Peebles Ditch	Lower Roaring Fork	Yes
Aspen Golf Course	115	184	Marolt Ditch Holden Ditch	Upper Middle Roaring Fork Upper Roaring Fork	Yes
Maroon Creek Club	130	n/a	Herrick Ditch Willow Creek Ditch	Maroon/Castle Creek Upper Middle Roaring Fork	Yes
Ironbridge	230	260	Roaring Fork River	Lower Roaring Fork	No
Ranch at Roaring Fork	15	n/a	Roaring Fork River	Lower Middle Roaring Fork	No
River Valley Ranch	150	n/a	Crystal River	Crystal	No
Roaring Fork Club	85	n/a	Spring Creek Ditch Kester Ditch Elxis Arbony Ditch Shehigh Ditch	Upper Middle Roaring Fork	Yes
Snowmass Club	70	83	Brush Creek E. Snowmass Creek Snowmass Creek Capitol Creek	Upper Middle Roaring Fork Snowmass/Capitol Creek	No

Sources (contacted spring/summer 2008): Aspen Golf Course - Steve Aitkin; Maroon Creek Club - Scott Miller; Roaring Fork Club - Matt Brewer; Ironbridge - Eric Forester; Ranch at Roaring Fork - Tom Vail; River Valley Ranch - Steve Ehnes; Snowmass Club - Al Ogren; and Aspen Glen Club - Jason Miller.

There are five ski areas in the watershed, covering a total of almost nine square miles. All five divert water from streams to support snowmaking activities, which occur on as little as 4 percent of the ski area's acreage (Sunlight Mountain Resort) to as high as 31 percent (Aspen Mountain) (Table 1.5). A large portion of the five ski areas falls within the White River National Forest.

Table 1.5. Ski areas and snowmaking activities in the watershed.

SKI AREA	ACRES WITH SNOWMAKING (% of total area)	2004-2005 WATER USE FOR SNOWMAKING (change from 2003-2004)	SOURCE	SUB-WATERSHED
Aspen Mountain	210 (31%)	126.2 acre-feet (− 19.3 acre-feet)	Maroon Creek Castle Creek	Upper Roaring Fork
Aspen Highlands	110 (11%)	52.2 acre-feet (− 3.07 acre-feet)	Maroon Creek Castle Creek	Maroon/Castle Creek
Buttermilk	108 (23%)	119 acre-feet (+ 4.59 acre-feet)	Maroon Creek	Maroon/Castle Creek and Upper Middle Roaring Fork
Snowmass	185 (6%)	205.6 acre-feet (+ 46.0 acre-feet)	Snowmass Creek	Snowmass/Capitol Creek and Upper Middle Roaring Fork
Sunlight Mountain	20 (4%)	9.7 acre-feet (n/a)	Fourmile Creek	Lower Roaring Fork

Sources: Aspen Skiing Company, Sustainability Report: 2004-2006; Tom Hays, Mountain Manager, Sunlight Mountain Resort, personal communication, January 18, 2008; and Bill Blakeslee, Division 5 Water Commissioner, personal communication, February 12, 2008.

1.3.2 Land Use Regulations

Management of the watershed's USFS public lands is guided by the 2002 White River Land and Resource Management Plan (Forest Plan) in making decisions that may influence streams and their riparian areas (http://www.fs.fed.us/r2/whiteriver/projects/forest_plan/plan/plan_with_errata.pdf). The Forest Plan has four goals:

1) Promote ecosystem health and conservation using a collaborative approach to sustain the nation's forest, grasslands, and watersheds.
2) Provide a variety of uses, products, and services for present and future generations by managing within the capability of sustainable ecosystems.
3) Develop and use the best scientific information available to deliver technical and community assistance to support ecological, economic, and social sustainability.
4) Engage the American public, interested organizations, private landowners, state and local governments, federal agencies, and others in the stewardship of National Forest Systems lands.

The Forest Plan's standards and guidelines most relevant to this report are those relating to water and riparian resources (White River National Forest, 2002). The Forest Plan also includes standards and guidelines for biodiversity, wildlife, noxious weeds, and recreation that are applicable to the Roaring Fork Watershed Plan.

The BLM is in the process of updating its 1994 Resource Management Plan. BLM land use plans ensure that these public lands are managed under the principles of multiple use and sustained yield. The scoping summary report for the planned update was completed in August 2007 (http://www.blm.gov/rmp/co/kfo-gsfo/documents/K-GSFO-Scoping-Rpt_FINAL_8-3-07_000.pdf). One of the 12 planning issues identified within the report relates to water and riparian resources, specifically: What measures will be implemented to protect water resources, especially riparian areas, from the effects of other uses? This issue reiterates the challenge in the watershed of finding a balance between accommodating various interests and activities, and protecting the habitat itself.

Although 76 percent of the watershed is federally managed, the percent of public land within 150 feet of streams decreases dramatically to 32 percent, indicating that a majority of the watershed's riparian corridors are in private or local government ownership. County and municipal land use regulations apply to the 68 percent of private streamside lands in the watershed. Table 1.6 compares county codes pertinent to streamside areas and water quality, especially stream setbacks and sewage treatment requirements. Appendix 1.4 lists the regulations that apply in unincorporated Eagle, Garfield, and Pitkin counties for the protection of water quantity and quality.

Table 1.6. County land use regulations most applicable to streams and riparian areas (see source documents for lists of exemptions and exceptions).

COUNTY	SLOPE OF LAND SUBJECT TO SPECIAL CONDITIONS	SET-BACK FROM HIGH-WATER MARK	WASTEWATER TREATMENT AND COLLECTION*
Pitkin	≥ 30 percent	· 100 feet for perennial and intermittent streams or streambeds, though the required setback may be increased or decreased by as much as 50 feet depending on the circumstances. · 25 feet for isolated wetland and riparian areas	· Required to connect within one-half mile of public system service area if the district is willing to provide service. · Septic tanks and absorption trenches and beds must be located at least 50 feet from any stream, river, lake, pond, wetland, or irrigation ditch, and 15 feet from any riparian area. · New or expanded systems may not be installed in a floodway. · Installation of new or expanded systems in a floodplain is prohibited if another suitable site exists on a property.
Garfield**	≥ 20 percent	· 30 feet	· Leach field must be located at least 50 feet from streams, water courses, and irrigation ditches.
Eagle	≥ 30 percent	· 75 feet or 100-year flood plain, whichever is greater	· Required to connect if the property is within 400 feet of a public sewer system. · Septic tanks must be constructed at least 50 feet from streams, water courses, lakes, ponds, and irrigation ditches.
Gunnison	> 30 percent	· Voluntary use of buffer strips	· Required to connect if the property is within 400 feet of a public sewer system · Septic tanks must be constructed at least 100 feet from streams, water courses, lakes, ponds, and irrigation ditches. · No new or expanded ISDS may be installed in a floodway or floodplain.

* Individual sewage disposal systems (ISDS) or on-site wastewater treatment systems (OTS) with an average daily flow of less than 2,000 gallons per day are subject to local regulation under the *Individual Sewage Disposal Systems Act*, Colo. Rev. Stat. §§ 25-10-101 through 25-10-113. Local ISDS regulations must be developed in accordance with guidelines developed by the Colorado Water Quality Control Commission (WQCC). In addition, any ISDS that will dispose of effluent by discharging into State waters must receive a discharge permit from the WQCC.

** Garfield County is in the process of revising its land use development regulations; table contains relevant provisions of July 2008 final draft.

Sources: Pitkin County, http://www.aspenpitkin.com/pdfs/depts/71/luc_chap07.pdf and http://www.aspenpitkin.com/pdfs/depts/12/isds.pdf; Garfield County, http://www.garfield-county.com/Index.aspx?page=578 (Draft standards); Eagle County, http://www.eaglecounty.us/commDev/planning.cfm and http://www.eaglecounty.us/uploadedFiles/commDev/Planning/Chapter4_%20ISDS.pdf; and Gunnison County,http://www.gunnisoncounty.org/dept/plan/index.php?Regulations_and_Guidelines. Gunnison's ISDS regulations are not available online, but can be obtained from the county's planning department.

Adoption and management of county and municipal land use regulations is influenced by several factors, namely inherent landscape characteristics, physical location, and the socio-economic factors discussed in Section 1.2. Pitkin County is located entirely in the watershed and comprises the majority of the watershed (66 percent). The recently adopted Pitkin County Land Use Code contains policies specific to water resources and aquatic/riparian/wetland areas (1-60-280) as well as other policies relevant to management of streams and riparian areas such as growth management, land use patterns, recreation, and trails (http://www.aspenpitkin.com/depts/71/deptmain.cfm).

Recognizing that geographic areas within the county may have different values and priorities, Pitkin County has encouraged the establishment of neighborhood caucuses to make recommendations to the county on matters affecting their areas of concern (http://www.aspenpitkin.com/depts/77/). Each of the seven main caucuses has adopted a master plan to guide planning matters. These caucuses are discussed in more detail in the relevant sub-watershed sections within Chapter 4, and Appendix 1.5 contains excerpts from these master plans pertinent to water issues.

Eagle, Garfield, and Gunnison counties account for 14, 13, and 7 percent of the watershed, respectively. Although only 6 percent of Garfield County is located within the watershed, it contains the confluence of two of the three major rivers and includes the more developed lower portion of the watershed. This fact significantly increases Garfield County's role in the watershed's land and water use planning. Garfield County is in the process of updating its land use regulations; the "certified" Draft Unified Land Use Resolution of 2007 is available at http://www.garfield-county.com/Index.aspx?page=578.

Twelve percent of Eagle County's total area is in the watershed, and has a predominantly rural flavor. The Eagle County line splits the Fryingpan River, Ruedi Reservoir, and the Town of Basalt, and contains a five-mile section of the Roaring Fork River where Pitkin and Garfield counties adjoin. This odd juxtaposition provides an ideal rationale for the unification provided by a watershed plan. In general, the linear political boundaries in the watershed make it difficult to adopt consistent policies towards river and water management. The Roaring Fork Watershed Plan is intended to provide a management framework that can be adopted across jurisdictional boundaries throughout the watershed.

Gunnison County, located in the headwaters of the Crystal River, has only three percent of its land area in the watershed. This less-populated county (four people per square mile) does not have zoning. Instead, it promotes a "Code of the West" which makes prospective residents and property owners aware that the county does not provide the same level of infrastructure and other amenities more typical of developed urban areas. Overall, Gunnison County's land use policies seek to protect rural land uses and values.

2. Regional Water Management

The adage "everything is connected to everything else" is often called the "first law of ecology," and could also be thought of as the "first law of water management" in Colorado. Over the last decade, Colorado has seen rapidly increasing demands placed on water by both traditional consumptive uses and, more recently, by non-consumptive uses (e.g., recreational and environmental). By the year 2030, Colorado's population is expected to grow to about 7.1 million people from the current estimate of 4.5 million. This population growth together with the recent drought (1999-2004) and global climate change raises serious concerns about the water supplies that Colorado has available to meet the needs of its citizens and the environment.

Water use and stream flows in the Roaring Fork Watershed are affected by transmountain diversions, water rights both within the watershed and the broader Upper Colorado River Basin, multi-state river compacts, and pressure by many interests to develop water supplies for future growth and development. What happens in the Roaring Fork Watershed has a significant impact on water management in the region and in the state, and vice versa. Given the pressures that have been placed on water resources through the settlement of the West, a variety of laws, policies, agencies, planning processes, and structural projects have emerged over the past hundred years that greatly influence how water resources are used in the watershed today. This chapter takes a broad view of water management and its effects on the watershed looking at existing influences on current water management and development, as well as considerations that could impact water quantity in the future.

2.1 Water Quantity – Existing Influences

The following section explores how Colorado's water law dictates water use in the Roaring Fork Watershed.

2.1.1 Water Law

The greatest influence on how water is managed in Colorado is the state's water law. Several agencies and institutions are responsible for different aspects of the water rights system, including:

- Colorado's Water Court – where all water right applications are filed, defended, challenged, and adjudicated;
- Colorado Division of Water Resources – which administers water use based on the prior appropriation system;
- Colorado Water Conservation Board (CWCB) – which has the mission of conserving, developing, protecting, and managing Colorado's water for present and future generations. The CWCB plays an important role in developing and implementing state water policies.

The Colorado Constitution states that the natural waters of Colorado's rivers and streams are a public resource dedicated to the use of the people and that the right to appropriate unappropriated water for beneficial use shall never be denied. Originally focused on supporting mining and agricultural activities, Colorado water law has evolved over time to serve a multitude of purposes. The state's prior appropriation system regulates the use of surface water in lakes, rivers and streams, as well as tributary groundwater that is connected to surface streams.

Colorado water law is known for its complicated nature. The main tenets of prior appropriation can be summed up by a few phrases such as: "first in time/first in right," "use it or lose it," and "beneficial use." Under Colorado water law, a senior right (one that is filed first in time) can "call out" upstream junior water rights, meaning that the junior water-right holder may have to cease diverting water to assure that the downstream senior right is satisfied. In some cases, a call within a river basin can be large and senior enough to impact many upstream users. Calls that impact the Roaring Fork Watershed are highlighted later in this section.

In the watershed, according to Colorado's Decision Support Systems Hydrobase 2004 version, more than 3,891 water rights have been filed during the last 127 years. These rights support consumptive uses such as irrigation, municipal water supply, and snowmaking, as well as non-consumptive uses such as supporting environmental and recreational needs and hydroelectric production. CWCB instream flows are discussed below and in Section 3.1.4.

This chapter does not attempt to explain Colorado water rights in detail. An excerpt from The Citizen's Guide to Colorado Water Law (Hobbs, 2004) is provided in Appendix 2.1 for those seeking a greater understanding of the prior appropriation system and water rights.

Augmentation Plans

Augmentation plans refer to a water management technique used in Colorado to replace out-of-priority depletions of surface or groundwater caused by the use of a junior water right. A Water Court-approved plan for augmentation allows a junior water right to divert out-of-priority by ensuring that adequate water replacement is made to the affected stream system, thereby preventing injury to the water rights of senior users.

In the Roaring Fork Watershed, much of the new, single family home development is dependent upon well water for its water supply. These wells are typically drilled into what is referred to as "tributary groundwater." Pumping tributary wells can often deplete nearby surface streams and thus injure senior water rights. An augmentation plan for tributary wells replaces these depletions by releasing water from a location and in an amount that satisfies senior water-right holders downstream. Those releases, however, seldom duplicate the natural hydrology. Although augmentation releases are necessary to comply with state water law, they can be detrimental to stream habitat by reconfiguring established streamflow amounts and the timing of those flows.

Within the watershed, the West Divide Water Conservancy District (West Divide) and the Basalt Water Conservancy District (BWCD) provide augmentation water to local residents by way of their contracts for Ruedi Reservoir water and from other sources. See Figure 2.1 for the respective areas serviced by these two water conservancy districts.

West Divide also utilizes Crystal River water rights decreed to the Avalanche Canal and Siphon for both augmentation and irrigation purposes within the watershed. Additionally, West Divide has an interest in senior irrigation and hydropower water rights in the Fourmile Creek drainage. These water rights are used to provide augmentation water to local residents in the Fourmile

Creek drainage (Kerry Sundeen, Grand River Consulting, personal communication, December 19, 2007).

BWCD owns several reservoir storage and direct-flow water rights that it uses to augment and offset the depletions made by residents in its service area. BWCD's primary water supply comes from Ruedi and Green Mountain reservoirs, where BWCD has contracted with the U.S. Bureau of Reclamation (BOR) for an annual delivery of 990 acre-feet and 1,000 acre-feet of water respectively. This water can either be used directly for municipal and domestic purposes or for augmentation.

In addition to these storage water rights, BWCD also owns direct-flow water rights in the Basalt Conduit and the Landis Canal, two structures proposed to be built in the late 1950s as part of the Basalt Project. While these diversion structures were never actually constructed, BWCD now uses these rights, with their 1957 appropriation date, for augmentation purposes. The decreed source of water for the Basalt Conduit is the Fryingpan River at the head of the outlet pipe for Ruedi Reservoir. The Landis Canal's decreed points of diversion are located on Coulter, Cattle, and Landis creeks, and other un-named tributaries of the Roaring Fork River. While water is not physically diverted at these locations, the decreed diversion points for these rights are relevant in the sense that BWCD can use the decreed water right for augmentation purposes downstream of each point.

In 1998, BWCD obtained additional augmentation water for residents on Blue Creek, near El Jebel by purchasing shares in the Robinson Ditch and Favre Domestic Spring and Pipeline. In addition, BWCD converted the direct-flow rights in the Troy and Edith Ditch to consumptive use credit, for use in future augmentation plans (Graham Gilbert, Resource Engineering, personal communication, December 26, 2007).

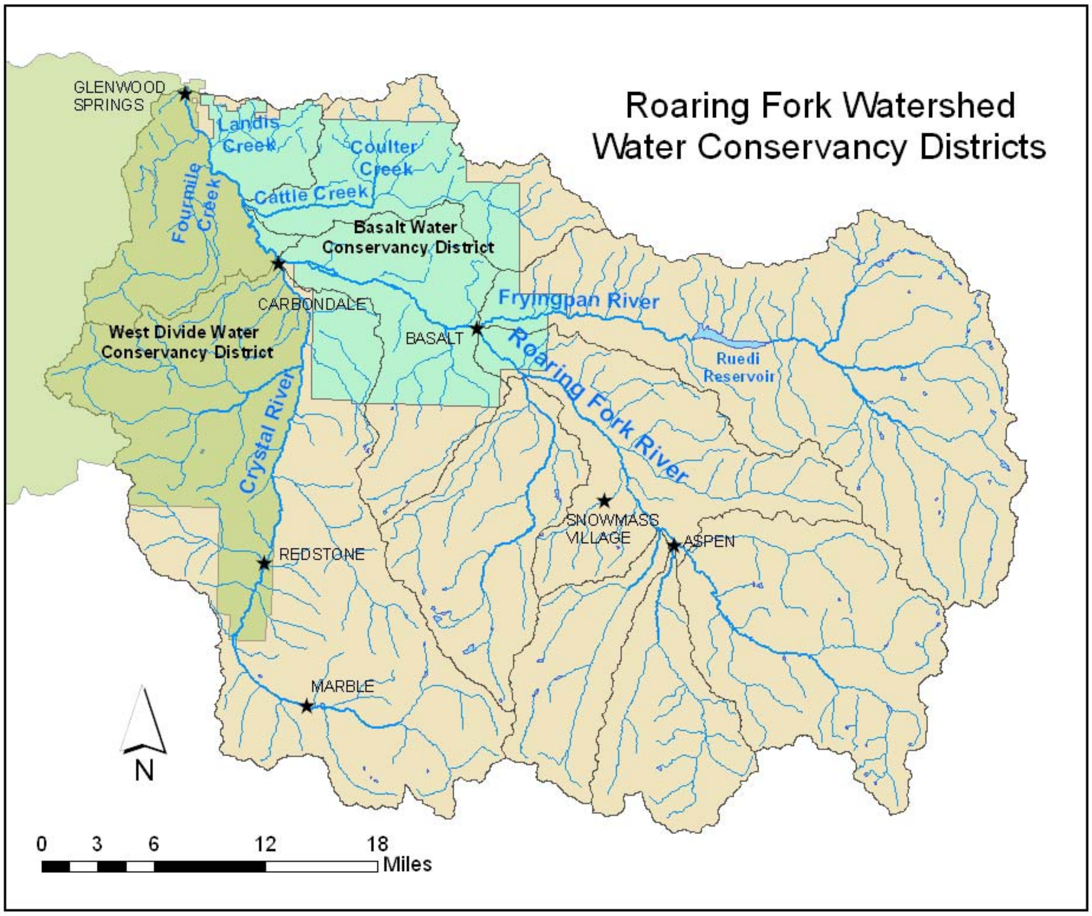


Figure 2.1. Areas covered by the two conservancy districts in the watershed.

Instream Flows

Flows in streams and rivers are often affected by diversions, which remove water from those waterways to meet urban and agricultural water demands. In 1973, the Colorado General Assembly passed Senate Bill 97, recognizing the need to “correlate the activities of mankind with some reasonable preservation of the natural environment” by creating the nation’s first Instream Flow Program (Colorado Revised Statutes § 37-92-102 (3)). This program gave the CWCB exclusive authority to protect streamflows through a reach of stream rather than just at one point, and to protect levels in natural lakes (CWCB, No date a). Until this law was passed, removal of water from its natural course was a prerequisite of legal appropriation with the exception of hydropower use. Once decreed by the Water Court, instream flow rights are assigned a priority, just as any other water right claim, and administered within the state’s water right priority system (CWCB, No date a). There are 64 instream flow rights as shown in Appendix 2.2 and 2.2a (Snowmass Creek multi-stage flows), and 58 natural lake level filings in the Roaring Fork Watershed (Appendix 2.3) (Rob Viehl, CWCB, personal communication, October 9, 2007). Additional discussion of instream flows can be found in Section 3.1.4 under “Environmental Needs.” For more information on the Instream Flow Program, refer to Appendix 2.4.

Recreational In-channel Diversions

Another form of non-consumptive water right has been created in the form of recreational in-channel diversions, or "RICDs." The impetus for this type of water right has been the growing popularity of commercial rafting and kayaking on Colorado's rivers and streams. In general, RICDs are similar to instream flow rights in that they allow a government entity to appropriate instream water for use within a specific stream reach. Physical control structures (often installed in the river channel to create a kayak course) are required to qualify a RICD as a beneficial use. See Table 3.1.2 for a list of existing and proposed RICDs in the Roaring Fork Watershed. More detailed discussion about the legal evolution of RICDs can be found in Appendix 2.5.

Cameo Call

The primary call on the Upper Colorado River (including the Roaring Fork Watershed) is associated with a number of senior water rights that divert for irrigation and power purposes in the Grand Valley area near Grand Junction (Figure 2.2). Collectively, the demands for these rights are referred to as the "Cameo Call." The magnitude of the Cameo Call is dependent upon operation of the Orchard Mesa Check, a facility near Palisade that can be operated in a manner that may reduce the need for the call under some circumstances by returning diverted water to the main stream channel. Generally, the Cameo Call benefits instream flows in the Roaring Fork Watershed by requiring junior water-right holders (including those who take water from the upper Roaring Fork River as transmountain diversions) to curtail diversions, thereby increasing flows in local waterways. At the same time, however, junior agricultural and municipal water-right holders may be impacted due to their inability to divert.

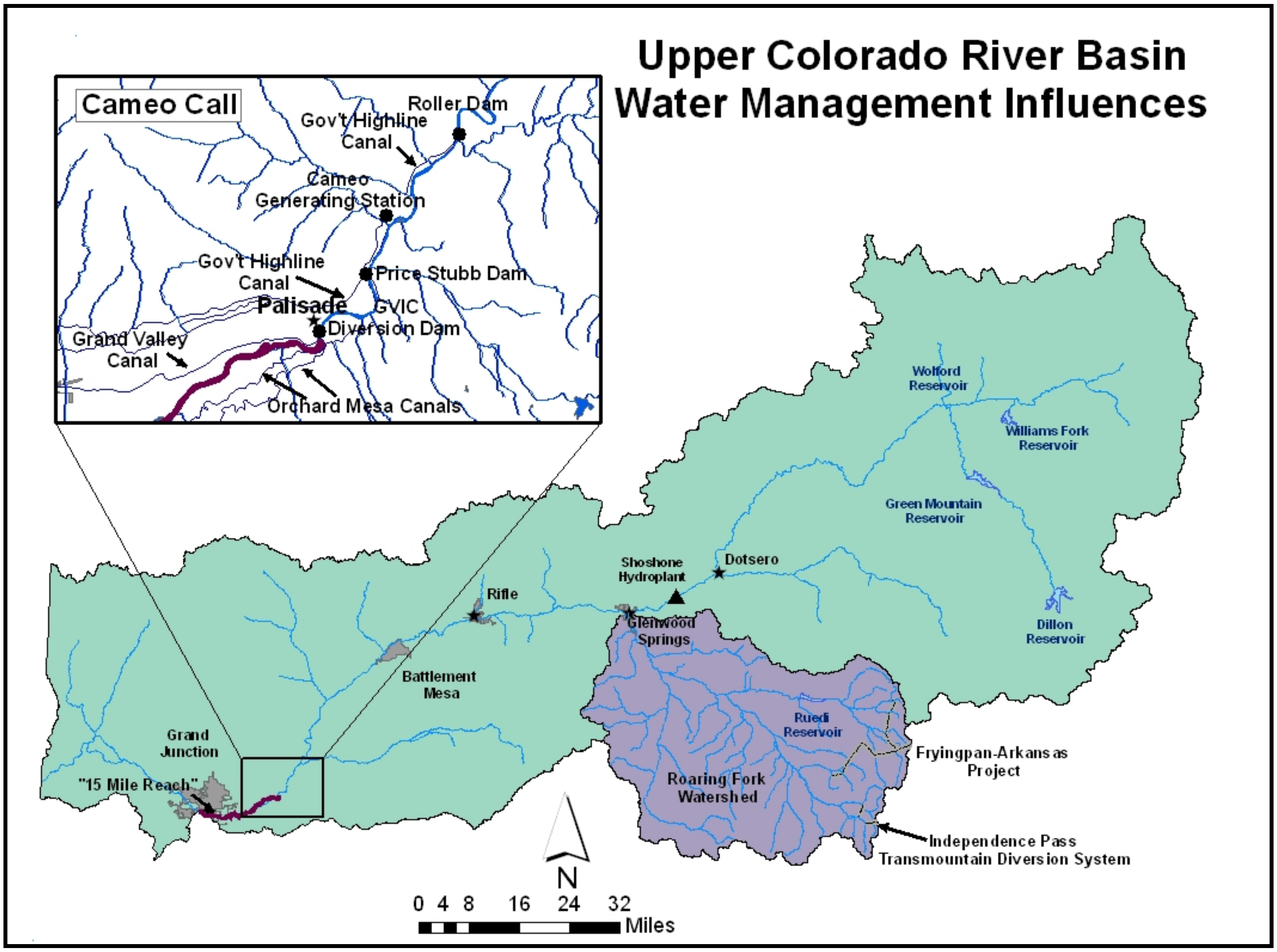


Figure 2.2. Upper Colorado River Basin water management influences on the Roaring Fork Watershed.

Shoshone Hydroelectric Plant and Call

The Public Service Company of Colorado (Xcel Energy) owns and operates the Shoshone Hydroelectric Plant in Glenwood Canyon, located 10 miles upstream of Glenwood Springs and the confluence of the Colorado River and the Roaring Fork River (Figure 2.2). The power plant has a 1,250 cubic feet per second (cfs) water right that was adjudicated in 1907, and an additional water right of 158 cfs decreed in 1956 (Enartech, 1995). The capacity of the power plant is 14,400 kilowatts. During low flows (less than 1,408 cfs), as the most senior water right on the Colorado River, Shoshone Hydroelectric Plant may divert the entire flow out of the river into its turbines, dewatering several miles of the Colorado River in Glenwood Canyon. However, use of the water is non-consumptive, meaning that almost 100 percent of the water it diverts returns to the river downstream.

During most years, the Shoshone water rights place an eight-month call on the river, from mid-August through mid-April of the following year. In dry years, the call may begin in early June. When this call is on, it requires diverters in the Colorado River above the Shoshone Plant to halt diversions, thus increasing stream flows through Glenwood Canyon. The other months of the year generally have enough water to satisfy this senior water right and all or most junior rights without any calls. The increased stream flows resulting from the Shoshone Call improve rafting conditions in the Colorado River and support the region's recreational economy. They also reduce the potential for a Cameo Call (which, as noted above, can affect water diverters on the Roaring Fork River). This is because stream flows created by the Shoshone Call are often enough to supply irrigation needs in the Grand Valley, thereby making a Cameo Call unnecessary. Paradoxically, while the Shoshone Call benefits stream flows and non-consumptive uses on the mainstem of the Colorado River, it may harm those same values in sections of the Roaring Fork Watershed by keeping junior diverters in priority, thereby preserving their ability to divert more water for a longer time.

2.1.2. Water Management Agreements, Policies, and Agencies

In addition to the solid foundation provided by Colorado water law, a variety of federal laws, regulations, and polices; multi-state agreements; and state-specific policies, planning processes, and agencies influence water management in the Roaring Fork Watershed.

Federal Laws, Regulations, and Policies

There are numerous federal laws, regulations, and policies that influence water use in the Roaring Fork Watershed. Some of the more significant include: the Endangered Species Act, the National Environmental Policy Act, the Federal Land Policy and Management Act, and the Wild and Scenic Rivers Act. Each of these is discussed below.

Endangered Species Act

Congress created the Endangered Species Act (ESA) in 1973 (16 U.S.C. § 1531-1599) to protect species and the ecosystems upon which they depend. Although there are no specific water-related species listed under the ESA in the Roaring Fork Watershed, the presence of four endangered warm water fish species in the Colorado River – the Colorado pikeminnow, razorback sucker, bonytail, and humpback chub – has implications for water flows in the watershed.

The Upper Colorado River Endangered Fish Recovery Program, administered by the U.S. Fish and Wildlife Service (USFWS), outlines strategies to recover these fish, while at the same time providing for future water development for agricultural, hydropower, and municipal uses. Figure 2.2 shows the location of the critical "15-Mile Reach" where most of the recovery efforts have been focused. Recovery strategies include conducting research, improving river habitat, providing adequate stream flows, managing non-native fish populations, and raising endangered fish in hatcheries for stocking.

In support of the stream flow goal, East Slope and West Slope water providers in the Upper Colorado River Basin have committed to permanently supply 10,825 acre-feet of water per year ("10,825 water") to augment flows in the 15-Mile Reach during the late summer and fall months. The commitment to provide "10,825 water" is divided equally between East Slope and West Slope water providers. See Section 2.2.2 for more information about the "10,825 water."

In addition to the "10,825 water" currently supplied on an interim basis from Wolford Mountain and Williams Fork reservoirs (Figure 2.2), the U.S. Bureau of Reclamation (BOR) supports recovery flows in the Colorado River with releases from Ruedi Reservoir. BOR has an agreement to provide 10,825 of interim water (for a 15-year period, expiring in 2012) and a permanent supply of 5,000 acre-feet per year plus 5,000 acre-feet in four out of five years. The obligations of Ruedi Reservoir for the Endangered Fish Recovery Program are found in the Programmatic Biological Opinion and the 2012 Agreement (USFWS, 1999; BOR Eastern Colorado Area Office, 2003). The water provided for endangered fish is called for by the USFWS when needed by the fish. These needs do not always coincide with local angling interests and the natural flow regime.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) (42 U.S.C. § 4321- 4370f) requires that, prior to taking any “major” or “significant” action, any federal agency must consider and disclose the environmental impacts of the action. A project is required to follow NEPA procedures when a federal agency provides any portion of the financing or approvals for the project. The law requires that an “environmental impact statement” (EIS) be written for all major federal actions which might have a significant impact on the environment. If a major federal action will not have a significant impact on the environment, the agency must prepare a shorter document called an “environmental assessment” (EA).

Federal projects may also be exempted from standard NEPA procedures if they fall under a “categorical exclusion” (CE). Categorical exclusions are unique to each agency, and generated by the agency, after consulting with the Council for Environmental Quality.

When NEPA procedures are required, the agency generally must involve the public by providing notice of and opportunities for comment on the proposal. With regard to water resources in the Roaring Fork Watershed, NEPA comes into play with proposed actions related to the federally-owned and managed Ruedi Reservoir. It also would apply to major actions proposed for U.S. Forest Service (USFS) or Bureau of Land Management lands.

Federal Land Policy and Management Act and the Colorado Ditch Bill

The Act of October 27, 1986 (100 Stat. 3047) amended the Federal Land Policy and Management Act of 1976 (43 U.S.C. § 1701-1787) to authorize the Secretary of Agriculture to issue permanent easements without charge for certain water conveyance systems that are on USFS lands and used for agricultural irrigation or livestock watering purposes. The Act, commonly referred to as the Colorado Ditch Bill, requires the granting of an easement if the water system meets the specific criteria of the Act. Thus, the granting of such easements is non-discretionary and not a major Federal action subject to NEPA analysis or review. The conditions imposed on the operation and maintenance activities of these easements are, however, discretionary and therefore subject to NEPA review and must comply with both state and federal law.

The Colorado Ditch Bill provided a 10-year window, ending December 31, 1996, during which time entities could file an application for a Ditch Bill easement. Within the Roaring Fork Watershed, the USFS White River National Forest (WRNF) received 64 applications for Ditch Bill easements, not all of which were granted (Andrea Holland-Sears, USFS, Hydrologist, personal communication, April 14, 2008).

Ditch Bill easements in the watershed may include any terms or conditions necessary to comply with current federal laws, regulations, and policies, including the Forest Plan for the WRNF. For example, there may be facilities where the diversion of water from natural streams may impact aquatic resources on USFS-managed lands. Easement conditions may stipulate the maintenance of instream flows sufficient to maintain aquatic habitats and support aquatic species. Each Ditch Bill easement has a "re-opener" clause that permits modification or revision of its terms and conditions if necessary to comply with, among other laws, the ESA.

Wild and Scenic Rivers Act

The Wild and Scenic Rivers Act (16 U.S.C. §§ 1271-1287) is intended to preserve in "free-flowing condition" certain rivers that possess "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values." Congress may designate rivers and states may recommend rivers for inclusion in the Wild and Scenic Rivers System, subject to approval by the Secretary of the Interior. In addition, Congress may recommend rivers for study and designation by the Secretary of the Interior, and if USFS lands are involved, by the Secretary of Agriculture.

In the Roaring Fork Watershed, the BLM is considering lower Thompson Creek for designation. Most of the National Forest lands adjacent to the Crystal River are eligible for inclusion in the Wild and Scenic Rivers System. The WRNF's 2002 Revised Forest Plan uses Scenic and Recreation River management prescriptions for these lands. In 1986, the Crystal Valley Environmental Protection Association proposed that the Crystal River be included in the Wild and Scenic Rivers system and continues to discuss this recommendation.

Colorado River Compact

The 1922 Colorado River Compact defined the relationship between what are known as the "Upper Basin states" (Wyoming, Utah, Colorado, New Mexico), where most of the river's water supply originates, and the "Lower Basin states" (Nevada, Arizona, California), where most of the water demands were developing during the early part of the 20th Century (BOR No date a) (Figure 2.3). The 1922 Compact divides the Colorado River Basin into an upper and a lower half, with each having the right to develop and use 7.5 million acre-feet (maf) of Colorado River water annually. In order to meet this obligation, the Upper Basin states must deliver 75 maf every 10 years to the Lower Basin states, as measured at Lee's Ferry, 15 miles downstream from Glen Canyon Dam.

Figure 2.3. Colorado River Basin map showing the Colorado River Compact designated "Upper Basin" and "Lower Basin". Source: http://www.crwcd.org/media/uploads/How_Much_Water_05-15-07.pdf .

When the 1922 Colorado River Compact was negotiated, the native flow of the Colorado River at Lee Ferry was assumed to be 17.2 maf per year (Kuhn, No date). Recent analysis, based on reconstructed tree-ring data from 1520-1961, indicates an average flow between 14.3 and 14.7 maf per year (Woodhouse et al., 2006). Also, Colorado River flows for the past 100 years have been highly erratic, ranging from a just over 5 maf per year to almost 25 maf per year (Figure

2.4). This overestimation of Colorado River flow has resulted in an over-appropriation of the Colorado River. The future implications of an over-appropriated Colorado River, in combination with climate change and increased demands for water, are of major concern to all Colorado Basin states and to Mexico which also depends on the Colorado River Compact to deliver water to the lowermost part of the watershed – the Colorado River Delta (Sonoran Institute, 2005).

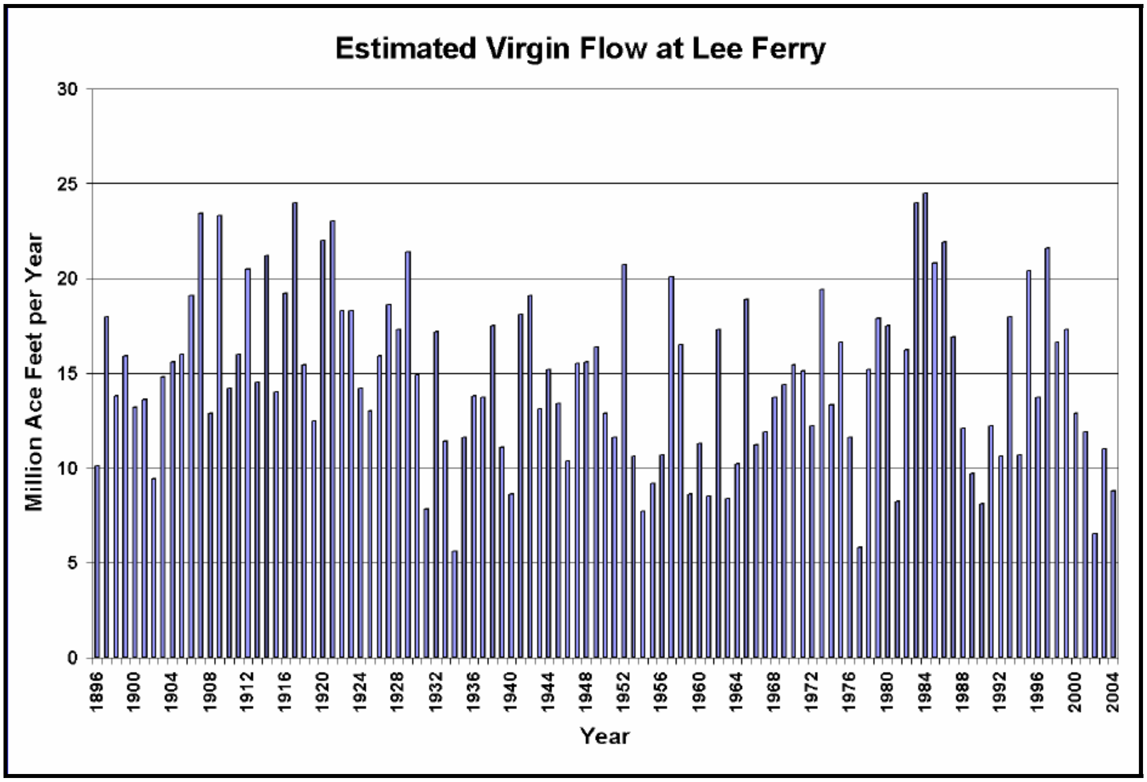


Figure 2.4. Estimated virgin flows on the Colorado River at Lee Ferry from 1896-2004. Source: Kuhn, 2005.

The Upper Colorado River Basin Compact of 1948 created the Upper Colorado River Commission and apportioned the Upper Basin's Colorado River allocation among Colorado (51.75 percent), New Mexico (11.25 percent), Utah (23 percent), and Wyoming (14 percent) (BOR, No date b). The portion of Arizona that lies within the Upper Colorado River Basin was also apportioned 50,000 acre-feet annually. Under this Compact, Colorado may be entitled to as much as 3.855 maf, annually, depending on the river's actual production.

Statewide Water Supply Initiative/Colorado Water for the 21st Century Act

Drought conditions in Colorado in 2001 and 2002 prompted the state to undertake a study of Colorado's future water demands and availability, a planning process known as the State Water Supply Initiative (SWSI). One of the most important findings of SWSI was that under the most optimistic scenario, projects and water management planning processes that local municipal and industrial (M&I) providers are implementing or planning to implement have the ability to meet about 80 percent of Colorado's M&I water needs through 2030, leaving a 20 percent gap (or 118,200 acre-feet of water) (CDM, 2004).

Several key issues emerged in the first phase of the SWSI process that received additional focus in later years, including the need to better understand and quantify recreational and environmental flows, future water demands for energy development, concerns about permanent dry-up of agricultural lands, and the potential importance of water conservation and efficiency measures. Overall, SWSI has continued to work toward prospective solutions to address the projected "gap" (CDM, 2007b).

With SWSI well underway, the Colorado Water for the 21st Century Act was passed in 2005 to facilitate continued discussions and negotiations among the various river basins within the state (see Colorado Revised Statutes, §§ 37-75-101 through 37-75-106). The Act created an Intrastate Basin Compact Committee (IBCC), made up of representatives of the seven major river basins in the state. The purpose of the IBCC is to facilitate processes to resolve supply and demand imbalances between the basins. The Act also created roundtables within each basin and identified representatives of many water interests to sit on those roundtables. The roundtables are charged with examining supply and demand issues within their basins and developing a firm understanding of local needs and resources. With this information, they can propose projects or methods (both structural and nonstructural) for meeting those needs and utilizing any unappropriated waters. If disagreements arise among basins with conflicting interests, the IBCC will mediate the dispute (CWCB, No date b). More information about the Colorado Basin Roundtable, including a member list with their affiliations and contact information, can be found at http://ibcc.state.co.us/Basins/Colorado/.

As a result of the expected gap between water supply and demand in Colorado, the SWSI Gap Committee was initially tasked to look at a number of previously conceived, large pumpback projects as potential solutions to fill the gap. This committee recommended that a number of those major water supply projects be studied further, including the Big Straw and Ruedi Pumpback (see Section 2.2.3 for further discussion of both projects), Green Mountain to Dillon Reservoir Pumpback, Yampa Pumpback (Yampa Straw), and Blue Mesa Pumpback. Before these studies got under way, however, concerns arose within the water stakeholder community. It was felt that studying any particular large scale solution(s) might be premature, given uncertainty surrounding the actual availability of present and future water supplies (both hydrologically and legally), and the potential impacts of the 1922 and 1948 Colorado River compacts. In response to these concerns, the Colorado General Assembly passed SB 07-122, providing $500,000 to support the Colorado River Water Availability Study. The study's purpose is to address the question of how much water from the Colorado River Basin is available to meet Colorado's current and future needs under the terms of the Compact. To fully answer the question, however, it will be important to examine the interplay between future consumptive uses and the demands of the 1922 Colorado River Compact. This study will also be complemented by another study on the water needs of future energy development in Colorado, including oil shale, coal gasification, and coal-bed methane (Kuhn, 2007b).

The CWCB is the state agency overseeing both the SWSI and IBCC processes. Further information for both initiatives can be found at the following CWCB websites: http://cwcb.state.co.us/IWMD/General.htm and http://ibcc.state.co.us/.

Colorado River Water Conservation District

The Colorado River Water Conservation District (River District) was created by the Colorado General Assembly in 1937 to promote the conservation, use, and development of the water resources of the Colorado River and its principle tributaries and to safeguard for Colorado all waters to which the state is equitably entitled under the Colorado River compacts. The River District plays a significant role in determining the policies and projects that govern use of the Colorado River.

The River District's jurisdiction includes all or part of 15 West Slope counties that are within the Colorado River Basin (including the four counties represented within the Roaring Fork Watershed) and is governed by a board with representatives from each of these 15 counties (Figure 2.5). It can appropriate water rights, litigate water matters, enter into contracts, operate projects, and perform other functions as needed to meet the present and future water needs of the district. The River District owns water rights, including contracts for 1,780 acre-feet and 5,000 acre-feet of Ruedi Reservoir water. It also has access in some years to 200 acre-feet of Twin Lakes Reservoir and Canal Company (Twin Lakes) storage water from the upper Roaring Fork drainage (Kuhn, 2007a).

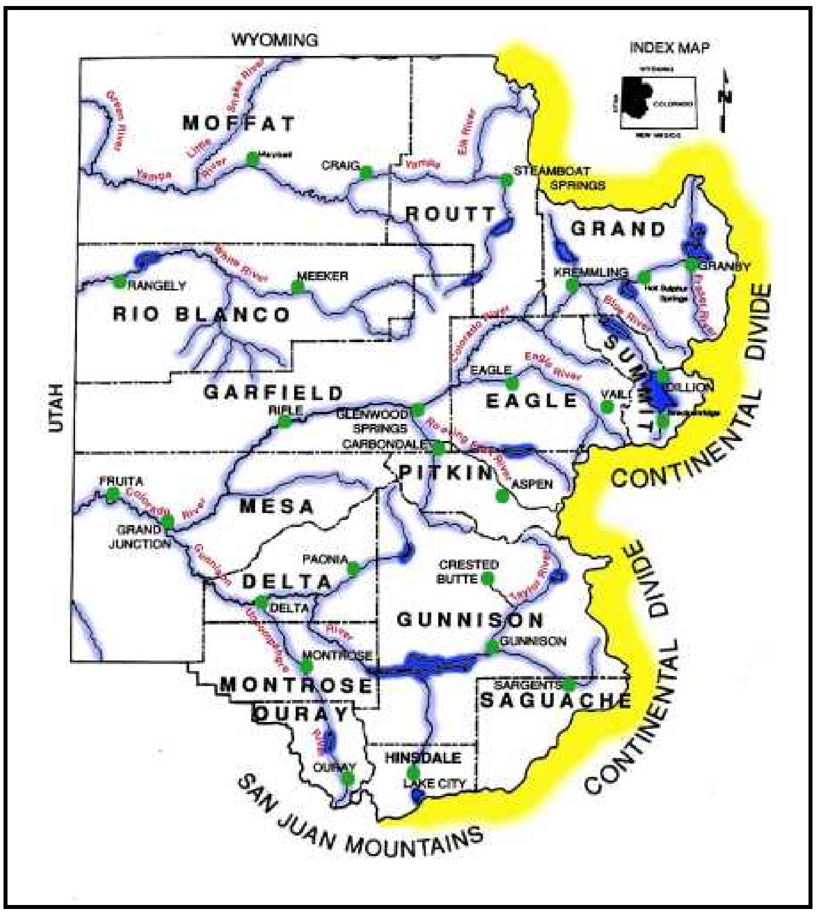


Figure 2.5. Colorado River Water Conservation District jurisdiction. Source: www.crwcd.org.

Green Mountain Reservoir – Historic Users Pool

Green Mountain Reservoir (Figure 2.2), constructed from 1938-1943, was the first feature of the Colorado-Big Thompson Project (C-BT) to be built. The West Slope fought against the original C-BT Project because its proposed depletions of Colorado River water would have impaired the West Slope's water supply and would have severely hampered its ability to grow. The idea of compensatory storage for the basin of origin was born from subsequent negotiations. As mitigation for present and future West Slope impacts, Green Mountain Reservoir was constructed to provide water storage for West Slope water users and to allow for future West Slope growth.

Initially, the reservoir was apportioned into two pools of water. The most senior of these two pools, or the first to fill, was the 52,000 acre-foot "replacement pool" from which water would be released to replace out-of-priority Colorado River water diverted to the East Slope by the C-BT. The remaining 100,000 acre-feet were for current and future uses on the West Slope. This is known as the Compensatory Storage Pool, or Power Pool, since hydroelectric energy is generated as the water is being released.

After the 1977 drought, reservoir operations were modified to divide the reservoir into four pools of water: 1) the 52,000 acre-foot C-BT replacement pool, 2) the 5,000 acre-foot Silt Project Pool, 3) the 66,000 acre-foot Historic Users Pool (HUP), and 4) the 20,000 acre-foot Contract Pool. Western Colorado water users that relied upon Green Mountain water prior to 1977 now have out-of-priority diversions replaced by the HUP. The Contract Pool meets the needs of industrial water users and post-1977 domestic and irrigation users, pursuant to individual water contracts through the BOR (River District, No date).

2.1.3 Structural Projects

Transmountain diversions in Colorado typically take water from the West Slope of the Continental Divide, where snowpack is relative abundant, to the more arid East Slope. In the Roaring Fork Watershed, there are three major transmountain diversions. The Fryingpan-Arkansas Project diverts water from the headwaters of the Fryingpan and Roaring Fork rivers. Twin Lakes' Independence Pass Transmountain Diversion System (IPTDS) diverts water from the headwaters of the Roaring Fork River. The smallest, the Busk-Ivanhoe Project diverts water from the headwaters of the Fryingpan River. All three diversions operate in the WRNF.

Fryingpan-Arkansas Project

The Fryingpan-Arkansas (Fry-Ark) Project is a large, federally-sponsored multipurpose transmountain diversion project that collects water in the headwaters of the Fryingpan and Roaring Fork rivers for delivery to the Arkansas River Basin on the East Slope. The Fry-Ark Project was constructed by the BOR between 1963 and 1980. Each year, on average, the Project diverts approximately 51,000 acre-feet of water from the Roaring Fork Watershed for use on the East Slope (CWCB and CDWR, 2007b). See figures 2.6 and 2.7 for illustrations of the Fry-Ark Project's area and infrastructure.

The Southeastern Colorado Water Conservancy District (Southeastern) was created in 1958, specifically for the purpose of developing and administering the Fry-Ark Project. Southeastern's territory extends along the Arkansas River from Buena Vista to Lamar, and along Fountain

Creek from Pueblo to Colorado Springs. Southeastern is legally responsible for paying BOR for the reimbursable portions of the Fry-Ark Project, and it holds legal title to the Project's water rights (CWCB and CDWR, 2007b).

West Slope Project Facilities

West Slope facilities for the Fry-Ark Project are divided into the North Side and South Side collection systems (see Figure 2.4). The two collection systems converge on the West Slope where all of the "Project Water" is then transported through the Boustead Tunnel to Turquoise Reservoir in the Arkansas River drainage. The rated capacity of this 5.4 mile-long, 10.5 foot-diameter tunnel is 945 cfs.

The North Side Collection System is designed to collect and transport approximately 18,400 acre-feet of water annually from the major tributaries of the North Fork of the Fryingpan River. Diversions are located on Mormon, Carter, Ivanhoe, Granite, Lily Pad, North Cunningham, Middle Cunningham, and South Cunningham creeks.

The South Side Collection System consists of diversions from both the Fryingpan River and Hunter Creek basins. South Side facilities in the Hunter Creek Basin include diversions from No Name, Midway and Hunter creeks. In the Fryingpan River Basin, South Side diversions are located on Sawyer and Chapman creeks, and both the South Fork and the mainstem of the Fryingpan River. Collectively, the South Side Collection System is designed to collect and transport approximately 50,800 acre-feet of water annually. See Appendix 2.6 for a description of the water rights for the West Slope facilities of the Fry-Ark Project.

Operating Principles

Prior to Congressional authorization, West Slope interests, led by the River District, negotiated with Southeastern for a number of specific restrictions on the Project's diversions. These restrictions were formally incorporated into a set of Operating Principles for the project, which were adopted by Colorado's General Assembly in 1959 and incorporated by the U.S. Congress into the project's authorizing legislation (P.L. 87-590) (http://www.secwcd.org/Operprin.htm).

The Fry-Ark Project's Operating Principles specify two minimum flow criteria for the Fryingpan River Basin. First, Fry-Ark Project diversions cannot reduce the combined streamflow at the points of diversions below 15 cfs from October through March or below 30 cfs from April through September. Second, Fry-Ark Project diversions cannot reduce the flow in the Fryingpan River, near Norrie (immediately below the confluence of the North Fork with the Fryingpan River) to less than the values in Table 2.1.

Table 2.1. Fry-Ark Project minimum bypass flows at Thomasville Gage.

MONTH	MINIMUM FLOW (cfs)
April	100
May	150
June	200
July	100
August	75
September	65
October – March	30

The Operating Principles also specify that the Project's maximum annual transmountain diversion in any one year cannot exceed 120,000 acre-feet. In addition, the aggregate diversions in any consecutive 34-year period cannot exceed 2,352,800 acre-feet, which is equivalent to an average annual diversion of 69,200 acre-feet.

There was no provision in the Operating Principles for minimum flows for the Hunter Creek Basin. In 1978, Congress amended the original authorizing legislation for the Fry-Ark Project to incorporate minimum bypass requirements for the diversion structures on Hunter, No Name, and Midway creeks (P.L. 95-586). In addition, P.L. 95-586 required that the Fry-Ark Project be operated in a manner that complies with both CWCB's minimum instream flow program and the Fry-Ark Project's 1975 Final Environmental Impact Statement. In order to comply with this mandate, the Bureau has established a set of minimum bypass requirements for nine of the thirteen diversion structures in the Fryingpan River Basin. See Section 4.1 for more information on P.L. 95-586, and see Appendix 2.6 for further explanation of the Fry-Ark Project's minimum bypass requirements in the Fryingpan Sub-watershed.

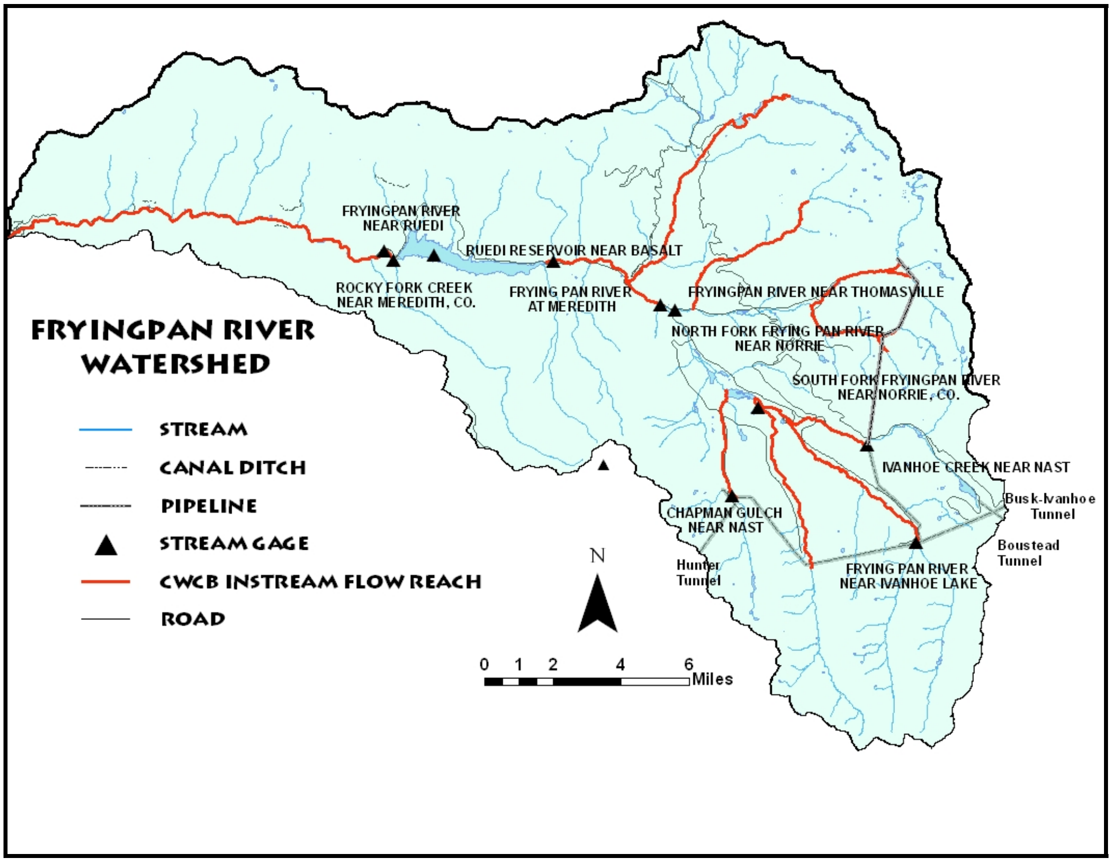


Figure 2.6. The Fry-Ark Project's diversion system within the Roaring Fork Watershed.

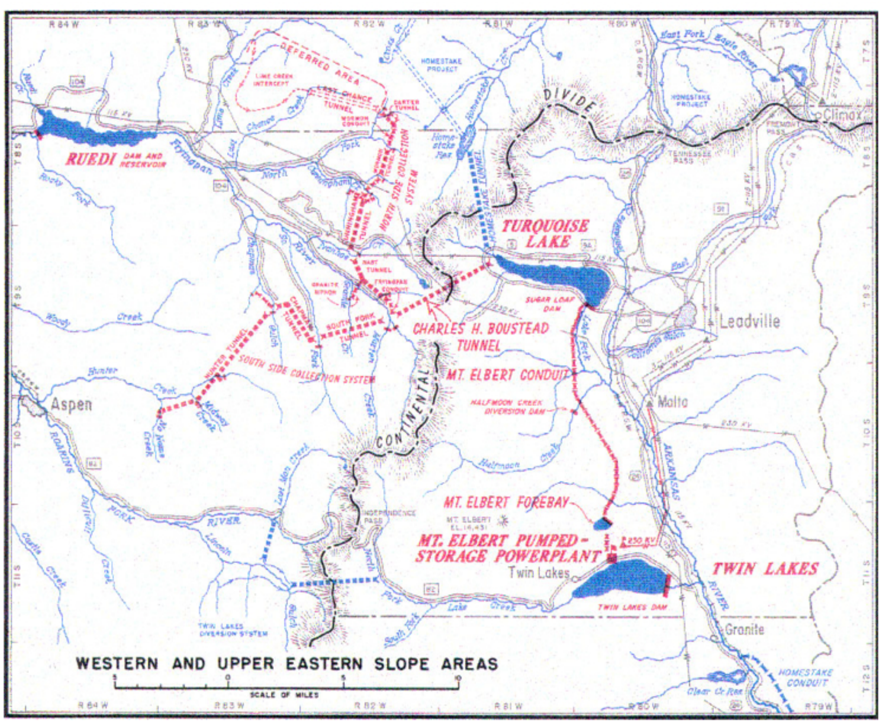


Figure 2.7. The Fry-Ark Project's transmountain diversion system. Source: Excerpted from http://www.usbr.gov/dataweb/html/fryarkmap.html.

Ruedi Reservoir

Ruedi Reservoir is the major West Slope facility of the Fry-Ark Project, built to provide replacement storage to the West Slope for out-of-priority diversions at the Fry-Ark Project's North Side and South Side collection systems and mitigation for water removed from the Colorado River Basin. Completed in 1968, the reservoir has a total capacity of 102,373 acre-feet and its outlet works have a 1,800 cfs capacity.

Ruedi's storage is divided into three pools of water. Approximately 28,000 acre-feet of Ruedi's total storage capacity is designated for replacement purposes ("Replacement Pool"). Approximately 18,000 acre-feet is designated for permanent storage ("Permanent Pool"), leaving approximately 56,000 acre-feet of water for use on the West Slope ("West Slope Pool"). Water stored in the West Slope Pool can be sold or leased by the BOR to water users in the Upper Colorado River Basin for any purpose. See Figure 2.8 for a view of the various designations of water storage in Ruedi Reservoir as well as existing uses and commitments.

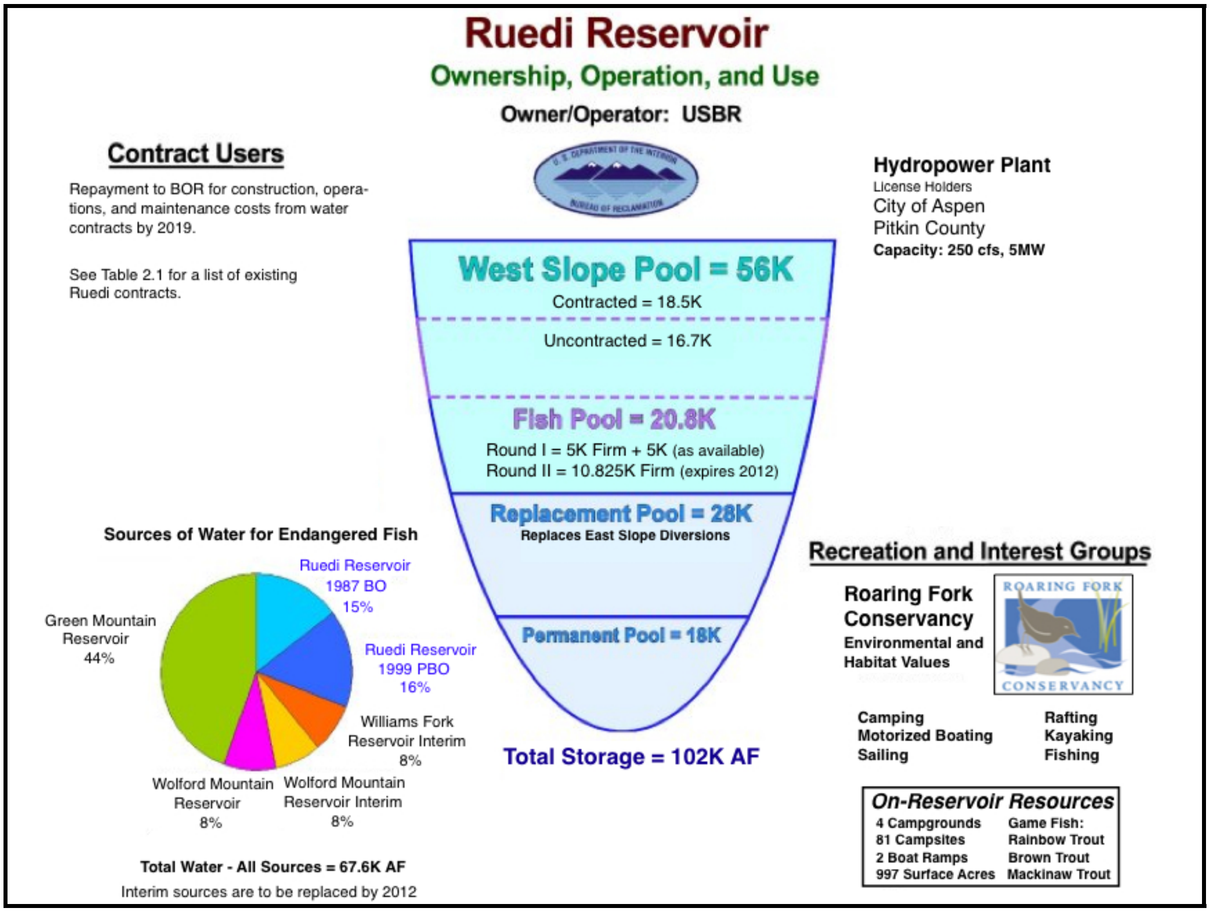


Figure 2.8. Ruedi Reservoir storage designations and uses. Source: adapted from River District diagram.

Ruedi Reservoir typically is operated to maximize control of spring runoff, accommodate recreational interests, and provide for downstream fishery requirements. Through releases to downstream endangered fish species and water contractors, the reservoir is typically drawn down during the fall and winter months, reaching a low point by March or April of the following spring. During the winter, release rates and drawdown targets are periodically adjusted as necessary to try and ensure a fill of the reservoir under anticipated runoff conditions. The reservoir is not normally drawn down to below the elevation of 7,706 feet (which corresponds to a storage volume of 53,000 acre-feet). Based on projections of the inflow to the reservoir, release rates are managed to achieve a fill during spring or early summer. Historically, the reservoir fills by late June or July. Once filled, the reservoir is operated as long as possible to enhance boating, angling, camping, and other reservoir uses.

The BOR has entered into a number of long-term (40 years) lease agreements for water in Ruedi Reservoir's "West Slope Pool." Many of these contracts are for augmentation purposes. Table 2.2 summarizes total contracts for water in Ruedi Reservoir as of December 2007. See Section 2.2.4 for a discussion of the possible ramifications of future water contracts from Ruedi Reservoir.

Table 2.2. Ruedi Reservoir contracts as of December 2007.

CONTRACTS	AMOUNT (acre-feet)
ROUND 1	
Basalt Water Conservancy District	500
Battlement Mesa Metro District	1,250
Exxon Company	6,000
West Divide Water Conservancy District	100
TOTAL	**7,850**
ROUND 2	
Thomas Bailey	35
Basalt Water Conservancy District	490
Town of Basalt	500
Town of Carbondale	250
Colorado River Conservation District	1,730
City of Glenwood Springs	500
Town of DeBeque	100
LPG-ONI Partnership	21
Mid Valley Metro District	300
Town of New Castle	400
Town of Parachute	75
City of Rifle	350
Ruedi Water and Power Authority	185
Starwood Metro District	43
Ted and Hilda Vaughn	15
West Divide Water Conservancy District	500
Westbank Ranch Homeowners Association	20
Wildcat Ranch Association	100
Crown Mountain Park and Recreation District	38
Colorado River Water Conservation District	5,000
TOTAL	**10,652**
COMBINED CONTRACTS	**18,502**

In addition to these contracts, as discussed in Section 2.1.2, Ruedi Reservoir supplies water for the Upper Colorado River Endangered Fish Recovery Program, supporting stream flows in the Colorado River's critical habitat area of the 15-Mile Reach.

The Fry-Ark Project Operating Principles specified the minimum streamflows in the Fryingpan River below the reservoir at 39 cfs or inflow to the reservoir, whichever is less from November through April, and 110 cfs or inflow, whichever is less, from May through October (CWCB and CDWR, 2007b).

See Section 4.7.3 for information on the Ruedi Reservoir Power Plant.

Independence Pass Transmountain Diversion System

The Twin Lakes Reservoir and Canal Company (Twin Lakes) has been diverting water from the headwaters of the Roaring Fork Watershed to the Arkansas River Basin since 1935. Twin Lakes' Independence Pass Transmountain Diversion System (IPTDS) includes diversions from the Upper Roaring Fork River, Lost Man Creek, New York Creek, Tabor Creek, and Brooklyn Gulch. Figure 2.6 shows the IPTDS facilities as well as instream flow rights within the Upper Roaring Fork Sub-watershed. Diverted water is collected in Grizzly Reservoir before being transported via Twin Lakes' Tunnel No. 1 to the Lake Creek drainage of the Arkansas River Basin (Figure 2.9). The tunnel is approximately 3.8 miles long and has an estimated capacity of 625 cfs. Twin Lakes is a private company whose stock is primarily owned by the water utilities of Colorado Springs and Pueblo.

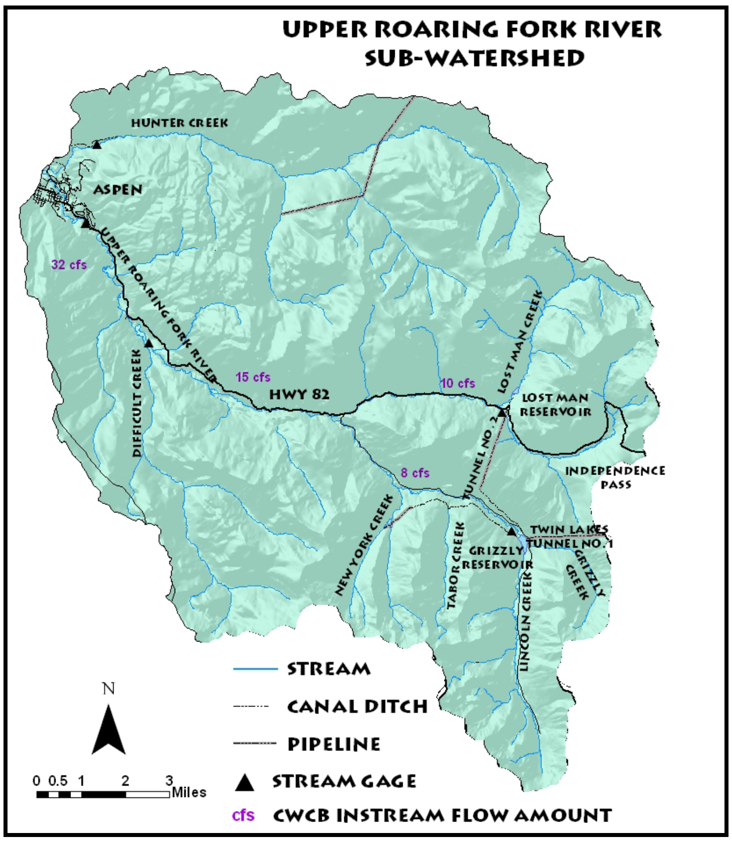


Figure 2.9. Independence Pass Transmountain Diversion System in the Roaring Fork Watershed.

Decreed before the value of instream flows was fully recognized, the water rights for the IPTDS do not include required minimum bypass flows at its diversion structures. See Appendix 2.6 for a description of the decreed water rights for the IPTDS. In a 1977 decree, which changed the use of the water rights, specific volumetric limitations were imposed on the Project diversions. First, the maximum diversion through Tunnel No. 1 cannot exceed 68,000 acre-feet in any one year; and second, diversions through Tunnel No. 1 cannot exceed a volume of 570,000 acre-feet in any consecutive 10-year period (an average annual diversion of 57,000 acre-feet per year)(CWCB and CDWR, 2007b). Typically, the IPTDS diverts about 38 percent of the native flow of the Roaring Fork River headwaters (calculated at the Roaring Fork at Aspen gage). Under normal operations, these diversions completely dewater Lost Man Creek year-round and the upper Roaring Fork River below the diversion structure for eight months of the year (October to June), unless they are called out by the Cameo Call.

Fry-Ark Project/Twin Lakes Exchange

In addition to the volumetric limitations on maximum annual and average diversions, the Fry-Ark Project/Twin Lakes Exchange was another provision included in the Fry-Ark Project Operating Principles intended to “mitigate” for water diverted from the upper Roaring Fork Watershed. Hunter Creek diversions occur with the condition that Twin Lakes bypass water it would otherwise be entitled to divert from the Roaring Fork Watershed. Water bypassed is replaced to Twin Lakes on the East Slope by water diverted by the Fry-Ark Project collection system.

As outlined in the Fry-Ark Project Operating Principles,
“An appropriate written contract may be made whereby Twin Lakes Reservoir and Canal Company shall refrain from diverting water whenever the natural flow of the Roaring Fork River and its tributaries shall be only sufficient to maintain a flow equal to or less than that required to maintain the recommended average flows in the Roaring Fork River immediately above its confluence with Difficult Creek in a quantity proportionate to the respective natural flow of the Roaring Fork River. The recommended average flows above mentioned are flows in quantities equal to those recommend as a minimum immediately above its confluence with Difficult Creek according to the following schedule submitted by the Unites States Fish and Wildlife Service and the Colorado Game and Fish Commission [reproduced as Table 2.3].

Table 2.3. Recommended average flows in the Roaring Fork River above its confluence with Difficult Creek.

MONTH	AVERAGE FLOW (cfs)	ACRE-FEET
October	44	2,700
November	35	2,100
December	29	1,800
January	26	1,600
February	25	1,400
March	24	1,500
April	64	3,800
May	100	6,200
June	120	7,100
July	100	6,200
August	63	3,900
September	44	2,600

In maintaining the above averages, at no times shall the flow be reduced below 15 cfs from August to April, inclusive, or below 60 cfs during the months of May to July, inclusive, providing the natural flow during said period is not less than these amounts."

Twin Lakes' bypass obligation is limited to "[the] quantity of replacement water [it] is furnished … without charge therefore through and by means of project diversions and storage." The obligation to supply the minimum streamflow specified in the above table is a Fry-Ark Project obligation, to the extent of 3,000 acre-feet of water per year, from "... waters diverted from the south tributaries of Hunter Creek, Lime Creek, Last Chance Creek, or any of them."

While the Operating Principles identify the flows in Table 2.3 as a recommended biological minimum, the actual flows in the Roaring Fork River, above the confluence with Difficult Creek, are generally far less due to legal reasons and natural flows. From a legal standpoint, Twin Lakes' bypass obligation is strictly limited to the amount of "replacement water" diverted by the Fry-Ark Project and delivered to Twin Lakes on the East Slope. And while the Operating Principles specifically state that the Fry-Ark Project is responsible for supplying water for the recommended minimum flows, this obligation is limited to 3,000 acre-feet of water per year.

If Twin Lakes stopped diverting, the natural flow still would often be insufficient to meet the recommended minimum flows. According to Grand River Consulting (2007), "...natural native stream flow is not adequate to meet the flow recommendations. If all upstream diversions were curtailed, the native flow of the Roaring Fork River would be about 5,700 acre feet short of the flow recommendations. Diversions by the Twin Lakes Project (in excess of the 3,000 acre feet bypass) contribute to about 4,500 acre feet of the monthly flow deficits."

Thus, given limitations to both the Fry-Ark/Twin Lakes Exchange and the area's natural flow, the Operating Principles' recommended "minimum" flows for the Roaring Fork River are rarely met.

The Fry-Ark/Twin Lakes Exchange has been operated each year from the early 1980s. Through 2003, it was operated informally by mutual consent of Twin Lakes, Southeastern, BOR, and the River District. From 1991 to 2002, the exchange amount averaged 1,880 acre feet per year. In 2004, Twin Lakes, the River District and Southeastern agreed to specific terms and conditions under which the exchange would operate for at least a 10-year period. Since the 2004 agreement, the River District, City of Aspen, Pitkin County, USFS, Twin Lakes, BOR, Southeastern, Roaring Fork Conservancy, The Nature Conservancy, and others have worked together to implement a biologically-based annual allocation of the 3,000 acre-feet within the confines of the existing infrastructure.

Under this collaborative arrangement, the 3,000 acre-feet that Twin Lakes bypasses are released according to a pre-determined schedule. The release is measured at two locations. One measurement is taken on the Roaring Fork River directly below the diversion dam for Twin Lakes Tunnel No. 2. Water from Lost Man Creek and the mainstem of the Roaring Fork pools above this dam before being transported through Tunnel No. 2 to Grizzly Reservoir. The second measurement is taken on Lincoln Creek directly below Grizzly Reservoir. Twin Lakes does not bypass water into Lost Man Creek, because there is no stream gage below the diversion point on Lost Man Creek. As a result, the stretch of Lost Man Creek from the diversion point for Twin Lakes to the confluence of the Roaring Fork River is generally dewatered year-round.

The Busk-Ivanhoe Project

The 9,394 foot-long Busk-Ivanhoe Tunnel (Figure 2.3) was a railroad tunnel that was converted to a highway and, since 1962, used for a transmountain diversion. In 1988 Aurora and Pueblo purchased the Busk-Ivanhoe Project. The Busk-Ivanhoe Project collects water from Ivanhoe Creek and historically has delivered it through the Busk-Ivanhoe Tunnel to Turquoise Reservoir. The water rights for the project are slightly senior to those of the Fry-Ark Project and are decreed for 120 cfs. The average annual diversion between 1974 and 1991 was 5,870 acre-feet per year, and the capacity of the Busk-Ivanhoe Tunnel is approximately 300 cfs (CWCB and CDWR, 2007b). However, due to the failure of several sections of the tunnel, the current capacity is limited to about 50 cfs through a 30-inch steel pipe installed on the floor of the tunnel. In order to make up for some of the lost capacity, Pueblo has contracted with BOR to take deliveries of a portion of the Busk-Ivanhoe Project diversions through the Boustead Tunnel. In addition, Aurora and Pueblo have contracted with the BOR for 10,000 acre-feet of storage in Turquoise Reservoir.

2.2 Water Quantity - Future Considerations

2.2.1 Water Law

Conditional Water Rights

Conditional water rights are granted under Colorado water law to provide a potential diverter with a priority date while he undertakes the physical and legal steps necessary to actually apply appropriated water to beneficial use, thereby making his claim of water rights absolute.

Conditional water rights are codified in Colorado Revised Statutes § 37-92-103(6). To acquire a conditional right, an applicant must be able to demonstrate the intent to appropriate water and undertake actions to support that intent (*Arapahoe Co. Bd. of Commrs. v. Upper Gunnison Water Conserv. Dist.,* 1992). Many conditional water rights were obtained in anticipation of water developments that have not occurred. However, because conditional rights can have priority dates senior to existing absolute junior rights, such conditional rights could adversely affect junior water-rights holders if they were to be developed. Thus, the actual development of existing conditional water rights could have a significant impact on future water management, both at a statewide and local level.

In the Roaring Fork Watershed, according to the 2006 Official Water Rights Tabulation for Division 5, there exist 330 conditional storage rights totaling 383,894 acre-feet and 780 conditional direct-flow rights totaling 3,940 cfs. The majority of the individual conditional rights are relatively small, either less than 1.0 cfs or 10 acre-feet. Tables 2.4 and 2.5 include information on the largest existing conditional direct-flow and storage rights in the watershed. Appendix 2.7 contains maps of the River District's conditional water rights for the Osgood Reservoir, Placita Reservoir, and Avalanche Canal projects; Yank Reservoir and Fourmile Canal projects; and West Divide Project.

Most of the conditional storage rights shown in Table 2.5 have been on the books since the 1950s. While these projects have not yet been built, these water rights have not been abandoned and the projects may become feasible in the future if circumstances change. They were often approved as part of a larger project that may not have been built out according to original plans. Of the list below, only Ruedi Reservoir was actually constructed.

Seventy-two percent of the conditional storage rights, or 275,737 acre-feet, are represented by only three projects: Osgood Reservoir and Placita Reservoir, both of which were adjudicated as part of the original West Divide Project, and Sweet Jessup Reservoir. Fifty-nine percent of the conditional, direct-flow rights are represented by power plants associated with the West Divide Project. These projects have been on the books since 1957, 1958 and 1968, respectively.

Table 2.4. Existing conditional direct-flow rights greater than 10 cfs in the Roaring Fork Watershed.

NAME OF STRUCTURE	SOURCE	CONDITIONAL (cfs)	ADMIN. NO.	OWNER	CASE NO.	WDID
West Divide Project - Osgood Power Plant	Crystal River	1000	39193	Colo. River Water Conservation Dist.	CA4613	381455
West Divide Project - Placita Power Plant	Crystal River	1000	39193	Colo. River Water Conservation Dist.	CA4613	381456
Basalt Project Conduit	Fryingpan River	446.091	39291	Basalt Water Conservancy Dist.	CA4613	38526
Ruedi Reservoir Power Plant	Fryingpan River	300	45950	Bureau of Reclamation	W2889	381360
Four Mile Canal	Thompson Creek	85	39617.36747	Colo. River Water Conservation Dist.	CA5884	381284
Basalt Project - Landis Canal	Fryingpan River	78	39291	Basalt Water Conservancy Dist.	CA4613	38809
Maroon Creek Plant & Diversion Dam	Maroon Creek	68.4	47481.42366	City of Aspen	80CW0564	381156
Indep. Pass TDS - Headgate No. 3	Lincoln Creek	61	45045	Twin Lakes Reservoir & Canal Co.	W1869	381766
Fry-Ark Project - Fryingpan Conduit	Fryingpan River	38	39291	Southeastern Colo. Water Conserv. Dist.	CA4613	381590
Indep. Pass TDS - Headgate No. 2	Lincoln Creek	35	45045	Twin Lakes Reservoir & Canal Co.	W1869	381765
Thompson Creek Pipeline	Thompson Creek	33	42719	Atlantic Richfield Co.	CA5884	381380
Basalt Project Stockmens Diversion	Roaring Fork River	30	39291	Basalt Water Conservancy Dist.	CA4613	381821
Indep. Pass TDS - Tunnel No. 2	Roaring Fork River	28	30941.29454	Twin Lakes Reservoir & Canal Co.	CA3082	381763
Indep. Pass TDS - Lost Man Diversion	Roaring Fork River	24	30941.29454	Twin Lakes Reservoir & Canal Co.	CA3082	381767
Indep. Pass TDS - Headgate No. 1	Lincoln Creek	20	30941.29454	Twin Lakes Reservoir & Canal Co.	W1869	381764
Indep. Pass TDS - Lincoln Connection Canal	Lincoln Creek	20	30941.29454	Twin Lakes Reservoir & Canal Co.	CA3082	381768
Pearson Ditch	Sopris Creek	20	37172	Sopris Mountain Ranch	CA4033	38932
Snowmass Divide Ditch	Snowmass Creek	20	42285	Juan Martinez	CA3082	381012
Brush Creek Hydro	Brush Creek	20	50038.4985	Robert L. Kopp	87CW0042	381567
Crane & Peebles Ditch	Roaring Fork River	20	52230.52045	Aspen Glen Corp.	93CW0192	38618
Glenwood Ditch	Roaring Fork River	20	52230.52045	Raymound Thompson	93CW0192	38712
Kaiser & Sievers Ditch	Crystal River	20	52230.52045	Aspen Glen Corp.	93CW0192	381347
Elk Creek Ditch	Snowmass Creek	18.71	23187.20939	Connie Harvey	CA1650	38650
Fry-Ark Project - Carter Creek Conduit	Carter Creek	17	39291	Southeastern Colo. Water Conserv. Dist.	CA4613	381585
Seventh Street Diversion Structure	Roaring Fork River	15	52595.50891	City of Glenwood Springs	94CW0358	381227
Glenwood South Diversion Structure	Roaring Fork River	15	52595.50891	City of Glenwood Springs	94CW0358	381230
West Three Mile Alternate 1	Three Mile Creek	14.4	51324	Bill Porter	90CW0338	381947
Thomson Creek Feeder Ditch - Headgate 1	Thompson Creek	12	37124	John Boulton	CA4033	381771
Fry-Ark Project - No Name Creek Conduit	No Name Creek	10	39291	Southeastern Colo. Water Conserv. Dist.	CA4613	381608
John Cerise Ditch	Roaring Fork River	10	53306	Reno Cerise	95CW0356	38784
RFC Ditch	Roaring Fork River	10	53306	Roaring Fork Club, L.P.	95CW0356	381541
Southard and Cavanaugh Ditch	Crystal River	10	54380	Aspen Glen Corp.	98CW0310	381018
Kaiser and Sievers Ditch	Crystal River	10	54380	Aspen Glen Corp.	98CW0310	381147

Note: According to Bill Blakeslee (CDWR, Division 5, Water Commissioner, personal communication, May 5, 2008) Pearson Ditch reduced its decree to 2 cfs in 2007. It diverts from Dry Creek a tributary to West Sopris Creek.

Table 2.5. Existing conditional storage rights greater than 1,000 acre-feet in the Roaring Fork Watershed.

Name of Structure	Source	Conditional (af)	Admin. No.	Original Applicant
West Divide Project - Osgood Reservoir	Crystal River	128,728	39193	Colo. River Water Conservation District
Sweet Jessup Reservoir	Thompson Creek	85,000	43274	Crystal River Ranch Co.
West Divide Project - Placita Reservoir	Crystal River	62,009	39193	Colo. River Water Conservation District
Ruedi Reservoir	Fryingpan River	31,514	47869	Colo. River Water Conservation District
Thompson Creek Reservoir	Thompson Creek	23,893	42719	Atlantic Richfield Co.
Yank Creek Reservoir	Yank Creek	13,695	39617.36747	Colo. River Water Conservation District
Yank Creek Reservoir	Yank Creek	12,303	47880	Colo. River Water Conservation District
Castle Creek Reservoir	Castle Creek	9,062	42203	City of Aspen
Maroon Creek Reservoir	Maroon Creek	4,567	42203	City of Aspen
Snowmass Reservoir	Brush Creek	4,118.7	42097	Snowmass American Corp.
Upper Chapman Reservoir	Fryingpan River	2448.8	41895	Colo. Game, Fish and Parks Commission
Coke Oven Reservoir	Fryingpan River	1009.04	39617.38636	Colo. Game, Fish and Parks Commission

2.2.2 Water Management Agreements and Policies

10,825 Alternatives for the Endangered Fish Recovery Program

As introduced in Section 2.1.2, four warm water fish species that inhabit the lower reaches of the Colorado River Basin in western Colorado have been listed as endangered under the federal ESA. East Slope and West Slope water providers in the Upper Colorado River Basin have committed to permanently supply 10,825 acre-feet of water per year (also known as "10,825 water") to assist with the recovery of the endangered fish. This water is supplied to the 15-Mile Reach of the Colorado River near Grand Junction during the late summer months and into the early fall. During this time of year, the stream flow of the Colorado River within the 15-Mile Reach is substantially impacted by upstream water diversions, and the supplemental 10,825 water is beneficial to the endangered fish recovery program.

The commitment to provide 10,825 water is divided equally between East Slope and West Slope water providers, with each responsible to supply 5,412.5 acre-feet per year on a permanent basis. Currently, the 10,825 water is provided on a temporary basis by Denver Water (from Williams Fork Reservoir) and by the River District (from Wolford Mountain Reservoir). The water providers must have permanent agreements in place that identify the permanent source of the 10,825 water by December 2009 (GEI Consultants, Inc., 2007).

The East and West Slope water providers have agreed to analyze and compare a wide range of alternatives to meet their obligations to provide summer and fall flow enhancements to the 15-Mile Reach on a permanent basis. The 10,825 Water Supply Study will develop and assess these cooperative alternatives. The study is being managed by Grand River Consulting Corporation and is directed by a steering committee made up of a broad coalition of water providers who use water from the Colorado River Basin and other interested stakeholders (GEI Consultants, Inc., 2007).

Colorado River Compact – An Uncertain Future

On December 9, 2007, facing the worst drought in a century and the threat of global climate change, the seven Colorado River Basin states reached a new pact on how to allocate water in times of shortage. The new accord, which will be in effect through 2026, defines how the three Lower Basin states, California, Arizona and Nevada, will share the impact of water shortages. The agreement also puts in place new measures to encourage conservation and management of Lake Powell and Lake Mead.

The agreement establishes criteria for the U.S. Department of the Interior to declare a shortage on the river, in which case water deliveries to the Lower Basin states would be decreased based on how much water levels drop in Lake Mead and Lake Powell (BOR, 2007a). The impacts on the Roaring Fork Watershed of future Upper Basin delivery shortages under the 1922 Colorado River Compact are unclear.

2.2.3 Structural Projects under Consideration

Preferred Storage Options Plan (PSOP)

In 2000, the Southeastern Colorado Water Conservancy District (Southeastern) developed the Preferred Storage Options Plan (PSOP) in response to an identified need for additional water storage capacity in the Arkansas River Basin. After considering more than 30 different alternatives, the study concluded that the projected storage demand would best be met through the modified use and expansion of existing Fry-Ark Project facilities. Specifically, PSOP proposes major revisions to the Operating Principles of the Fry-Ark Project and a feasibility study for enlarging storage in Turquoise and Pueblo reservoirs (Phase I).

Phase I of PSOP involves re-operation of the Fry-Ark Project in order to permit the storage of "non-Project" water in Fry-Ark Project storage space. Re-operation does not require any structural modifications to Fry-Ark Project storage facilities; rather, PSOP proposes modifying the operating principles of Fry-Ark Project reservoirs on the East Slope to allow non-Project storage in the Project facilities when there is surplus storage space.

Under the proposed re-operation, 48,500 acre-feet of the total 305,325 acre-feet of active Project storage space would become long-term contract space, available for contracting with BOR. Since this space could be used to store either Project or non-Project water, this change would facilitate the transfer and exchange of existing water supplies. Re-operation may thus allow entities within the Arkansas River Basin to use Project storage to help maximize the yield of their non-Project water rights. However, since non-Project water stored in the Project's reservoirs will be "junior water" and BOR's contracts for storage space will be "if and when" contracts, storage space and carry over storage will not be assured annually. This limitation may reduce the reliable yield and therefore utility of these contracts to water users.

Phase I of PSOP also calls for Congressional authorization of a feasibility study of additional storage capacity, first at Pueblo Reservoir and then at Turquoise Reservoir. Specifically, Southeastern proposes examining enlargement of Pueblo Reservoir by approximately 54,000 acre-feet and Turquoise Reservoir by 19,600 acre-feet. Pueblo and Turquoise reservoirs were selected for expansion because these two reservoirs, compared to the other possible storage solutions, offer the greatest degree of operational flexibility and storage efficiency.

If expansions of Turquoise and Pueblo reservoirs occur as a result of Phase I studies and subsequent approvals, additional water from the Roaring Fork Watershed may be able to be diverted under existing Fry-Ark Project authorizations. How increased storage capacity on the Front Range could affect the watershed is a matter of debate. The final PSOP report emphasizes that no plan exists to increase West Slope Fry-Ark Project diversions beyond those permitted under the Project's existing water rights. Supporters of the plan also say the additional Fry-Ark Project water could only be taken when snowpack is at or above average and there is "surplus" water available during runoff. The argument has also been made that new storage would facilitate the ability to make water transfers from agricultural to municipal use, which may be important for reducing Front Range demand for more Western Slope water. Opponents fear that PSOP would allow increased diversions by the Fry-Ark Project and Twin Lakes. Additionally, there is concern that taking water in "surplus" water years will deprive the upper Roaring Fork Watershed of beneficial "flushing flows." Aspen and Pitkin County have repeatedly opposed this legislation (Condon, 2005).

Regardless of questions about the PSOP proponents' intentions, the Fry-Ark Project may already be diverting all of the physically available water in most years, given existing diversion facilities and legal limitations. Specifically, under the Fry-Ark Project's Operating Principles, annual Fry-Ark Project diversions cannot exceed 120,000 acre-feet in any one year, and aggregate diversions in any consecutive 34-year period cannot exceed 2,352,800 acre-feet, which is equivalent to an average annual diversion of 69,200 acre-feet. Yet Fry-Ark Project diversions rarely approach either limitation. With the minimum bypass requirements on individual streams, the Fry-Ark Project has historically diverted, on average, only 51,000 acre-feet of water per year in Project water. Since diversions began in 1972, only once has the Fry-Ark Project diverted more than 100,000 acre-feet. This occurred in 1984 when 110,120 acre-feet were diverted. And Project diversions have exceeded 69,200 acre-feet in only seven of the 35 years of operations (BOR, 2007b). Thus, even though enlarging Turquoise and Pueblo reservoirs might technically permit additional Project diversions, the water for such additional diversions may only be available in years when the snowpack is well above average.

As for the IPTDS, as noted earlier in this chapter, since 1977 annual transmountain diversions have been legally limited to no more than 68,000 acre-feet in any one year, and no more than 570,000 acre-feet in any consecutive 10-year period (CWCB and CDWR, 2007b). Since that time, annual diversions have averaged only 39,292 acre-feet, and only twice have annual diversions exceeded 60,000 acre-feet − in 1983 and 1993 (60,451 acre-feet and 62,656 acre-feet, respectively). The largest volume of water diverted in any consecutive 10-year period was 417,438 acre-feet − between 1989 and 1998.

While the diversion records for both the Fry-Ark Project and the IPTDS suggest that neither Project is diverting its respective legal limits, the diversion records do not indicate whether this is due to natural limitations on the water supply on the West Slope, insufficient storage on the East Slope, or possibly some combination of these factors. A comparison of the annual diversion records for both projects with the annual runoff in the Roaring Fork Watershed provides some insight into some of the factors that restrict these diversions.

Historical flow data for the stream gage on the Roaring Fork River at Glenwood Springs, dating back to 1972, indicate an average flow of 1,187 cfs, with the two highest average flows occurring in 1984 (2,092 cfs) and 1995 (1,969 cfs). In 1984 the Fry-Ark Project diverted 110,120 acre-feet of water through the Boustead Tunnel, the largest annual diversion to date. That same year, the IPTDS diverted only 8,790 acre-feet of water through Tunnel No. 1, the smallest annual diversion to date. The records from 1995 are similar. That year, the Fry-Ark Project diverted 90,500 acre-feet of water, the second-largest annual diversion on record. Conversely, the IPTDS diversions were well below average, totaling 32,218 acre-feet. Based on this comparison, it appears that the Fry-Ark Project is limited by the natural water supplies on the West Slope, whereas the IPTDS may be constrained by demand or storage capacity on the East Slope.

Colorado River Return/Big Straw

In late 2002, the CWCB agreed to ask the General Assembly for authorization to study a proposal to pump water back from below Grand Junction up the I-70 corridor to the Front Range. This proposed project has commonly been referred to as the Colorado River Return Project or "Big Straw."

The Big Straw study was completed by the end of 2003 and is still being considered by the SWSI Gap Committee. This project would pump or return water from the Colorado River near the Utah border for upstream uses in the South Platte, Arkansas, and Colorado River basins. The study evaluated three potential corridors (North, Central, and South), five potential pipeline alignments (one in the North Corridor, two in the Central Corridor, and two in the South Corridor), and three levels of diversions (250,000 acre-feet per year, 500,000 acre-feet per year, and 750,000 acre-feet per year). The three potential corridors include the North Corridor, which traverses the

White/Yampa River Basin; the Central Corridor – of most interest to the Roaring Fork Valley – which extends up the Colorado River mainstem and its upper basin tributaries; and the Southern Corridor, which traverses the Gunnison River Basin.

The potential impact of the 1922 Colorado River Compact regarding the project and the future availability of water at both a state and local level will be clarified by the Colorado River Availability Study discussed in Section 2.1.2.

Ruedi Pumpback

Another alternative to increase the delivery of West Slope water to the East Slope is a proposal to pump back water from Ruedi Reservoir for delivery to the Arkansas River Basin via the Boustead Tunnel. The proponents of this proposal are the cities of Aurora and Colorado Springs (Enartech and GEI, 1999). The River District supported studying a pumpback as an alternative to the development of Homestake Partners' water rights in the Eagle River Watershed (Don Meyer, River District, personal communication, September 2, 2008).

According to this proposal, significant Ruedi Reservoir releases currently occur during the winter baseflow period to evacuate storage space in anticipation of the next snowmelt runoff. The winter releases are not delivered to contracted water users and are not generally applied to beneficial use within the state of Colorado. The pumpback project would only divert a portion of these winter reservoir releases. It is anticipated that the proposed project would divert an average of 20,000 acre-feet per year with an annual minimum of 10,000 acre-feet and maximum of 24,000 acre-feet. According to the feasibility assessment, "the most significant environmental issue associated with the pumpback project may relate to changes in stream flow below Ruedi Reservoir. The project would reduce winter stream flow of the Fryingpan River by an average of about 50 cfs which could increase the formation of anchor ice (Miller Ecological Consultants, Inc., 2006). Winter discharge of the Roaring Fork River below Basalt would be reduced by about 10 percent. Baseflow discharge of the Colorado River would be reduced about 3 percent." As with the Big Straw, the outstanding question of how the 1922 Colorado River Compact would affect the project's viability is meant to be clarified by the Colorado River Availability Study (see Section 2.1.2).

2.2.4 Future Water Demands

Oil Shale Development

Within Colorado, commercial oil shale development is being considered for the Piceance Basin in the northwestern part of the state. Conservationists have called on the energy industry to disclose fully to West Slope residents and governments how oil shale development will impact water supplies and water quality (Western Resource Advocates, 2007). Two studies have attempted to quantify the amount of water that would be used for oil shale production. A 2005 study by the Rand Corporation estimated that oil shale operations require approximately three barrels of water per barrel of oil produced (Bartis et al., 2005). A study by the Los Alamos National Laboratory on the White River in Colorado estimated that a storage volume of 15,500 acre-feet is needed to sustain production of 500,000 barrels of oil per day (see the following Water Research Institute weblink: http://wrri.nmsu.edu/publish/sympabs/posters2006.pdf, page E-32).

Ruedi Uncontracted Water

There is approximately 16,700 acre-feet of uncontracted water remaining in Ruedi Reservoir, which may increase by 10,825 acre-feet in the year 2012 when the BOR's current agreement to augment flows in the 15-Mile Reach for the Endangered Fish Recovery Program expires. This water is currently available for long-term lease to West Slope customers. The price of this water was approximately $1,120 per acre-foot as of July 2007, and will increase in 2008 (Terry Gomoll, BOR, personal communication, November 15, 2007).

Ruedi Reservoir's future value as a recreational and environmental resource will be dependent on who purchases this water and how and when it gets delivered to those purchasers. If, for instance, water is delivered in large amounts over a short period of time, the availability of the reservoir and the Fryingpan River for recreational use could be significantly diminished. Impacts of releases on instream and riparian habitat are less certain but could be detrimental, depending on specific circumstances.

To put this into perspective, only a few thousand acre-feet of contract water is currently released to the Fryingpan River. Under full contracting and with an actual demand for water by all contract users, as much as 46,500 acre-feet of contract water could be released in a given year. If, for instance, all the available water is contracted and released, this would drastically change the existing hydrology of the Fryingpan River. Thus, the development of additional water demand in the Colorado Basin (e.g., oil shale) is of particular importance to future water management in the Roaring Fork Watershed.

3. Water Topic Overview

Within the Roaring Fork Watershed, the topics of water quantity, water quality, and riparian and instream areas are of extreme interest both from a human and broader environmental perspective. Their importance can be demonstrated by the fact that they each have been targeted during the past several years by well-supported initiatives including the Roaring Fork Conservancy Stream Flow Survey Project (Clarke, 2006), Water Quality Retrospective Study (U.S.Geological Survey), Stream Health Initiative (Malone and Emerick, 2007a), Measures of Conservation Success (The Nature Conservancy, 2008), the Hydrologic Systems Analysis studies carried out in Pitkin County (Kolm and van der Heijde, 2006 and Kolm et al., 2007), and Climate Change and Aspen: An Assessment of Impacts and Potential Responses (Aspen Global Change Institute, 2006). These data sources and assessments along with other available information provide a detailed view of the condition of water quantity and quality, and riparian and instream areas throughout much of the Roaring Fork Watershed. For each of these four topics, the following pages discuss data sources and assessments, data and knowledge gaps, and functions and value, along with factors that affect them. Chapter 4 provides a discussion of each of these topics for the nine sub-watersheds.

3.1 Water Quantity

Major consequences can arise from not having enough water in a stream. These consequences are often highly visible, such as water rights not being met, a dewatered stream reach (Figure 3.1.1), or, in extreme cases, dying fish. Flood flows that exceed streambed capacity can also have noticeable consequences, like threats to human safety and property. These flows also have benefits, because they maintain healthy creeks and riparian areas, recharge the groundwater that contributes to stream base flow, and provide water for wells. According to a 2007 Pitkin County Community Survey, 94 percent of all homeowners said that maintaining good stream flows for aesthetic purposes, recreation, and support of fish and wildlife was beneficial (http://www.surveyco.org/Pitkinpdf/2007PitkinCountySpreadsheetsp.pdf).

Figure 3.1.1 Lower Crystal River, September 2, 2004.

This section discusses existing water quantity information for the watershed, ranging from water availability, especially in streams, to the watershed's various water demands. Little reference is made to groundwater in this section because of the lack of information available about specific groundwater tables, aquifers, and connections with surface water. Information about groundwater resources specific to a particular sub-watershed is presented in Chapter 4.

As general background, snowpack in Colorado provides approximately 75 percent of streamflow and therefore a large portion of the water supply (http://waterknowledge.colostate.edu/). Most of Colorado's snow falls on its western mountain ranges. In winter, when moisture-laden Pacific air masses moving eastward encounter the Rockies, the air mass is forced to rise, causing it to cool and leading to moisture falling as snow on the state's West Slope. As the Pacific air mass passes over the East Slope, it descends, warms, and the relative humidity decreases thereby making precipitation less likely (Mutel and Emerick, 1992).

This climate-induced pattern of snowpack distribution has consequences for the condition of headwater streams in Colorado and – because stream ecosystems are longitudinally linked – also for larger downstream reaches. Although most of Colorado's water is on the West Slope, most of the state's population and agricultural production occurs on the East Slope where low precipitation results in semi-arid climate conditions. Many headwater streams on the west side of the Continental Divide have been diverted to the East Slope to support its agriculture and development, often reducing West Slope stream flows below what is necessary to sustain aquatic wildlife. Thus the lack of congruence between the location of the state's natural precipitation and its agriculture and population starkly points out tradeoffs associated with the development and distribution of its water.

3.1.1 Data Sources, Assessments, and Tools

A variety of sources provide information about stream flows, diversions, water rights, instream flows, groundwater wells, climate, and flooding. These sources are described below. Chapter 4 contains maps of diversions coded by diversion amount, Colorado Water Conservation Board instream flows, stream gages, wells, and climate stations within each sub-watershed. Extensive work has been done using stream flow and diversion data to model stream flows in a more comprehensive way through time across the watershed. Two assessment projects, USGS Aggregate Water-Use Data System (USGS, No date) and Statewide Water Supply Initiative (CDM, 2004) have examined historic, current, and projected water withdrawals. Finally, software tools are available to analyze surface flows, and methods have been proposed to determine environmental responses to changes in stream flow patterns. The ultimate goal of these analysis tools is to facilitate management of water resources for environmental, political, and social needs.

Stream Gages

In the Roaring Fork Watershed, stream gages (including transmountain diversion and reservoir gages) are operated by the U. S. Geological Survey (USGS), Colorado Division of Water Resources (CDWR), and U.S. Bureau of Reclamation (BOR) (http://waterdata.usgs.gov/co/nwis/nwis; www.dwr.state.co.us/SurfaceWater/default.aspx, and http://www.usbr.gov/gp/hydromet/). Although historically 81 stream gages have been in the watershed, only 26 currently collect real-time data. Maps in each of the sub-watershed sections within Chapter 4 show gage locations, and Appendix 3.1.1 provides a listing of the gages. The Roaring Fork Conservancy website provides links to all currently operating stream gages in the watershed (http://www.roaringfork.org/sitepages/pid41.php).

Water Rights and Diversions

The CDWR and Colorado Water Conservation Board (CWCB) have developed the Colorado Decision Support Systems Structure Data Selector to access statewide diversion data (http://cdss.state.co.us/DNN/ViewData/StructuresDiversions/tabid/75/Default.aspx). A web-based search for the Roaring Fork Watershed (Division 5, District 38) can be refined to a specific structure type. Searches can be made by structure name, structure identity, source, legal location, decreed amounts, owner name, or case number. However, owner name may not indicate current ownership because the database is not updated when ownership changes. Search results are available onscreen and in several output formats. This tool also provides diversion records and structure summaries. A companion water rights data selector (http://cdss.state.co.us/DNN/WaterRights/tabid/76/Default.aspx) can be searched by water right name, case number, source, priority number, legal location, use, decreed amount, and structure identity. Official Water Rights Tabulations are available online (http://water.state.co.us/pubs/tabulation.asp). These tabulations list the current status of decreed water rights in order of seniority. The current status is represented by the net amounts of absolute and conditional water rights, along with alternate points of diversions and exchanges. Net amounts are computed and reported by structure and priority date.

Instream Flow and Natural Lake Level Data

The CWCB maintains both a searchable instream flow and natural lake level water rights database (http://cwcb.state.co.us/Streamandlake/Database/). Instream flow and natural lake tabulations are also available by water division (http://cwcb.state.co.us/Streamandlake/Database/Downloads/Div5IsfTab+Appendix.pdf and http://cwcb.state.co.us/Streamandlake/Database/Downloads/Div5LakesTab.pdf). Chapter 4 sub-watershed maps show locations of instream flow reaches that fall under the CWCB's jurisdiction and Appendix 2.2 and Appendix 2.3 contain instream flow and natural lake tabulations for the entire watershed. A map viewer can be used to locate and construct a custom map of instream flow water rights (http://cdss.state.co.us/DNN/MapViewer/tabid/62/Default.aspx).

Climate Stations

The CWCB maintains a searchable climate database (http://cdss.state.co.us/DNN/ViewData/ClimateData/tabid/61/Default.aspx). Data on precipitation, temperature, snow depth, evaporation, and frost dates are found in this database. It also includes historical information for the six SNOTEL (snowpack telemetry) sites in the watershed. At the SNOTEL sites, snow pillows are used to measure weight of the snow, which is converted to the snow's water equivalent − that is, the actual amount of water in a given volume of snow (SCS, 1994). The amount of snow and timing and rate of melting influence not only water quantity, but also water quality and riparian and instream areas. The Roaring Fork Conservancy website provides links to all currently operating SNOTEL sites in the watershed (http://www.roaringfork.org/sitepages/pid147.php). Maps showing climate station locations for each sub-watershed are located in Chapter 4. Appendix 1.2 provides information on all climate stations in the watershed. Additional data exists in some sub-watersheds for sites associated with the Colorado Collaborative Rain, Hail, and Snow Network (these sites are also listed in Appendix 1.2) (http://www.cocorahs.org/). These data, collected by a volunteer network, are best used for assessing daily conditions. Because of the number of data gaps, they are of limited use in looking at trends and summarizing historical conditions.

Flood Potential

Maps issued by the Federal Emergency Management Agency are available online for viewing with a map viewer (http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1) or hard copies can be purchased (maps are not available digitally for the watershed). These maps show areas within the 100- and 500-year floodplains. The National Weather Service has an Advanced Hydrologic Prediction Service (AHPS) (http://www.crh.noaa.gov/ahps2/index.php?wfo=gjt) that displays information for Aspen, Thomasville, Redstone, and Glenwood Springs. AHPS forecasts the chances and severity of flooding and uses hydrographs to forecast the level to which a river will rise and when it is likely to reach its peak.

The Roaring Fork and Fryingpan Rivers Multi-Objective Planning Project (BRW Inc. et al., 1999) identified areas of high flood hazards on the Roaring Fork River downstream of Aspen and on the Fryingpan River below Ruedi Reservoir.

The Upper Colorado River Basin Water Resource Planning Model

The Upper Colorado River Basin Water Resource Planning Model dataset (2007) was developed by the CWCB and CDWR under the Colorado Decision Support System (CDSS). The model is built with streams, gaging stations, diversions, water rights, and reservoir operation data. The advantage of using this system is that the relationships and model already have been built. Within the model, stream gage and water diversion data are linked together. Overall, StateMod consists of four major components: Base Flow Module, Simulation Module, Report Module, and Data Check Module. The Base Flow Module produces a set of monthly stream flows for the water years 1909 through 2005 (a water year runs from October through September of the following year), and daily stream flows for the water years 1975 through 2005 that would have occurred without human development such as diversions and dams. For this report, these are called “pre-developed” stream flows. The Simulation Module operates the river system and accounts for inflows, river gains, diversions, instream flows, well-pumping, and reservoir operations through time – referred to as “historical conditions.” Combining these two modules by taking the current depletions and applying them to the pre-developed flow record results in a third modeled output, referred to in this report as “developed” stream flow conditions. The goal of this model was to represent 75 percent of the decreed water rights in the Colorado River Basin. To achieve 75 percent representation, diversions greater than 11 cubic feet per second were initially selected for use in the modeling. Current information from the Division Engineer’s Office was used to add or remove diversions. The state developed the model in order to make comparisons of historical and future water management policies.

Water Withdrawal Assessments

The USGS Aggregate Water-Use Data System (AWUDS) (USGS No Date) has estimated historical water withdrawals for the categories of public supply, self-supplied domestic, industrial, and irrigation. Since 1950 these assessments have been done every five years at the county level throughout the United States. In 1985 the USGS began storing its water use data, now available to the year 2000 at http://water.usgs.gov/watuse.

As noted in Section 2.1.2, Phase I of the Statewide Water Supply Initiative (SWSI) compiled information about projected future water supplies and needs (CDM, 2004). Appendix E of the SWSI report contains statewide municipal and industrial water demand projections (Davis et al., 2004). Information specific to the Colorado Basin was compiled in a separate report, "Water Supply and Needs Report for the Colorado River Basin" (CDM, 2006).

Non-Consumptive Use Information

As a follow-up to Phase I of SWSI, an environmental and recreational technical roundtable was formed to further identify and quantify non-consumptive water needs. The roundtable mapped environmental and recreational attributes to help basins prioritize key river and wetland resources and identified approaches for quantifying environmental and recreational flows (CDM, 2007a). Data, concepts, and approaches identified by this technical roundtable form the cornerstone of the ongoing Statewide Non-consumptive Needs Assessment (NCNA), originally set up through the state's Inter-basin Compact Commission process. Each basin roundtable is charged with developing a basin-wide consumptive and non-consumptive needs assessment. As part of its outreach, the Roaring Fork Watershed Plan is coordinating with both the Statewide and Colorado Basin Roundtable NCNA committees to track progress and methods, share ideas, and ensure that this report is used to inform the NCNA.

The NCNA is taking a two-pronged approach (CDNR, 2007). The first prong is to prioritize stream reaches by identifying the attributes at risk (e.g. geomorphic, aquatic ecological, and riparian/wetland ecological functions; water quality; and recreational boating) and reaches where these attributes should be addressed. The other component is flow quantification using a site-specific approach for a few sites and the Watershed Flow Evaluation Tool (WFET) for selected pilot watersheds, including the Roaring Fork Watershed. The WFET will provide explicit information on the relationship of selected attributes to flow components and provide a measure of risk of losing the attribute under varying hydrologic status. The condition or risk of loss can be mapped across a watershed (John Sanderson, The Nature Conservancy, personal communication, June 6, 2008). For a theoretical, snowmelt-driven river system, Figure 3.1.2 shows how recommended flows thought necessary to sustain ecological function, physical processes, and associated recreational use could be graphed.

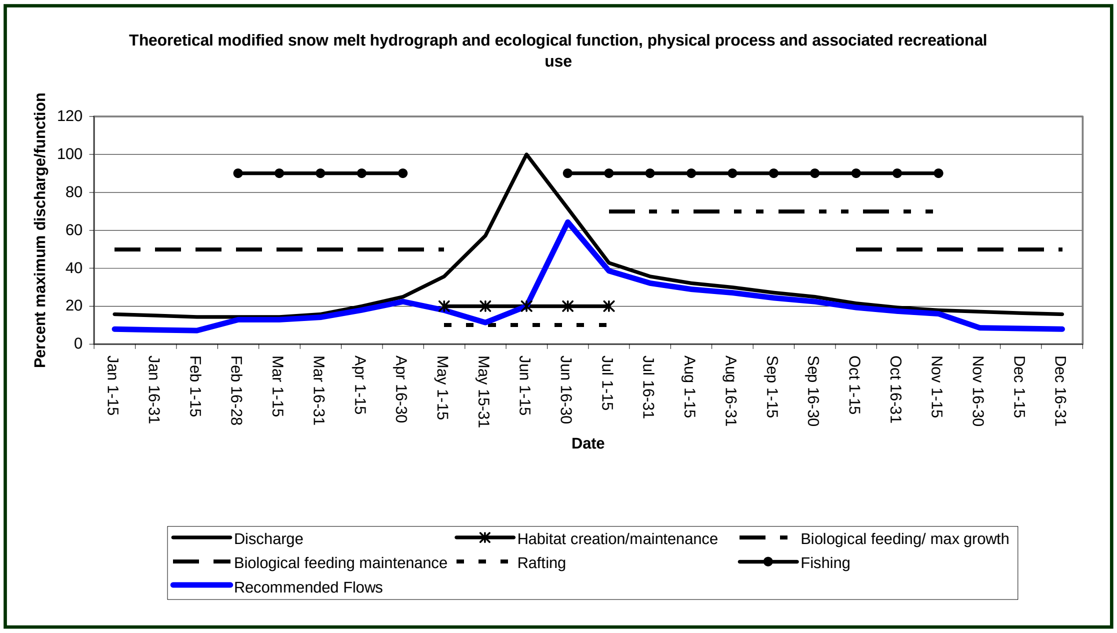


Figure 3.1.2. Recommended biological and recreational flows within a theoretical, modified snowmelt system (flow amount would be the percentage multiplied by the discharge). (Source: Bill Miller, Miller Ecological Consultants, personal communication, May 13, 2008).

In the other component of the NCNA, the set of environmental and recreational attributes determined in SWSI's Phase II have been refined, expanded, and used to establish priorities. Both the templates and identified priorities can then be applied to select which streams should be targeted for site-specific quantification and to guide the following implementation objectives:

- Encourage water suppliers to consider this information when planning their projects and processes.
- Identify projects and processes to meet these needs.
- Identify additions to processes or projects developed for other needs that might also meet the non-consumptive needs.
- Identify and assist in securing funding for such projects and processes.
- Ensure development and implementation of sufficient projects and processes to meet these non-consumptive needs.

In addition to the above-described approach, analysis of modeled stream flow data can be used for the NCNA. The Stream Flow Survey Study (Clarke, 2006) compared modeled pre-developed and developed CDSS monthly flow data in the Roaring Fork Watershed to provide a broad-scale assessment of changes in monthly stream flow. Results show where and when the greatest changes in the natural hydrograph occur. For this report, recent modeling of daily pre-developed and developed flows from 1975-2005 (CWCB and CDWR, 2007a) allowed completion of a more current assessment of daily stream flow alteration using The Nature Conservancy's Indicator of Hydrologic Alteration (IHA) software. The locations of the CDSS modeled stream flow nodes[1] within each sub-watershed are found on maps within the sub-watershed sections in

[1] The term "node" is used to denote a physical location where developed and pre-developed flows were simulated.

Chapter 4. Percent alteration and statistical significance[2] was calculated for flow parameters representing all five hydrological components: magnitude, duration, timing, frequency, and rate of change (Appendix 3.1.2). The average frequency of small and large floods for pre-developed and developed flows was also calculated using the IHA (Appendix 3.1.2). Figures 3.1.4 – 3.1.6 are maps of the watershed showing flow alteration, represented by a histogram for each node. Figure 3.1.3 explains how to interpret the maps using two example histograms representing monthly percent flow alteration. This analysis and the Stream Flow Survey Study results are discussed for each sub-watershed in Chapter 4. The pre-developed data will be useful for developing the NCNA model hydrographs. The developed data can be compared to the NCNA templates to identify where flows may not meet the needs of specific ecological functions and/or recreational activities. This analysis will be an important next step in the development of objectives and recommended actions for Phase II of the Roaring Fork Watershed Plan.

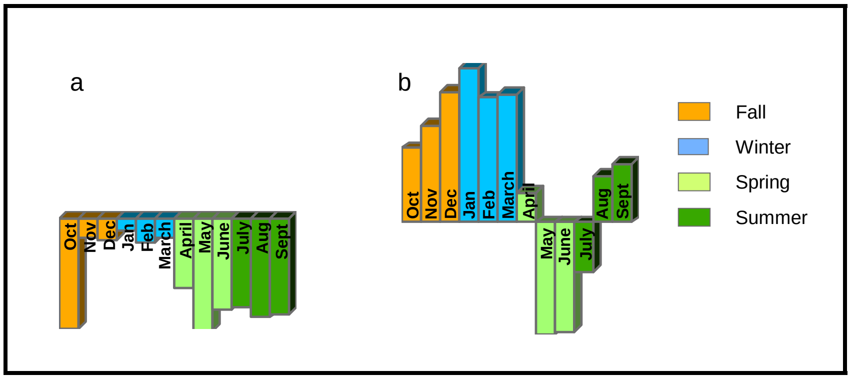


Figure 3.1.3. Example histograms showing monthly percent flow alteration. In Figure 3.1.3.a, developed flows are lower than pre-developed flows throughout the year, with the greatest percent flow alteration in the spring, summer, and early fall (April-October). In Figure 3.1.3.b, developed flows are higher than pre-developed flows in the late summer, fall, winter, and early spring (August-April), and are lower during peak runoff months (May, June, and July).

[2] The Kruskal-Wallis non-parametric test was used to test the assumption that the median values were equal. If the P-value was less than .05, the hypothesis for the assumption that pre-developed and developed medians were the same was rejected.

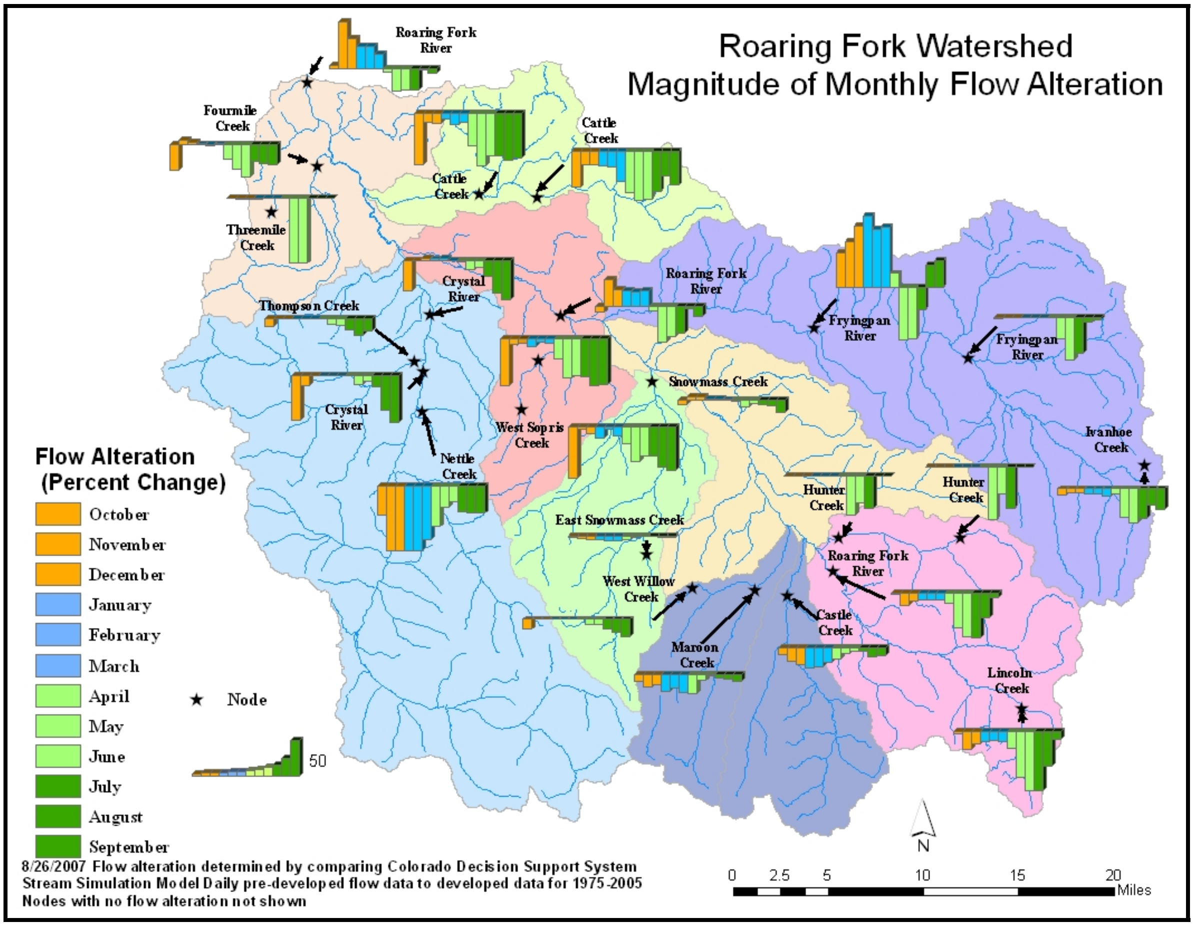


Figure 3.1.4. Magnitude of monthly flow alteration: developed flow compared to pre-developed flow conditions for streams throughout the Roaring Fork Watershed.

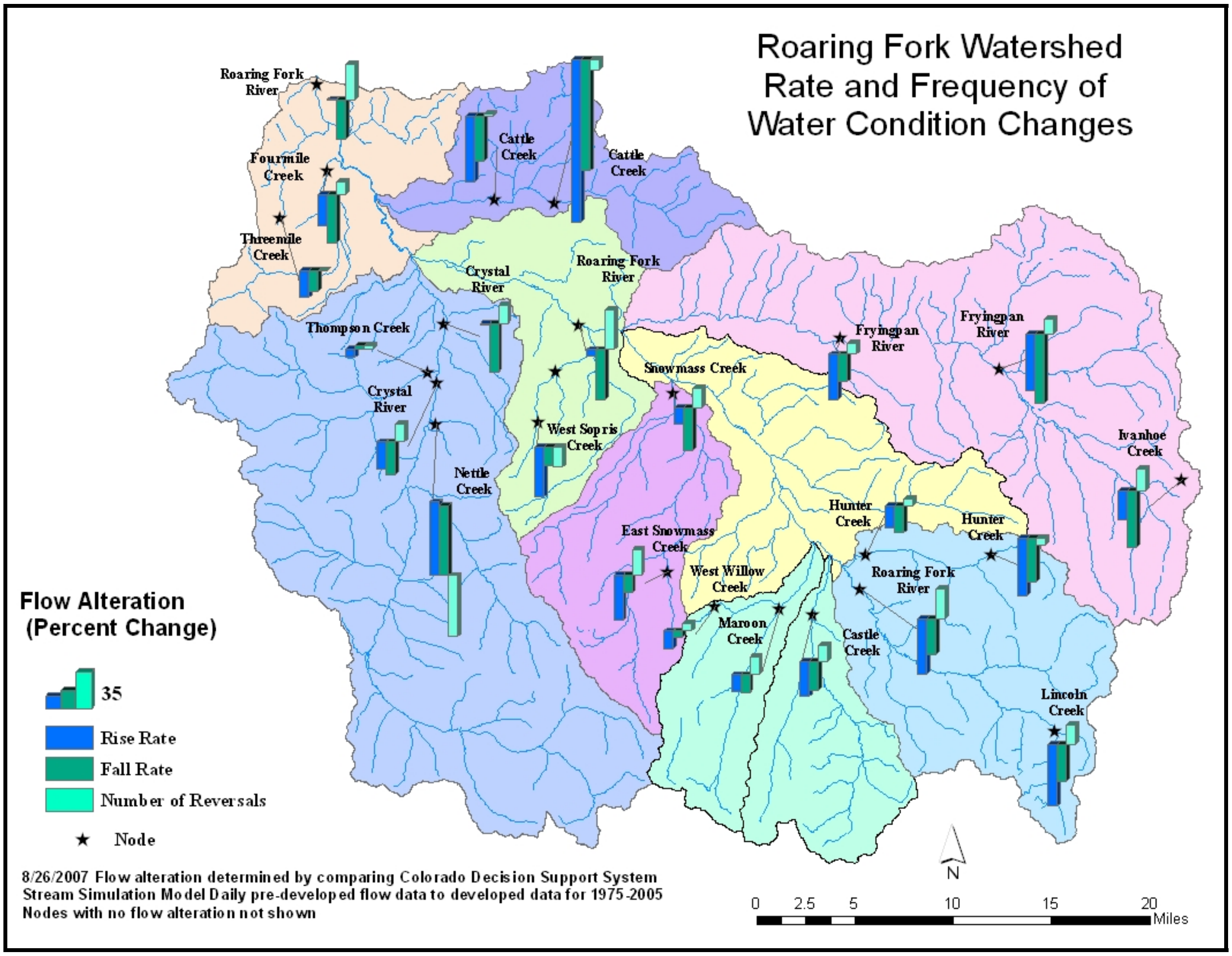


Figure 3.1.5. Changes in annual rates of rising and falling stream flows and fluctuations between increases and decreases in flows (number of reversals), for developed flows compared to pre-developed flow conditions, and for streams throughout the Roaring Fork Watershed.

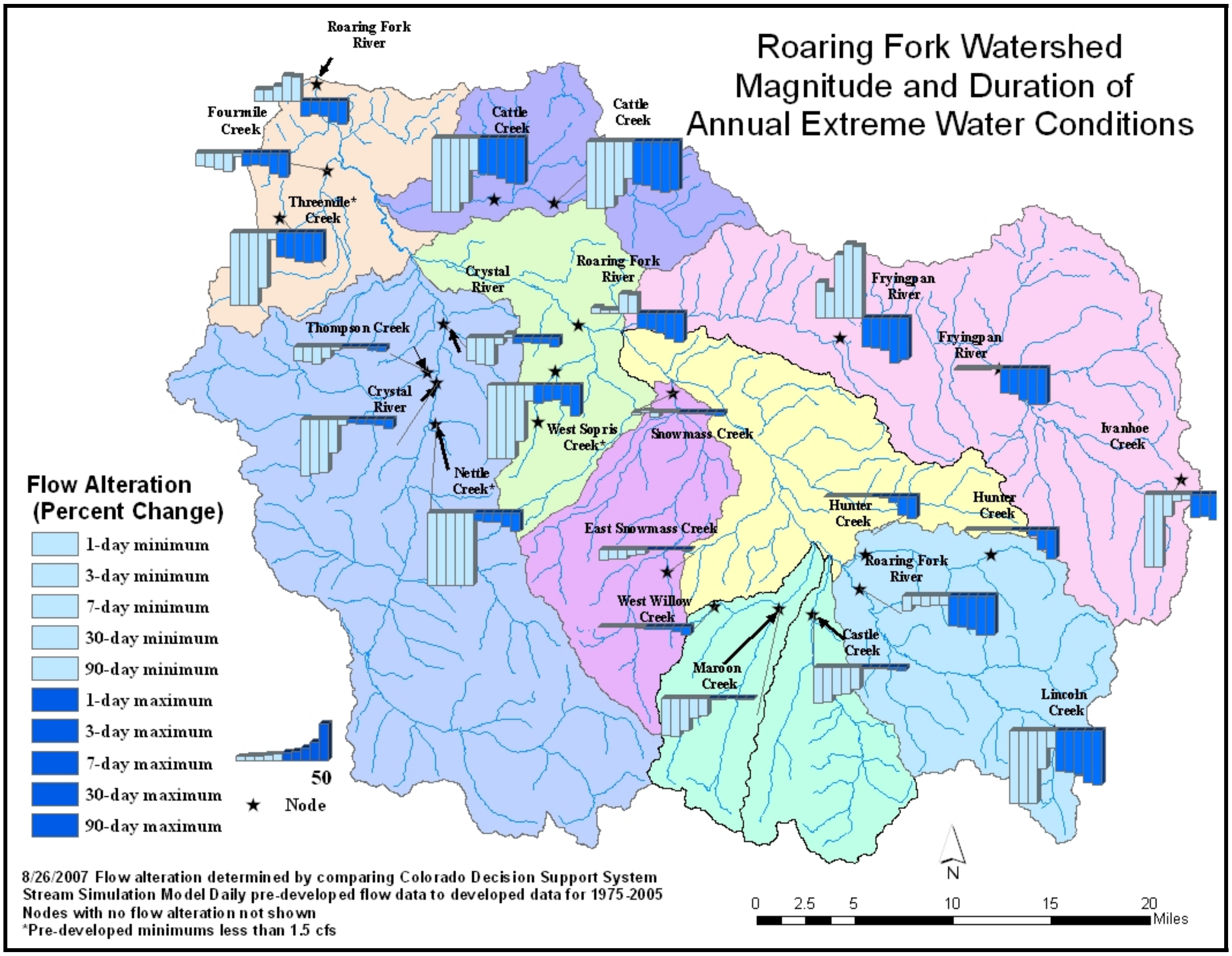


Figure 3.1.6. The change in magnitude and duration of annual minimum and maximum flow events for developed flows compared to pre-developed flow conditions for streams throughout the Roaring Fork Watershed. Note: The bar in each histogram corresponds to the key, with the 1-day minimum at far left and 90-day maximum at far right.

3.1.2 Data and Knowledge Gaps

In order to look at the current status of surface water conditions and determine trends, consistent and representative data are needed. Two broad categories of data gaps, spatial and temporal, limit the ability to access status and trends. Spatially, data may not exist for a specific stream or reach, it may be compiled at too broad a scale (i.e. the Colorado River Basin), or it may be compiled at a county level making extrapolation to the Roaring Fork Watershed difficult. Pitkin County is the only county located entirely within the watershed. Only a small percentage of each of the other counties' land areas falls within the boundaries of the watershed, and often these areas are not representative of the broader county environmental or social characteristics. From a temporal standpoint, data may not exist for a long period of record, may not represent current conditions, or may not be useful for projecting into the future. Knowledge gaps also result from using limited data to try to understand ecosystem functions. The following paragraphs discuss specific deficiencies in spatial and temporal data and in our knowledge of ecosystem processes.

Spatial and Temporal Data Gaps

The national water use data set compiled by the USGS-AWUDS (USGS, No date) gives statistics by county. Because of the time-consuming nature of this national-scale effort, available data is not up to date. Data for 2005 has been collected, but has not yet been compiled and distributed. Water withdrawal data and projections developed through the SWSI process are compiled by major river basin or county and not specifically for the Roaring Fork Watershed.

The CDWR recently enhanced web accessibility for its water diversion and water rights data bases. Data gaps result mainly from omissions or inaccuracies in what has been reported throughout the period of operation.

Assessment of environmental flow needs is hampered by: 1) spatially and temporally limited stream gage and modeled flow data, 2) lack of adequate ecological and geomorphical data (covered in more detail in sections 3.3 and 3.4), and 3) limited understanding of the specific relationships among biological and geomorphological processes and flows.

Second order[3] and higher streams in the watershed with significant diversions and no active stream gage or no gage located below the major diversion structures include: Brush, Fourmile, Threemile, Cattle, Hunter, Woody, Sopris, Snowmass, Capitol, Maroon, Owl, Landis, and Thompson creeks. Some gages are no longer operating (Cattle, Fourmile, Maroon, Thompson, Owl, and Castle creeks). Many of the existing stream gages are relatively new, so their records do not include a significant period of pre-diversion flows (see Appendix 3.1.1).

In some cases, modeled data can be used to assess flow alteration in areas with a limited period of record or without an active stream gage. These data have limitations because they are based on a model that represents only about 75 percent of the total diversions. In addition, the modeled data rely on extrapolation from existing stream gage records, which sometimes are from gages outside the watershed. While these modeled data cannot nor are they meant to provide precise monthly and daily flow data for the modeled period, they are useful for comparing developed flows relative to pre-developed flows. Modeled data are not available for Capitol, Landis, Brush and Owl creeks, or for the downstream reaches of some streams below major diversions (including Sopris, Snowmass, Threemile, Woody, and Hunter creeks). Modeled data are also not available for the upper Roaring Fork River below the Independence Pass Trans-mountain Diversion System's Tunnel Number 2 or for the Roaring Fork River upstream of the confluence with the Fryingpan River.

[3] Strahler Stream Order is used to define stream size based on a hierarchy of its tributaries. See Figure 3.4.1. for a map of stream order in the Roaring Fork Watershed. At the headwaters a stream has a stream order of 1, also known as a "first order" stream. When two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream. Streams of lower order joining a higher order stream do not change the order of the higher stream. Thus, if a first-order stream joins a second-order stream, it remains a second-order stream. It is not until a second-order stream combines with another second-order stream that it becomes a third-order stream.

Understanding Ecosystem Processes

Finally, in addition to gaps in data, limitations exist in the scientific community's understanding of the complex interactions between individual flow components, inter-annual variation, and physical alterations in the instream and riparian areas. These factors together with inherent differences among streams make relating flow to ecological and geomorphological processes a difficult task. New approaches have been proposed to develop environmental flow recommendations (Arthington et al., 2006; Richter et al., 2006). Both approaches outline methods to examine the intricate relationships between flow and natural processes to better understand potential ecological changes associated with increasing levels of flow alteration. Ecologically Sustainable Water Management (ESWM) (Richter et al., 2003) links this information to social and political realities to develop flow prescriptions and potential tradeoffs. Data/research gaps are identified as part of this approach. Recognizing the challenges inherent in identification of a flow prescription intended to meet environmental, social, economic, and political objectives, ESWM recommends monitoring and adapting management when stated objectives are not met.

3.1.3 Consumptive Uses

Consumptive uses of water include municipal, industrial, and agricultural uses. Figure 3.1.7 depicts the amount and percentage of water that evaporated and was used by agriculture, other consumptive uses, and transmountain diversions in the Roaring Fork Watershed for the 2003 irrigation year. Fourteen percent of the entire flow of the watershed was diverted to the Front Range. The largest consumptive use in the watershed was agriculture. Less than one percent (4,500 acre-feet) of the water was lost to evaporation or used for other uses which include municipal uses.

How much and when the water is available and the quality of the water are important components of consumptive uses, met by both surface and groundwater sources. Domestic water needs are typically served by municipal water supplies or community groundwater systems in urban areas, or are self-supplied in rural areas. Self-supplied water most commonly comes from wells, but also can be from surface water sources such as a spring or small creek.

Water from a municipal water supply is more tightly controlled than self-supplied water because it must conform to state drinking water standards, and fees are charged for the amount used. Appendix 3.1.3 identifies the municipal water suppliers in the watershed, their service areas and water sources, and current and projected demands (if available). Information for individual water suppliers is discussed in Chapter 4 under the corresponding sub-watershed.

Evaporative losses from ponds, reservoirs, and through the process of runoff are considered consumptive uses accounted for in a water right. See Table 3.1.1 for an example of evaporative losses at the Meredith Climate Station in the Fryingpan Sub-watershed (Appendix 1.2).

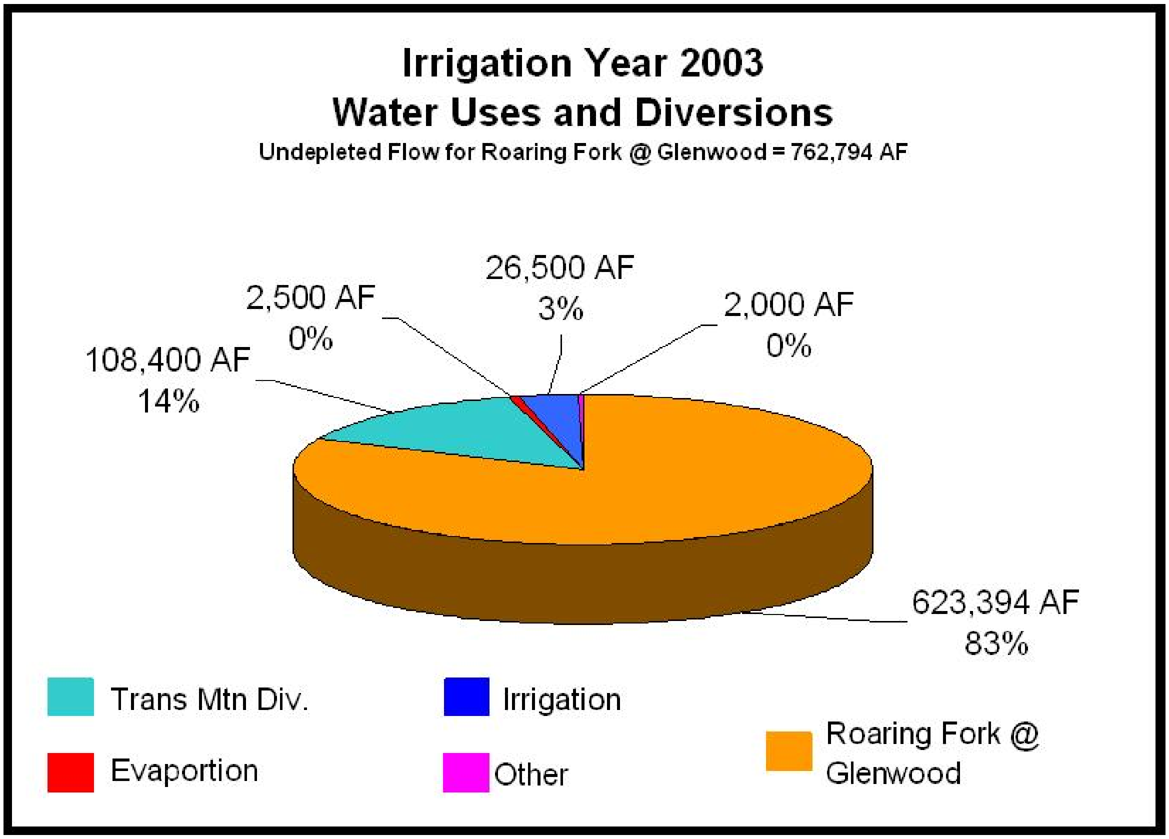


Figure 3.1.7 Water uses and transmountain diversions in the Roaring Fork Watershed (Source: Alan Martellaro, Division 5, Colorado Division of Water Resources, presentation to the American Leadership Forum, March 10, 2005).

Table 3.1.1. Average evaporative losses measured at the Meredith Climate Station, elevation 7,700 feet (1963-2005).

MONTH	MAY	JUNE	JULY	AUG	SEPT	OCT	**TOTAL**
Evaporative Loss (inches)	7.7	8.3	8.3	7.0	5.2	3.2	**39.8**

Evaporative losses from a pond that is 1/3 of an acre in size would provide the yearly water needs of a family of four as calculated using this evaporative loss amount and the estimated annual water use of a family of four in the Colorado River Basin (CDM, 2006).

Municipal and Industrial Water Use Data

The USGS AWUDS is useful for looking at historical water use trends. Based on these data, it is estimated that in the year 2000, 90 percent of water users in Pitkin County obtained their water from a public water supply. Percentages were less for the other three counties, with Eagle County at 80 percent; Gunnison County, 71 percent; and Garfield County, 66 percent. This is a shift from 1985 when Pitkin County had the lowest percentage of public-supplied water users at 69 percent and each of the other counties had at least 10 percent more public supply water users than in 2000 (Figure 3.1.8). Figures 3.1.9 and 3.1.10 show trends in total municipal and self-supplied domestic water supply withdrawals from 1980-2000 by county. One of the more notable trends is a significant increase in domestic self-supplied water withdrawals in Eagle, Garfield, and Gunnison counties, corresponding to the increased population in more rural areas of these counties, away from organized water supply facilities.

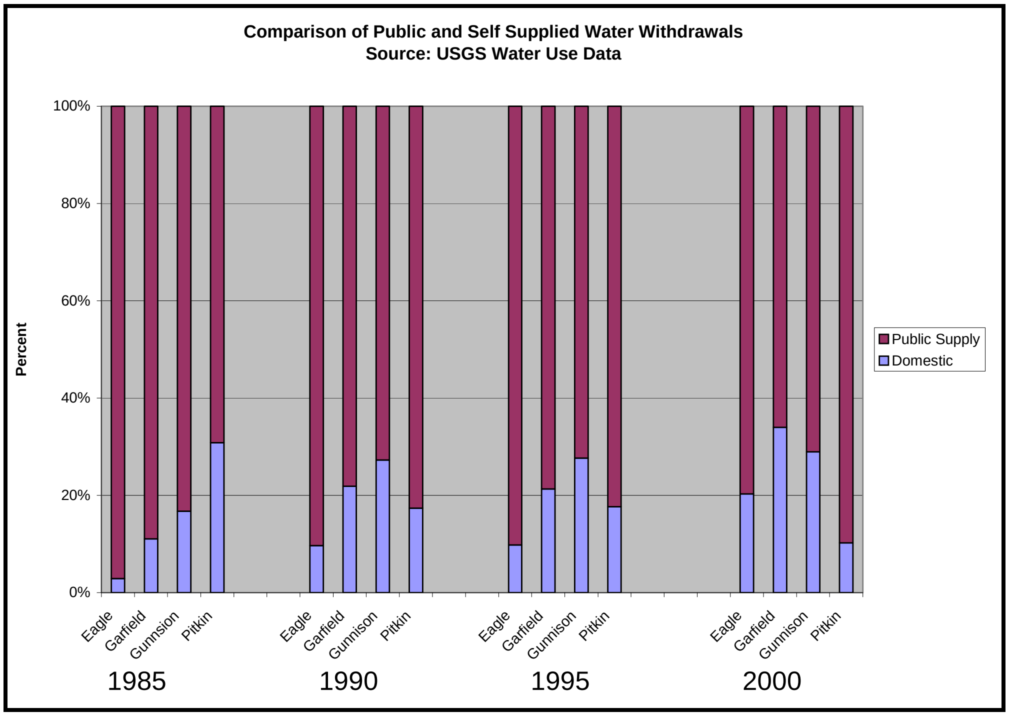


Figure 3.1.8. Comparison of public- and self-supplied water withdrawals.

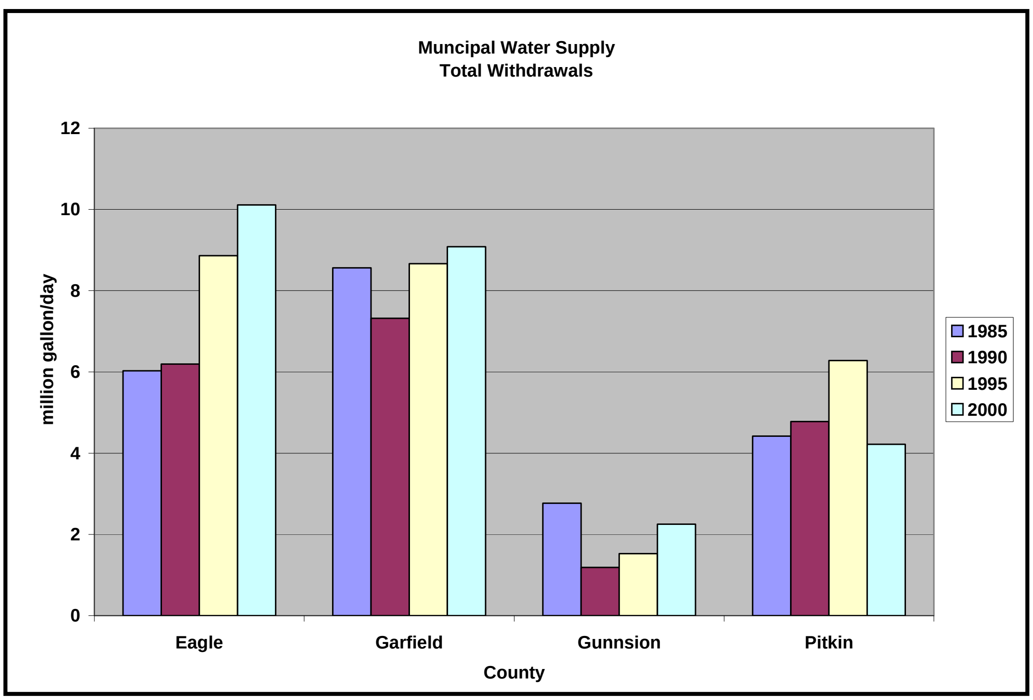


Figure 3.1.9. Trends in total municipal water supply withdrawals from 1980-2000 by county.

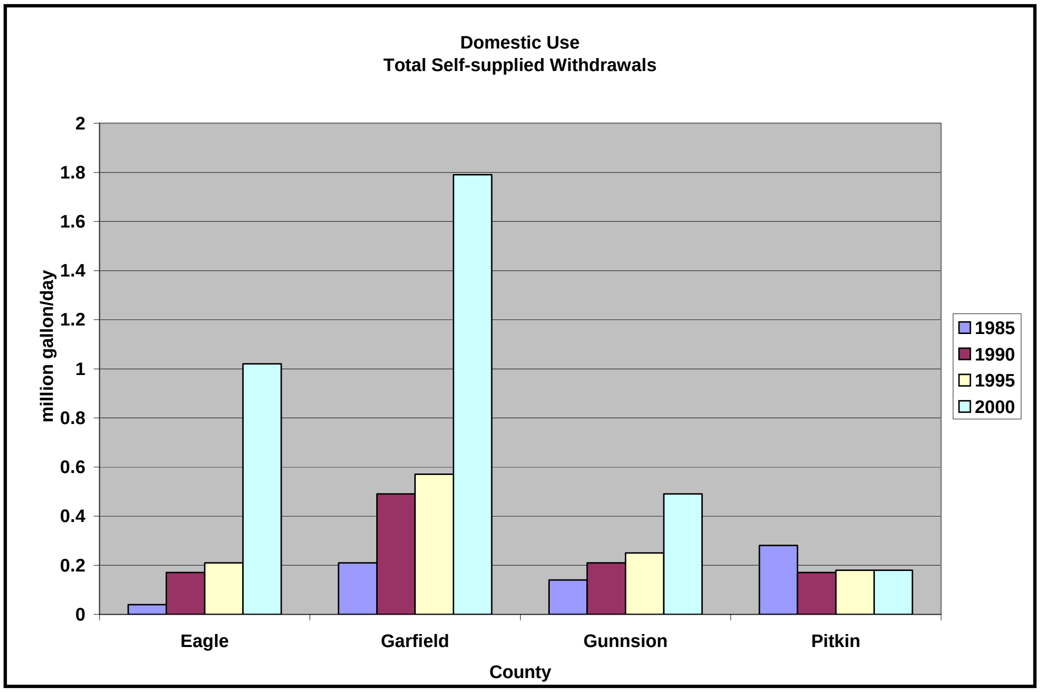


Figure 3.1.10. Trends in self-supplied domestic water supply withdrawals from 1980-2000 by county.

Figure 3.1.11 shows the amount of each county's municipal water withdrawals derived from surface and groundwater from 1985 through 2000. Pitkin County draws the least from groundwater sources, while Gunnison County has the highest use of groundwater sources. In general, across all counties, the use of groundwater for municipal water supply has decreased.

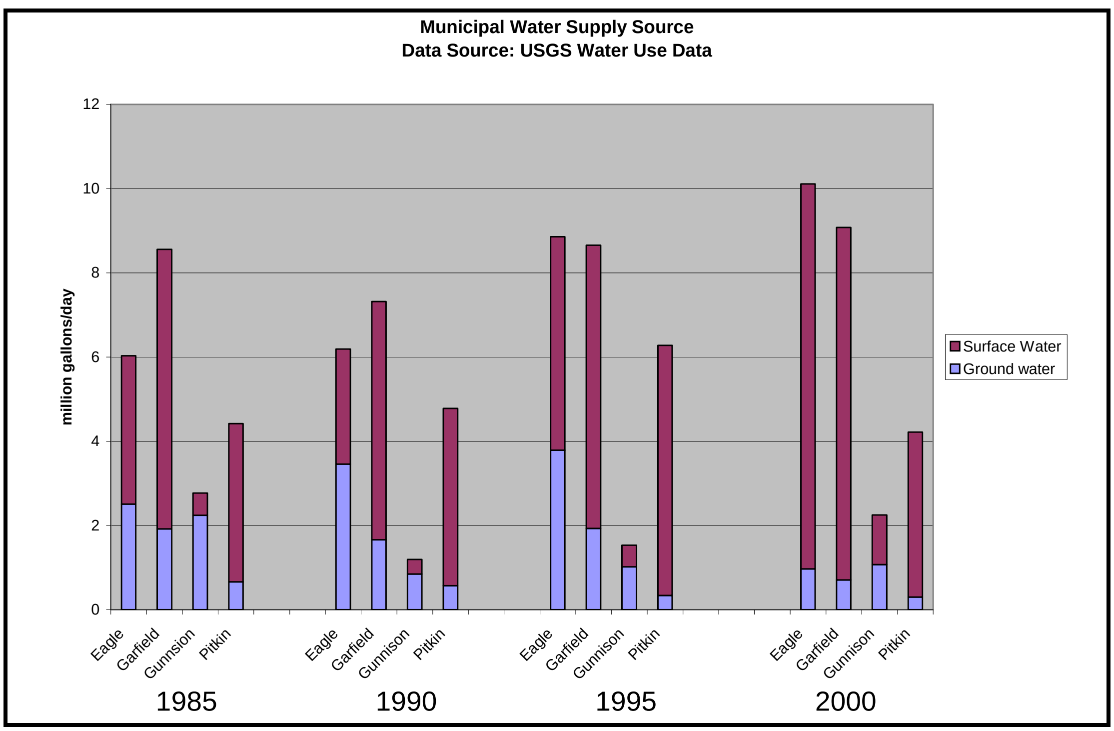


Figure 3.1.11. Amount of municipal water supply from surface water and groundwater.

Information generated from the SWSI process (Davis et al., 2004) paints a picture of current and projected trends in consumptive water use. SWSI estimated current and projected consumptive demands assuming a value of 244 gallons per capita per day for the Colorado River Basin, and county-level population estimates for the years 2000 and 2030. Gross demand includes both municipal and industrial (publicly-supplied and self-supplied residential, commercial, institutional, and industrial water uses) and major self-supplied industrial uses such as snowmaking. Appendix 3.1.4 contains gross demands for the year 2000 and projected demands for 2030. Projected demands are made with and without five levels of conservation (Appendix 3.1.4 lists the types of programs, percent reduction in future municipal and industrial demand, and cost per acre-foot for each active conservation level). For example, the types of programs listed in a Level III conservation effort are: plumbing codes, fixture standards from the National Energy Policy Act, metering, leak detection, education, rebates for toilets and washers, residential and commercial audits, landscape audits, and increasing rate structure. In 2000, all four counties in the watershed achieved a Level III conservation effort. Overall consumptive use is reduced through conservation: For instance, consumptive demands for the Colorado River Basin are projected to increase by 66 percent if Level III conservation efforts are maintained. With a Level V conservation effort, increase in consumptive use is projected to be 21 percent. Without any conservation measures, the increase in consumptive use in the Colorado River Basin is projected to be 94 percent, the highest increase among the eight basins in the state. The same analysis done at the county level indicates that the biggest increase in consumptive demand is projected for Garfield County (117 percent), closely followed by Eagle County (99 percent). Pitkin County, at 69 percent, is slightly above the statewide average increase of 61 percent. Gunnison County is projected to have an increase of 43 percent. Overall, within the four counties, municipal and industrial demands are expected to increase by about 38,843 acre-feet per year (90 percent) and snowmaking demands by 1,659 acre-feet per year (58 percent) by the year 2030.

Agricultural Use Data

Only a portion of water diverted for agricultural irrigation is considered consumptive use, since a portion of the diverted water is returned to the stream. The SWSI process estimated current agricultural water demand to be 1,764,000 acre-feet per year (AFY) in the Colorado River Basin, with a projected decrease by 2030 to 1,644,000-1,707,000 AFY. Using AWUDS, year 2000 water withdrawal figures can be determined by county. Garfield County's agricultural demand was the highest (459,530 AFY) followed by Gunnison County (268,140 AFY). As expected, in the two more mountainous counties, Eagle and Pitkin, agricultural withdrawals were significantly less (145,120 and 43,480 AFY, respectively). In all four counties, groundwater withdrawals for irrigation comprised less than one percent of the total irrigated agriculture withdrawals. Colorado Decision Support System data was used to compare irrigation type in the watershed between 1993 and 2000 (Figure 1.16). An estimated 35 percent decrease in flood irrigated acreage and a 28 percent decrease in sprinkler irrigated acreage took place in this time period.

3.1.4 Non-Consumptive Uses

Understanding and defining non-consumptive uses, including environmental, recreational, and hydropower uses in the watershed, is a complicated endeavor that requires evaluation of a broad set of hydrologic parameters. The magnitude, timing, and duration of flows; rate of change; and frequency of flow events are all components of non-consumptive needs. These five components influence biological and geomorphological processes. Appendix 3.1.5 contains a detailed summary of linkages between flow parameters and their ecosystem influences. Examples of important non-consumptive uses and values include:

- Maintenance or restoration of high quality habitat for fish and aquatic life,
- Sufficient flows for channel and riparian area maintenance,
- Support of water-based recreation, including rafting, kayaking, and angling,
- Adequate flows to support hydropower generation,
- Flushing flows to remove sediment deposition that may smother spawning beds,
- Groundwater recharge, and
- Adequate flows to maintain high water quality.

A non-consumptive needs assessment should define and quantify flows necessary for the protection of environmental and recreational uses and values.

Environmental Needs

In terms of environmental needs, many ecologists recognize stream flow as a “master variable” because of the considerable influence it exerts over water quality and interaction among species (Postel and Richter, 2003). The Nature Conservancy’s Ecologically Sustainable Water Management (ESWM) framework defines ecosystem flows as the flow of water in a natural river or lake that sustains healthy ecosystems and the goods and services that humans derive from them (Richter et al., 2003). Flow needs for rafting and kayaking activities are based on judgments from the recreational communities about flows to sustain a quality recreational experience (see Appendix 3.1.6). Flows for angling relate both to what is needed to maintain a healthy fishery and, in the case of fly fishing, to angler access to the stream (sometimes called “wadeability”).

As introduced in Section 2.1.1, the CWCB’s Instream Flow Program is designed to address environmental non-consumptive needs. Location of the CWCB’s instream flow appropriations in each sub-watershed are shown on maps within Chapter 4. Generally these are based on biological recommendations provided to the CWCB by various state and federal agencies and follow the premise that the amount of water necessary to preserve an aquatic indicator species (e.g. a trout species) is the same amount of water necessary to preserve the entire natural environment (Espegren, 1998). CWCB’s procedure for quantifying instream flows is consistent with Castleberry’s three-step adaptive management approach which recommends:

1) Setting conservative interim flow standards based on current methodologies,
2) Monitoring the adequacy of the interim standards, and
3) Revising interim flow standards as necessary (Espegren, 1998).

While the Instream Flow Program is viewed as a positive step toward protecting environmental needs, it has several limitations. Instream flow rights (ISF) are not always met because all new appropriations are dated post-1973 and administered within the state’s prior appropriation system (see Section 2.1.1 for further discussion about the state’s water rights system). The ability of the Colorado Department of Water Resources (CDWR) to place calls to meet CWCB ISFs is hampered where stream gages are not present and cannot provide an accurate real-time measurement of flow conditions. In 1996, an Instream Flow Subcommittee was assembled by the

CWCB to gather input on the public's desire for the future direction of the CWCB instream flow program (Espegren, 1998). It concluded that instream flow amounts do not directly consider the importance of other aquatic organisms or inchannel and over-bank indicators and suggested the CWCB consider the following inchannel indicators: 1) quantifying channel-forming maintenance flows, 2) integrating water quantity with water quality and water temperature parameters, and 3) considering flows for recreation purposes. To address overbank indicators, a more holistic, ecosystem approach was suggested, recognizing the importance of appropriating flows to maintain riparian and side-channel habitats.

Within the context of non-consumptive uses, peak flows and associated overbanking flows are an often neglected part of the hydrograph. As an example, cottonwood germination is dependent on the "perfect flood" – one that occurs at the right time of year with flooding that retreats slowly and results in bare, disturbed mudflats (Kingery, 1998). This combination of events provides the necessary soil conditions and amount of water during an appropriate length of time to enable seed germination. Without such periodic overbanking flows, mature cottonwoods are present but few young trees grow to replace mature trees when they die. The ESWM approach discussed above looks closely at peak flows when prescribing flow regimes to support ecological needs.

Recreational Flows

As discussed in Section 2.1.1, Recreation In-channel Diversions (RICDs) have recently won legal status as a type of non-consumptive use. They can be used to preserve adequate flows for whitewater boating and engineered whitewater kayak parks. The City of Aspen was the first entity to file for an RICD in the watershed. Basalt, Carbondale, and Glenwood Springs have discussed the possibility of acquiring RICD water rights. Table 3.1.2 lists the proposed or existing RICDs in the watershed. Glenwood Springs is considering the use of an RICD water right for the mainstem of the Colorado River below its confluence with the Roaring Fork River. Appendix 3.1.6 provides a description of the watershed's stream reaches that are suitable for rafting and kayaking, including suggested flows.

Table 3.1.2. Existing and proposed RICD water rights in the Roaring Fork Watershed.

STREAM	LOCATION	STATUS	AMOUNT	OWNER
Roaring Fork River	City of Aspen	· 1992 appropriation; Case No. 00CW0284	June: 270 cfs July: 350 cfs August: 33 cfs	City of Aspen
Roaring Fork River	Carbondale Gateway Boating Park	· Application pending	Ranging from 230-1600 cfs	Town of Carbondale
Roaring Fork River	Town of Basalt	· Included in "5-year window" for Basalt River Master Plan	n/a	n/a

Hydropower Generation

Although hydropower generation is considered by some to be a non-consumptive use of water, some alteration to flows can occur depending on the type of facility. Flow alteration below a reservoir occurs whether the facility is for hydropower generation or for other uses. Hydropower generation from facilities located along a river, known as “run of the river” hydropower plants, can decrease flows in the stream section between the point of diversion into the penstock and where the flow is returned, generally just downstream of the powerhouse. Dewatered or reduced flows in this reach can affect fish and macroinvertebrate species and impact riparian plant communities. In addition, the upstream diversion structure to put water into the penstock may be a fish barrier. Water temperature can also be influenced by reservoirs. Thermal monitoring in the Fryingpan River below Ruedi Reservoir showed that water temperatures are warmer in winter and cooler in summer due to the effects of the reservoir (Ptacek et al., 2003). The Federal Power Act requires Federal Energy Regulatory Commission (FERC) licenses for most hydropower projects, with some minor exemptions for small micro-hydro facilities. Part of the FERC licensing process involves determination of bypass flows and facility infrastructure for biological sustainability.

Pitkin County's land use code permits landowners to construct micro hydroelectric systems within stream channels and riparian areas, provided that any adverse impacts are adequately mitigated. The landowner must submit a site analysis to the board of county commissioners identifying any riparian, wetland, and inchannel habitat that will be disturbed by the project, as well as a mitigation plan. With respect to hydrology, the County requires that the construction and maintenance of micro hydroelectric system does not alter either the historical flow patterns and runoff amounts for the area; nor should such development result in sedimentation or increases in water temperatures. Finally, the system must be designed to fit the stream channel. Special review is required for systems proposed to be built on slopes with a gradient of greater than or equal to 30 percent. Table 3.1.3 provides a summary of the watershed’s existing and proposed water rights for hydropower generation.

Table 3.1.3. Existing and proposed water rights for hydropower generation. Source: http://cdss.state.co.us/DNN/WaterRights/tabid/76/Default.aspx.

WATER RIGHT NAME	STRUCTURE ID	SOURCE	AMOUNT*	APPROPRIATION DATE
Brush Creek Hydro	1567	Brush Creek	20 cfs	6/26/1986
Redstone Water System	1357	East Creek	10 cfs	5/12/1985
Ruedi Reservoir Power Plant	1360	Fryingpan River	900 cfs	10/22/1975
Snowmass Project PABST R PC	1737	Snowmass Creek	600 cfs	9/29/1978
Atkinson Ditch	516	Fourmile Creek	2.0 cfs	9/29/1979
Midland Flume Ditch	869	Castle Creek	60 cfs	11/16/1885
Maroon Creek Plant	1156	Maroon Creek	68.4 cfs	8/12/1892
Darien Pipeline No. 1	1564	Crystal River	3.0 cfs	1/11/2006
Finley No. 1 Ditch	678	Sopris Creek	6.4 cfs	8/20/1986
Nickelson Ditch No. 1	1520	Capital Creek	1.0 cfs	11/21/1984
Ruedi Ditch Alternate Point	1796	Ruedi Creek	3.66 cfs	6/30/1996
Willow Creek Ditch No. 2	1102	Willow Creek	1.0 cfs	8/1/1882
Wing Pipeline	1922	Landis Creek	0.5 cfs	12/31/1961
Yeomen Creek Pipeline	1962	Cattle Creek	0.11 cfs	7/31/1993

* Absolute decreed rate

3.1.5 Factors that Affect Water Quantity

In the watershed, the primary issues related to water quantity are lack of sufficient water for consumptive uses (including high quality drinking water), and alteration of the timing, frequency, duration, magnitude, and rate of changes of flows, which can harm stream ecosystems, affect water-based recreation activities, and/or decrease the supply of water for hydropower generation. The major factors that lead to reduced water availability and flow alteration in the watershed are: transmountain and inbasin diversions, downstream water calls, reservoir operations, and changes in land use. Chapter 2 looks at future water quantity considerations such as changes in water policy and management, water rights and calls, structural projects, and additional out-of-basin demands that may affect water quantity. Section 3.5 discusses how climate change may alter stream flows.

Transmountain diversions can result in year-round flow alteration. More discussion of the watershed's three transmountain diversions can be found in Chapter 2 and sections 4.1 and 4.7. Unlike inbasin diversions which return some water back to the stream system after use (e.g. runoff from irrigated fields, treated wastewater), transmountain diversions deplete 100 percent of the diverted water.

Large inbasin diversions related to agricultural irrigation often lead to low summer stream flows with direct effects on aquatic life. Diversions for municipal use occur throughout the year, and account for less water use than those for agriculture. Another important difference between these two water uses is that agricultural return flows occur along an entire stream reach while municipal water is returned to the stream at the specific location of the wastewater treatment plant outlet.

Inbasin diversions are also used for snowmaking (Table 1.5). Ski areas in the watershed have adopted snowmaking practices to help establish a base of snow early in the season and to provide a supplemental source of snow, albeit artificial, in drier years. Because streams and lakes are generally at their lowest flow levels in late summer and early winter, removing water to make snow from a stream already at its base flow can harm fish populations and riparian vegetation (Sibbernsen et al., 2001).

Groundwater is influenced by use of wells to supply water. Groundwater withdrawals in Colorado commonly require augmentation plans to account for the impacts that wells have on surface water supplies and the administration of water rights. These plans are required to help provide water to senior water rights holders in times when groundwater withdrawals might typically injure those holders.

Implementation of augmentation plans can benefit or harm instream flows on any given reach of river or stream. Augmentation plans in the Roaring Fork Watershed often utilize Ruedi Reservoir to put water back in the system to compensate for groundwater withdrawals (see Section 2.1.1). However, if the withdrawal from the system is not near Ruedi Reservoir, the release of water for augmentation may not benefit the stream reach impacted by the original withdrawal. In other words, augmentation plans are required to preserve the ability of downstream water-right holders to divert, not to mitigate the ecosystem effects of upstream withdrawals. The areas where streamflows are bolstered by augmentation releases will be directly below the point of augmentation (in this example, Ruedi Reservoir and the Fryingpan River), not necessarily near the point of the original diversion.

Downstream water calls under the Colorado Water Priority System influence flows in the watershed. To meet a downstream senior water right, more junior consumptive water users may be required to stop diverting (in other words, they are called out). However, this can benefit non-consumptive uses because the shutoff of upstream junior water rights means that water that otherwise would have been withdrawn stays in the stream until it is diverted further downstream.

The operation of Ruedi Reservoir has reduced spring peak flows and increased baseflows in the lower Fryingpan and Roaring Fork rivers. Flow alteration due to reservoir operations is discussed in more detail in section 4.7.

Throughout the watershed, the flow regime is altered by increased amounts of impervious surface caused by urbanization, road development, and developed recreation activities. Precipitation falling on an impervious surface enters the channel faster and more directly than it would if it is allowed to infiltrate into a soil layer where it is released more gradually to a stream channel. Rain and snowmelt runoff on a sufficient area of impervious surfaces can result in flooding which can cause bank erosion, increased sedimentation, and channel incision (see sections 3.3 and 3.4 for further discussion). This rapid runoff can also reduce ground water storage thus decreasing base flows. Future land use changes will continue to affect water quantity.

It has been documented that dust from ranching, mining, energy exploration, and other local, regional, and more distant upwind activities is causing snow to melt earlier and quicker. This occurs when wind-driven dust covers a layer of snow leading to the snowpack absorbing more of the sun's warmth because of its darker color. Moreover, projected increases in drought intensity and frequency and associated increases in dust emission from the desert Southwest may further reduce snow cover duration (Painter et al., 2007). These types of activities are already present within the Roaring Fork Watershed to varying degrees. Energy exploration in the form of natural gas drilling is increasing in scope and pace throughout the broader Upper Colorado River Basin, as is the potential for future oil shale exploration within the region. How this phenomenon of dust fallout affects the Roaring Fork Watershed's snow-melt cycle, or could affect it in the future, is currently unclear, but is an important issue to follow.

3.1.6 Flood Control Issues

As has been previously discussed, flood flows are desirable to support numerous ecosystem services within river systems. However, development in flood plains and controlled flows related to operation of dams and diversions, in combination with large storm events, can lead to flooding issues. The highest peak flow recorded on the Roaring Fork River at the Glenwood Springs gage was 19,000 cubic feet per second (cfs) on July 1, 1957, before construction of the Fry-Ark Project. Since completion of the Fry-Ark, the two highest flows have been 12,100 cfs on June 25, 1983 and 13,000 cfs on July 13, 1995 (Figure 3.1.12). Preceding both events, the snowpack was higher than average and the runoff had a later peak and longer duration than average (see figures 3.1.13 and 3.1.14).

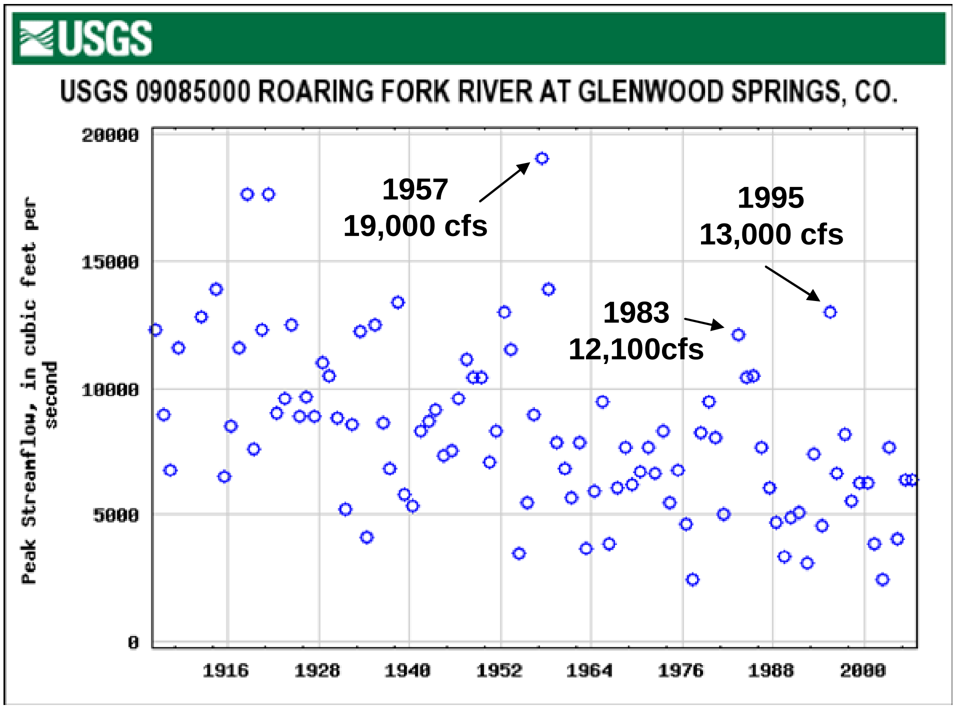


Figure 3.1.12. Peak flows recorded at the Roaring Fork River at Glenwood Springs stream gage.

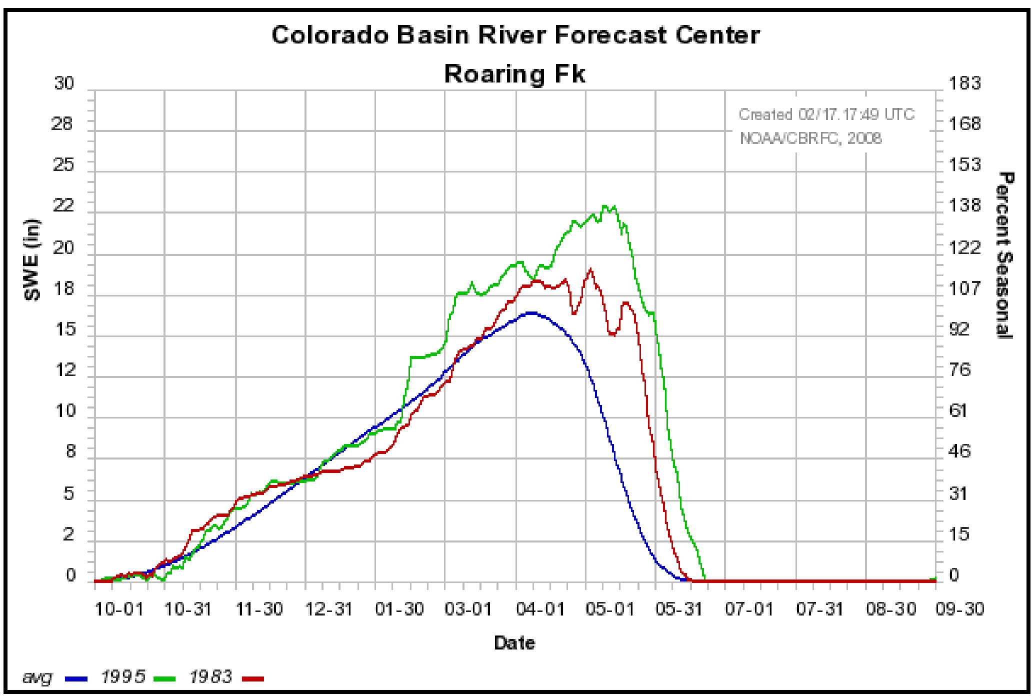


Figure 3.1.13. Snowpack in the Roaring Fork Watershed preceding the high peak flow years of 1983 and 1995.

Figure 3.1.14. Downtown Basalt during Spring, 1995 Flood (Source: unknown).

The high flows in 1995 resulted in bank erosion and channel migration throughout the Roaring Fork Valley, leading to damage to property, infrastructure, and river corridor habitat. In 1996, state legislation (Senate Bill 96-153, Section 7) was approved to conduct the Roaring Fork and Fryingpan Rivers Multi-Objective Planning Project (Multi-Objective Study) (BRW, Inc. et al., 1999) to evaluate channel instability. After flooding of the Roaring Fork River in 1995, landowners realized that poorly designed and sited channelization structures often contributed to channel instability. Local residents and governments identified the need to take a more holistic view of river health, stability, and management. Channel instability on the Roaring Fork River has led to:

- Threats to roadways, utilities, infrastructure, and development in the geomorphic floodplain,
- Loss of property due to channel migration,
- Loss of trout habitat, especially for rainbow trout, because of the change from a pool-riffle sequence to predominantly fast-moving water in continuous riffle sections, and
- Loss of wetlands and riparian zones due to high width-to-depth ratios and lateral bank migration.

The Multi-Objective Study identified high flood hazard areas, causes and areas of instability, and infrastructure at risk along the Roaring Fork River below Aspen and on the Fryingpan River below Ruedi Reservoir. These are discussed in more detail in the corresponding sub-watershed sections found in Chapter 4 (sections 4.2 - 4.4, and 4.7).

In 2002 the Town of Basalt revised its Master Plan and followed up on the Multi-Objective Study with the development of the Roaring Fork River Stewardship Master Plan (http://www.basaltriverinfo.net/master_plan.htm). Two examples of projects undertaken based on recommendations from the Roaring Fork River Stewardship Master Plan are:

Example 1 – Completed Old Pond Park to improve public access and stormwater management, including removal of several mobile homes from the floodplain and reclamation of the area to provide open space, habitat restoration, bank stabilization, and improved flood conveyance capabilities.

Example 2 – Working on plan to purchase Pan-Fork Mobile Home Park to mitigate potential flood impacts in this area and restore a portion of the river floodplain to an undeveloped condition.

More information about the Multi-Objective Study's recommendations and master plan goals can be found in Appendix 3.1.7.

3.1.7 Water Conservation and Drought

Water conservation and drought are topics of constant interest given the arid climate and landscapes of the Roaring Fork Watershed and broader Upper Colorado River Basin. The state works to monitor, forecast, mitigate, and prepare for drought. It also provides technical assistance and grant money to help develop drought mitigation plans through its Office of Water Conservation and Drought Planning within the Colorado Water Conservation Board (http://cwcb.state.co.us/Conservation/Drought/index.htm).

In 2004, this agency produced a statewide Drought and Water Supply Assessment that included summaries for the major river basins (http://www.cwcb.state.co.us/Conservation/Drought/droughtWaterSupplyAssessment.htm) (CWCB, No date d). The assessment was based on results of an opinion survey administered to water managers and planners. Sixty survey participants in the Colorado River Basin (CRB) represented municipalities (42 percent), agriculture (23 percent), and federal agencies, state agencies, water conservancy districts, industry, and other (35 percent).

Statewide water users indicated that meaningful and effective drought and water conservation measures and programs should include the following components: public education and involvement, lawn and garden watering restrictions, fines and tiered rates for water use, metering, distribution/transmission system leak detection, water conservation cooperative agreements/operating agreements, alternative irrigation practices (including alternative crops and planting strategies), lining of ditches and canals, conjunctive use of surface and groundwater, and use of recycled water.

Water users in the CRB identified both structural and non-structural drought mitigation projects, as shown in tables 3.1.4 and 3.1.5.

Table 3.1.4. Structural projects identified by CRB water users as effective means to mitigate effects of drought (CWCB, No date d).

TYPE OF PROJECT	PERCENTAGE OF CRB WATER USERS SUPPORTING PROJECT
New storage for surface water	32%
New or upgraded pipelines	22%
New or upgraded water distribution systems	22%
Lining of ditches	16%
New aquifer storage recovery	12%
Large-scale/multi-basin projects	12%
New storage for groundwater	2%

Table 3.1.5. Non-structural projects identified by CRB water users for drought mitigation (CWCB, No date d).

NON-STRUCTURAL PROJECT	PERCENTAGE OF CRB WATER USERS SUPPORTING PROJECT
Improved water conservation methods	34%
Public education and awareness	31%
Technical support in drought and conservation planning	27%
Technical support in water supply planning	25%
Improved water conservation measurement methods	19%

The summary of the Colorado River Basin Assessment (CWCB, No date d) states that: "Division 5 (Colorado Basin) will realize substantial growth over the coming decades and will need to develop additional water supplies, as well as improve demand management, to meet the water needs of the future. Given its physical setting, Division 5 will also be instrumental in the future water supply planning related to other major river basins in Colorado. Therefore, state involvement in public education, infrastructure funding and technical assistance will be vital to support the long-term health of this basin."

In 2005, the CWCB produced a document to assist in development of water conservation plans (http://www.cwcb.state.co.us/Conservation/Conservation/hb1365/index.htm) required under §37-60-126, C.R.S. (hereafter the "Water Conservation Act") for those entities that receive financial assistance from either the CWCB or Colorado Water Resources and Power Development

Authority. In accordance with the Water Conservation Act, water conservation plans must be prepared and submitted to the Office of Water Conservation and Drought Planning for review prior to the release of loan proceeds to determine whether the plans comply with the requirements of the Water Conservation Act.

3.2 Water Quality

Author: U.S. Geological Survey

As already discussed in Section 3.1, in the watershed there are many uses of water. And these uses, while they require adequate water quantity, most often also require good water quality. Drinking and domestic water supplies, irrigation water, and water that provides habitat for wildlife are all dependent on good water quality. In addition, water quality is valued for water-based recreation activities, and overall quality of life – which translates into healthy water resources for the people that live in and visit the watershed, as well as its biotic communities. Water quality in the Roaring Fork Watershed has been monitored for over five decades and many studies have been conducted looking at water quality and related issues. Organizations like the Roaring Fork Conservancy, Colorado Department of Natural Resources, Colorado Department of Public Health and Environment (CDPHE), Colorado Division of Wildlife's River Watch Program (Colorado River Watch), U.S. Environmental Protection Agency (USEPA), U.S. Forest Service, and U.S. Geological Survey (USGS) have spent considerable time and resources monitoring water quality in the watershed. Water quality data summaries and limited data analysis have been periodically performed and used to help inform water quality management decisions (Roaring Fork Conservancy, 2006a; O'Keefe and Hoffman, 2005; Hempel and Crandall, 2001; Britton, 1979). The Northwest Colorado Council of Governments (NWCCOG) developed a watershed plan in 2002 as part of Section 208 of the Clean Water Act. This plan provided guidance with respect to water quality monitoring needs and various watershed improvement projects (Northwest Colorado Council of Governments, 2007). The Safe Drinking Water Act requires that all of the municipalities in the watershed monitor their drinking water (see Section 3.2.6 for more information). The consumer confidence reports of some of the municipalities can be found online (Table 3.2.1).

Table 3.2.1. Location of drinking water consumer confidence reports for various municipalities in the Roaring Fork Watershed.

MUNICIPALITY	DRINKING WATER CONSUMER CONFIDENCE REPORT
Aspen	www.aspenpitkin.com/pdfs/depts/58/ccr2006final.pdf
Snowmass Village	www.swsd.org/2006-monitoring-results
Basalt	Available at 200 Fiou Lane, Basalt (970-927-4723)
Carbondale	www.carbondalegov.org/vertical/Sites/{E239F6F5-CCA3-4F3A-8B27-95E8145FD79A}/uploads/{CCBABC55-C8F6-460C-9DC3-7B4970FAF3E3}.PDF
Glenwood Springs	www.ci.glenwood-springs.co.us/departments/publicworks/water/files/ccfinal07.pdf

3.2.1 Data Sources and Assessments

Water quality data from six agencies at 301 sites have been compiled into a relational database. This web-accessible common data repository provides all interested parties equal access to the latest water quality information. Using this common data repository, water quality data were evaluated for uniformity and then used to establish the baseline of available water resources data for the watershed (http://co.water.usgs.gov/cf/roaringforkcf/default.cfm).

Approximately 70 percent of water quality sites in the watershed are streams, 21 percent are groundwater (wells and springs), and the rest are lake/reservoir, effluent, or mine sites. Table 3.2.2 provides a summary description of these data by responsible agency stored in the common data repository. The primary purpose of the water quality data analysis and summaries included in this report is to describe and explain recent water quality conditions. For that purpose, a subset of all available water quality data was created that consisted of data from 1995 to the present. This subset was retrieved from the common data repository for detailed summary and analysis (appendix 3.2.1). The analysis focused on water quality locations with adequate data to describe existing water quality conditions; therefore, only sites with five or more water quality samples were retained. It was possible that while 5 samples were collected, not all constituents were collected during each of those 5 samples; therefore, data can be summarized based on less than 5 values. Where appropriate, multiple water quality sampling sites that generally represent the same geographic location were combined into a single site. This was done so that all available data for a given location could be evaluated as a single more comprehensive water quality data set.

Table 3.2.2. All data information for water quality data compiled in the Roaring Fork Watershed and stored in the web-accessible common data repository.

AGENCY	NUMBER OF SITES	NUMBER OF SAMPLES	DATE RANGE
Colorado Department of Natural Resources	10	251	1966-1968
Colorado Department of Public Health and Environment	48	1,934	1968-2003
Colorado River Watch	41	4,710	1990-2007
U.S. Environmental Protection Agency	12	59	1969-2000
U.S. Forest Service	35	350	1973-1980
U.S. Geological Survey	174	12,500	1949-2007

As part of various water quality monitoring programs, 500 distinct water quality constituents have been analyzed for in the Roaring Fork Watershed. This large number of constituents represents a combination of changing techniques, different agencies collecting similar constituents, and the collection of organic samples (pesticides and volatile organics) that have numerous constituents analyzed in a single sample. Water quality monitoring efforts have provided information for a particular time period, area, site type (streams, groundwater, mines, effluent, lakes or reservoirs), and/or sampling medium (water, sediment, tissue). Constituents were selected that have been recently and regularly collected at a large number of sites to describe recent water quality conditions in the watershed and to compare sub-watersheds.

The existence of an applicable water quality standard was another factor used to prioritize which constituents to use in this report. The following constituent groups were selected for water quality analysis in this report: field parameters, major ions, nutrients, trace elements, and on a more limited basis, microorganisms and total suspended solids/suspended sediment. While many other constituent groups have been collected in the watershed, these constituent groups were chosen because they are effective measures of existing water quality conditions, and help in understanding common factors that effect water quality.

Constituents like nutrients and trace elements are not typically found in high concentrations in the environment unless there is some source (continuous, episodic, etc.). Therefore, the detection or lack of detection of a constituent is as important as their concentration when they are detected. When a constituent is not detected in a sample, there are a variety of ways of handling reporting this. One approach is to report the concentration as zero; however, this approach is somewhat misleading. By reporting the concentration as zero, this implies that the concentration is zero, however, this is not known. What is known is that the constituent was not able to be detected in the sample using a particular method. For every constituent, there can be multiple methods of analysis that have varying abilities to detect that constituent in a sample. Therefore, the more appropriate approach to reporting a constituent as “not detected” is to report it as less than the method reporting limit (MRL) of the given method. An MRL for a particular method is the concentration at which a constituent can accurately be reported. When a constituent is reported as less than the MRL, we call this constituent value a censored value (Helsel, 2005). For example, a censored cadmium concentration could be reported as less than 5 micrograms per liter (<5 µg/L). The actual measured concentration of cadmium may be 4.1 µg/L; however, that concentration cannot be reported with any certainty because the particular method is only accurate for concentrations greater than 5 µg/L.

CDPHE has developed acute and chronic water quality standards for several different constituents. An acute standard quantifies a higher constituent concentration for which, during a short exposure (1 day), an aquatic organism would die. A chronic standard is a lower constituent concentration that would, during extended exposure, cause adverse effects including increased mortality and decreased biologic integrity. As such, chronic standards are meant to be compared to 30-day average concentrations; however, very few sites have monthly data let alone more than one sample in a month. Therefore, for the purposes of this analysis, it was necessary to assume that constituent concentrations were representative of a 30 day average. It is important to note that when a sample exceeds an acute or chronic standard that it is an indication of elevated concentrations, but <u>does not</u> indicate that the site is out of compliance with the standard. These standards are often based in part on the relative hardness of the stream and can be referred to as table value standards (TVS). (Colorado Department of Public Health and Environment, 2007b).

Figure 3.2.1. Cattle Creek Stream Team February 17, 2007(Photo Credit: Chad Rudow)

Previous work

A number of site- and issue-specific studies have been undertaken within the watershed pertaining to water quality. These are summarized within this sub-section. For detailed results, the reader should refer to the particular study of interest.

Evaluations of current and suggested stormwater best management practices were conducted for Basalt and Glenwood Springs. These evaluations identify possible water quality issues and suggest future water quality monitoring (Matrix Design Group, 2001 and 2003). An evaluation of various structural and non-structural best management practices appropriate for golf course design, construction, and maintenance was conducted using Maroon Creek Golf Club as a case study. The evaluation recommended water quality monitoring for both surface water and groundwater for chemical, physical, and biological parameters in receiving waters (Wright Water Engineers, 1996).

Specific conductance and total dissolved solids have been the focus of several studies in the watershed because they are a robust measure of the dissolved solids content. In a literature review to evaluate the effect of deicers in Colorado, USGS and Roaring Fork Conservancy data were analyzed to look at trends in chloride, specific conductance, and streamflow. A non-linear relationship was observed between chloride and specific conductance, while a linear relationship was found between streamflow and both chloride and specific conductance (Fischel, 2001). Specific conductance, salinity, temperature and pH were monitored at 112 study sites during October 1997 to establish a relationship between the geology of the Carbondale area with increases in salinity observed in streams during base flow conditions (Kirkham et al., 1999). This study was based, in part, on a groundwater contribution study of the Upper Colorado River Basin that used dissolved-solids concentrations and streamflow to determine the salt load that the Roaring Fork is contributing to the Colorado River (Warner et al., 1985).

Other studies within the watershed have endeavored to understand specific processes and factors that influence water quality. A study of the geologic and hydrologic factors governing development impacts on the Crystal River near Marble was used to provide a suitable basis for establishing appropriate land use and environmental policies for future development in the area (Rold and Wright, 1996). Stream sediment data were sampled for heavy mineral concentrations in the Maroon Bells/Snowmass Wilderness (McHugh et al., 1987).

Stream restoration efforts on Brush Creek are ongoing to improve stream stability, function, aquatic habitat, and associated riparian areas. These efforts have been underway since 1992 and the Greenway Plan is intended to provide a comprehensive view of the stream and context for community investment and future improvements (Town of Snowmass Village, 2007). The Roaring Fork Conservancy initiated a targeted study on Brush Creek to establish baseline data, evaluate pH and phosphorus levels, and identify appropriate management strategies for open space parcels (Roaring Fork Conservancy, 2007). High pH values were found to coincide with low streamflow, therefore, the study recommended that streamflow be monitored on Brush Creek to better understand this relationship.

3.2.2 Data and Knowledge Gaps

The process of evaluating and assessing the available water quality data has served to partially identify spatial, analytical, and temporal data gaps. In order to provide a more in-depth analysis of all existing water quality data, completion of the USGS water quality retrospective will include a more comprehensive assessment of historical data. This assessment is intended to provide a more complete understanding of baseline conditions, seasonal and spatial trends, analysis of other water quality constituents, similarities and differences across the watershed, and the influence of upstream water quality conditions on downstream reaches.

Because recent groundwater quality data for the Roaring Fork Watershed does not exist, it is difficult to determine site-specific groundwater issues and data gaps. However, there are some areas were baseline groundwater quality monitoring might be of use. As an example, Basalt and Carbondale use groundwater (springs or wells) as a municipal water supply (O'Keefe and Hoffman, 2005). Source water assessments have been conducted for these municipalities and have identified the potential for contamination of these municipal water supplies (Colorado Department of Public Health and Environment, 2004a and b). As population growth continues in the watershed, land use will change from natural and more rural settings to residential and urban types of land use. Local governments need information to help them evaluate the most suitable locations for domestic wells and light industry such as auto repair shops, cemeteries, and dry cleaners. It is also not known what effects onsite wastewater disposal (septic) systems have on the groundwater quality.

Tools are needed to identify areas with the highest predisposition to groundwater contamination and areas of surface and groundwater interaction so that wise land-use decisions can be made. In the Eagle River Watershed, a neighboring watershed, a groundwater susceptibility assessment study is being conducted by the USGS to address this need. The overall goal of this project is to develop maps that show the predisposition of the primary alluvial aquifer in the Eagle River Watershed to groundwater contamination. These maps will assist stakeholders in Eagle County to make land-use decisions using scientifically defensible information to aid in long-term water-resource protection and management. The results of this project will also help determine groundwater/surface-water interactions, sources of recharge to the groundwater, and the age and flow directions of the groundwater. As development continues, local organizations need tools to evaluate potential land development effects on ground- and surface-water resources. For instance, it is not known what the recharge sources are for the alluvial aquifer; some portions of the aquifer may be recharged through upwelling of groundwater from the surrounding bedrock, and other areas may be recharged by infiltration from the Eagle River.

Measuring streamflow during water quality data collection is an extremely valuable addition to Colorado River Watch because it provides the ability to track changes in constituent loads and load sources. In addition to instantaneous streamflow data collection, continuous water quality monitors that can measure parameters such as temperature, specific conductance, and/or dissolved oxygen would enhance the ability to observe daily, seasonal, and annual water quality conditions, and would provide a more detailed context for understanding how streamflow, land use, climate, and other natural factors influence water quality.

Additional collection of microorganism data would aid in understanding their occurrence. Water-based recreation is a major attraction to the watershed and increasing microorganism sample collection would help to inform regulators and users alike to the potential threat of water-born diseases.

The addition of wastewater compounds (or emerging contaminants) to water quality data collection would provide a baseline of data to describe the existence of these compounds in the watershed. Wastewater compounds are organic compounds of natural or synthetic origin typically found in domestic and industrial wastewaters. These compounds include flame retardants, industrial solvents, domestic pesticides, pharmaceutical, and personal-care products (Zaugg et al., 2002). Wastewater treatment processes are not designed to remove all of these compounds from water, resulting in many of these compounds being expelled into streams as treated water (Lee et al., 2004). Several wastewater compounds were detected in samples collected downstream from the discharge of treated wastewater on Boulder Creek during a study conducted in 2000 indicating that these compounds were not removed during secondary treatment (Murphy et al., 2003).

A subset of wastewater compounds includes substances that are known or suspected to disrupt endocrine function in vertebrate organisms. Termed endocrine-disrupting chemicals (EDCs), these compounds are defined by the USEPA (U.S. Environmental Protection Agency, 1997) as: “. . . an exogenous agent that interferes with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis, reproduction, development, and (or) behavior.”
Initial studies of EDCs and their effect on vertebrates demonstrated adverse effects on test organisms in controlled laboratory settings (Taylor and Harrison, 1999; Kaiser, 2000). More recently, causal relations have been established linking environmentally relevant concentrations of EDCs and adverse effects in aquatic organisms (Schoenfuss et al., 2008; Bistodeau et al.,

2006). In contrast to many toxic chemicals, effects from EDCs on test organisms have been observed at very low concentrations, well below concentrations typically considered “safe” (Kaiser, 2000). To date, most studies have focused on the effects of a single compound; toxic effects of chemical mixtures are not known (Sullivan et al., 2005). It is thought that long-term, continual exposure to EDCs may have subtle effects on vertebrate populations over time through adverse effects on reproduction (Daughton and Ternes, 1999).

3.2.3 Water Quality Constituents: Significance and Standards

The following descriptions are for the various water quality constituents that have been tracked within the watershed.

Field Parameters

Field parameters are physical properties measured to establish the environmental conditions at the time that the water quality sample is collected, and they help in understanding water-chemical and biological data. These parameters include pH, temperature, dissolved oxygen, specific conductance, and total dissolved solids.

pH, is the negative logarithm of hydrogen ion concentration and relates to the health of aquatic organisms because it is a key determinate for the overall water chemistry. CDPHE has established an instream standard for pH in the range of 6.5 to 9.0 units (Colorado Department of Public Health and Environment, 2007b). Some portions of the watershed have naturally elevated pH values because of the geology of the area, so occasional exceedances of the standard would not be of high concern. However, pH values consistently above the standard at a given site could be considered a water quality concern.

Water temperature can influence the metabolic rates of stream organisms. Consistently elevated stream temperatures are a water quality concern. The CDPHE maximum instream standard for water temperature is 20°C (68°F) (Colorado Department of Public Health and Environment, 2007b). Exceptions to this standard are the Fryingpan River from Ruedi Reservoir Dam to the confluence with the Roaring Fork River and the Roaring Fork River from the confluence with the Fryingpan River to the confluence with the Colorado River. These two segments are designated as Gold Medal fisheries by the Colorado Wildlife Commission and have a chronic temperature standard of 18.2°C (64.8°F) (Colorado Department of Public Health and Environment, 2007b). The interim temperature standards for rivers and streams above 7,000 feet that have cutthroat or brook trout populations is not to exceed an average weekly temperature of 17.22°C (63°F).

Adequate dissolved oxygen concentrations in surface water are an important factor to maintaining a healthy stream ecosystem because many aquatic organisms depend on dissolved oxygen for respiration. CDPHE’s minimum instream standard for dissolved oxygen is 6.0 milligrams per litre (mg/L) except during spawning periods for cold water fish when the standard is 7.0 mg/L (Colorado Department of Public Health and Environment, 2007b).

Specific conductance is a measure of the ability of water to conduct an electrical current (Hem, 1992). Specific conductance is often used as an indication of the mineral content (total dissolved solids) of water. It can be monitored on a continuous basis in streams, which provides an opportunity to understand the relationships between constituent concentrations and their relationship to streamflow. No water quality standard exists for specific conductance.

Major Ions

The relative percentages of the major ion concentrations in a water sample may indicate the water type and can help identify the water source (Freeze and Cherry, 1979). Understanding the source of a water sample will aid in interpreting the water quality findings. The major ions dissolved in most natural waters typically include calcium, magnesium, potassium, sodium, carbonate, bicarbonate, chloride, fluoride, sulfate, and silica. Complete major-ion data have not been routinely collected at all sites throughout the watershed. Five sites had sufficient data to characterize water type (Appendix 3.2.2, figures 1-5):

- Roaring Fork River above Difficult Creek near Aspen (Site 2),
- Roaring Fork River near Emma (Site 18),
- Roaring Fork River at Glenwood Springs (Site 24),
- Crystal River above Avalanche Creek near Redstone (Site 42),
- Crystal River below Carbondale (Site 46).

Because chloride and sulfate have a 250 mg/L standard, these major ion constituents were evaluated and summarized for most sites (Colorado Department of Public Health and Environment, 2007b).

Hardness is defined in terms of the presence of calcium and magnesium cations in water and cannot be attributed to a single constituent, but is reported in terms of an equivalent concentration of calcium carbonate. Hardness in the range of 0 - 60 mg/L is considered soft while hardness greater than 180 mg/L is considered very hard (Hem, 1992). Soft waters (low hardness) are associated with rocks that are resistant to weathering like igneous rocks. Hard water (high hardness) could indicate that the water was in contact with calcite-rich rocks like limestone. Higher hardness concentrations buffer the effects of some trace elements, which is why the Table Value Standards (TVS) for trace elements are computed based on hardness.

Total dissolved solids (TDS) is a measure of the concentration of dissolved ions (mostly major ions) in water and is commonly referred to as salinity. CDPHE does not currently have a TDS standard; however, TDS concentrations above 1,000 mg/L are considered slightly saline (Hem, 1992).

Nutrients

Nutrients (nitrogen and phosphorus) are essential for plant and animal nutrition but excessive concentrations in water can have adverse ecological and human health effects. Nitrogen and phosphorus occur in different chemical forms, including ammonia, nitrate, nitrite, orthophosphate, and in organic compounds. Natural sources of nutrients to streams include the erosion and dissolution of phosphorus minerals from geologic formations, soils, and the decomposition of organic material. Anthropogenic sources of nitrogen and phosphorus include the use of fertilizers in agricultural and urban areas, effluent from wastewater treatment plants, seepage from combined-animal feedlots, and septic systems, and use of detergents containing phosphates. Atmospheric deposition of nitrogen can result from naturally occurring nitrogen compounds in the atmosphere or from nitrogen compounds created through fossil fuel combustion.

Excessive concentrations of nitrogen and phosphorus in a waterbody can cause eutrophication, possibly resulting in excessive algal growth or blooms, low dissolved oxygen concentrations, fish kills, and a decline in the health and diversity of aquatic communities such as invertebrates and fish. Elevated concentrations of un-ionized ammonia (NH_3) in a stream can be toxic to fish.

Nitrite is an intermediate form of nitrogen and is typically found in high concentrations in association with untreated sewage or other organic waste. Outside of these circumstances, nitrate is the more stable nitrogen species found in natural waters and can exist in a wide range of environmental conditions (Mueller et al., 1995). In water sample analysis, nitrogen is most commonly reported as nitrite plus nitrate, but can be assumed to consist almost entirely of nitrate unless an obvious source of nitrite is present. Phosphate is the only significant form of dissolved phosphorus in natural water (Hem, 1992) and is only moderately soluble. Compared to nitrate, phosphate is not very mobile in a groundwater setting. Instead, phosphorus is often found in sediment and organic particulates, therefore, erosion can transport considerable amounts of suspended phosphorus to surface waters (Mueller et al., 1995).

Instream State water quality standards have been established for nitrite (0.05 mg/L), nitrate (10 mg/L), and un-ionized ammonia (has a TVS) by CDPHE for selected stream segments in the watershed (Colorado Department of Public Health and Environment, 2007b). A nitrate standard has not been established for Brush Creek. CDPHE has not established an instream standard for total phosphorus. As an approach to developing an actual nutrient criteria for streams, the State of Colorado Water Quality control Division is currently working to understand the link between nutrient criteria for streams and their designates uses, aquatic life, and recreation (Colorado Water Quality Forum, 2008). As a general water quality recommendation, the USEPA recommends that total phosphorus concentrations be less than 0.1 mg/L for streams and less than 0.05 mg/L for streams flowing directly into lakes and reservoirs in order to control eutrophication of the water bodies (USEPA, 1986). The USEPA developed a national strategy for developing regional nutrient criteria for regions that are aggregates of USEPA's level III ecoregions. In each region, naturally occurring conditions for nutrients are similar. The total phosphorus regional nutrient criteria were developed and represent reference conditions (conditions that reflect minimal impact to waterbodies by human activities). These criteria represent a starting point for States and Tribes in developing water quality standards to protect aquatic life and water uses. Reference conditions for the Roaring Fork River Basin (part of level III ecoregion 21, Southern Rocky Mountains) is 0.01 mg/L for total phosphorus (U.S. Environmental Protection Agency, 2000). For this analysis, the 0.1 mg/L was used as a "standard" for comparison instead of the 0.01 mg/L concentration for several reasons. As with both of these concentrations, they are recommendations and not actual standards. In addition, it was beyond the scope of this effort to apply the 0.01 mg/L concentration as many of the sample's method report limits (MRLs) are equal to or exceeded the 0.01 mg/L standard. Adding to this complexity, many sites had multiple MRLs.

Trace Elements

Many trace elements in natural waters are vitally important to human health, plant nutrition, and aquatic life. For example, fluoride concentration in drinking water and its relation to prevention of tooth decay was discovered in the 1930s (Hem, 1992). However, in larger concentrations, trace elements can be toxic to plants and animals and, in sufficient concentrations, to humans. Trace elements are often defined as those elements that generally occur in concentrations less than 1,000 microns per litre (µg/L) (Hem, 1992). Unless stated otherwise, trace element concentrations refer to dissolved concentrations.

There are natural (geology) and anthropogenic sources of trace elements in streams. Anthropogenic sources can include mining activity and urban land uses that act to increase trace element contributions to streams. Mining (both active and historical) in the watershed has provided conduits for water and air to come in contact with the underlying geologic material, where both physical and chemical weathering can dissolve and transport trace elements. Waste streams from human activities in urban areas also can mobilize trace elements in the environment. Arsenic, cadmium, copper, total recoverable iron, lead, manganese, selenium, and zinc concentrations were all evaluated for this report with respect to TVS exceedances (Colorado Department of Public Health and Environment, 2007b).

Microorganism Data

Microorganism data were summarized where available and compared to standards for two indicator organisms, fecal coliform and *E. coli*. USEPA recommends fecal coliform testing for recreational waters (U.S. Environmental Protection Agency, 2007b). CDPHE has set a numeric standard of 200 colony forming units per 100 milliliters (CFU/100 mL), which is also the suggested USEPA guideline. Studies comparing fecal coliform to *E. coli* indicate that illnesses attributed to swimming in water contaminated by fecal matter correlate more strongly with *E. coli* colony counts (Dufour and Cabelli, 1984). Based on this information, the USEPA has recommended the use of *E. coli* as a fecal indicator. There is a standard of 126 CFU/100 mL for *E. coli* in the Roaring Fork Watershed.

Suspended Solids

High levels of suspended solids can impair aquatic ecosystems by increasing the temperature of the water, abrading and clogging fish gills, and smothering plants, insects, and fish spawning beds. Two types of suspended solid-phase material data were available within the watershed: total suspended solids (TSS) and suspended sediment (SS). Studies by Gray et al. (2000) have concluded that SS and TSS are not comparable and that SS is the more reliable and reproducible measure of suspended matter in natural waters. SS in streams and rivers is compositionally identical to TSS with the exception that SS includes sand-sized (and larger) particles that TSS may not include. Where available, SS data are used to describe suspended solid-phase material, and in its absence, TSS data are used.

3.2.4 Influences on Water Quality

Water quality can be influenced by natural and anthropogenic sources, which originate from either point or nonpoint sources. A point source is a single localized source of pollution, while a nonpoint source is a diffuse source. Various point and nonpoint sources were identified for the

Roaring Fork Watershed in the 208 plan developed by Northwest Colorado Council of Governments (NWCCOG) in 2002. These include wastewater treatment plant discharges, population growth, and industrial discharges. The water quality section for each sub-watershed in Chapter 4 has a map that shows the location and size of wastewater treatment plants and sanitation districts. Nonpoint sources included runoff from urban land use, hydrologic modifications, mining, recreational activities, and agricultural activities (Northwest Colorado Council of Governments, 2007). As urban and residential land uses increase in the watershed, changes in water quality will likely be observed in streams and groundwater. Increases in impervious surfaces can act to create chemical runoff, increase stream temperatures, and decrease the amount of infiltration that occurs during precipitation and snowmelt events. Low stream flows intensify the concentration of chemicals and can adversely affect water quality. For example, the allowable concentrations of constituents in wastewater effluent are calculated based upon the quantity of the receiving water. If the use of independent septic drainage systems increased in the watershed, the potential for groundwater contamination from nutrients and microorganisms could also increase.

3.2.5 Water Quality Regulations

This section focuses on federal and State regulations (some of which were briefly mentioned in Section 3.2.1) that determine how water quality is evaluated and protected generally and within the Roaring Fork Watershed.

Federal

The Clean Water Act (CWA), 33 U.S.C. Secs. 1251, et seq., is the cornerstone of surface water quality protection in the United States (the act does not deal directly with groundwater or water quantity issues). It is administered by the USEPA, and employs a variety of regulatory and non-regulatory tools to sharply reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." An introduction to the CWA can be found at: http://www.epa.gov/watertrain/cwa/.

For many years following the passage of the CWA in 1972, the USEPA, States, and Indian tribes focused mainly on the chemical aspects of the "integrity" goal. During the last decade, however, more attention has been given to physical and biological integrity. Also, in the early decades of the CWA's implementation, efforts focused on regulating discharges from traditional point source facilities, such as wastewater treatment plants and industrial facilities, with little attention paid to runoff from streets, construction sites, farms, and other "wet-weather" sources.

Starting in the late 1980s, efforts to address polluted runoff have increased significantly. For nonpoint source runoff issues, voluntary programs, including cost-sharing with landowners, are often used. For wet weather point sources like urban storm sewer systems and construction sites, a regulatory approach is being employed.

Evolution of CWA programs over the last decade also has included a shift from a program-by-program, source-by-source, pollutant-by-pollutant approach to more holistic watershed-based strategies. Under the watershed approach, equal emphasis is placed on protecting healthy waters and restoring impaired ones. A full array of issues are addressed, not just those subject to CWA regulatory authority. Involvement of stakeholder groups in the development and implementation of strategies for achieving and maintaining State water quality and other environmental goals is another hallmark of this approach

One of the key issues in the CWA relevant the to the State of Colorado and the Roaring Fork Watershed is the extent to which it can address the water quality effects of water withdrawals and diversions under the Colorado water law system. In this regard, the Colorado General Assembly enacted H.B. 1132 in 2007. This new law provides that, when a water judge issues a decree for a change of type of use of irrigation water rights that transfers more than 1,000 acre-feet of consumptive use of water per year, the water judge may include a term or condition that addresses decreases in water quality caused by the change. This new law only applies to water rights applications filed after the effective date of the legislation (Feb. 28, 2007).

The Safe Drinking Water Act (SDWA) 42 U.S.C. Secs. 300f to 300j-9 was originally passed by Congress in 1974 and amended in 1986 and 1996. The law protects public health by regulating the nation's public drinking water and its sources, which include rivers, lakes, reservoirs, springs, and groundwater wells (SDWA does not regulate private wells that serve fewer than 25 individuals). SDWA authorizes the USEPA to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water. The USEPA, States, and private or public water systems then work together to make sure that these standards are met.

There are a number of threats to drinking water, including improper disposal of chemicals, animal wastes, pesticides, human wastes, wastes injected deep underground, and naturally-occurring substances. Drinking water that is not properly treated or disinfected, or that travels through an improperly maintained distribution system, also can pose a health risk. Originally, SDWA focused primarily on treatment as the means of providing safe drinking water at the tap. The 1996 amendments greatly enhanced the existing law by recognizing source water protection, operator training, funding for water system improvements, and public information as important components of safe drinking water. This approach ensures the quality of drinking water by protecting it from source to tap. For additional information about the SDWA, go to: http://www.epa.gov/safewater/sdwa/30th/factsheets/understand.html.

State

The following information was taken from “The Citizen’s Guide to Water Quality Protection” (Colorado Foundation for Water Education, 2003), which can be referred to for more detailed information.

The CDPHE is the State agency in charge of water quality protection. The Water Quality Control Commission (WQCC), Water Quality Control Division (WQCD), Operators Certification Board, and the Board of Health are all part of CDPHE. The WQCC develops the rules for water quality management while the WQCD implements management policies established by the Commission and Board of Health. CDPHE is Colorado's lead agency for surface and groundwater monitoring, protection, and restoration. It regulates the discharge of pollutants into the State's surface and groundwater and enforces the Colorado Primary Drinking Water Regulations. The Colorado Board of Health sets State drinking water standards, minimum standards for individual sewage disposal systems, and land application of water treatment plant sludges. The Colorado Water and Wastewater Facility Operators Certification Board licenses operators of facilities that treat and manage drinking water and sewage. Additionally the Colorado Division of Wildlife provides input to the WQCC/WQCD regarding the health of the State's aquatic life. Colorado's water quality protection framework has three main components:

- Use classifications
- Water quality standards
- Anti-degradation provisions

The WQCC adopts use classifications for each current or future use to be protected, based on how the water is currently used and what beneficial uses are desired in the future. To protect these uses, the State sets numerical and narrative standards. The primary purpose of anti-degradation provisions is to protect current water quality, especially where that quality is better than necessary to protect a water body's classified uses. More detail about these standards is provided above in Section 3.2.3.

The WQCD coordinates the State's stormwater permitting program. All construction that disturbs more than one acre of land is required to develop a Stormwater Management Plan and apply for a Stormwater Discharge Permit. This program does not set numerical standards or require sampling, but rather puts the onus on the permittee to implement a series of best management practices to assure that no pollutants will enter a water of the State via stormwater runoff.

Within the stormwater program, local communities are encouraged by CDPHE to contract with the WQCD to conduct inspections on permitted and non-permitted construction sites. The municipalities and counties within the Roaring Fork Watershed are small and have not yet entered the USEPA-mandated phase of implementation of stormwater programs. As a result, most jurisdictions in the watershed have not yet begun to develop criteria or programs to manage those discharges associated with storm events.

3.3 Riparian Areas

Riparian ecosystems are unique kinds of wetlands located adjacent to streams and rivers. Moisture-loving plants and periodically flooded soils define and characterize riparian areas. In the Roaring Fork Watershed the landscape experiences sharp transitions between uplands and riparian areas. Mountain uplift and volcanism followed by glaciations have sculpted a dramatic landscape with steep valleys further eroded by streams. Riparian areas have formed where gradients decrease so that streams flow outside of their channels, or where meandering creates point bars or mid-channel islands suitable for establishment of new vegetation. In this narrow area where soils and soil moisture are influenced by the adjacent stream, a distinct zone of vegetation develops. This section provides information about the kind and scope of riparian information available for the Roaring Fork Watershed, gaps in information, functions of riparian areas, factors that affect them, and biological indicators useful in assessing condition of riparian habitat and wildlife.

On a landscape level, the riparian zone has been described as the “interface between man’s most vital resource, namely, water, and his living space, the land” (Odum, 1981). As an interface, riparian ecosystems are laterally connected to upland and aquatic systems and functionally connected to up- and downstream aquatic ecosystems. Compared with the expansive wetlands of the Southeast or the coastal wetlands of eastern North America, riparian areas in the Mountain West are typically long, narrow features of the landscape, best characterized as a distinct habitat mosaic within the larger landscape (Gregory et al., 1991). The contrast in elevation and vegetation between upland and bottomland is usually sharp and distinctions are clear – uplands are drier and warmer than nearby riparian bottomlands; upland vegetation is drought tolerant, riparian vegetation is moisture-requiring; upland vegetation is judiciously spaced, riparian vegetation is lush and dense; and upland vegetation spreads widely across hillslopes while the riparian zone is confined to a narrow area adjacent to streams.

Riparian systems have the highest species richness of all major ecosystem types in Colorado, but cover only one to two percent of the land area (Fitzgerald et al., 1994). Riparian vegetation enhances wildlife potential by increasing the diversity and structural complexity of both terrestrial and aquatic wildlife habitat. Native riparian vegetation provides wildlife with shelter, forage, nest and breeding sites, refuge from extreme temperatures, and protected migratory passages. Riparian vegetation also stabilizes stream channels and enhances the structural diversity of instream habitat. In most stream types, except those that are bedrock controlled, riparian vegetation is essential to maintaining a naturally sinuous channel shape and, consequently, a variable stream bottom, depth of water, and flow velocity.

Structurally, riparian ecosystems are a complex mosaic of vegetative stands that differ in species composition (Mutel and Emerick, 1992). As an example, within riparian areas willow carrs are interspersed with wet meadows, moist meadows, and groves of trees. This provides a diversity of resources that, in turn, enables the development of a rich community of wildlife. Typically, in an undisturbed riparian system, the herbaceous understory is lush and diverse; it is not unusual for the riparian floodplain to have three times the number of plant species of adjacent upland forests (Mutel and Emerick, 1992).

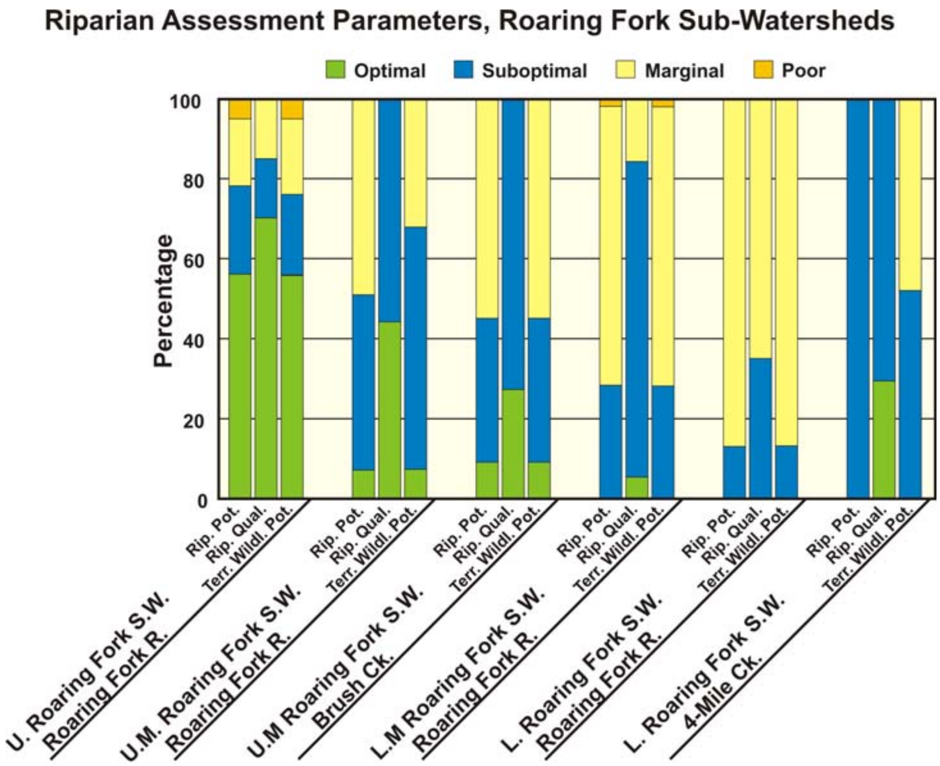
3.3.1 Data Sources and Assessments

Several types of information are available to evaluate riparian areas in the watershed, including field-based riparian surveys, breeding bird counts, identification of natural heritage areas and species of concern, mapped riparian vegetation communities, and predicted species distribution maps. These sources are described below.

Stream Health Initiative

In 2007, the Stream Health Initiative (SHI) completed a comprehensive assessment of riparian areas in the Roaring Fork Watershed (Malone and Emerick, 2007a). During three years of field work, from 2003 to 2005, SHI conducted a riparian habitat study on approximately 185 total stream miles in the watershed, including the Roaring Fork River from its headwaters to its confluence with the Colorado River, significant portions of Lost Man, Castle, Maroon, Brush, Snowmass, Cattle, and Fourmile creeks, and the Fryingpan and Crystal rivers. This assessment used the Natural Resource Conservation Service's (NRCS) Riparian Assessment method (NRCS, 2004) to evaluate the condition of riparian and stream ecosystems in the watershed and to identify recovery strategies that could reverse downward trends in site stability. The NRCS method evaluates riparian habitat condition and functionality – the ability to maintain a sustainable ecosystem – by characterizing 11 parameters encompassing the amount of riparian cover and its condition, the type of riparian cover with regard to its stabilizing ability, and the stability of the stream channel. For each stream reach evaluated by the SHI, field-based visual assessments were made of riparian, flood-prone, and upland vegetation, and of the condition of stream banks and the channel. Native vegetative species were recorded in order of abundance, their condition assessed, and they were classified according to soil-stabilizing ability using the NRCS Plant Stability Rating Table. Weedy plant species were also identified and evaluated for degradative potential. This information was used to rank the condition of the left and right bank riparian habitat from high quality to severely degraded as portrayed on the sub-watershed maps and discussed in Chapter 4 ("left" and "right" bank corresponds to orientation when looking downstream).

Riparian habitat assessment results from the SHI have been summarized in charts that report riparian condition in the following categories: riparian potential, which is evaluated by parameters including riparian zone width; vegetative protective cover and soil condition; riparian quality, which includes vegetative quality, vigor, age class distribution, and noxious weed occurrence; and terrestrial wildlife potential, which includes riparian condition and quality plus human activities and disturbances (Figures 3.3.1). Appendix 3.3.1 contains the actual percentage values for each of these categories within each sub-watershed.



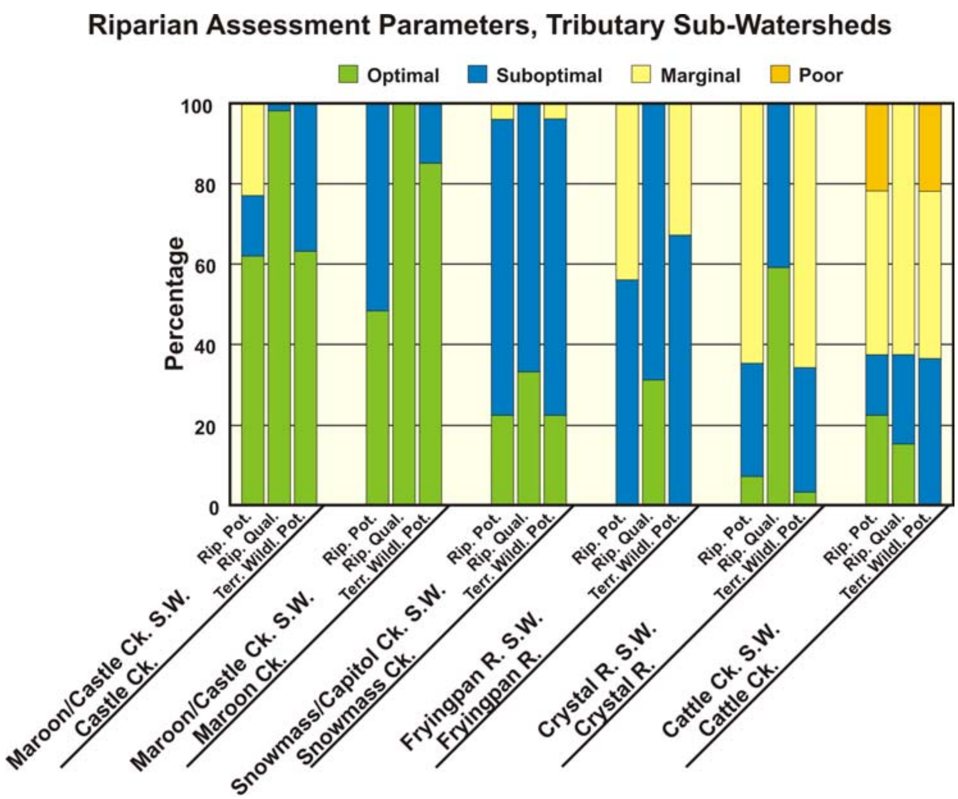


Figure 3.3.1. Riparian assessment parameters by sub-watershed.

During the SHI assessment, Conservation Areas of Concern (CAC) were identified. These areas are, or have potential to be, especially valuable to wildlife, but are at risk due to current or potential threats to stream and wildlife values. Some of these areas are currently in ecologically sustainable condition, while others are in need of management action to restore ecological health. These CACs are shown in Figure 3.3.2. They are also described and shown on the riparian and instream maps in the sub-watershed sections within Chapter 4.

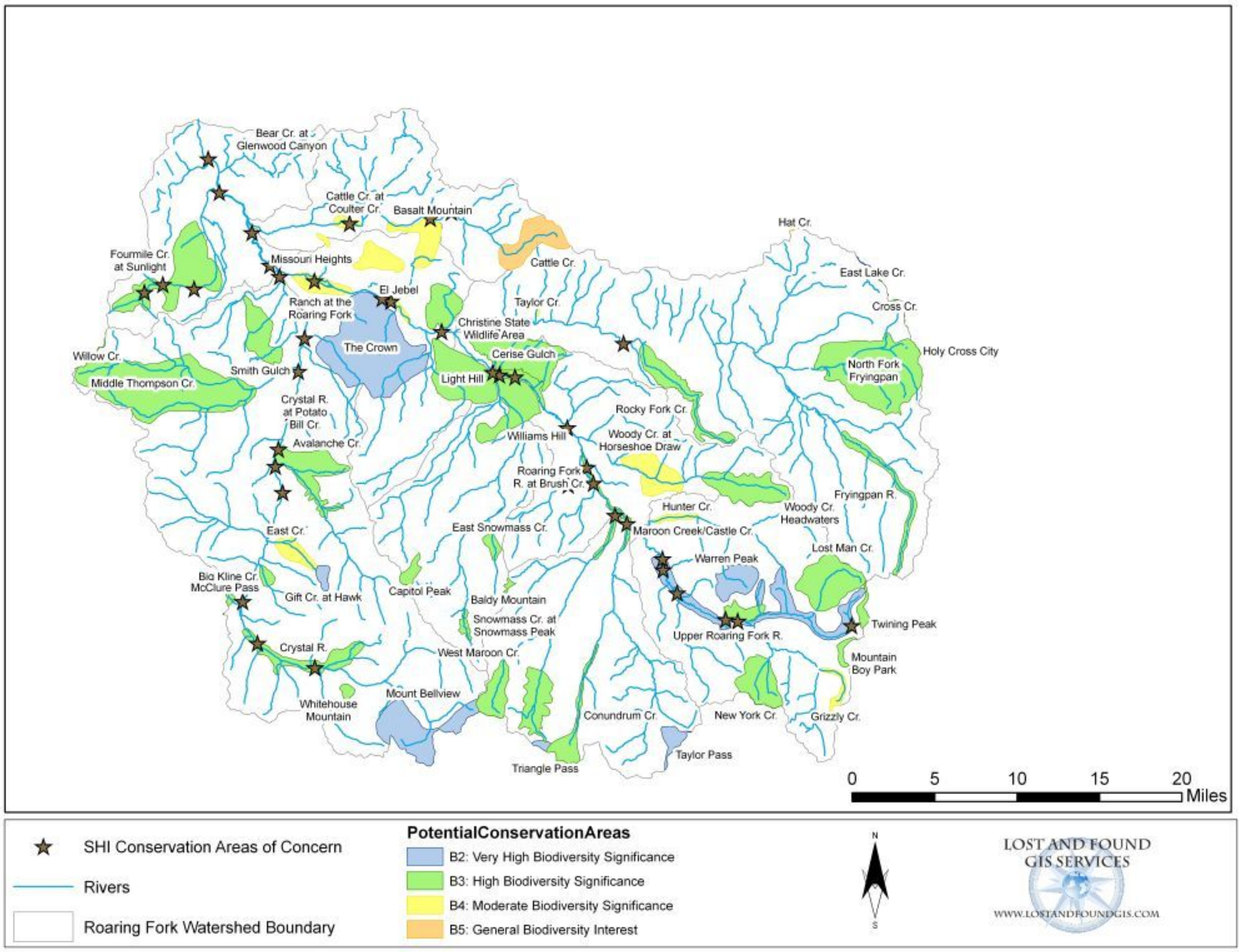


Figure 3.3.2. CNHP Potential Conservation Areas (PCA) and SHI Conservation Areas of Concern (CAC) in the Roaring Fork Watershed (Source: Spackman et al., 1999 and Malone and Emerick, 2007a).

Native birds are good indicators of the health of the natural environment. As one aspect of the SHI riparian assessment, riparian breeding bird point count surveys were conducted on specific reaches in each sub-watershed. SHI used an Intensive Point Count protocol (Ralph et al., 1993) modified with regard to the shape of the surveyed area so that surveys were conducted along a transect line that ran parallel to the stream corridor (rather than in a grid form). Additionally, on each reach where bird surveys were conducted, vegetation characteristics, structure, and composition were evaluated using a method developed by Bingham and Ralph (Ralph et al., 1993).

Bird Data

Breeding bird surveys have also been conducted in the watershed by the Roaring Fork Valley Bird Monitoring Project (Vidal and Fidel, 1997) and by the Elk Mountain Biological Survey (PanJabi, 1995). The North American Breeding Bird Survey (BBS) has taken place in the Aspen area since 1988, and the Christmas Bird Count has been conducted throughout the Watershed since 1978 (Linda Vidal, personal communication, 2008). On a few Pitkin County Open Space properties, bird surveys have been done to help guide the development of management plans (http://www.aspenpitkin.com/depts/21/). These and other projects have collected breeding bird data using point counts, and in some locations have done nest searches and banding. The resulting information contributes to our knowledge of local bird communities and habitat health. Ongoing data collection at the same sites surveyed by the BBS and Christmas Bird Count have contributed to the ability to evaluate long term population trends and thereby assess the potential impacts of changing land uses on bird communities and on riparian habitat health.

The Colorado Breeding Bird Atlas (Kingery, 1998) establishes a “snapshot in time” of the breeding birds in Colorado. Maps in the atlas provide information about breeding bird richness, abundance, distribution, and habitat use. With ongoing monitoring, the atlas offers the possibility to detect changes in species range and population status. An updated atlas that will provide a better understanding of population trends, is now in preparation.

The Important Bird Area (IBA) program, which is administered globally by the National Audubon Society, highlights areas that provide essential habitat for one or more bird species. IBAs are designated to help protect habitats that have any of the following:

- Species of conservation concern (e.g. threatened and endangered species)
- Range-restricted species (species vulnerable because they are not widely distributed)
- Species that are vulnerable because their populations are concentrated in one general habitat type or biome
- Species, or groups of similar species (such as waterfowl or shorebirds), that are vulnerable because they occur at high densities due to their congregatory behavior

Natural Heritage Areas and Species of Concern

The Colorado Natural Heritage Program (CNHP) conducted an assessment of the natural heritage values of lands in the Roaring Fork Watershed (Spackman et al., 1999). CNHP’s goal was to identify areas in the watershed with natural heritage significance. They found more than 78 rare or imperiled plant or animal species and significant plant communities, collectively called “elements.” CNHP concluded that due to the concentration of these elements in the watershed, their conservation would have statewide and global significance. One outcome of the assessment was the identification of Potential Conservation Areas (PCAs). PCAs are areas essential to the protection of identified elements. These PCAs are shown in Figure 3.3.2 and are specifically described in Chapter 4 in the sub-watershed section in which they occur. Appendix 3.3.2 lists the PCAs in the watershed, their biodiversity significance, and protection and management urgency. A goal of the assessment and PCA assignment was to delineate ecologically sensitive areas and to develop and suggest implementation plans for protecting the PCAs. In 2005, the Aspen Valley Land Trust updated some of this information for private lands within the watershed (AVLT, 2005).

The Nature Conservancy worked with several project partners to produce the Roaring Fork Watershed Measures of Conservation Success (2008). This document outlines a site specific conservation strategy to ensure the long-term survival of native species and communities. It identifies stresses, sources of stress, strategies to mitigate or eliminate threats and enhance biodiversity, and a method for assessing success. Key riparian-related conservation targets identified by this project include: willow hawthorn, canyon bog orchid, hanging garden sullivantia, altai cottongrass, montane riparian forests, willow carrs, kettle ponds, and riparian ecological systems.

Appendix 1.3 notes the riparian-related species of concern and their occurrence by sub-watershed, based both on listings and designations at the federal and state level and those made by CNHP and Audubon. Named are 23 bird species, eight mammal species, 10 plant species, and 29 plant communities.

Riparian Vegetation and Species Distribution Mapping

The Colorado Division of Wildlife (CDOW) mapped riparian vegetation communities for parts of the state using 1:40,000-scale color infrared aerial photography (http://ndis1.nrel.colostate.edu/riparian/riparian.htm). This information is available to public and private agencies and individuals to aid with environmental assessment, proprietary land management, resource planning, and general scientific reference. This information is available for the watershed but the scale of the maps is too coarse to provide the detailed information needed for a reach-level assessment. The data are useful as a “coarse filter” – for instance, in providing landscape and distribution patterns of vegetation and potential wildlife habitat.

CDOW Natural Diversity Information Source (NDIS) tracks 748 animal species, including, when available, a species’ life history text, a photo, maps, and a listing status (http://ndis.nrel.colostate.edu/wildlife.asp). The only Colorado species not tracked are "accidental" occurrences or species considered "extinct." In addition, sub-species are not tracked unless listed in some way (for example, the greenback cutthroat trout is on the federal- and state-threatened list). NDIS Geographic Information System (GIS) spatial data are available for several riparian-related species found in the Roaring Fork Watershed – Northern river otter, osprey, great blue heron, and bald eagle (figures 3.3.3, 3.3.4, and 3.3.5) (http://ndis.nrel.colostate.edu/ftp/index.html).

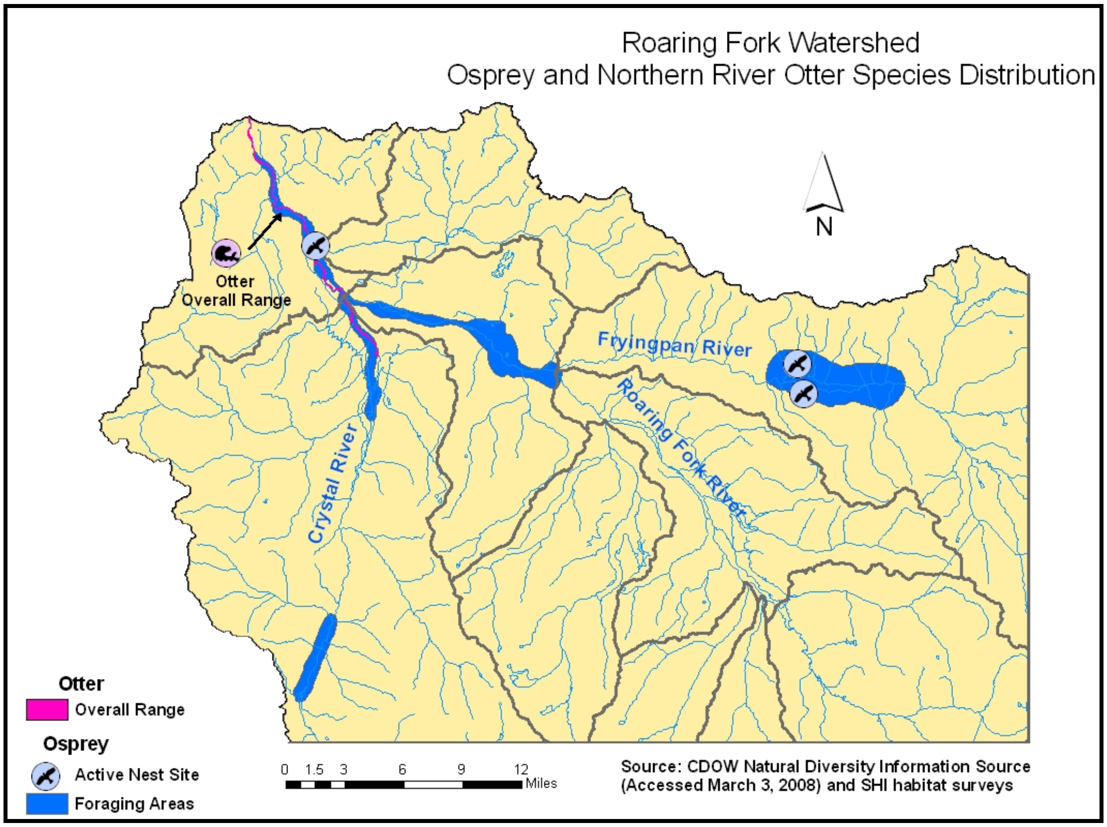


Figure 3.3.3. Osprey and Northern river otter species distribution in the Roaring Fork Watershed.

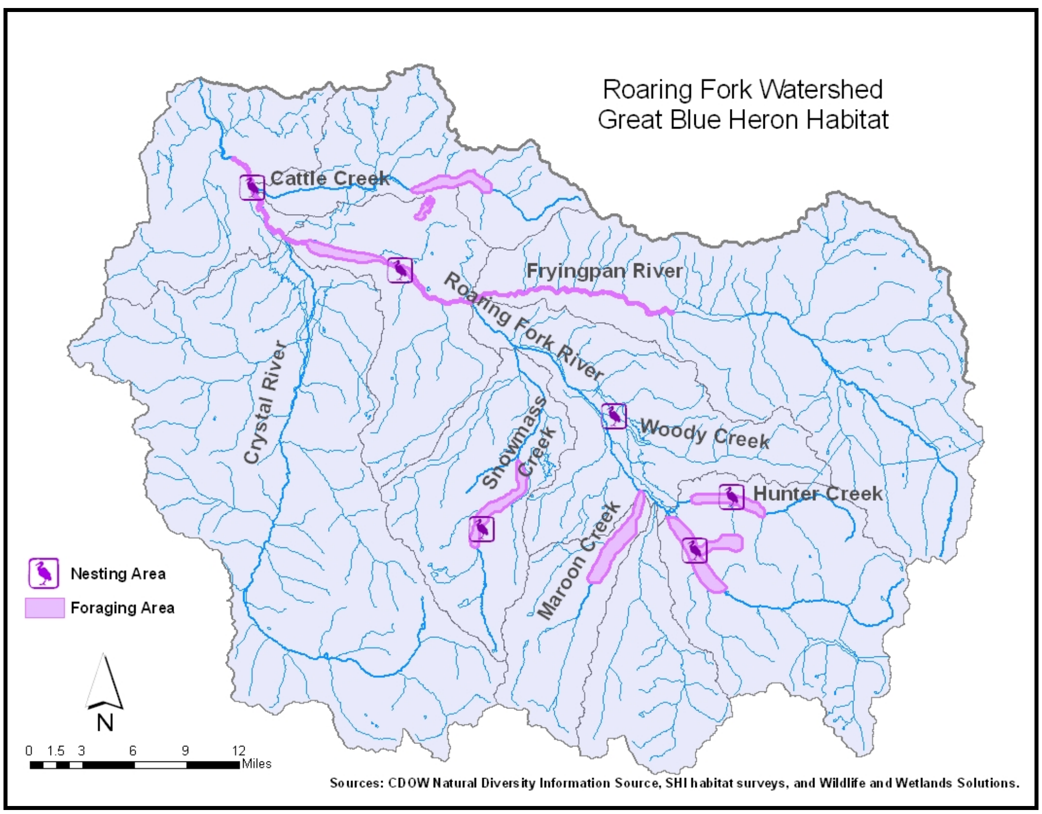


Figure 3.3.4. Great blue heron nesting and foraging areas in the Roaring Fork Watershed.

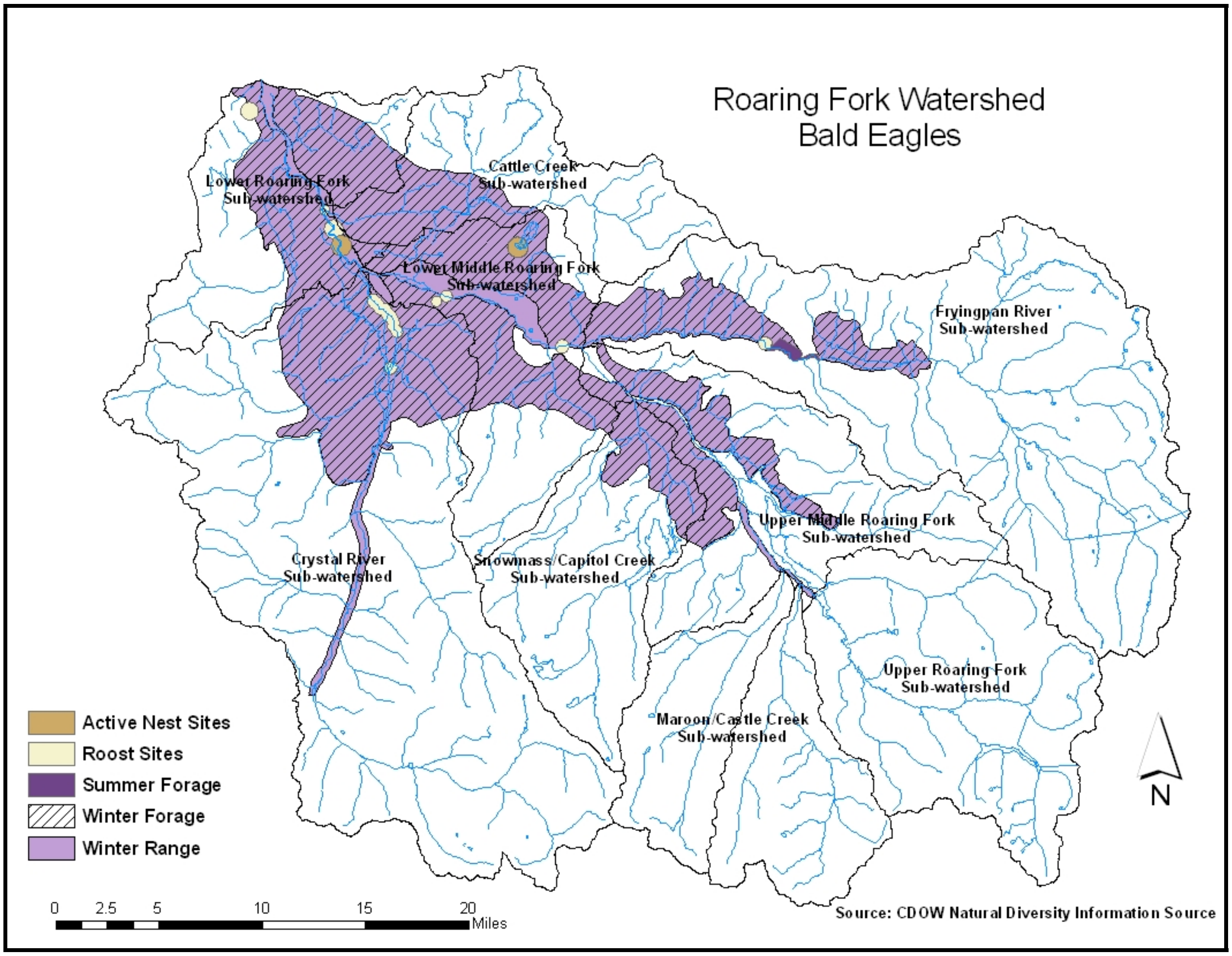


Figure 3.3.5. Bald eagle activities and ranges in the Roaring Fork Watershed.

Predicted species distribution maps are available from the Colorado Gap Analysis Project (http://ndis1.nrel.colostate.edu/cogap/cogaphome.html). Given the importance of riparian habitat, a special sub-model was developed to account for riparian species distribution. Maps of 597 vertebrate species, including birds, mammals, reptiles, and amphibians, are available statewide. These broad-scale maps are useful for identifying where to look for specific vegetative or wildlife communities. They were not used in the sub-watershed assessments because finer-scale data was available to evaluate actual habitat conditions and wildlife.

3.3.2 Data and Knowledge Gaps

SHI is useful for assessing the status of riparian areas for a majority of medium to large streams in the watershed. A re-survey of these streams at regular time intervals is needed to detect trends in riparian area condition. A riparian monitoring strategy and plan is needed to determine frequency and location of re-surveying efforts, and to establish a consistent protocol so that these trends can be found. Additionally, SHI did not survey all major streams. Streams that could be considered for future efforts include: Hunter, Woody, Lincoln, Capitol, Sopris, Coal, Prince, Thompson, and Threemile creeks and the upper Fryingpan River.

Species distribution information and population status and trends are needed for breeding, resident, and wintering birds as well as for small, medium, and large mammals. Important migratory stopover sites should be identified. Although the North American BBS has long-term monitoring data, information is generally sparse with only 23 percent of species being well-monitored (Partners in Flight, 2008).

Although the SHI used breeding bird diversity and evenness scores as indicators of habitat condition, such diversity information cannot detect changes in the composition of the bird community. Given this data gap, the SHI is developing an Index of Bird Integrity (IBI) specifically tailored to the watershed (Malone and Emerick, 2007b). Preliminary conclusions indicate that by categorizing bird species into groups, such as Neotropical migrants and disturbance intolerants, and using these groupings in combination with diversity scores, an IBI can be developed that is sensitive to even subtle habitat disturbances. Results so far indicate a statistically significant relationship between the presence of specific bird groups and habitat quality. However, because only one year of bird data was collected, further census data are needed to account for natural fluctuations in bird distribution and abundance. To fill in this gap and further develop an IBI, SHI plans to collect breeding bird data in 2008 and 2009.

An assessment of upland habitat condition, including soil disturbance, vegetative ground cover, deforestation, browse level, and erosion, would improve identification of factors influencing stream health. Reassessments of CNHP PCAs should be continued in order to assess current conditions and identify any changes in resource conditions or management needs.

In terms of knowledge gaps, several questions warrant further study:

- What are the impacts of riparian alteration and disturbance on the native wildlife community, including breeding bird and small mammal reproductive success, community assemblage, and diversity; and migration patterns of birds and mammals?
- What are the long-term impacts of flow alteration on the sustainability of riparian habitat and riparian forest regeneration? What streamflow levels (including base flow, flooding flow, duration, and timing) are needed to sustain riparian habitats?
- What management strategies are needed to protect and conserve identified PCAs and CACs? Development of specific management recommendations would require more detailed and comprehensive assessments.
- How will climate change influence riparian areas and the species that depend on these areas?

3.3.3 Function of Riparian Areas

Given their influence on instream physical habitat and water quantity and quality, riparian areas are both ecosystems in themselves and are critical components of stream ecosystems (Ward, 1989 and Gregory et al., 1991). Mountain riparian areas represent important connections between upstream and downstream, and upland and stream ecosystems. They store nutrients, transform inorganic nutrients to organic matter, and filter pollutants that come from upland runoff. Maintaining these connections is vital to successful stream conservation and wildlife community sustainability (Figure 3.3.6).

Figure 3.3.6. High quality riparian habitat on Castle Creek.

The structure and processes of riparian areas depend on the stream's ability to meander, to abandon those meanders, and to flood out of its banks. As mountain streams flow through glacial valleys or where the elevational gradient is not steep, they can meander widely. As streams flow across their floodplains, new meanders are created and old meanders are abandoned, leaving oxbow ponds. As an example of natural succession, these oxbow ponds change with time, gradually becoming vegetated as rich organic soils develop from sediments deposited by the stream. Open ponds become marshes with submerged aquatic vegetation such as pond-weed and taller emergents along the edge such as sedges or rushes (Mutel and Emerick, 1992). Eventually soil depth increases and these marshes become willow carrs or wet meadows characterized by new species of sedges, rushes, and other flowering plants such as bog orchids, monkey flower, bitter cress, and star gentian. For additional detail about oxbow pond succession, see Figure 4.1.2, an infrared aerial photograph of the North Star Nature Preserve and Appendix 3.3.3.

Riparian ecosystems are living filters, facilitating a complex process that starts with the breaking down of pollutants by soil microbes into essential chemical nutrients. The vegetation takes up and transforms those nutrients into plant tissue (leaves, stems, flowers, and roots) that then stabilizes stream and riparian habitat, and provides wildlife with a rich diversity of essential resources. The functions and values of riparian areas are determined by these natural processes and fall into five categories: protecting water quality, maintaining sustainable instream flows (Figure 3.3.7), maintaining the natural shape of the stream channel, maintaining biodiversity, and providing sustainable wildlife habitat (Figure 3.3.8). These functions contribute benefits to humans in the form of tangible ecosystem services (see Section 1.2.3 for further discussion of ecosystem services). The following is a summary of each of these functions, with greater detail provided in Appendix 3.3.3.

Figure 3.3.7. Riparian areas supports stream flow replenishment – here, groundwater discharges back into the Roaring Fork River.

Figure 3.3.8. On Castle Creek, riparian vegetation supports habitat sustainability as it filters pollutants, stabilizes banks, and prevents erosion.

Protecting Water Quality

Riparian vegetation maintains water quality by:

- Maintaining cooler water temperatures with the shade created by the tree and shrub canopy;
- Filtering out sediment with woody plant stems, native grasses, and sedges, all of which slow surface runoff allowing sediment to be deposited onto the floodplain rather than in the stream;
- Trapping pollutants such as pesticides and biologic pathogens that bind to sediment;
- Transforming nutrient pollutants into plant tissue; and

- Removing chemicals from the water through extended contact with the root systems.

Riparian soil helps maintain water quality by:

- Capturing soil microbes and decontaminating runoff-borne pollutants; and
- Recycling nutrients back into the forest, thereby preventing excess nutrients from entering stream systems.

Maintaining Sustainable Stream Flows

An important function of riparian areas is helping to sustain stream flows. Together, riparian vegetation and soil act as a sponge, soaking up flooding flows (thereby reducing flooding) and later releasing that stored water into the stream (Figure 3.3.9). Water stored in soil is discharged back into the stream during late summer and early autumn, and is essential to maintaining sustainable stream flows. Increased infiltration occurs (percolation of rain, melting snow, or out-of-bank stream flow into soil) due to the physical interception and slowing of runoff, which allows more time for porous soils to soak up and store water. Plant roots increase infiltration by improving soil porosity, which enables more precipitation runoff and out-of-bank flow to soak into and be stored by soil. Soil porosity is also increased by organic matter from riparian vegetation (leaves, decaying logs, and, especially, decaying roots), which improves infiltration and water storage.

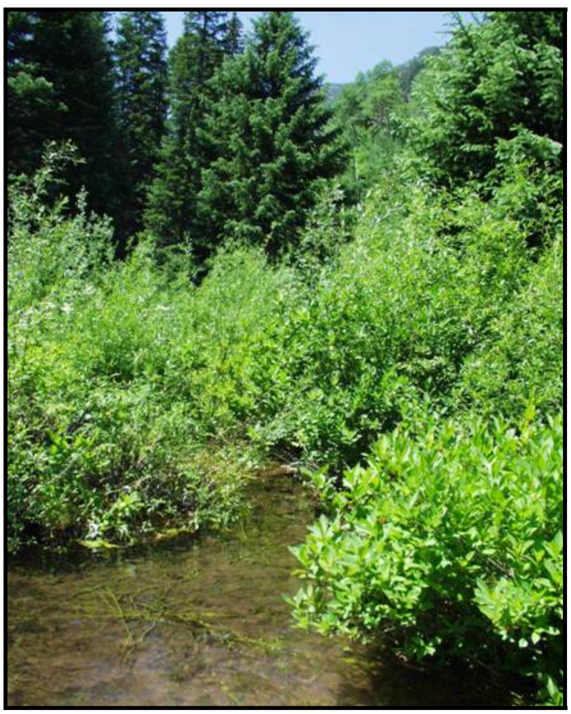


Figure 3.3.9. Riparian areas on Maroon Creek soak up out-of-bank flows, replenishing soil moisture and nutrients.

Maintaining Natural Channel Shape

Healthy riparian areas contribute to the maintenance of channel shape. Root systems of riparian vegetation anchor streambank soil, stabilize banks, and stop excessive erosion. By preventing excessive lateral and vertical erosion, the natural shape of the stream channel is maintained. A sinuous channel shape, bank roughness, and dense bank vegetation dissipate floodwater by physical interception, further protecting from excessive erosion and flooding. Large wood (e.g. logs, snags, root wads) in the stream enhances stream stability and increases habitat variety by creating pools, backwaters, and areas with slower flow.

Providing High Quality Wildlife Habitat

Riparian habitat has a disproportionately large impact on the survivability of natural wildlife communities in the West. In Colorado, riparian habitat represents no more than 3 percent of the landmass (Kingery, 1998) but has the highest species richness with 75 - 80 percent of wildlife species using riparian habitat during some part of their life cycle (Howe, 1996 and Lovell, 2000). In mountainous landscapes, riparian ecosystems are ecotonal habitats that connect upland and instream habitats, providing wildlife with refuge, access to critical food and other resources, and passageways for daily and season migration. Specifically:

- The tree and shrub canopy provides shade that maintains cooler air and stream water temperatures. These cooler conditions create a refuge for terrestrial wildlife from extreme upland temperatures and maintain sufficiently cool water temperatures for aquatic wildlife.
- A greater diversity of trees and shrubs increases the variety of food resources, which supports a greater diversity and abundance of wildlife throughout the year.
- Structurally complex riparian vegetation is essential to maintaining biological diversity. Patchy habitats with numerous layers of trees, shrubs, and herbs provide protected breeding sites (Figure 3.3.10) and rearing habitat for a wide diversity of birds (including Neotropical migrant songbirds, raptors, and shorebirds), large mammals (like deer, elk, black bears, lions, coyotes, and weasels), and small mammals (such as shrews, mice, and voles).
- Migrating birds seek out riparian habitat for stopover sites where they can safely rest and feed before continuing their migration. Large mammals use riparian areas as migration corridors to move between summer and winter habitat.
- Undercut streambanks, stabilized by vegetation, create protected and shaded resting habitat for fish.
- Vegetation that overhangs the streambank provides sites where aquatic insects lay their eggs; these insects are the primary food source for fish. Vegetation is the source of instream large wood, an essential structuring component in mountain streams.

Figure 3.3.10. Dense wetland vegetation on the Crystal River provides excellent nest habitat.

Human Uses

As noted earlier in this section, riparian areas fulfill a number of ecosystem services important to human needs, such as water quality treatment, management of hydrologic patterns and water quantity, biodiversity maintenance, and support of recreation activities (including angling, hiking, birding, picnicking, and camping). Riparian areas also provide rich environments for nature study, and aesthetic benefits through their shaded, quiet surroundings and scenic appeal.

3.3.4 Factors that Affect Riparian Areas

In the Roaring Fork Watershed, factors like development, roads, grazing and agriculture, recreational activities, mining, and beaver eradication all can alter or eliminate riparian vegetation, increase non-native plant and animal species, and disturb riparian soils. As a result, the functions that riparian areas provide are impacted. Each factor is discussed briefly in this section and in more depth in Appendix 3.3.3.

Development

Development in riparian areas can have severe and enduring impacts (Figure 3.3.11). Development that eliminates riparian vegetation also eliminates the ecosystem services that riparian vegetation provides such as water purification and flood attenuation. The development of permanent structures and surfaces precludes the opportunity to restore natural vegetation. It also increases impermeable surface area, leading to decreased infiltration and associated reduction in groundwater essential to sustaining riparian vegetation and streamflows.

Figure 3.3.11. Urbanization of riparian habitat on the Roaring Fork River.

Roads

A highway or road runs adjacent to almost every major stream in the watershed (Figure 3.3.12 and Table 3.3.1). Roadways sever the connection between upland and riparian ecosystems, can change groundwater flow, constrain a channel's ability to meander (Figure 3.3.13), and impact the ability of wildlife to safely access water, forage, and cover. Roads cause erosion, damage roots of nearby trees, change soil density, soil temperature, and soil water content, increase light levels, create dust, pollute surface waters, change patterns of runoff and sedimentation, and add heavy metals, salts, organic molecules, and nutrients to roadside environments (Trombulak and Frissell, 1999). These effects extend beyond the road to penetrate and negatively impact surrounding habitat. Riparian areas are highly susceptible to rutting, erosion, displacement, and compaction when low-standard roads or trails cross them, or the areas are used by all-terrain or off-road vehicles. Indirect impacts include streambank erosion, bank failure, and loss of wetland function (Douglass et al., 1999).

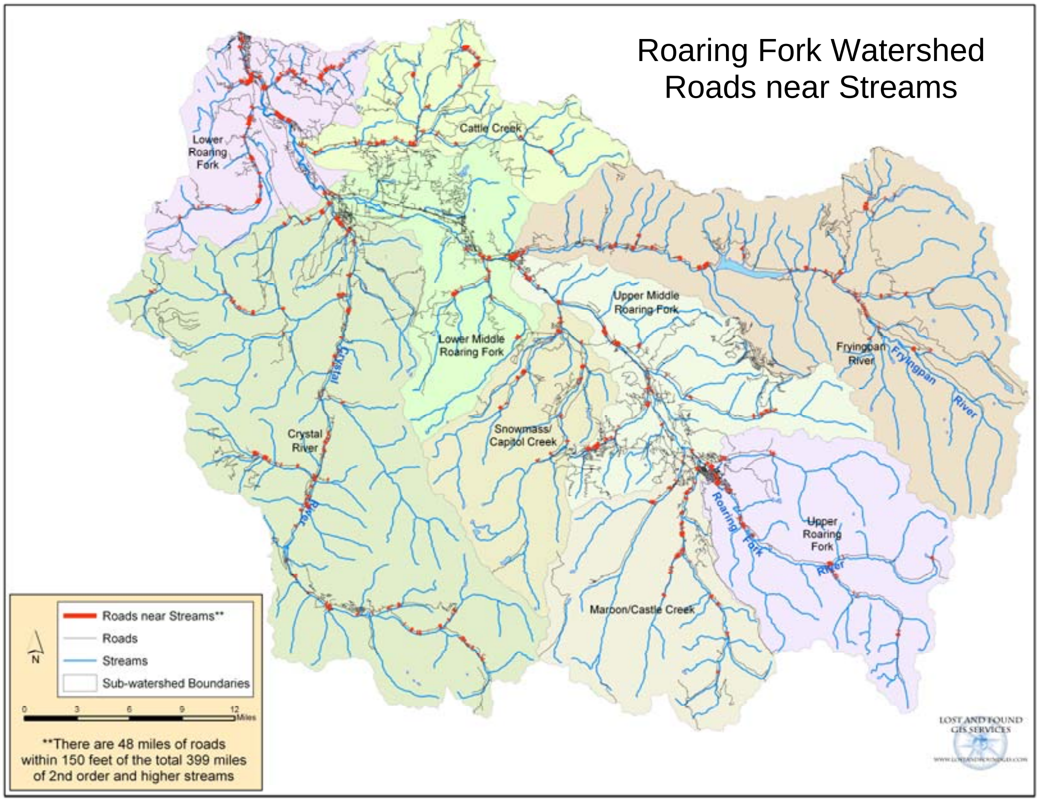


Figure 3.3.12. Roads within 150 feet of streams in the Roaring Fork Watershed.

Table 3.3.1. Roads within 150 of streams in each sub-watershed.

SUB-WATERSHED	TOTAL STREAM MILES (second-order and higher)	TOTAL ROAD MILES (within 150 feet of streams)	PERCENTAGE
Upper Roaring Fork	45	4	8.9
Upper Middle Roaring Fork	38	5	13.2
Lower Middle Roaring Fork	30	3	10.0
Lower Roaring Fork	36	9	25.0
Maroon/Castle	36	4	11.1
Snowmass/Capitol	32	2	6.3
Fryingpan River	64	6	9.4
Crystal River	88	10	11.4
Cattle Creek	30	4	13.3
		AVERAGE	**12.1**

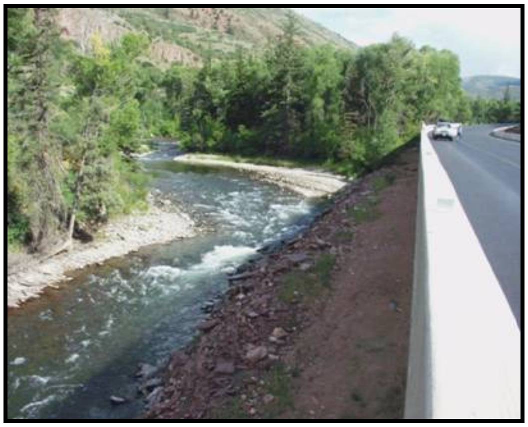


Figure 3.3.13. The development of Highway 82 has caused channelization of the Roaring Fork River.

Transportation corridors also increase the ease of human access into previously inaccessible riparian wildlife habitat. Human access into riparian areas brings disturbance that results in habitat loss, and can create intolerable levels of stress in many native wildlife species (e.g. Gutzwiller et al., 1998; Knight and Cole, 1991; Miller et al., 1998).

Grazing and Agriculture

The presence of livestock in riparian areas can result in ecosystem-level damage (Rueth et al., 2002). In the arid West, moisture-loving cattle concentrate in riparian zones and streams, eating the lush grassy and woody vegetation (Figure 3.3.14). As with mining and commercial logging activities, domestic livestock grazing is less common than it was historically, but grazing-induced habitat damage often continues to impact riparian and instream habitat long after grazing has ceased. In many areas of the watershed, grazing still occurs, affecting riparian areas and wildlife. For instance as a result of grazing and trampling of vegetation by cattle, many riparian areas have lost all understory vegetation at a time when it is most critical as cover and food source for bird species (Krueper, 1996). In addition, seedlings and saplings are eliminated, resulting in forest declines and loss due to reduced regeneration.

Figure 3.3.14. Cattle in the riparian zone on Snowmass Creek.

Recreation Activities

Outdoor recreation, already an enormous attraction of the Roaring Fork Watershed, can be expected to grow commensurate with population growth. Conflicts can be expected to escalate between human demand for recreation on public lands and the need to protect habitat and biodiversity from further degradation (Tomback and Kendall, 2002). Recreational hiking, walking, and fishing trails are common along river corridors (Figure 3.3.15). Trails compact soil, exacerbate erosion, facilitate the invasion of non-native plant and animal species (Kaiser, 1999), and reduce the quality of animal habitat by increasing human presence (Willard and Marr, 1970). Recreationists can severely disturb many native wildlife species, altering their distribution and use of habitat and disrupting breeding and raising of young. Human presence in wildlands disturbs ground- and shrub-nesting birds and small and large mammals whether or not the humans are on- or off-trail (Malone and Emerick, 2003; Miller et al., 1998; Knight and Cole, 1995). Trails and the presence of recreationists can also fragment wildlife habitat, and can cause avoidance behavior in some animals and attraction behavior in others that seek human food (Knight and Cole, 1991). Recreational impacts to riparian soils, vegetation, and wildlife occur at campgrounds, on trails, or low-standard roads, and at cross-country ski areas such as the North Star Nature Preserve. Common trail impacts include vegetation loss and compositional changes, soil compaction, erosion, muddiness, exposure of tree roots, trail widening, and the proliferation of visitor-created side trails (Marion, 2006).

Recreational development activities have also altered vegetation, soils, and habitat quality through disturbance and by direct removal. For example, development of golf courses in riparian areas and along streams has caused replacement of high quality riparian vegetation and habitat with low quality lawns, and has compacted soil and eliminated the litter layer (Figure 3.3.16). Recreational impacts negatively affect ecosystem processes and stream sustainability and have far reaching implications. For example, trampling of vegetation by recreationists damages and eliminates vegetation along streambanks and results in bank destabilization and erosion, which in turn leads to stream sedimentation. Vegetation conversion and soil compaction from recreational disturbance contribute to alteration in surface water flow, introduction of invasive plants, and disturbance of wildlife. All of these effects can extend considerably further into natural landscapes (Marion, 2006).

Figure 3.3.15. Elimination of understory vegetation at a campground on the Crystal River.

Figure 3.3.16. Habitat conversion at a golf course development on the Roaring Fork River.

Mining

Historic and current mining activity in the watershed is less extensive than in other areas of Colorado. Mining has had considerably less impact in the watershed than other types of development. However, the legacy of the mining boom of the late 1800s persists and continues to affect riparian areas in parts of the watershed. Placer mining destabilizes streambanks and aggregate mining harms groundwater systems. The practice of lode mining produces toxic mine drainage that harms riparian areas. Metal and coal mining also directly impact riparian areas with waste rock dumps, tailings and mill sites, and the installation of tailings ponds and waste disposal sites (Figure 3.3.17). These developments can destabilize hillslopes, eliminate riparian vegetation, severely degrade riparian soils, and inhibit re-vegetation for decades after mining activity has ceased. Even with restoration, the results of mining will continue to degrade the landscape into the future. An exception is aggregate mining, which, if the mine site is appropriately located and mining activities fit the site, often can be rapidly and successfully remediated. All of the types of mining described above have been practiced historically, and/or occur within the watershed today. Specific mining-related impacts are discussed in the sub-watershed discussions in Chapter 4.

Figure 3.3.17. A mine dump adjacent to Castle Creek.

Beaver Eradication

Although beaver are fairly common in the watershed, their populations are much diminished from historic levels due to loss of habitat and trapping. Removal of riparian vegetation also diminishes the potential for beaver populations and the benefits to riparian and instream habitat that result from beaver activity. Beaver cannot make their structures without appropriate and abundant riparian vegetation (including plant species such as willow, cottonwood, alder, and birch), which provides forage as well as dam- and home-building materials.

Beaver are keystone species – meaning that they significantly influence ecological functions, and if they are eliminated, other species decline or disappear from the ecosystem (Meffe and Carroll, 1997). Keystone species are discussed further in Section 3.4. Beaver activity modifies stream channel form and habitat structure. Unlike the steep and fast flowing streams that characterize today's rivers, beaver activity prior to human development created a stepped stream structure delineated by beaver dams on almost every first to fifth order stream in the West (Wohl, 2001; Pepin et al., 2002; and Windell, 1992). This stepped structure slowed flooding flows, increased out-of-bank flows, increased water storage and groundwater recharge, trapped sediment and nutrients, improved water quality, improved nutrient cycling, enhanced environmental conditions necessary for the establishment and maintenance of riparian vegetation, and created a complex habitat mosaic for aquatic and semi-aquatic species including fish, amphibians, and waterfowl. Figure 3.3.18 shows an example of a beaver dam and how it supports these functions.

Figure 3.3.18. Beaver dam on Castle Creek.

3.3.5 Biological Indicators of Riparian Habitat Condition

The following section describes important indicators that are used to assess the health of riparian habitat.

Vegetation Composition

In general, healthy native vegetation is essential to ecosystem function and sustainability (Figure 3.3.19). Sustainable and functional riparian ecosystems require native vegetation with high quality, vigor, good cover, even distribution of all age-classes of woody plant species, and no noxious weeds. Plant cover and quality is a direct indicator of stream and riparian habitat sustainability (NRCS, 2004). Vigor refers to the plant's ability to survive, grow, and thrive, and is an essential aspect of habitat maintenance and the ability to recover from disturbance. Vigor can be diminished by excessive browsing by domestic or wild animals; thus, the amount of browse can serve as an indicator of plant vigor and habitat sustainability.

Where woody species are an important component of the historic plant community, an even distribution of all age-classes of woody plant species provides ecosystem resilience and is essential to site maintenance and recovery from disturbance. Age-class distribution is an indicator of a riparian site's ability for maintenance, recovery, resilience, and long-term sustainability. Noxious weeds affect ecosystem functions by displacing native plant communities, and their presence indicates a decline in ecosystem health.

Figure 3.3.19. Dense, native, high quality, stabilizing vegetation on the Fryingpan River (upper photo) and Castle Creek (lower photo).

Wildlife Species

Wildlife species are an important part of conservation management plans. Wildlife species can be used successfully to indicate habitat condition and to monitor and assess the effects of land uses and management strategies. Wildlife species integrate and respond to environmental characteristics, selecting habitat based on the presence and quality of those characteristics. While some species (habitat specialists) have very specific habitat requirements, others (habitat generalists) have more general requirements and tolerate a wider range of environmental conditions.

Specialist species can be good indicators of habitat condition by acting as surrogates for the condition of the rest of the ecosystem. Indicator species have a highly specific niche and narrow ecological tolerance, are tied to a specific biotic community, and can reliably be found in certain environmental circumstances but not in others. Indicator species are also more sensitive to environmental change than other species, respond quickly and consistently to environmental change, and directly indicate a cause of change. Mammalian indicators of good quality riparian habitat include mink (*Mustela vison*), Western jumping mouse (*Zapus princeps*), and water shrew (*Sorex palustris*).

Birds are good indicators of habitat quality, are relatively easy to monitor, and are responsive to environmental changes. For many bird species, habitat requirements are precise and well known. Some bird species are more selective than others, some species tolerate disturbance while others do not, some species require specific foraging or nesting resources while others are more flexible in their requirements, and some species select only intact natural habitat while others can survive in disturbed areas. Habitat preferences cause the variety of birds to increase as the number of distinct habitats increases (Gill, 1995). Because birds differ in their breeding habitat requirements and response to disturbance, the composition of the breeding bird community is a good indicator of habitat condition (Burnett et al., 2005; Rich, 2002; Bryce et al., 2002). In the Roaring Fork Watershed, depending on elevation, the presence of disturbance-intolerant, riparian-dependent songbirds such as Lincoln's sparrow, Wilson's warbler (Figure 3.3.20), willow flycatcher, MacGillivray's warbler, red-naped sapsucker, Swainson's thrush, and Lewis's woodpecker are good indicators of intact riparian habitat.

Figure 3.3.20. A juvenile Wilson's warbler is a high priority species. The presence of a juvenile Wilson's warbler indicates good quality breeding habitat, which corresponds with overall high quality habitat.

3.3.6 Riparian Regulations

Many federal, state, and local laws, regulations, and policies pertain to riparian areas. More information about most of these can be found in previous sections. The Endangered Species Act, the National Environmental Policy Act, the Federal Land Policy and Management Act, and the Wild and Scenic Rivers Act are discussed in Section 2.1.2 and Section 3.2.5 talks about the Clean Water Act. A discussion of local land use regulations is discussed in Section 1.3.2.

3.4 Instream Areas

The previous section focused on riparian areas and this section takes an in-depth look at habitat and wildlife within the stream channel. These two area types – riparian and instream – are fundamentally linked. Riparian areas influence instream conditions by improving water quality, maintaining channels, and providing direct organic matter (such as large wood, plant material, and terrestrial insects) to the floodplain or active channel. Instream areas influence riparian areas by providing nutrients and to maintain riparian vegetation. Healthy riparian communities and complex instream habitats have a more resilient response to natural fluctuations such as droughts, floods, and debris flows. The following section describes the type and scope of instream information available for the watershed, gaps in information, functions of instream areas, factors that affect them (including potential future issues), and biological indicators that can be used to help track their health.

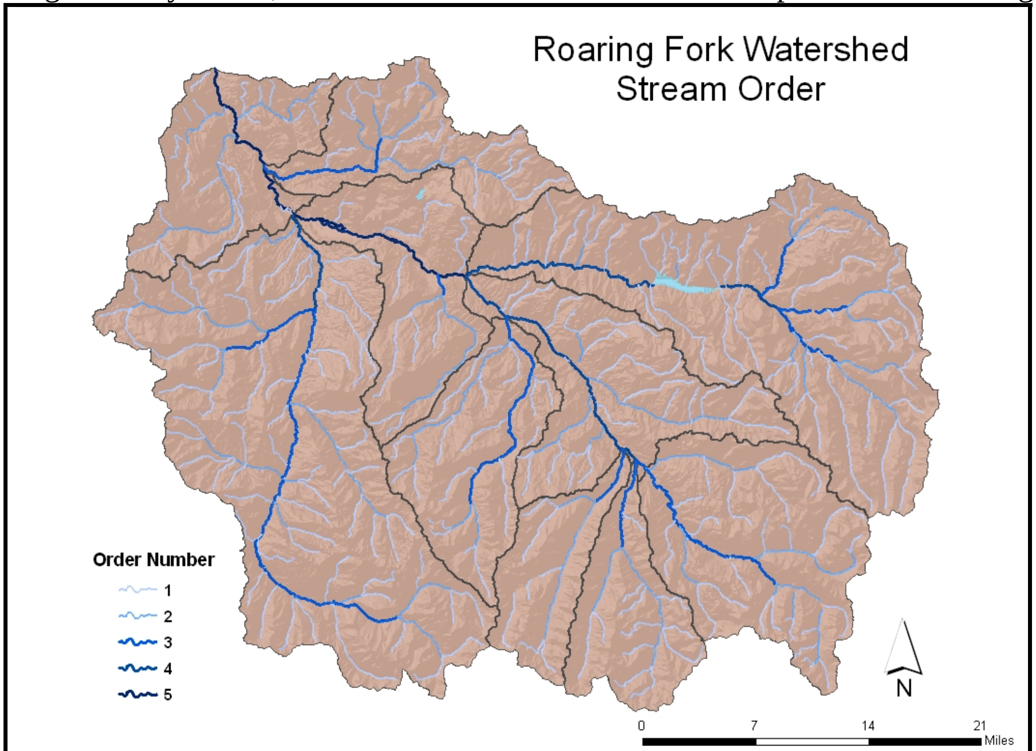
Streams in the Roaring Fork Watershed are dominated by montane, cold headwater streams that supply high quality water to downstream habitats, thus providing for a wide array of aquatic and terrestrial species. Streams provide recreational opportunities such as boating, fishing, wildlife viewing, and general enjoyment of streams' scenic settings, and support hydropower production as well as consumptive water uses like agricultural irrigation, domestic and industrial activities, and municipal drinking water.

Stream systems are affected by direct factors including modification of stream channels (e.g. dams, dredging, and channel straightening), and changes in the stream flow regime, resulting primarily from water diversions. Indirect factors influencing stream channels and habitat include modification of riparian and/or upland habitat (for example through urbanization or grazing) that can alter the flow regime and water quality conditions. All of these factors can potentially influence the integrity of a stream system, which is based on the stream flow regime, habitat structure, energy sources, biological factors, and water chemistry. The earlier parts of this chapter cover flow regime (3.1) water quality, including water chemistry and nutrients (3.2), and riparian areas (3.3), while this section focuses on habitat structure and biological factors within streams.

Stream characteristics vary by location in the watershed and by channel type. Streams are longitudinally linked, causing physical, chemical, and biological conditions to change from upstream to downstream (Mitch and Gosslink, 2000). Stream characteristics are very different at the headwaters of the Roaring Fork River compared to those at its confluence with the Colorado River in Glenwood Springs. Physical changes occur as a continuum when progressing in the downstream direction, including the following:

- Stream gradient and substrate size (stream bottom material) decrease,
- Nutrients become more abundant and food particle size becomes smaller,
- Water temperatures become progressively warmer, and
- Aquatic wildlife richness and abundance increase, relating to changes in nutrients and biological communities driven by physical conditions such as water temperature.

Streams can be classified according to their position within the watershed, which corresponds to their stream order (Figure 3.4.1). In this classification scheme, headwater streams with no tributaries are designated as first-order streams with the order increasing whenever two or more streams of the same order converge. Collectively, small headwater streams have an importance that is disproportionate to their individual small size. Small first-, second-, and third-order headwater streams constitute almost 94 percent of the total stream mileage in the watershed. As these small streams coalesce into higher order streams, nutrients, sediment, and pollutants carried into the stream from the surrounding landscape also accumulate and, because streams are longitudinally linked, the condition of headwater streams impacts the entire length of the stream.



Source: Streams-CDSS 2006 Dataset; stream order added

Figure 3.4.1. Stream order in the Roaring Fork Watershed.

Streams can be further classified into two broad categories, constrained or unconstrained (Figure 3.4.2). Unconstrained stream channels, characterized by a meandering channel shape, are formed within sediment (alluvium) that has been previously transported and deposited by the stream to form floodplains. Constrained stream channels are controlled and prevented from meandering by materials that cannot be mobilized, such as bedrock or large boulders. Although both stream types are stable in natural landscapes, constrained streams are resistant to change, whereas unconstrained, alluvial streams are more fragile and easily disturbed.

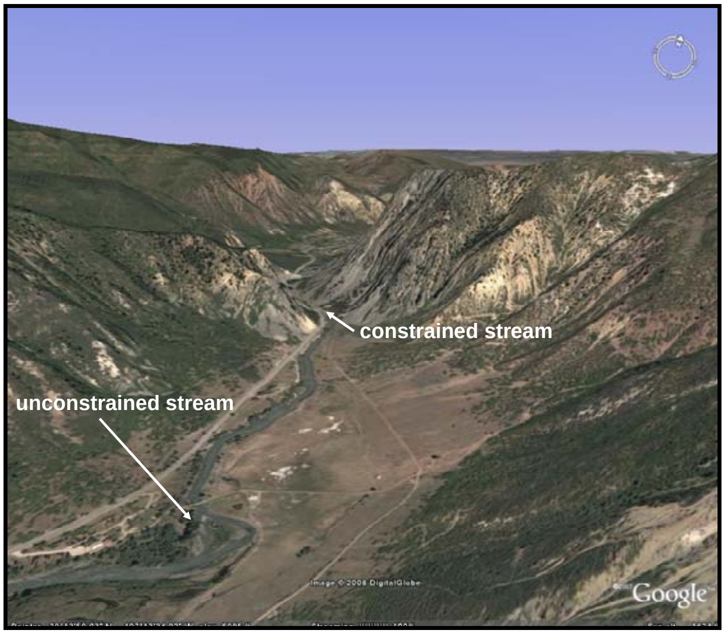


Figure 3.4.2. Example of an unconstrained channel and constrained channel at Filoha Meadows on the Crystal River (Source: Google Earth image, downloaded April 22, 2008).

Natural perturbations like floods or debris flows can temporarily destabilize a stream, but self-regulating mechanisms such as instream large wood, channel substrate (like cobbles and boulders), beaver ponds, and bank vegetation, tend to return stability to a stream. As with most natural ecosystems, streams have evolved with and depend on natural disturbances, with flooding being the most important to stream ecosystems. Floods shape the channel and floodplain, recharge groundwater, and maintain instream habitat for animals and plants. High flows scour away fine sediment, keeping gravel clean for fish. Floods also redistribute gravel, cobble, and large woody debris to form pool and riffle habitat.

3.4.1 Data Sources, Assessments, and Tools

Several types of information are available to evaluate instream areas in the watershed, including fish and aquatic habitat surveys, macroinvertebrate surveys, amphibian surveys, identification of natural heritage areas and species of concern, and evaluation of channel instability. These sources are described below.

Fish and Aquatic Habitat Surveys

In 2007, the Stream Health Initiative (SHI) completed a comprehensive assessment of instream areas in the Roaring Fork Watershed (Malone and Emerick, 2007a). During three years of field work, from 2003 to 2005, the Stream Health Initiative conducted an instream habitat assessment on approximately 185 total stream miles in the watershed, including the Roaring Fork River from its headwaters to its confluence with the Colorado River, plus significant portions of Lost Man, Castle, Maroon, Brush, Snowmass, Cattle, and Fourmile creeks, and the Fryingpan and Crystal rivers. Fish, macroinvertebrate, and instream habitat surveys are used to assess the health of instream habitat. To assess instream habitat, the SHI survey modified the U.S. Environmental Protection Agency's (EPA) Rapid Bioassessment Protocol (RBP) for use in wadeable streams and rivers (Barbour et al., 1999). EPA's RBP for habitat assessment evaluates the structure of the surrounding physical habitat that influences aquatic life and potentially limits biological community potential. Parameters representing channel condition, stream balance, and aquatic wildlife potential were evaluated at each designated reach and rated on a scale of 0 (worst) to 20 (best). The scores were totaled and then compared to a regional reference site to provide an assessment of habitat quality. Stream habitat condition, as determined by the RBP Habitat Assessment score, was used to rank habitat condition from high quality to severely degraded – rankings discussed and shown on maps within the sub-watershed sections in Chapter 4. These instream habitat assessment data from the SHI have also been summarized by sub-watershed in charts that report habitat condition in the following parameter groups:

- Channel Condition, with parameters such as channel alteration, riffle frequency, sinuosity, and energy dissipation ability;
- Stream Balance, which includes bank stability, sediment deposition, lateral- and downcutting; and
- Aquatic Wildlife Potential, including epifaunal substrate, embeddedness, velocity/depth regime or pool variability, and flow status (Figure 3.4.3).

Appendix 3.3.1 contains the actual percentage values for each of these categories within each sub-watershed.

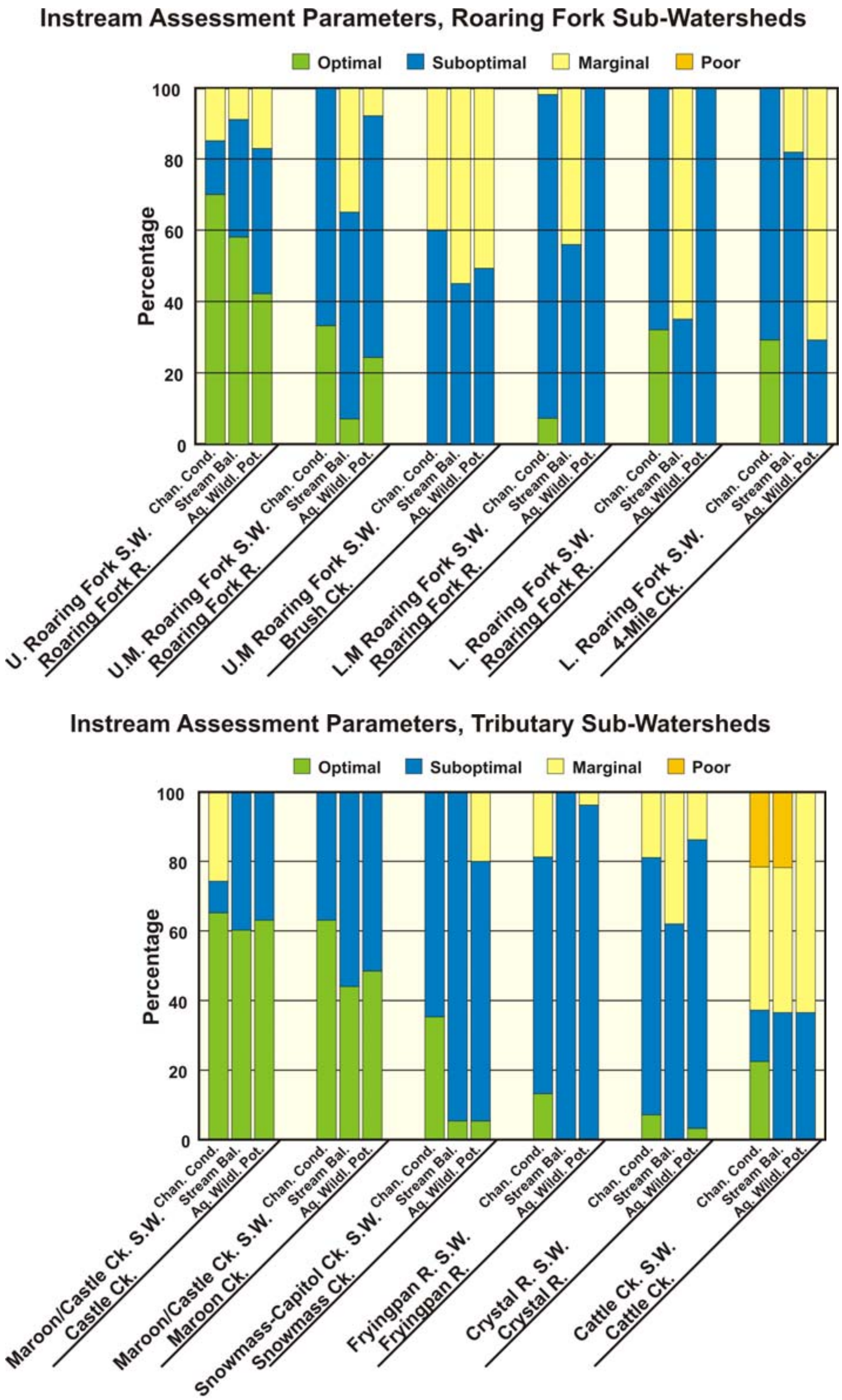


Figure 3.4.3. Instream assessment parameters by sub-watershed.

EPA's RBP for benthic macroinvertebrates was modified to assess macroinvertebrate community assemblage as an indicator of stream health, and EPA's Regional Tolerance Values for Macroinvertebrates were used to determine category assignment. American dipper (Cinclus mexicanus) surveys used a protocol developed by the Resources Information Standards Committee in British Columbia (ILMB, 2007). The Rosgen stream classification system and "stream order" were used to classify stream types in the watershed (Table 3.4.1 and Figure 3.4.4).

Table 3.4.1. General characteristics of Rosgen's stream types (Rosgen & Silvey, 1996).

STREAM TYPE*	WIDTH/DEPTH RATIO	DOMINANT SLOPE	COMMENTS
A	< 12	4-10%	· Steep with high sediment transport. Influx of large organic debris can often influence overall channel stability.
B	> 12	2-4%	· Rapids dominated bed morphology. Should have low streambank erosion rates and scour pools
C	> 12	< 2%	· Riffle/pool spacing is usually 5-7 bankfull widths and often occurs every 1/2 meander wavelength. Channel aggradation/degradation is dependent on stability of streambank and upstream watershed conditions.
D	> 40	< 4%	· Unstable braided channel with high sediment load.
DA	n/a	< 0.5%	· Multiple stable channels.
E	< 12	< 2%	· High meandering stable systems that are highly sensitive to disturbance.
F	> 12	< 2%	· Often re-establishing a functional floodplain inside the confines of a channel that was often historically entrenched and widened by disturbance.
G	< 12	2-4%	· Deeply incised with high bank erosion, often caused by disturbance.

* Stream types in **bold** are found in the Roaring Fork Watershed.

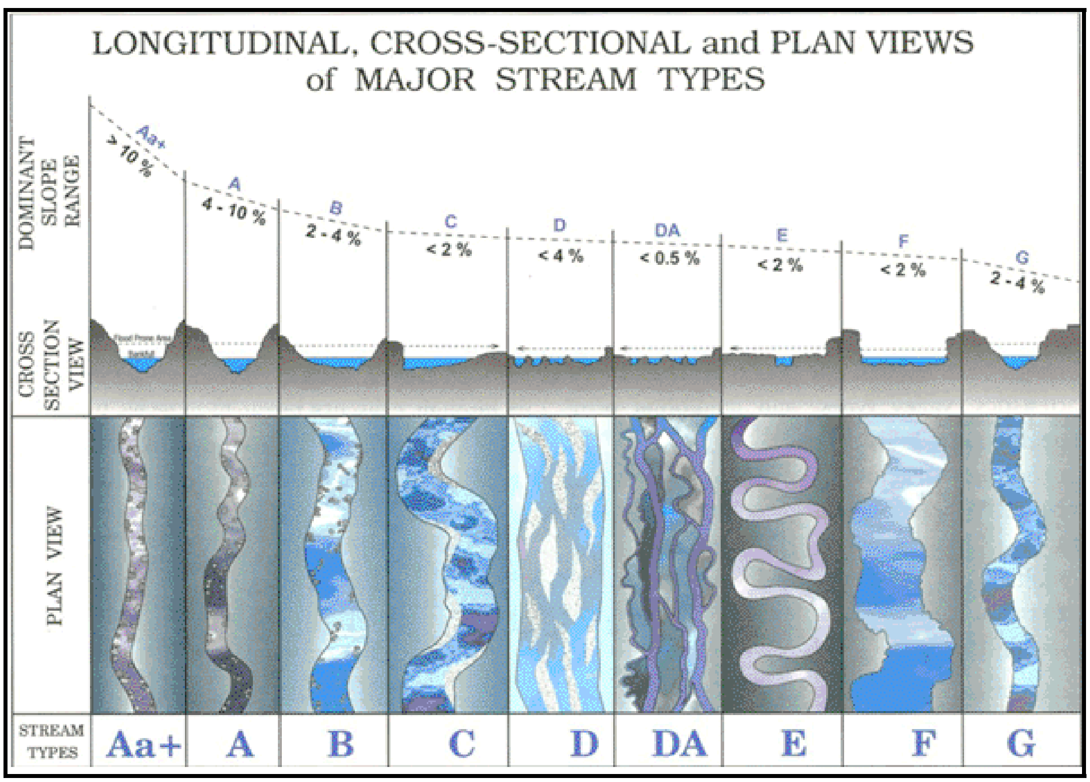


Figure 3.4.4. Longitudinal, cross-sectional, and plan views of major stream types (Source: Rosgen 1994a).

The Bureau of Land Management (BLM), U.S. Forest Service (USFS, which manages the White River National Forest (WRNF) in the watershed), and Colorado Division of Wildlife (CDOW) have conducted fish and aquatic habitat surveys throughout the watershed. All fish surveys by federal agencies are coordinated with the CDOW and data is submitted to the CDOW for its Aquatic Data Management System (http://wildlife.state.co.us/Research/Aquatic/DataManagement/). Because fish and habitat surveys were conducted for different purposes, for different time periods, and using various sampling protocol, they are not always useful for assessing watershed-wide conditions or trends. The best data for detecting trends are CDOW historic fish surveys that electroshock 300-foot stream sections to determine species composition, size distribution, and population estimates. Repeat surveys have occurred at four sites on the Roaring Fork River. The BLM and USFS have coordinated with the CDOW to repeat surveys for some of these sites and additionally have established new sites with similar sampling and reporting protocol. The USFS has additional site-specific information for watershed health and biological communities throughout the watershed. Much of this information is collected to analyze various projects across the watershed regarding management (such as grazing, recreation, and timber) and is available at the USFS Aspen Sopris Ranger District office in Carbondale. The USFS is currently collecting instream habitat, fish, and macroinvertebrate survey information in the Crystal River Sub-watershed to complete a watershed assessment report specific to WRNF lands. The Crystal River assessment will be the first one done by the USFS in the Roaring Fork Watershed.

The CDOW uses fish surveys to determine fish species occurrence by 10-digit Hydrologic Unit Code (HUC) which corresponds to the nine sub-watersheds in this report, with the exception of the Maroon/Castle Creek Sub-watershed (which comprises two separate 10-digit HUCs). These data were provided for the Roaring Fork Watershed by Harry Vermillion (CDOW, personal communication, March 3, 2008). CDOW Natural Diversity Information Source (NDIS) tracks 748 animal species, providing, when available, a species' life history text, a photo, maps, and a listing status (http://ndis.nrel.colostate.edu/wildlife.asp). The only Colorado species not tracked are "accidental" occurrences or species considered "extinct." In addition, sub-species are not included unless listed in some way (for example, the greenback cutthroat trout is on the federal- and state-threatened list). NDIS Geographic Information System (GIS) spatial data are available for several aquatic species found in the Roaring Fork Watershed, including boreal toad range and Colorado River cutthroat trout distribution (figures 3.4.5, 3.4.6, and 3.4.7) (http://ndis.nrel.colostate.edu/ftp/index.html).

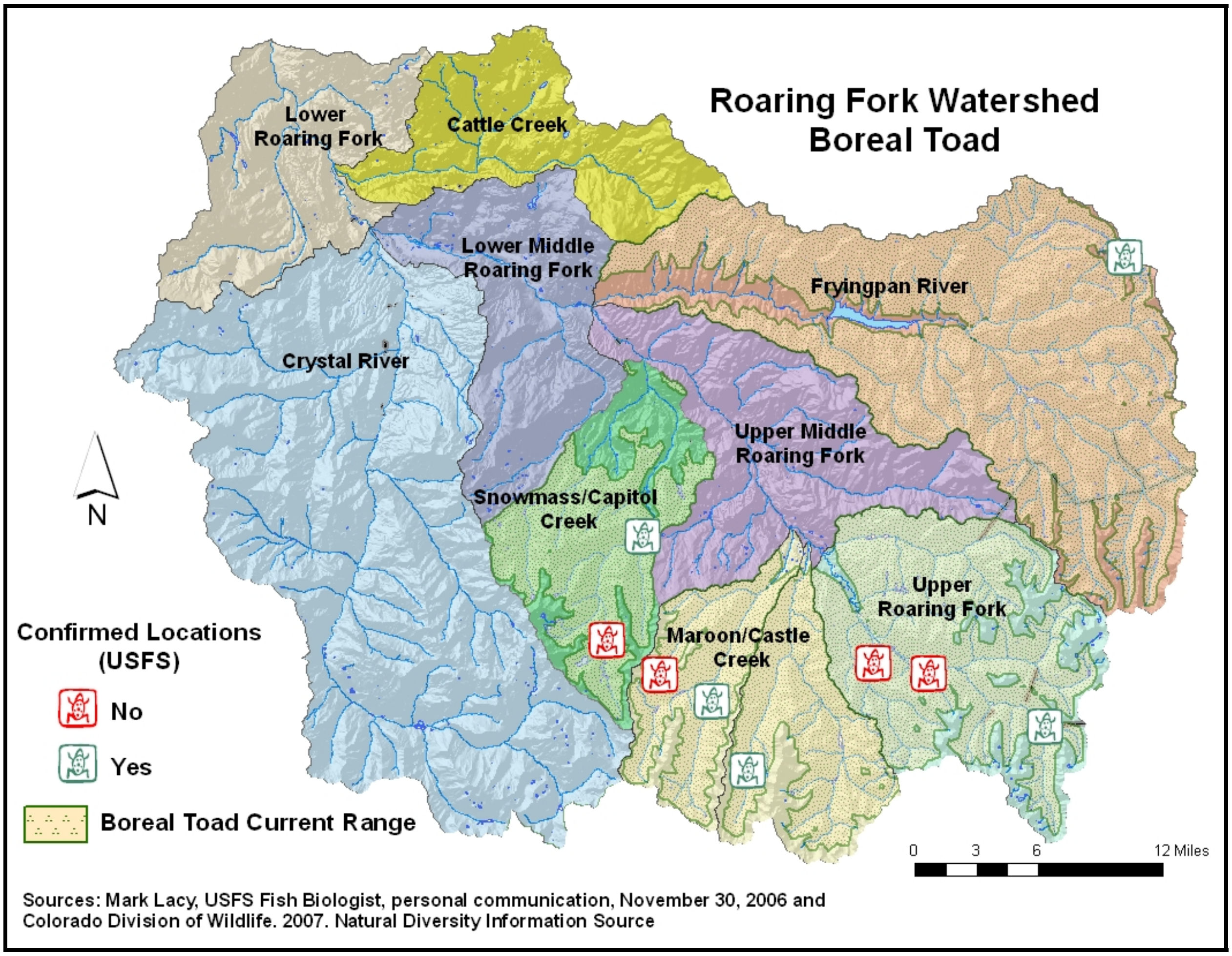


Figure 3.4.5. Boreal toad locations and range for the Roaring Fork Watershed.

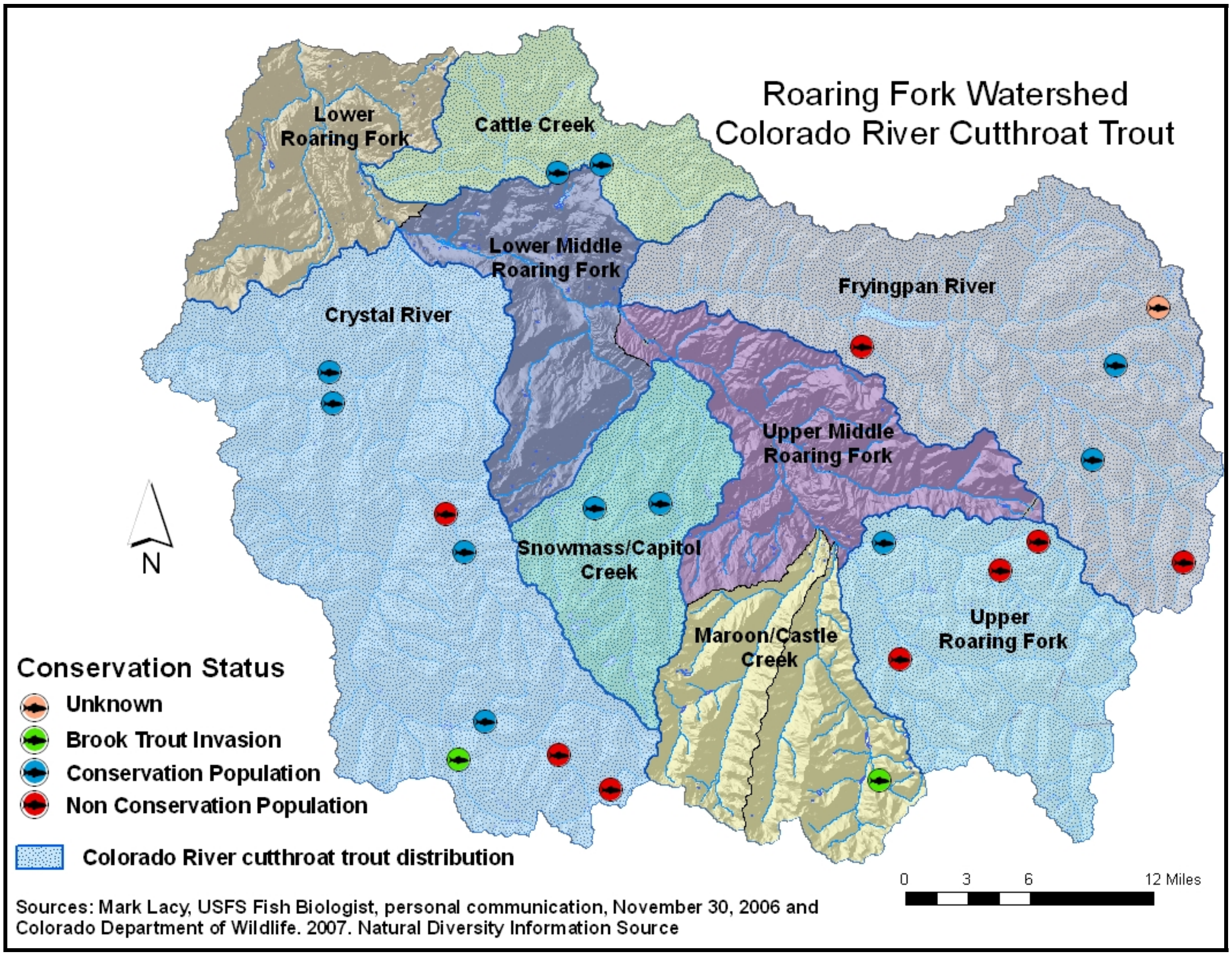


Figure 3.4.6. Colorado River cutthroat trout locations and distribution in the Roaring Fork Watershed.

Figure 3.4.7. Colorado River cutthroat trout (Photo credit: Mark Lacy).

Stocking records are also kept by CDOW. These records include date stocked, species, stream/lake name, number of fish, and fish length (Jenn Logan, CDOW Wildlife Conservation Biologist, personal communication, April 19, 2007). The species stocked and the stream or lake name is listed under the recreation heading for each sub-watershed in Chapter 4. Additionally, CDOW determines management categories for stream reaches (such as Gold Medal, Wild Trout, and cold-water stocked streams). The agency is currently refining its management categories and, by fall 2008, will have data available to produce maps of management categories within the watershed (Sherman Hebein, CDOW Senior Aquatic Biologist, personal communication, February 27, 2008). The Fryingpan River below Ruedi Reservoir to the confluence with Roaring Fork River and the Roaring Fork River down to the confluence of the Colorado River is classified as Gold Medal. Gold Medal Trout standards designate waters that provide the greatest potential for trophy trout and angling success. The criteria specify that a stream provides at least 60 pounds per acre of trout and more than 12 trout greater than 14 inches per acre. This status is supported by the high productivity of wild brown trout (Kendall Ross, CDOW Aquatic Biologist, personal communication, June 6, 2008).

The WRNF's Land and Resource Management Plan Revision (Forest Plan) was completed in 2002. The Forest Plan's Ecosystem Health Goal and Objectives section for Management Indicator Species (MIS) includes the following: "within 15 years, demonstrate positive trends in habitat availability, habitat quality, or other factors affecting sensitive species and Management Indicator Species." MIS trends will be evaluated at the Forest scale. The WRNF began implementing MIS surveys in 2003 to collect fish, habitat, and macroinvertebrate data. The WRNF was divided into 10 management combinations based on Forest Plan land allocation and livestock grazing. One site from each management combination was randomly selected for monitoring each year for five years (50 sites total). The randomly selected sites will be resampled every five years to determine Forest-wide trends. Forest-wide trend information will start to become available after the 2008 field season when the 2003 surveys are repeated. By 2013 two data sets will exist for each of the 50 streams and will provide trend information within the Roaring Fork Watershed and the WRNF. Of the 50 MIS sites on the WRNF, 13 are located in the watershed (Figure 3.4.8). Existing survey information can be found in Appendix 3.4.1 and annual updates will be available from the WRNF.

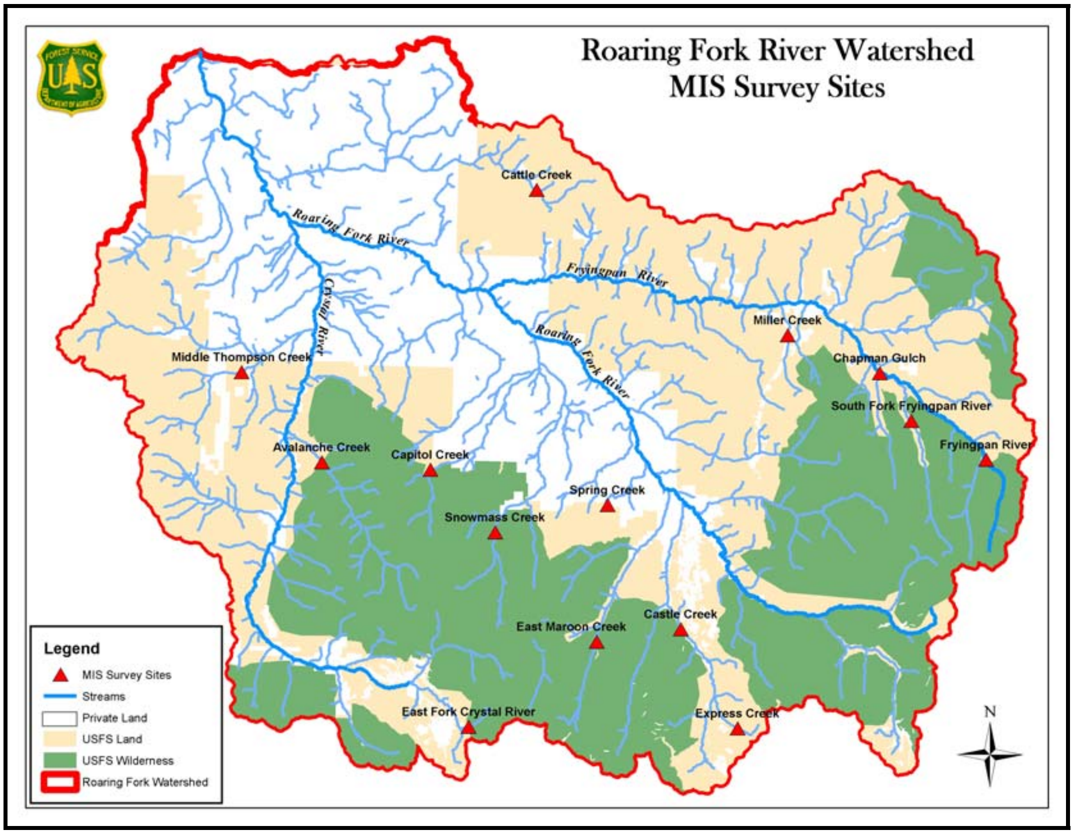


Figure 3.4.8. USFS Management Indicator Species survey sites (Source: Matt Grove, USFS Fish Technician, personal communication, January 23, 2008).

Macroinvertebrate Surveys

Macroinvertebrate information is fairly extensive in the watershed. Miller Ecological Consulting collected and analyzed macroinvertebrate data in the lower Fryingpan River (2006 and 2008). The Roaring Fork Conservancy collected macroinvertebrates in October 2001 for 13 sites in the watershed. The Family Biotic Index (FBI) was used to analyze these data and results were reported in the Roaring Fork Watershed Water Quality Report (Roaring Fork Conservancy 2006). The USFS has data from its MIS survey sites (Figure 3.4.8) and also for stream reaches for specific projects and to determine water-quality issues. Data is available from Coal Creek in the Crystal River Sub-watershed (mining), from Lincoln Creek in the Upper Roaring Fork Sub-watershed (mining and transmountain diversions), and from Cunningham Creek in the Fryingpan River Sub-watershed (transmountain diversions). Additional sites were collected in the upper Roaring Fork Watershed for reference sites (Brian Healy, USFS Fish Biologist, personal communication, June 5, 2006) (see Section 4.1 for data analysis).

In the fall of 2006, a graduate student working with the Roaring Fork Conservancy sampled 18 sites throughout the watershed (Figure 3.4.9). Macroinvertebrates, substrate, basic water quality, and field data were collected to assess the influence of flow alteration on macroinvertebrates. Figure 3.4.10 shows some preliminary analysis of these data. The “Observed” number of taxa divided by the “Expected” number of taxa (OE score) was used to rate disturbance level. OE scores were lower below the three transmountain diversion structures than above them. Below Lost Man Reservoir and the South Fork Fryingpan River diversions, the OE score changed from a "least disturbed" rating to a "most disturbed" and "moderately disturbed" rating, respectively. The OE score was "least disturbed" above the major diversions on Thompson and Cattle creeks and changed to "most disturbed" below these diversions on Thompson Creek and to "moderately disturbed" on Cattle Creek. No change in disturbance class was seen in the OE score from above to below major diversion structures on Brush, Sopris, or Fourmile creeks.

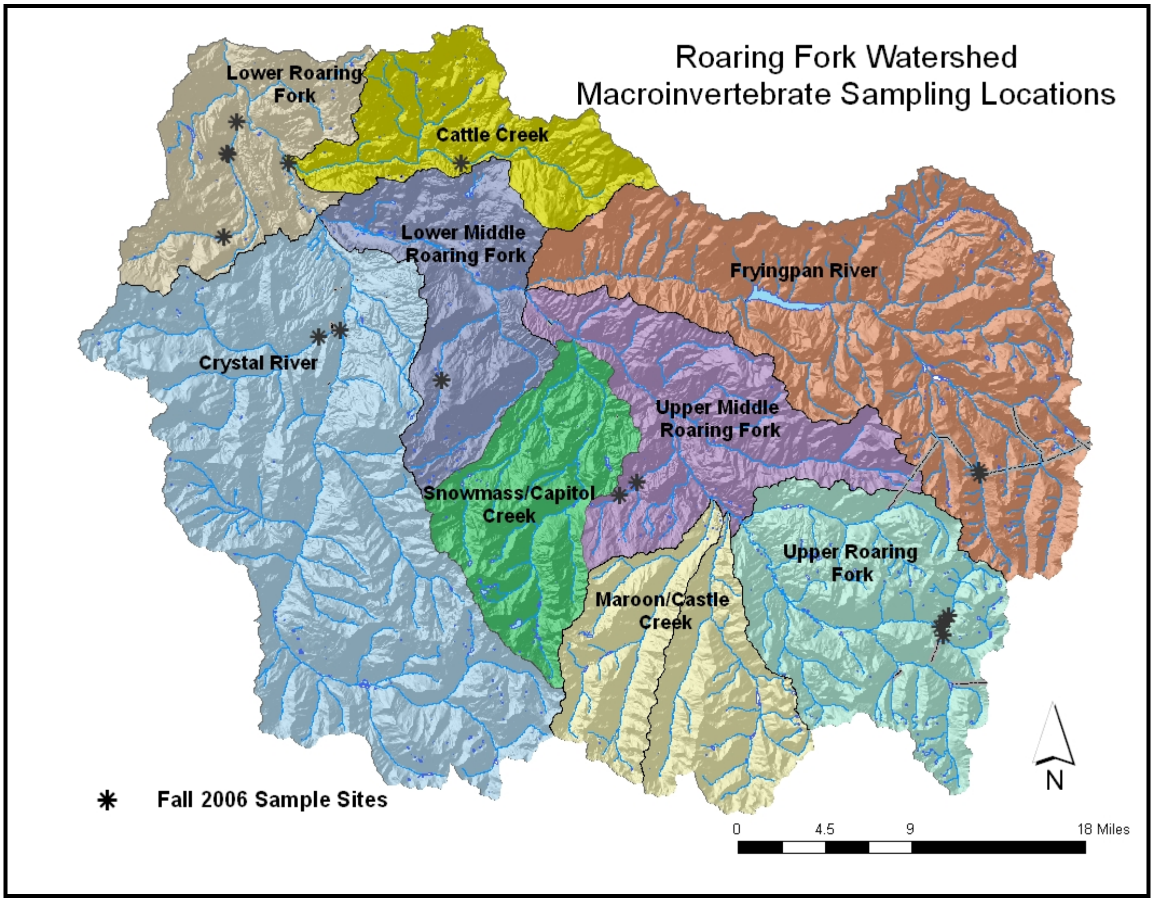
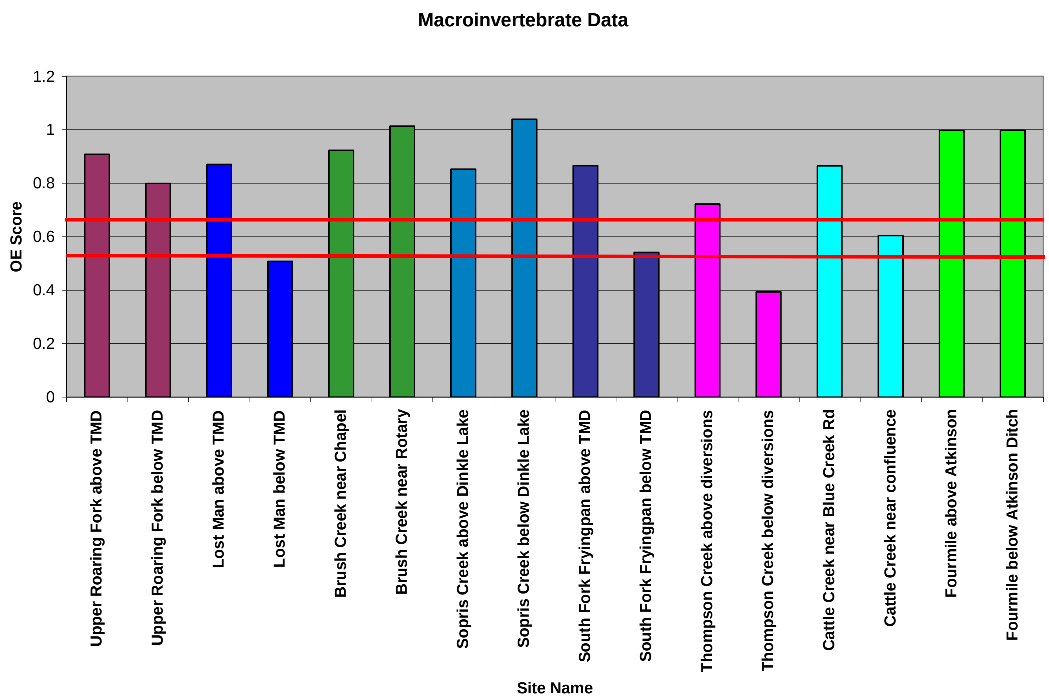


Figure 3.4.9. 2006 macroinvertebrate sampling locations in the Roaring Fork Watershed.



TMD: transmountain diversion
OE Score: Observed number of taxa/expected number of taxa
Least disturbed rating is OE value >= 0.69
Moderately disturbed rating is OE value < 0.69 and >= 0.57
Most disturbed rating is OE value < 0.57

Figure 3.4.10. Preliminary analysis of macroinvertebrate data collected in September 2006 by Sheree Lynne (graduate student, Colorado State University-Colorado Springs) and Roaring Fork Conservancy. OE calculation by Chris Theel, Physical Science Researcher II, Colorado Department of Public Health and Environment Water Quality Control Division - Monitoring Unit, April 9, 2007.

Amphibian Surveys

The USFS and CDOW have survey data for amphibians. Most of the amphibian surveys are presence/absence surveys. In addition, the USFS, in cooperation with CDOW and the Colorado Natural Heritage Program, monitors boreal toad breeding sites (Figure 3.4.11). Five known breeding populations are in the watershed. Since 2006, two populations and four suspected locations have been found (Figure 3.4.5). In 2002 the USFS expanded its amphibian surveys, an effort that has helped to find new breeding populations and obtain better distribution information. This information is available at the USFS Aspen Sopris Ranger District in Carbondale or from CDOW in Glenwood Springs. The CDOW is assessing Northern leopard frog populations (Figure 3.4.12) across the state and has asked the public for help in reporting Northern leopard frog observations (Jenn Logan, CDOW Wildlife Conservation Biologist, personal communication, December 5, 2007). Sightings can be reported to CDOW or the statewide Herp Atlas (http://wildlife.state.co.us/Education/ServiceLearning/HerpetofaunalAtlas/HerpAtlas.htm). The atlas also contains information on other species.

Figure 3.4.11. Boreal toad (*Bufo boreas complex)* (Photo Credit: Mark Lacy).

Figure 3.4.12. Northern leopard frog (*Rana pipiens*) (Photo credit: http://ndis.nrel.colostate.edu/herpatlas/coherpatlas/).

Natural Heritage Areas and Species of Concern

Additional studies are useful for assessing instream conditions throughout the watershed. In 1999, the Colorado Natural Heritage Program (CNHP) conducted a biological inventory of the watershed (Spackman et al., 1999). The inventory identified 55 locations with natural heritage significance (Potential Conservation Areas – PCAs) throughout the watershed (Figure 3.3.2 and Appendix 3.3.2). Biodiversity significance as well as protection and management urgency were ranked and justified, and natural heritage element occurrence identified for each PCA. In 2005, the Aspen Valley Land Trust updated some of this CNHP information for private lands within the watershed.

Appendix 1.3 lists the aquatic species of concern and their occurrence by sub-watershed, based on listings and designations at the federal and state level, and those made by CNHP and Audubon. The following species of concern are found in the watershed: fish are flannelmouth sucker, Colorado River cutthroat trout, and mountain whitefish; amphibians are boreal toad and Northern leopard frog.

The Nature Conservancy worked with several project partners to produce the Roaring Fork Watershed Measures of Conservation Success (2008). This document outlines a site-specific conservation strategy to ensure the long-term survival of native species and communities. The document identifies stresses; sources of stress; strategies to mitigate or eliminate threats and enhance biodiversity; and a method for assessing success. Key instream related conservation targets identified by this project include Colorado River cutthroat trout (CRCT), boreal toad, and aquatic ecological systems.

Channel Instability

The Roaring Fork and Fryingpan Rivers Multi-Objective Planning Project (BRW, Inc. 1999) was initiated in response to the 1995 flood in the watershed. Its main goal was to evaluate channel instability. More details about this project can be found in Section 3.1.7 and results are discussed in the relevant sub-watershed sections in Chapter 4.

3.4.2 Data and Knowledge Gaps

To evaluate the status of instream areas in the watershed, the Stream Health Initiative (SHI) provides data about channel condition, stream balance, and aquatic wildlife potential. Fish, aquatic habitat, macroinvertebrate, and amphibian surveys have been conducted throughout the watershed and an evaluation of channel instability was completed for the Roaring Fork and Fryingpan rivers. Temporal and spatial data gaps remain and more information is needed regarding invasive species, disease, hybridization, and climate change (these topics are discussed in sections 3.4.4 and 3.4.5). Knowledge gaps also exist in understanding ecological processes that govern stream systems.

Data Gaps

Although the SHI project provides a useful snapshot in time of instream conditions, resurveys are needed to assess trends in instream conditions. Additionally, not all major streams in the watershed were surveyed by SHI. Streams that should be considered for future survey efforts are: Hunter, Woody, Lincoln, Capitol, Sopris, Coal, Prince, Thompson, and Threemile creeks and the upper Fryingpan River. Fish and instream habitat surveys conducted by the USFS, CDOW, and BLM on streams throughout the watershed are useful as baseline information; resurveys are needed for trend detection. In addition to these surveys, the USFS MIS surveys, discussed above, will be used to ascertain trends (Appendix 3.4.1). A resurvey plan should identify locations, indicators (fish, habitat, and macroinvertebrates), sampling protocols, and resurveying intervals needed to assess trends in condition.

Additional fish surveys in the watershed would provide a more complete understanding of the distribution for all fish species and assemblages in the watershed (including surveys of trout; sculpin; dace; mountain, bluehead, and flannelmouth sucker; roundtail chub; and mountain whitefish). Surveying above natural and man-made barriers would help to determine if there are additional populations of CRCT in the watershed. Although there are no surveys of non-game fish in the watershed, CDOW has coarse-distribution maps for speckled dace, mottled sculpin, mountain whitefish, and white, flannelmouth, and bluehead suckers (CDM, 2007a). Some non-game fish data are collected by the USFS, BLM, and CDOW and noted in survey reports, but have not been used to determine status and trends. Surveys of potential boreal toad wetland habitats are needed to determine if additional populations exist in the watershed.

In terms of knowledge gaps, several questions warrant further study:

- What are the long-term impacts of flow alteration on the sustainability of instream habitat and aquatic wildlife? What stream flow levels (including base flow and flooding flows, and duration and timing) are needed to sustain instream habitat and aquatic wildlife?
- What is the effect of acute and chronic sediment pulses on aquatic ecosystems?
- What is the expected distribution of large wood and beaver dams/complexes across the watershed?
- What are the potential stream temperature limitations on aquatic species distribution? Additional stream temperature data is needed across the watershed for baseline information.
- What are the potential implications of climate change on aquatic species? Baseline stream temperature and dissolved oxygen data are necessary to better understand this relationship.

3.4.3 Functions of Instream Areas

Functions of instream areas include transport of water, nutrients, sediment, and other materials; provision of aquatic wildlife habitat; and support of human needs including water for consumptive uses, recreation, and aesthetic appreciation. The stream's ability to perform these functions depends on a variety of factors including channel structure and flow regime. Fully functioning river systems have channels that are naturally sinuous (when not constrained by geology or topography) and structurally complex, and natural flows with highs and lows linked to climate and to adjacent riparian and upland habitat. Channel characteristics develop within the context of the landscape and, in natural channels, are in a state of dynamic equilibrium with the surrounding landscape. A stream that has achieved dynamic equilibrium is stable in that it tends to transport water and sediment produced by the watershed in a way that, over time, maintains its dimension, pattern, and profile while neither degrading nor aggrading (Rosgen, 1994b). Consequently stable streams are characterized by relatively regular seasonal environmental conditions that relate to flow, temperature, dissolved oxygen, nutrient concentrations, and sediment loads.

Stream Transport Functions

Stream transport functions involve draining the watershed and transporting and distributing water, sediment, nutrients, and other materials through the watershed to lower stream reaches, floodplains, and riparian areas. The extent to which water and materials reach the floodplain or lower stream reaches depends on channel structure and stream flows; channel alterations such as dams, downcutting, and riprapping inhibit this function while habitat features like beaver dams and spring flooding flows enhance it. More specific stream transport functions include the following:

- Streams drain the surrounding watershed and transport and deliver water, sediment, nutrients, and other materials to downstream parts of the watershed.
- Spring flooding flows flush sediment and nutrients from pools and riffles thereby restoring habitat for fish and aquatic macroinvertebrates.
- Overbanking stream flows replenish riparian areas and floodplains with water, nutrients, and sediment.
- Plant metabolic waste products are flushed from the floodplain, transformed, and redistributed to lower parts of the watershed.

Instream Habitat Functions

Instream habitat functions include providing reliable resources for aquatic and terrestrial native wildlife. A stream's physical habitat forms the template within which biological communities develop, and influences water quality and quantity and the health of the aquatic wildlife community (Barbour et al., 1999). Habitat functions are improved with increasing variety and structural complexity, providing mechanisms to maintain a dynamically stable stream system. Channel complexity is enhanced by characteristics such as large wood, sinuosity, and bank roughness, and is maintained by flooding flows that create undercut banks, scour sediment, and flush nutrients from pools and riffles.

Trout and other native cold water fish species require clean, cold water; naturally-fluctuating flows; clean, well-aerated gravel with low levels of fine sediment on the channel bottom for successful spawning; deep pools for resting and over-wintering; and stable streambanks with abundant vegetative cover for protection. Mink are dependent on the stream for their fish prey and utilize well-vegetated streambanks for protective cover. American dippers require diverse instream habitat for foraging sites, an abundance of high-quality macroinvertebrate prey, and stable streambanks for nest sites (but have adapted to using bridges as alternative nesting habitat). The ways that instream habitat supports aquatic and terrestrial wildlife include the following:

- Bankfull and flooding flows structure a diverse aquatic wildlife habitat by increasing channel meandering, scouring pools, redistributing cobbles to create riffles, increasing bank roughness and transporting large wood into the stream.
- Habitat variety supports an adequate year-round food supply and refuge from floods, low flows, predators, and extreme water temperatures.
- Flooding flows maintain healthy aquatic habitat by scouring out fine sediment from pools, cobble, and gravel – keeping gravel and cobbles clean and pools deep for fish.
- Streams maintain sustainable year-round flows through their interaction with the streambed, adjacent streambanks, and riparian and upland habitat. Structural characteristics such as meandering prolong the interaction, and beaver activity increases the interactions between instream and riparian habitat.
- Bankfull and flooding flows restore riparian soil moisture, thereby supporting riparian vegetation. Vegetative shade maintains more constant and cooler water temperatures for fish, and provides cover and resources for aquatic and terrestrial wildlife.

- Tributary junctions and low gradient reaches are important areas (hot spots) for aquatic life because they contribute increased flow, nutrients, sediment, and organic material that are often stored in alluvial areas, and thus support complex habitat and refugia areas for various aquatic life stages.

Provision of Human Functions

Human uses supported by instream habitat depend on the stability of the stream ecosystem. Instream areas provide humans with essential resources, including:

- Water for drinking, agriculture, domestic livestock, and mining
- Flood and drought protection
- Aesthetic and scenic values
- Recreational opportunities including fishing, kayaking, rafting, birdwatching, and hiking/walking

3.4.4 Factors that Affect Aquatic Wildlife and Instream Areas

Modifications of stream ecosystems have the potential to impact water and sediment movement, aquatic habitat and species, water quality, fishing, boating, and scenic values. In the Roaring Fork Watershed, several factors such as whirling disease, hybridization, and species competition directly influence fish health, while both direct and indirect types of channel alteration affect instream areas.

Direct Affects on Aquatic Species

Stream depletions from diversions and the diversion structures themselves can impact fish. Diversion structures may impede upstream or downstream movement of aquatic species, with the degree of impact depending on flow levels, aquatic life stages, and species (for example, adults may be able to jump over a diversion structure but juveniles cannot, or trout can pass the structure but mottled sculpin cannot). The ditch (or pipeline) itself may also divert and trap aquatic species. Base flow reductions and the loss of the high flows that maintain high quality habitat lower the carrying capacity for aquatic species. Spring diversions reduce overbanking and groundwater recharge and also reduce channel scour and bedload transport that clean gravels of fine sediments and reduce compacted substrate. Sediment that fills the spaces between cobble and gravel (interstitial spaces) eliminates spawning habitat for fish and protective habitat for aquatic insects that fish depend on for food. Reduction in flooding flows also results in pools filled with sediment and reduced pool diversity. Pools provide places for fish to overwinter, evade predators, and take refuge during high flows. Summer diversions reduce instream habitat, thus limiting the true carrying capacity of the stream for aquatic species. Fall diversions impact fall spawning fish species, such as brook and brown trout, by reducing available spawning habitat. If dewatering occurs after fish have spawned, such diversions can also dewater gravel spawning beds where fish have laid their eggs (redds). Fall diversions also reduce opportunities for fish to redistribute throughout the available habitat prior to winter and increase their risk of becoming trapped in less desirable habitats (Rees et al., 2003). Winter diversions can reduce available habitat, dewater redds (causing the eggs to freeze), and cause low enough water temperature to delay hatching of eggs (Walsh and Walsh, 1995). Limited winter habitat can lead to both intra- and interspecies competition and increased energy expenditures. Reductions in velocity can decrease the amount of oxygen delivered to incubating eggs and cause deposition of fine sediments into interstitial spaces in the gravels (Walsh and Walsh, 1995). Winter diversions can also accelerate the formation of anchor ice, a phenomenon that can adversely impact aquatic habitat (Rees et al., 2004).

Rainbow trout and Colorado River cutthroat trout (CRCT) are affected by whirling disease. The CDOW website describes how whirling disease affects fish (http://wildlife.state.co.us/Fishing/Management/WhirlingDisease.htm). The whirling disease parasite (*Myxobolus cerebralis*) has a two-host life cycle that involves trout and an alternate host, a common bottom-dwelling tubifex worm. When an infected trout dies, large numbers of hard spores are released. These hard spores are hardy, resist freezing and drought, and can remain viable for decades. After release from the host fish, they can be ingested by the tubifex worm. The worms are then parasitized by the organism, the end result of this phase being a delicate, water-borne spore. When released from the worm, these water-borne spores can infect susceptible fish by attaching to their bodies, or when fish eat infected worms. Although the disease may not directly kill trout, affected trout can become deformed or exhibit the erratic tail-chasing behavior from which the disease gets its name. Eventually, heavily infected young fish may die. CDOW is stocking Hofer rainbow trout that are resistant to whirling disease in the Fryingpan and the Roaring Fork rivers to increase fishing opportunities for rainbow trout (Kendall Ross, CDOW Aquatic Biologist, personal communication, June 6, 2008). Brown trout have developed a natural resistance to the parasite; however, these fish can still carry and transmit the spore. Whirling disease is having an unknown (and currently being investigated) impact on mountain whitefish (Kendall Ross, CDOW Aquatic Biologist, personal communication, June 6, 2008).

CRCT have hybridized with non-native salmonids (rainbow and other sub-species of cutthroat trout, including the Yellowstone and greenback sub-species) in many areas, reducing the genetic integrity of this sub-species. Dilution of genetics from other subspecies of cutthroat trout and hybridization with rainbow trout is recognized as a major contributor to declining CRCT status.

Other non-native trout have impacted CRCT populations and their distribution within the watershed. Brook and brown trout are fall spawners and have a two-fold competitive advantage over non-native rainbow trout and native CRCT. Fall spawners deposit their eggs in the gravels anytime from August until October, depending upon elevation. These eggs remain in the gravel over the winter then hatch in late spring and early summer. Spring spawners (rainbow and cutthroat) deposit eggs in the gravels from April through early June; and the eggs hatch from early June through July, depending upon elevation. As a consequence, fall-spawned fry emerge from the gravels sooner than the spring-spawned fry emerge, thus the fall fry (brook and brown) have a size advantage and also have occupied the preferred small fish habitats prior to the spring-spawned fry emergence from the gravel. In addition, the fry of fall-spawning fish are larger and may prey upon newly emerging cutthroat fry. This interspecies competition has reduced and/or eliminated CRCT from much of its historic range. Rainbow trout are non-native competitors with native cutthroat trout because they are also spring spawners, therefore competing with cutthroat trout for spawning habitats. After rainbow trout fry and CRCT fry emerge, they compete for food and space, further stressing that CRCT population.

The boreal toad is listed by Colorado as an endangered species. Since 1970, there has been a dramatic decline in boreal toad and other amphibian populations. Reasons for the decline have not been definitively identified but may include a variety of factors such as toxins or habitat disturbance that suppress the immune system, making the toad more susceptible to disease-causing pathogens (Jackson, 2005). Chytridiomycosis is a pathogenic fungus strongly suspected to be the direct cause of this decline. First discovered in dead and dying frogs in Queensland, Australia in 1993, chytridiomycosis is a highly infectious disease of amphibians, caused by the amphibian chytrid fungus Batrachochytrium dendrobatidis. Research since then has shown that the fungus is widespread across Australia and has been present there since at least 1978. It is also found in Africa, the Americas, Europe, New Zealand, and Oceania. The fungus invades the surface layers of the amphibian's skin, causing damage to the keratin layer, but it is not yet known exactly how this kills the toad. It usually causes mortality in an infected individual, and often kills the entire population in a breeding pond. No known treatment exists once the fungus is contracted. Chorus frogs are also killed by chytridiomycosis, but tiger salamanders are believed to be able to shed it from their skin. One breeding population of boreal toads in the Roaring Fork Watershed is thought to have been extirpated by chytridiomycosis and the fungus has been documented in another population.

Direct Modifications of Stream Channels

Direct modifications to stream channels can alter stream gradient, sinuosity, shape, and/or channel structure. This process, known as "hydrologic modification" or "hydromodification", is one of the top three leading sources of water quality impairment in the United States – agriculture and urban runoff are the others (USEPA, 2006a). Hydromodification occurs when the physical structure of the stream channel or streambanks is altered, leading to changes in the stream's natural maintenance functions. There is also another type of change in instream conditions, known as "hydrologic alteration" (or flow alteration). This varies from hydrologic modification in that it refers only to changes in stream flow.

Major human activities causing hydromodification include channel modification, streambank disturbance, and dams. These changes to stream ecosystems can result in altered flows, increased sedimentation, higher water temperatures, decreased oxygen levels, degradation of stream habitat structure, loss of fish and other aquatic and terrestrial populations, and water quality degradation due to increased levels of nutrients, bacteria, pesticides, hydrocarbons, and metals (USEPA, 2006b). Alteration of the natural flooding regime also contributes in a major way to hydrologic modification. As noted earlier, flooding is the primary disturbance factor in stream ecosystems (Saldi-Caromile et al., 2004) and is vital to maintaining channel structure and function. Flooding maintains channel capacity and a natural channel shape with diverse aquatic habitat, and flushes excess sediment from riffles and pools. Dams and diversions reduce flows (Figure 3.4.13), resulting in less frequent and lower magnitude floods.

Figure 3.4.13. Stream diversion on West Sopris Creek, September 9, 2006.

Throughout the West and within the Roaring Fork Watershed, accommodation for various kinds of development has resulted in extensive hydromodification. Channel modification is widespread as a result of roads and urbanization, stream straightening, bank armoring, extirpation of beaver and removal of beaver dams, removal of large woody debris, and loss of a natural flooding regime on dammed or diverted streams. Removal of native riparian and bank vegetation has resulted in extensive bank erosion. Dams and diversions have severely altered natural stream flows, changing the structure and function of stream channels. Altered flood regimes have led to reduced abundance of pools, side channels, and oxbows with a consequent loss of fish spawning habitat and refugia. More detailed description of the causes and effects of direct alterations to stream channels is provided in Appendix 3.4.2.

Historic and current mining activity in the watershed is less extensive than in other areas of Colorado, and, consequently, has had considerably less impact than other types of development. However, the legacy of the mining boom of the late 1800s persists and continues to impact instream areas in parts of the watershed. Placer mining destabilizes streambeds. Aggregate mining, if in the stream, alters stream structure, gradient, and suspended load. The practice of lode mining produces toxic mine drainage that impacts stream habitat. Metal and coal mining also directly impact riparian areas with dumps, waste rock, tailings, mill sites, and the installation of tailings ponds and waste disposal sites. These developments can destabilize hillslopes and increase sediment yield to receiving streams (Figure 3.4.14).

Figure 3.4.14. Sediment from Coal Creek entering the Crystal River at Redstone on May 15, 2008.

Indirect Alteration

Streams are intimately connected to their floodplains. Human-induced alteration to riparian or upland habitat that modifies the precipitation runoff regime, soil, or native vegetation also impacts stream integrity. Indirect alteration to stream channels results from activities including upland habitat modification, unsustainable wildlife management practices, invasion of non-native plant species, and human-induced elimination or exacerbation of natural disturbance regimes that alter runoff and erosion patterns or wildlife community assemblage. Modification of upland habitat within the watershed from agriculture, urbanization (including roads), recreation activities, and extractive land uses has indirectly led to changes in stream channel structure and function, and has degraded water quality due to increased stream sedimentation and runoff-introduced pollutants.

Urbanization creates impervious surfaces such as roads, parking lots, lawns, and roof tops. Impervious surfaces decrease infiltration and increase runoff, thereby modifying stream hydrology and channel characteristics. Water that runs over impervious surfaces carries urban pollutants and nutrients that do not have a chance to be detoxified by soil microbes or filtered by riparian vegetation before entering the stream. Consequently, activities such as the application of sand and chemical agents to impervious road surfaces for traction in winter and the use of magnesium chloride for dust suppression in summer cause sedimentation and chemical pollution. Impervious surfaces also prevent precipitation (rain and snow) from infiltrating into soil where it can be stored temporarily and slowly released into streams over the course of the year. Storage and slow release is important for preventing flooding and maintaining base flows. Increased impervious surface thus leads to less water in streams during dry periods because of decreased water retention, and to more water in streams during wetter periods along with increased velocity, which causes bank erosion (Saldi-Caromile et al., 2004).

Deforestation indirectly modifies stream hydrology by increasing runoff and decreasing infiltration, thereby altering runoff patterns and increasing erosion. Deforestation can disturb soils and destabilize hillslopes, leading to the erosive loss of forest soils and nutrients. Then these upland-sourced nutrients, sediment, and pollutants are carried with runoff over compacted soils into streams where they degrade stream water quality.

As noted in Section 3.3, recreational roads and trails that parallel streams often impact riparian habitat through vegetation trampling or removal. Vegetation degradation along streams has resulted in indirect effects on stream channels within the watershed in the form of bank erosion and stream sedimentation.

Overgrazing compacts soil and destroys vegetation. Consequences of improperly managed grazing include destabilized streambanks, degraded water quality due to excess sediment and nutrients, and stream flows frequently reduced below that necessary to maintain sustainable aquatic wildlife habitat.

3.4.5 Biological Indicators of Aquatic Habitat Conditions

Biological communities reflect the integrity of a stream ecosystem. Because wildlife species must integrate numerous environmental variables into their life histories, they can provide an aggregate picture of habitat stresses and limitations. The presence of certain wildlife species can be used as a gage for the condition of a particular habitat, community, or ecosystem. These indicator species act as surrogates for the condition of the rest of the wildlife community.

Good indicator species have a highly specific niche, narrow ecological tolerance, are tied to a specific biotic community, and can be found in certain environmental circumstances and not in others. Good indicator species are more sensitive to environmental change than others, and respond quickly and consistently to environmental change. Biological indicators can be an effective and efficient means of assessing aquatic habitat condition.

Biological Indicators

Benthic macroinvertebrate species are good indicators of stream health because of their limited mobility, short life cycle, and known tolerance levels. Collectively, macroinvertebrates exhibit a wide range of tolerance to various environmental conditions, but certain species have a narrow range of tolerance. Those species that do not occur or are reduced in abundance in severe environmental situations are considered to be “intolerant.” Species with a wide range of tolerance but unable to tolerate extreme environmental conditions are considered “facultative,” and those species present under severe environmental conditions are considered “tolerant” (Ward and Kondratieff, 1992). Lists are available that indicate tolerance levels of specific taxonomic groups of macroinvertebrates to particular environmental conditions. For example, because *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisfly) taxa (also known as the “EPT” taxa) are considered to be intolerant of pollution, the percent of EPT taxa present in a stream reach or system is often used as an indicator of aquatic health (Figure 3.4.15). Generally, a stream with a wide diversity of macroinvertebrates that are intolerant of extreme ecological conditions characterizes a healthy stream (Windell, 1992).

(Photo Credit: http://www.cirrusimage.com/ephemeroptera_mayflies.htm)

(Photo Credit: Milton Rand/Tom Stack & Associates http://www.everythingabout.net/articles/biology/animals/arthropods/insects/stonefly/index.shtml)

(Photo Credit: G.I. Bernard/Oxford Scientific Films http://www.everythingabout.net/articles/biology/animals/arthropods/insects/caddisfly/)

Figure 3.4.15. EPT taxa: mayfly, stonefly and caddisfly.

Periphyton (the matrix of algae species attached to rocks, logs, and plants) is also a good indicator of stream water quality. Periphyton represents the primary producer level in a stream ecosystem, exhibits a wide range of sensitivities, and can often directly indicate effects only indirectly observed in benthic macroinvertebrate and fish communities (Barbour et al., 1999). Algae are primary producers and thus are directly affected by changes in physical and chemical stream conditions. Algae also have rapid reproduction rates and short life cycles, making them valuable indicators of immediate or short-term impacts (Barbour et al., 1999).

Fish are good indicators of long-term effects and broad habitat conditions because they are relatively long-lived and mobile (Karr et al., 1986). Because environmental requirements and life-history traits are typically well known, changes in the fish community are good indicators of environmental modification. Because fish are near or at the top of aquatic food web, they also integrate effects of lower trophic levels and concentrate environmental pollutants (Barbour et al., 1999) thus providing an aggregate assessment of ecosystem integrity.

Among birds, the American dipper (Cinclus mexicanus) (Figure 3.4.16) is a good indicator of stream habitat quality. It is an aquatic song bird that has evolved to a top-level predator-specialist in fast-flowing mountain streams of western North America. Dippers use several environmental characteristics to select suitable nesting sites, including water quality, stream habitat quality, and riparian habitat quality. Prey abundance, foraging ease, and nesting habitat are dependent on these environmental variables, and if any of these variables are impaired dippers will reject the site. Although dippers can compensate for a degraded resource by increasing territory size, at a certain point energetics dictate against selecting an impaired territory. The dipper diet consists almost exclusively of macroinvertebrates and fish (Vickery, 1991). Dippers prey selectively on caddisfly and mayfly nymphs and dipper abundance has been strongly correlated with the abundance of these insects (Tyler and Ormerod, 1994). Members of both of these macroinvertebrate groups are generally intolerant of pollution or extreme ecological conditions. Pollution or sedimentation can destroy macroinvertebrate populations causing dippers to abandon the site (Sibley, 2001).

Figure 3.4.16. Photo of a dipper (Photo credit; Robin Henry).

Keystone Species

Keystone species contribute to and can be good indicators of ecosystem integrity. Keystone species play a disproportionately large role, compared to their abundance, in structuring natural communities. A species may be considered keystone because of its trophic (feeding) position, for instance as a top predator, or because it produces a food or habitat resource essential to other wildlife species. Without these species, major ecological relationships and functions are altered.

Beaver are an aquatic habitat-dependent keystone species because of their role in habitat modification through their dam and canal building activities. These modifications improve water quality, sustain stream flows, and create habitat for other wildlife species. Beaver dams create open-water pools which, through the process of ecological succession, develop into wetland and riparian habitats that provide essential resources for other wildlife, including waterfowl, shorebirds, songbirds, and fish. Beaver dams conserve water and modify stream flows by dissipating flood energy, increasing out-of-bank flows, and by storing water for later release back into streams during low-flow season. Water quality is improved by beaver dams due to sediment removal and nutrient capture that occurs in beaver ponds.

3.4.6 Instream Regulations

Many federal, state, and local laws, regulations, and policies pertain to instream areas. More information about most of these can be found in previous sections. The Endangered Species Act, the National Environmental Policy Act, the Federal Land Policy and Management Act, and the Wild and Scenic Rivers Act are discussed in Section 2.1.2 and Section 3.2.5 talks about the Clean Water Act. A discussion of Colorado water law is found in Section 2.2.1 and local land use regulations are discussed in Section 1.3.2. A section of the Clean Water Act, § 404, that specifically relates to instream areas is discussed below.

Enacted in 1977, § 404 of the Clean Water Act (33 U.S.C. § 1344) established a permitting program for the discharge of dredged or fill materials into navigable waters of the United States, including wetlands, to be administered by the U.S. Army Corps of Engineers. Activities in waters of the United States regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States, unless the activity is exempt from § 404 regulation (e.g. certain farming and forestry activities). The basic premise of the program is that no discharge of dredged or fill material may be permitted if either a practicable alternative exists that is less damaging to the aquatic environment or the nation’s waters would be significantly degraded.

3.4.7 Future Considerations

New Zealand mud snails

New Zealand mud snails are very small snails (up to 6 millimeters in length) that have invaded streams across the West (Figure 3.4.17). The snail has been confirmed in Colorado in two locations – Boulder Creek and Pueblo Reservoir (CDOW, 2007b). This invader reproduces quickly and masses in high densities. By out-competing native invertebrates for food resources, these snails displace native species. Native invertebrates are an important food resource for fish but New Zealand mud snails are not a viable food source. By causing the decline of native invertebrates, they could compromise the integrity of aquatic food webs and cause a decline in fish populations.

The rapid spread of this snail may have been assisted by humans. Although the snail can spread by clinging onto wildlife, human activities have played a large role in its spread. Because they are resistant to desiccation, the snails can stowaway on recreational gear such as boats, boots, waders, nets, and other fishing gear, then be introduced into previously snail-free streams days or even weeks later. These snails are highly resilient to variable and extreme environmental conditions, can reproduce asexually (only one is required to start a new population), and thus are almost impossible to contain once they have invaded an area. Preventing their invasion is essential to maintaining stream integrity. The only sure control is to wash thoroughly and then soak boots, waders, fishing gear, and other equipment in a solution of 50 percent water and 50 percent Formula 409® for five to 10 minutes before the equipment is used in another stream (CDOW, 2007b).

Figure 3.4.17. New Zealand mud snails (Photo credit: http://www.clr.pdx.edu/projects/volunteer/nzms.php).

Didymosphenia geminata (didymo)

The occurrence of Didymosphenia geminata also known as “rock snot” has been documented on several tributaries in the Roaring Fork Watershed (Malone and Emerick, 2007a). In 2007, the U.S. Geological Survey confirmed the presence of didymo in three samples taken from the Roaring Fork River through Aspen and one sample taken from West Maroon Creek below Maroon Lake (Gilman, 2007b). Didymo is a diatomaceous algae that forms extensive masses that can cover almost all of the organisms that live on or in the bottom of a stream. The dense mats prevent the growth of other algae that are an important food for aquatic invertebrates. The resulting decline in aquatic invertebrates causes a decline in food available for fish (Spaulding and Elwell, 2007). Didymo is a native species characteristic of high-gradient, high-elevation, low-nutrient streams that has taken on characteristics of an invader and may be expanding into other habitats (Spaulding et al., 2006). Fisheries managers are concerned about the spread, but impacts to fish populations are still unknown. The diatom has a demonstrated ability to cross watershed boundaries and large populations are correlated with declines in some aquatic invertebrates and increases in chironomids (Spaulding et al., 2006). The U.S. Environmental Protection Agency is interested in helping to start monitoring efforts in the watershed to track the spread of didymo. Additional research also is needed to determine what has caused its rapid spread (Gilman, 2007a).

3.5 Climate Change

Global warming from greenhouse gas (GHG) emissions and land use changes affects the temperature, precipitation, and streamflow of the Roaring Fork Watershed and the greater Colorado River Basin. These physical climate changes will impact the ecosystems and socioeconomics of the Roaring Fork Watershed. A recent review of six major studies on the Colorado River finds that stream flows will likely be reduced due to climate change (Udall, 2007). This has major significance for resource management: although demand is increasing, supply is projected to decrease. High-elevation tributaries such as the Roaring Fork River provide 85 percent of the total Colorado River Basin flow (IPCC, 2008; Milly et al., 2005). This critical water resource makes settlement in much of the Southwest possible, serving the water needs of seven U.S. states, two Mexican states, and 34 Native American tribes – a total population of 25 million that is expected to exceed 38 million by the year 2020 (Pulwarty et al., 2005; IPCC, 2008). It is imperative that a better understanding of how climate change will alter the hydrology, ecosystems, and socioeconomics of the Roaring Fork Watershed be incorporated in its emerging watershed planning process.

Present-day climate modeling techniques have limited accuracy at the scale of the Upper Colorado River Basin and even greater limitations at the scale of the Roaring Fork Watershed; however, because of the importance of the Upper Colorado River Basin to the entire Southwest, many climate modeling studies have focused on this region. During the last decade climate studies have been done for the western U.S., Colorado River Basin, Upper Colorado River Basin (Mote et al., 2005; Hamlet et al., 2005, 2007; Barnett et al., 2005; Udall, 2007; Christensen et al., 2004; Barnett et al., 2008; IPCC, 2008), and the upper part of the Roaring Fork Watershed (AGCI, 2006). These studies reflect a growing consensus on how climate change may affect these regions, and, although concerned with various spatial scales and using varying methods, they are generally consistent in their overall findings. Models show confidence in the direction of temperature change, but exhibit less confidence in projections of precipitation.

Climate research indicates that, by 2050, major droughts in the Southwest U.S. – as occurred in the 1950s – could become the norm (IPCC, 2008). One study characterizes water availability in the western U.S. as “a coming crisis” with shortages, lack of storage, and shifting demand from agricultural to urban uses (Barnett et al., 2008). As global warming unfolds over the course of the 21st century, it will give rise to greater weather and climatic extremes surpassing those planned for under existing water management framework, and will create a new set of management challenges for assessing future risk, reducing vulnerability, and devising workable watershed management plans.

The nexus of global warming, natural variability, and human population growth will put unprecedented pressure on water resources in the West in the 21st century, and set a broader context for assessing the present state of Roaring Fork Watershed and planning for the management of its future.

Key direct effects of climate change projected for the Roaring Fork Watershed are:

- Warmer temperatures,

- More precipitation as rain, with less as snow,
- Decreased snow cover and snowpack,
- Earlier snowmelt and runoff, and
- Decreased runoff.

These changes will drive secondary changes within the watershed, such as:

- Earlier drying of soil moisture and riparian habitats;
- Increase in evapotranspiration and water demand;
- Increase in fire risk and insect outbreaks;
- Elevational shifts in plant and animal communities and reduction or loss of alpine tundra;
- Shifts in the geographic ranges, reproductive timing, competitive interactions, and relative abundances of aquatic species;
- Potential for more extreme weather events (e.g. droughts and floods); and
- Less insulating snow cover leading to greater risk of frost exposure to roots and soil organisms.

Change to the physical and biological aspects of the river system will also impact the built environment and affect how water resources are managed. Some of these effects will include altered timing and amount of water available for irrigation and groundwater recharge, stresses on municipal water supplies and other consumptive uses such as snowmaking, and greater demand from diversions and downstream calls. Overall, competition for water will increase among municipal, agricultural, recreational, industrial, and ecological uses.

3.5.1 Climate Observations and Projections

This sub-section provides specific data about observed and projected changes in climate from various models and studies. Global and continental-scale climate models predict that temperatures will be warmer and the overall amount of runoff will be reduced. However, these models also predict that more extreme precipitation and rain on snow events could increase the risk of floods. A recently completed study for the upper Roaring Fork River Watershed couples past and projected climate variability data for the Upper Colorado River Basin with local data to make localized snowmelt and runoff predictions. For the Roaring Fork Watershed, the combination of past dry conditions and future predicted warming with related impacts on flows presents a new challenge in assessing and planning for future water availability and demand. This process may necessitate development of new strategies to increase resiliency and reduce risk.

Warming in the West

The world as a whole is getting hotter. The latest Intergovernmental Panel on Climate Change (IPCC) assessment of climate science – which represents the consensus of more than 2000 scientists from around the world working together since 1990 – says that warming is "unequivocal." The map shown in Figure 3.5.1 illustrates global temperature trends at the surface of the Earth based on observations since 1970. The observations generally show more warming in the continental areas and a greater rate of change in the western U.S. compared to the rate of change for the U.S. as a whole. IPCC model projections for the 21st century show a continuation of this warming trend (IPCC, 2007a).

Using a medium IPCC greenhouse gas emissions scenario (A1B), data from 21 climate models project a 3.9 °C (6.9 °F) increase in annual temperature and a 3 percent decrease in precipitation for our region by 2080-2099 (change is from the 20-year mean of 1980-1999). On the other hand, if worldwide emissions follow a lower IPCC emissions scenario (B1), models project a 2.6 °C (4.7 °F) temperature increase (AGCI, 2006). This more conservative projection still exceeds the 2 °C (3.6 °F) threshold that some experts estimate could lead to “dangerous interference” in the climate system. It should be noted, however, that the introduction of policies to lower emissions to specific stabilization targets is not included in any of the Special Report on Emissions Scenarios (SRES), including the IPCC B1 scenario.

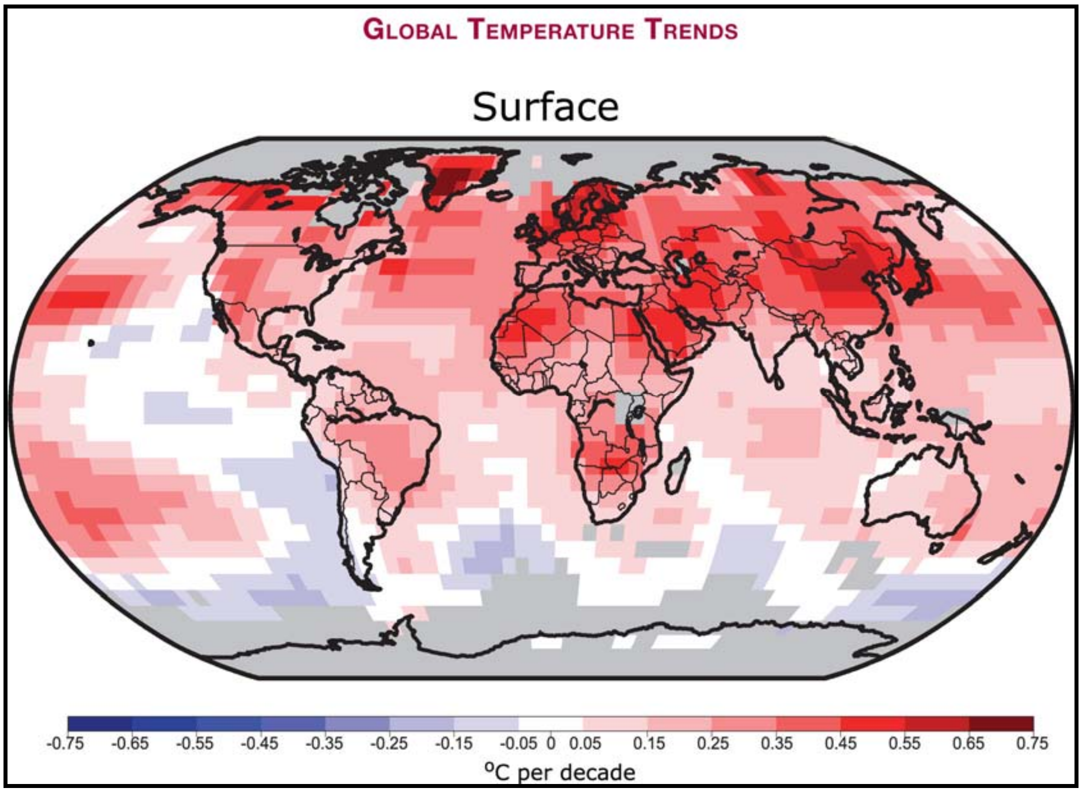


Figure 3.5.1. Global map of temperature trends since 1970. The colors represent the rate of change per decade in degrees C. Blue colors represent a cooling, red a warming. Darker colors represent greater rates. White areas show no change. The interior West of the U.S. shows a regional rate of change per decade of 0.35 to 0.45 ˚ C (0.63 to 0.81˚F) (Source: IPCC, 2007a).

Changes in Runoff

The 2007 IPCC Working Group II report looked at the projected change in annual runoff by mid-21st century for North America, with results shown in Figure 3.5.2. The figure shows a significant change in runoff for the western U.S.

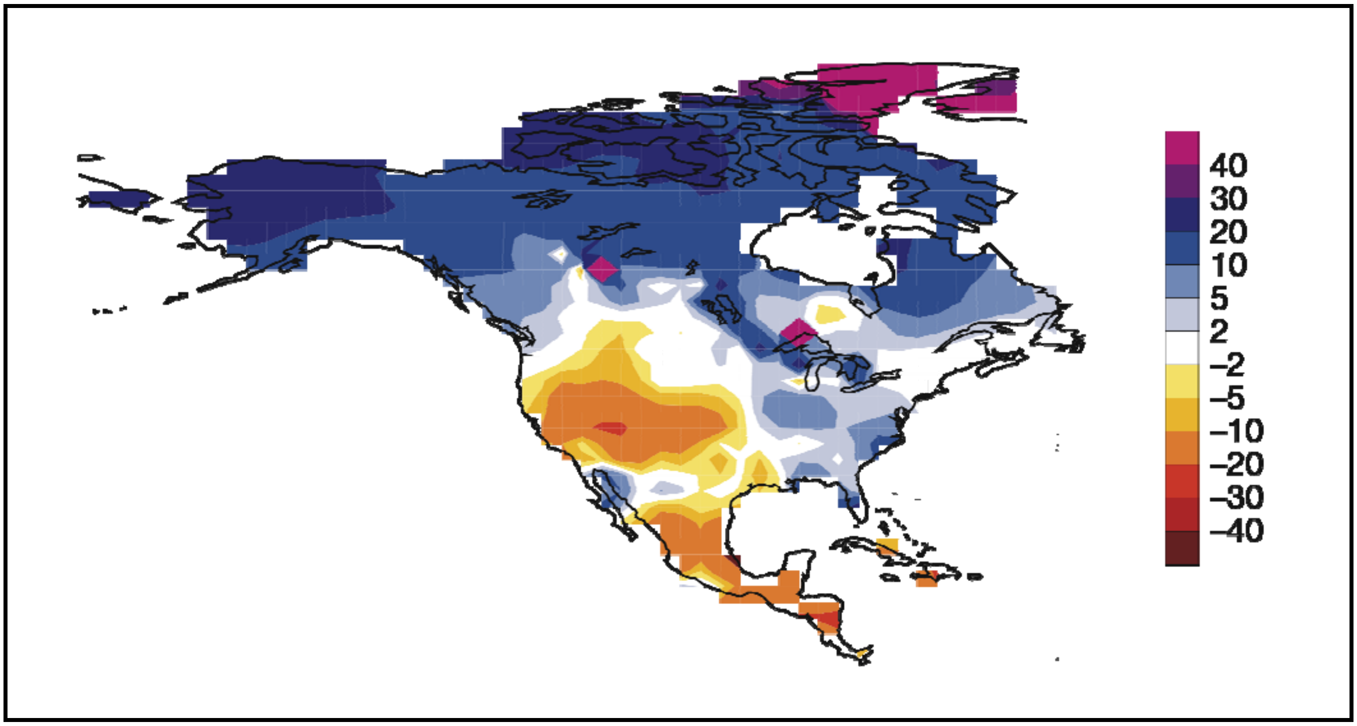


Figure 3.5.2. Percentage change in average annual runoff by 2041-2050, relative to 1900-1970, using the middle of the IPCC standard emissions scenarios (A1B). Shown is the North American portion of the world map. Source: Milly et al., 2005; IPCC, 2007b.

As snowmelt driven systems, upper basin tributaries of the Colorado River, such as the Roaring Fork River, are particularly prone to disruption in the historical pattern of spring runoff as a consequence of increasing temperature (Barnett et al., 2005; IPCC, 2007b). While precipitation and temperature both contribute to runoff, studies indicate temperature is likely to dominate. A study of the overall Colorado River Basin projects a slight decrease in precipitation during the 21st century (Christensen et al., 2004). Udall, in an overview of recent climate studies of the Colorado River, states that current models indicate "precipitation will remain approximately the same" and, when combined with temperature increases, where stronger agreement exists, indications are that "runoff will be reduced" (Udall, 2007). Aggravating the effect of higher temperatures on snow cover and snowpack is the increased rate of melt that results from darkening of the snowpack through deposition of windblown dust (Painter et al., 2007; Neff et al., 2008).

If projections are correct and annual precipitation remains about the same or somewhat less, it is not clear how this translates to flood risk. Even if total annual precipitation is reduced, individual precipitation events can be extreme, leading to flooding. Flooding associated with spring melt of the snowpack, particularly if it is above average, is tied to spring temperature fluctuations. A rapid spring warm-up and sustained high temperatures pose a serious risk, while a gradually warming spring can melt an above average snowpack without flooding. Another important consideration is rain on snow events that can cause flooding by rapidly melting the snowpack. The climate modeling conducted for the Aspen study (AGCI, 2006) indicates a greater possibility for mid-winter and early spring temperatures to produce rain events on snow. For a full discussion of flood risk based on observed warming in the 20th century and how it has affected flood risk in the western U.S. (including the Colorado River Basin) see Hamlet and Lettenmaier, 2007.

Warmer temperatures mean that a greater proportion of annual precipitation will fall as rain rather than snow. This is a widespread phenomenon; 74 percent of the mountains in the western U.S. already experienced this shift between 1949 and 2004 (Knowles et al., 2006). Increased temperatures melt snowpack earlier in the spring, leading to earlier peak runoff and a potential decrease in annual flow as warming continues (AGCI, 2006; IPCC 2007a).

Climate Variability: Past and Projected

Major climate patterns such as the Pacific Decadal Oscillation, the El Nino Southern Oscillation, and prevailing storm track and jet stream patterns are all sources of natural variability and play a critical role in Colorado's climate. To best project future variability, climate scientists first look to the past. Techniques such as tree ring analysis establish long-term stream flow records to understand better the natural variability. Colorado River flows reconstructed from tree ring data from the year 800 to the present were compared to the 1906-2004 mean of observed natural flows (i.e. periods where flows were above or below 10 to 15 percent of the past 100-year mean – see Figure 3.5.3). These data indicate considerable variability with approximately eight wet and dry periods. This reconstructed record shows evidence of a prolonged major drought in the mid-1100s (Meko et al., 2007), and shows that the natural variability of the past far exceeds infrastructure and allocations based upon flows of the 20th century alone. As described in Section 2.1.2, for the Colorado River Basin the water management legal stipulations (established in the 1922 Colorado River Compact and 1948 Upper Colorado River Compact) and infrastructure development were based on flows from a wet period.

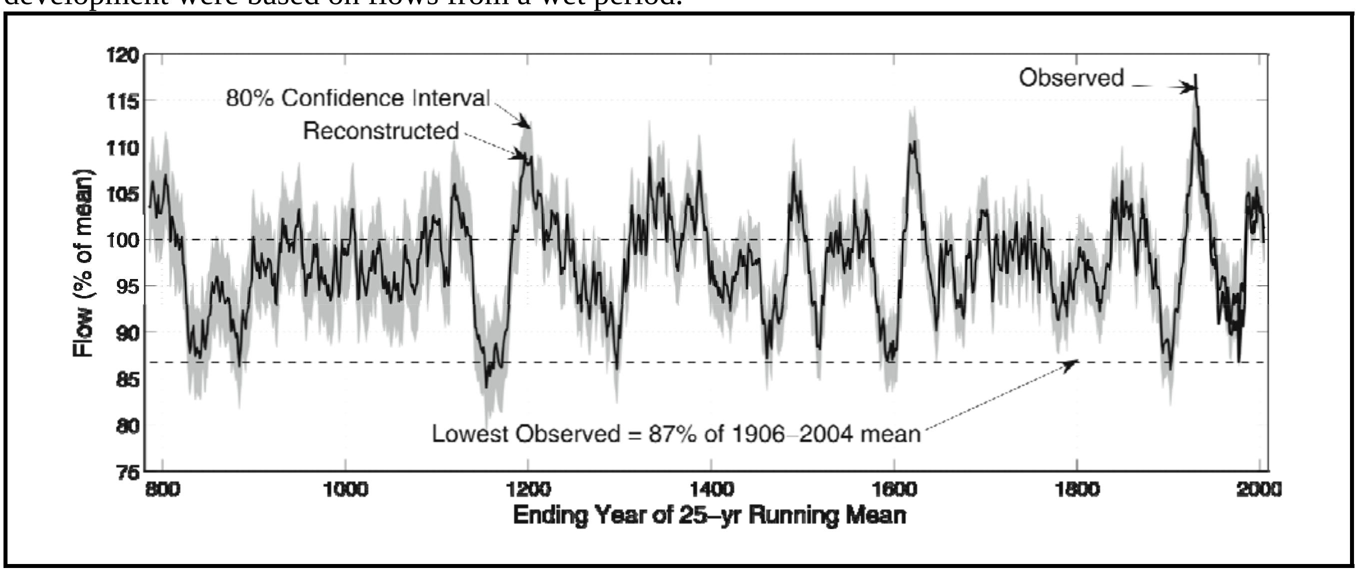


Figure 3.5.3. Upper Colorado River Basin flows reconstructed from tree ring data plotted as a percentage of the 1906-2004 mean of observed natural flows (dashed line at 100%). Lowest of the dashed lines is the 25-year running mean of observed flows for 1953-1977. Source: Meko et al., 2007.

In a related study, McCabe and Wolock modeled how a 0.86 and 2.0˚C (1.6 and 3.6˚F) increase in temperature commensurate with low and middle emission climate projections for the 21st century would affect flows in the Upper Colorado River Basin if added to the temperatures of the driest 100 years (1573-1672) in the 500 year record (1490-1998). They found that flows would not satisfy the water allocation amounts of the 1922 Colorado Compact more than 50 and 75 percent of the time, respectively. The same study showed that the effect of a 2.0˚C (3.6˚F) increase in temperature on the 20th century flows would result in insufficient flows to meet the Compact quotas more than 35 percent of the time. For a more complete description of the method and analysis see McCabe and Wolock, 2007.

Upper Roaring Fork Watershed Snowmelt and Runoff

A 2006 study by the Aspen Global Change Institute (AGCI), "Climate Change and Aspen: An Assessment of Impacts and Potential Responses," used the IPCC low, medium, and high emission scenarios combined with climate models and a snowmelt model to simulate how Roaring Fork River flows at the confluence with Woody Creek could be altered by climate change by 2030 and 2100. [For a complete discussion of the IPCC emission scenarios, see the 2000 IPCC "Special Report on Emission Scenarios." For more detailed information on climate models and their application in the Aspen report, see AGCI 2006 and the Working Group II's contribution to the IPCC's Fourth Assessment Report, "Climate Change 2007: Impacts, Adaptation and Vulnerability."] As shown in Figure 3.5.4, the projected runoff results for the low, medium, and high emissions scenarios indicate a clear shift to an earlier peak runoff of about one month. This figure also portrays a mid-winter runoff in all three scenarios and the retention of a summer monsoon.

As mentioned earlier, it is important to keep in mind, however, that the skill of climate models, while improving, is limited at the regional scale and very limited at the sub-regional scale. Serious limitations exist in downscaling climate models to project changes in climate for geographic areas as small as the Roaring Fork Watershed; however, by placing the study in the context of larger scale studies, much can be ascertained about future climate and potential vulnerabilities of the Colorado River and the Upper Colorado River Basin with direct relevance to the Roaring Fork Watershed.

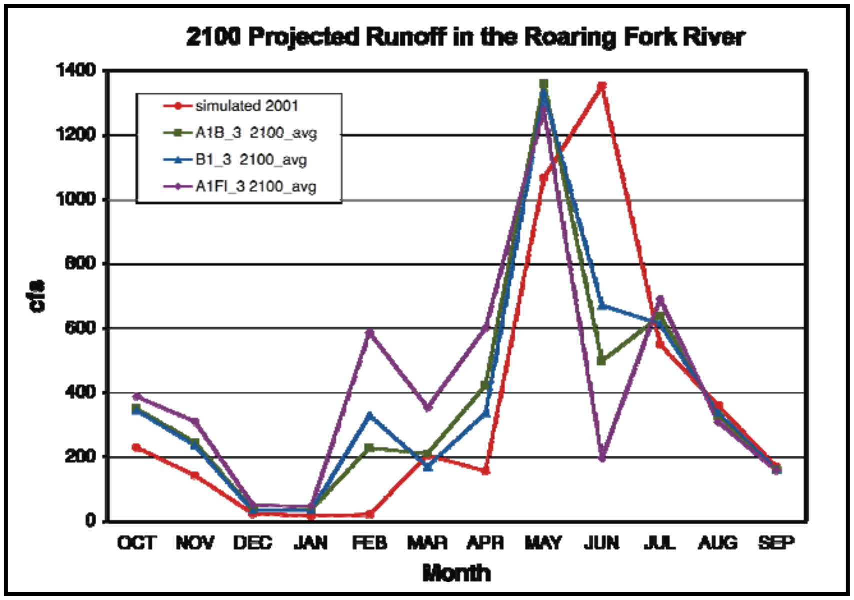


Figure 3.5.4. Projected runoff in the Roaring Fork River at the Woody Creek confluence for the year 2100 with low (B1), medium (A1B), and high (A1FI) IPCC emission scenarios. Note that this does not include base flows and is a snowmelt/runoff projection utilizing the Snow Runoff Model. Source: AGCI, 2006.

3.5.2 Impacts to Ecosystems

Watershed Interactions

The types of climate changes underway drive a complex set of interactions for the Roaring Fork Watershed. The flow chart in Figure 3.5.5 illustrates these interrelationships. Local environmental impacts such as land use change now are compounded by the regional effects of global-scale climate change. As the 21st century progresses, aquatic and terrestrial habitat will be increasingly impacted by warmer air and water temperatures, earlier spring runoff, and altered soil moisture and precipitation patterns. Traditional management strategies need to be modified to accommodate these new factors.

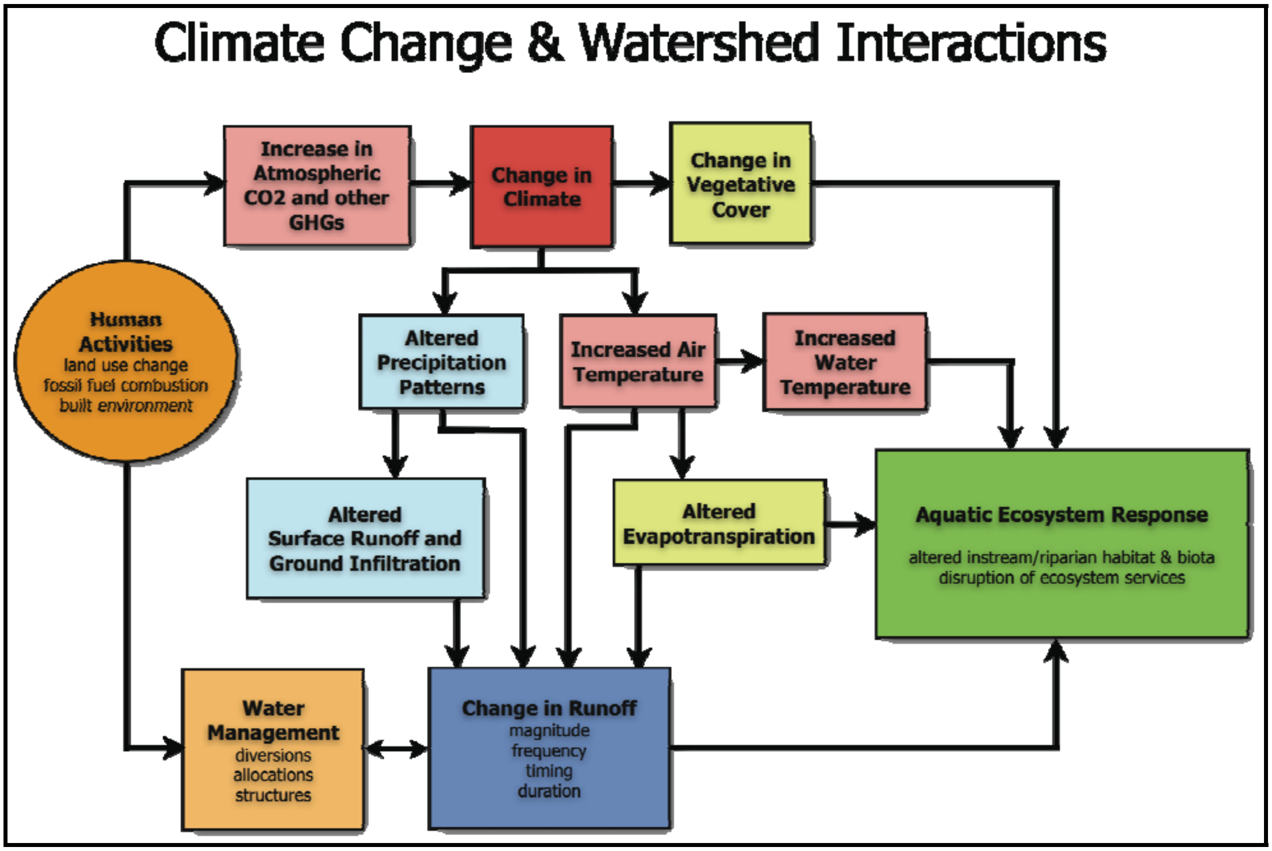


Figure 3.5.5. The complex interactions between human and natural systems in the Roaring Fork Watershed. Adapted from Poff et al., 2002.

Some of the most pronounced evidence of climate change already occurring in the U.S. has been observed in the Colorado River Basin (Saunders et al., 2008). Within the lower 48 states, the Colorado River Basin has experienced greater temperature increases than any other region in the last 30 years (NRCNA, 2007). As a result of continued change, aquatic and terrestrial ecosystems of the Roaring Fork Watershed will experience stress and transformation over the course of the 21st century. Over time, human-driven changes to the Earth's climate will alter the physiochemical properties of instream and terrestrial areas as well as the geographic distribution, relative abundances, and types of species within them (Poff et al., 2002; Robinson and Covich, 2003). Climate change will likely intensify the effects from other anthropogenic stressors that are already disrupting local alpine aquatic environments, including invasive species, stream depletions from diversions, municipal stormwater drainage, altered landscape runoff, and habitat fragmentation from development. All of these burden fragile ecosystems and contribute to biodiversity loss (Fahrig, 2003; Smith, 2001; Lockwood, 2004). Global warming in the 21st century will likely become an additional stressor (Poff et al. 2002), potentially driving conditions beyond the range of natural variability to which present-day species are best suited. The following discussion looks at how global climate change may affect terrestrial and instream areas within the Roaring Fork Watershed.

Terrestrial Areas

Site-specific research is needed to project specific ecological changes to the Roaring Fork region. Vegetation and fire risk modeling for the upper watershed was conducted as part of the upper Roaring Fork/Aspen climate change study (AGCI, 2006), with results summarized below. In the absence of more extensive local studies, the following section also includes a literature review of projected climate change impacts for western and alpine terrestrial ecosystems. Research suggests that combined ecological effects from changes to snowpack, wildfire frequency, insect outbreaks, soil moisture and temperature, and evapotranspiration may be equally as important as total change in temperature and precipitation. Expected temperature-driven changes in water demand by plants should be a paramount concern for resource planners charged with assessing future water requirements and availability. Despite the possibility of speciation occurring in response to changing conditions, the prime concern for alpine ecosystems is that the rate of change will outpace the ability of species to adapt (Smith and Tirpak, 1990). The growing body of evidence suggests that genetic variation will be lost. Many alpine species are particularly sensitive to climatic changes, including those that are habitat specialists, slow reproducers, poor dispersers, geographically isolated, or at the edge of their range (AGCI, 2006). An inability of individuals to adapt via migration or other behavioral modification will result in the reduction or extinction of single populations, whole species, distinct communities, or – in the most extreme cases – complete ecosystems. Warming in the Southern Rocky Mountains is likely to result in a population contraction of cold-adapted species sensitive to temperature increases, such as many mammals and birds, while more temperature-tolerant species like reptiles and amphibians may increase in number (Hansen et al., 2001).

Snow Cover and Soils

As snow cover retreats, surface albedo (a measure of the amount of solar radiation reflected from a surface) decreases considerably (IPCC, 2007a). Exposed dark ground absorbs more solar radiation than ground covered with white snow, amplifying warming and melt rates. Climate models suggest significant decreases in winter and spring water storage (in snow and soil) as a consequence of reduced snowpack (Hall et al., 2008). This in turn affects summer soil moisture. Summer drying is compounded by the direct effects of higher temperatures on soil moisture content. Moreover, a large enough reduction in summer soil moisture can suppress evapotranspiration, thereby further enhancing warming (Manabe et al., 2004).

Snowpack is also an important insulator and helps to protect soil biota against winter freeze events (Marchand, 1987; Jones, 1999; Groffman et al., 2001). Satellite observations from 1966-2005 show an appreciable decline in snow cover in the Northern Hemisphere, most notably during the spring and summer (IPCC, 2007a). The largest changes have occurred in the lower reaches of high-elevation sites such as the Rocky Mountains and Swiss Alps (IPCC, 2007a). Areas with current temperature ranges close to the rain/snow temperature threshold will experience the greatest changes in snowpack (Cooley, 1990).

In the future, the Aspen area is likely to face both a delay in early season snow accumulation and an earlier spring melt. Models project the snow season to be 1.5 weeks shorter by 2030 and four to 10 weeks shorter by 2100. More radical temperature increases in the second half of the century indicate that lower elevation areas, including the base area of Aspen Mountain, are unlikely to have sustained winter snowpack by 2100 in the absence of a swift and rigorous reduction in global emissions (AGCI, 2006).

Shifts in Biotic Communities and Migrations

Climatic factors like temperature and moisture are prime determinants of the distribution of plant and animal species. Research has shown that observed changes to mountain snowpack and snowmelt timing can be correlated to parallel shifts in vegetation (Stewart et al., 2005; Mote et al., 2005; Breshears et al., 2005). Over the last several decades, the mountainous regions of the West have witnessed shifts in temperature and precipitation patterns accompanied by a gradual disappearance of alpine tundra (NAST, 2000; IPCC, 2007a; Diaz and Eischeid, 2005). Changes in snowpack and spring melt, reduced soil moisture, and hotter summers will affect riparian habitats from Glenwood Springs to Independence Pass.

Model projections indicate that continued anthropogenic warming will give rise to widespread biome shifts (Watson et al., 1997). Temperature-sensitive species are likely to seek out cooler conditions in higher altitude and/or latitude locations in response to warming. Paleoclimatology evidence supports most scientists' opinion that the projected rate of climate change will exceed the dispersion potential of most forest tree species (Roberts, 1989).

Within the mountain environment of the Roaring Fork Watershed, the uneven topography combined with human-caused habitat fragmentation can impede the ability of species to adapt to climate change via migration. On the other hand, mountains offer higher-elevation escapes that may facilitate successful migration for certain species (NAST, 2000), although these species will be restricted to smaller and smaller geographic areas and will likely face population squeezes as they move higher and higher upslope (AGCI, 2006). If global warming is allowed to progress unchecked, some alpine species – and eventually entire alpine ecosystems – will vanish completely.

High-elevation headwater ecosystems such as alpine meadows and subalpine forest are predicted to gradually decline and eventually disappear from some areas. Vegetation modeling conducted for the Aspen area projects a transformation of dominant vegetation from taiga-tundra to boreal conifer forest in as few as 20 years (AGCI, 2006). Analysis by the U.S. Environmental Protection Agency suggests that tree lines in the Southern Rocky Mountains will migrate 350 feet upwards in elevation for every 1°F (0.56°C) increase in temperature (USEPA, 1997b).

Vulnerable Species

Many alpine species such as those found in the Roaring Fork Watershed possess characteristics that make them especially vulnerable to environmental changes. Mountain animal species are often poor dispersers and slow reproducers with low productivity and long generation times, making rapid adaptive response to new climatic conditions difficult (Krementz and Handford, 1984). Within the watershed, populations currently inhabiting the highest elevations and/or those located at the edge of their geographic range are at the greatest risk from warming (AGCI, 2006).

Specialist species – those species requiring a narrow range of ecological conditions to survive and whose diet is often limited to only one or two food sources – are also generally less capable of adapting to change. Although specialists thrive in reasonably stable conditions as a result of highly specialized co-evolution with other organisms, they are greatly dependent on the habitat characteristics of the ecological niches to which they have acclimated. Generalist species like mice and coyotes, on the other hand, are able to survive in a broad range of habitats and use a varied diet. These species can be found throughout the watershed at elevations anywhere from 6,000 – 13, 000 feet (AGCI, 2006). Consequently, habitat specialists face greater risk of extinction than generalist species under changing environmental conditions (Benayas et al., 1999). Two such specialists expected to face population extirpation from climate change are the American pika and white-tailed ptarmigan (Beever et al., 2003; AGCI, 2006; Saunders et al., 2008).

Because plants and animals initiate certain behaviors based on climatic signals (including temperature, precipitation, and runoff), an earlier spring melt can upset the normal timing of biological events, triggering earlier migrations, breeding, emergence from hibernation, and flowering (Saunders et al., 2008; AGCI, 2006). Varied responses among predator, prey, and competitor species will weaken existing ecological relationships and define new ones. The IPCC reports that such phenological changes are already being observed in the West and can be directly attributed to local temperature increases (IPCC, 2007a). In the second half of the 20th century, accelerated phenology ranging from a few days to several weeks has been documented in the egg lay date of tree swallows, migration by American robins, hatching in white-tailed ptarmigan, nesting by Mexican jays, and emergence from hibernation of yellow-bellied marmots (Dunn and Winkler, 1999; AGCI, 2006; Hobbs et al., 2003; Li and Brown, 1999; Inouye et. al., 2000). Across species, chicks are now emerging at a time when food supplies are less readily available.

Some mountain species have seasonal ranges, inhabiting higher elevations during the summer and migrating to lower elevations in the winter to escape cold temperatures and deep snowpack. Warmer winter conditions in the future could allow these animals – which include Rocky Mountain bighorn sheep, mule deer, and Rocky Mountain elk – to remain at higher elevations year round. Modeling suggests that while warmer winters would result in a contraction of overall range, population sizes would increase substantially (AGCI, 2006).

Invasive Species

Non-native invasive species already pose a threat to many Rocky Mountain ecosystems (NAST, 2000), and climate change stands to increase the likelihood of invasions. Because they are capable of reproducing and dispersing rapidly, invasive plant species are well suited to respond and adapt to climatic disturbances. Certain weeds may also benefit from increased CO_2 concentrations, including Canada thistle, field bindweed, leafy spurge, and spotted knapweed - all of which appear on the 2005 Pitkin County Noxious Weed List (AGCI, 2006; Ziska, 2003). Meanwhile, native vegetation will be stressed by higher temperatures. Competition from invasive species will likely jeopardize native species' ability to adapt successfully to climatic changes.

Forests

Another important terrestrial biotic community to examine is that of forests, which play an important role in the hydrological cycle. Alterations to forest coverage or composition – as those caused by drought, fires, or insect infestation – can affect water flow, storage, and filtering (Lemmen et al., 2004).

As temperature rises, plant evapotranspiration and water demand increases (Goyal, 2004). When that demand is not met – such as during periods of drought – trees undergo stress. The recent and dramatic decline of aspen trees in Colorado has been attributed to high temperatures and dry conditions (Worral et al., 2008). This trend is expected to accelerate with global warming. Stands on south- and west- facing slopes, which receive the most solar radiation and thus experience the highest temperatures during the growing season, are most vulnerable (Saunders et al., 2008).

Climate change increases the likelihood of insect outbreaks (IPCC, 2007b). Recent warming trends in alpine areas have improved the overwinter survival of insect species that kill trees and make forests more susceptible to fires (Ebi et al., 2007). In the past, sustained cold winter temperatures have kept beetle populations in check (Saunders et al., 2008), but higher summer temperatures are expected to enable epidemic level population increases (Hansen et al., 2001). Research needs to be undertaken to compare temperature thresholds for alpine insect species to the current climate of the Roaring Fork Watershed.

As to wildfires, since 1980 the annual acreage of U.S. land burned from wildfires has increased 70 percent from the average for the 1920-1980 period (IPCC, 1997). Global warming is likely to accelerate this trend in the West (NAST, 2000). According to the Pew Center on Climate Change, severe western fires, like those in Yellowstone in 1988 and Hayman in 2002, were triggered by “extreme climate signals, which could become more dominant in a warmer future” (Ebi et al., 2007). Slopes disturbed by fire are more vulnerable to erosion, which has profound implications for stream water quality.

Westerling et al. (2006) reported a high correlation between increased fire risk activity in the western U.S. and warmer temperatures (about 1.0°C/1.8°F warmer), and also between wildfire activity and earlier spring snowmelt (one to four weeks earlier) (Figure 3.5.6). Increased temperatures and earlier spring snowmelt are both trends being observed in the Upper Colorado River Basin (Ebi et al., 2007; Westerling et al., 2006; AGCI, 2006). The same study also found that the greatest increase in western U.S. wildfire activity since the mid-1980s has occurred at elevations near 7,000 feet (Figure 3.5.7). Greater variability in precipitation can also increase fire risk regardless of a positive or negative change in total precipitation; wetter years increase plant productivity, thereby prompting a buildup of the organic matter that fuels fires in drought years (NAST, 2000).

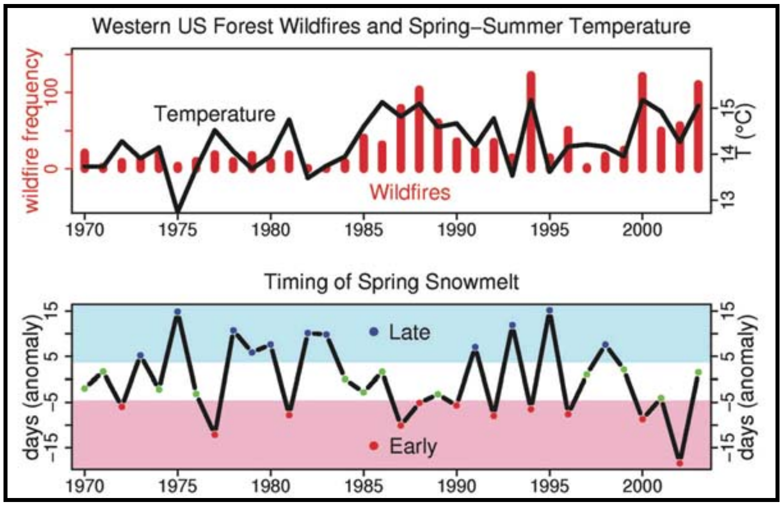


Figure 3.5.6. Western U.S. forest fires and spring-summer temperature. Correlations between temperature, timing of spring snowmelt, and wildfire frequency are shown. Note that both the top and bottom graphs are on the same time scale, and that during early melt years (pink band), the frequency of wildfires goes up. Warming trends indicated for the western U.S. are mirrored in local data reported in AGCI 2006. Source: Westering et al., 2006.

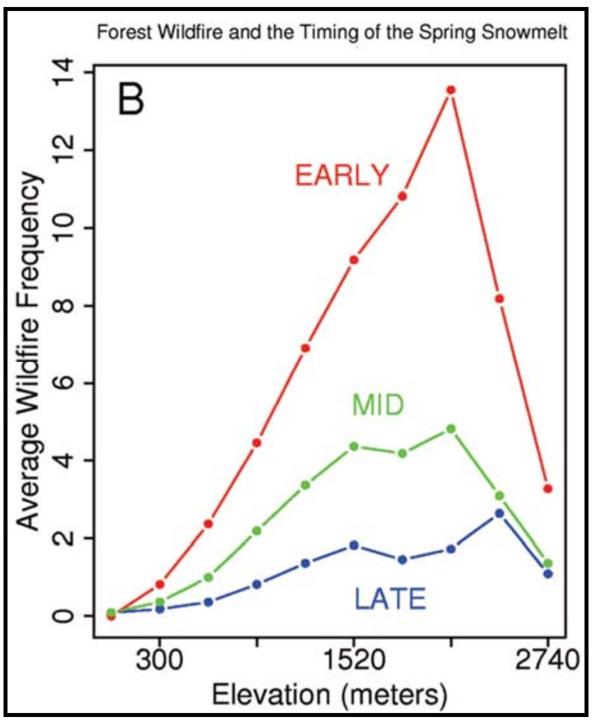


Figure 3.5.7. Forest wildfire and the timing of spring snowmelt. Average western U.S. wildfire frequency from 1970-2002 is shown by elevation for early, mid, and late snowmelt years. Fire frequency during early snow melt years peaks at 2130 meters, or about 7000 feet. An earlier peak flow is projected for the Roaring Fork Watershed (AGCI 2006). Source: Westering et al., 2006.

Climate modeling conducted for the greater Roaring Fork Watershed region projects temperature increases of 1.7-2.2 °C (3-4 °F) by 2030, and roughly 2.8-9.4 °C (5-17 °F) by 2100 (largely dependent on how quickly and seriously the world responds to the climate crisis); summer temperatures are predicted to increase more than winter temperatures, and precipitation is projected to decrease slightly (ACGI, 2006). Such conditions would worsen drought and increase the risk of high-elevation forest fires (NAST, 2000; Seager et al., 2007). Fire risk modeling conducted for the Aspen area predicts larger average fire sizes during the first half of the 21st century, and more frequent but smaller fires during the second half of the century (AGCI, 2006).

Instream Areas

The relationship between climate change, water temperature, stream flows, and instream habitat and species is multi-faceted and complicated. This sub-section offers an overview of this relationship and related potential effects within the watershed. A more in-depth discussion of the potential implications of climate change on instream areas, particularly trout species and populations, is provided in Appendix 3.5.1.

Aquatic species' physiological processes and geographic ranges are tied directly to water temperatures. Since the 1970s, rising air temperatures in high altitude locations have been mirrored in rising alpine stream temperatures; these changes are expected to accelerate in the coming decades (Hari et al., 2006). Since snowmelt runoff can mediate otherwise warmer water temperatures, higher elevation stream reaches – those in closest proximity to snowpack – will have an advantage over lower elevation reaches as air temperatures warm. However, because global warming will reduce the extent of snowpack feeding cool meltwater into streams, stream temperatures in the Roaring Fork Watershed are expected to track more closely with air temperatures in the future.

Compounding direct temperature impacts, a projected shift in the timing and seasonal volume of runoff in the upper Roaring Fork River related to future climate trends could prove disruptive to flora and fauna communities throughout the watershed (AGCI, 2006). Crucial aquatic habitat components such as dissolved oxygen, water temperature, water depth and velocity, and availability of food supply are highly correlated with streamflow (Ptacek et al., 2003). Additionally, aquatic species have evolved behavioral survival strategies based on existing, natural flow regimes. Any alteration to this flow regime as a result of warming temperatures and precipitation change will be mirrored in alterations to aquatic ecosystems, creating opportunity for some species and increased vulnerability for others. Both the extent and rate of change are equally important in determining the ability of freshwater species to successfully adapt.

The 2007 IPCC report reconfirmed model projections of more extreme precipitation events during the course of the 21st century (IPCC, 2007a). Accordant with these findings, the upper Roaring Fork/Aspen climate change study projected the occurrence of possible, but not certain, July monsoons toward the end of the 21st century for the greater Roaring Fork Watershed area. While such precipitation events could help alleviate the impact of otherwise low summer flows, intense rains can generate heavy, disruptive stream flows that cause channel erosion, sedimentation, and bank instability – all of which affect aquatic habitat (AGCI, 2006). The projected increase in precipitation variability also suggests a greater risk of prolonged drought periods, as more rainfall will be concentrated into fewer rain days. In arid mountain regions, more frequent drought events associated with climate change will exacerbate low flow conditions, leading to reduced aquatic habitat and biological diversity (Poff et al., 2002).

Trout are an important aquatic species within mountain stream ecosystems. These coldwater fish are considered to be keystone species, meaning that without equivalent replacement by another species, the removal of trout from a river system would leave an ecological gap causing a ripple effect throughout the food chain. For example, the disappearance of trout from a stream could result in an overpopulation of the insects on which they feed, while land vertebrates that prey on trout would lose an important food source (Willson and Halupka, 1995).

Trout are dependent on clear and cold water – both at risk from global warming. Of all the freshwater fish species, salmonids (which include trout, salmon, and whitefish) are likely to face the greatest negative impacts from climate change (IPCC, 2007b). Extended periods of high temperatures and low flows in summer months may leave streams too warm and too shallow to provide sufficient fish habitat (AGCI, 2006). Secondary changes to stream cover, food supply, and competitive interactions will further influence trout populations. The IPCC projects a 15 to 40 percent loss in total fish habitat in the Rocky Mountains, depending on global emissions levels (IPCC, 2007b). A recent report by Trout Unlimited projected that trout populations in the western U.S. could be reduced by more than 60 percent in some areas (Williams et al., 2007). A 1996 study by Keleher and Rahel found that Rocky Mountain salmonids were restricted to streams in regions where average July air temperatures remained below 22 °C (72 °F), corroborating findings from similar studies. Projected increases in summer maximum temperatures and even greater increases in winter minimum temperatures are likely to cause an upstream shift in the boundaries of fish ranges (Meisner, 1990). Coldwater species may be excluded from presently inhabited downstream stretches of the river, while more heat-tolerant species may expand their range (Chu et al., 2005). Habitat fragmentation that acts as a barrier to migrations may increase the likelihood of local population extinctions.

While no significant trends in water temperature are evident from the available historical data for the Roaring Fork River, data collected from the Roaring Fork at Glenwood Springs gage shows 2002-2007 average maximum water temperatures peaking in August at around 15 °C (59 °F) (maximum water temperature data dates back to 1980, but a data gap exists between 1985 and 2002; analysis of the 1980-1984 data shows average maximum water temperatures for this period also to be near 59°F). Therefore, taking into consideration the positive but less than 1:1 correlation between air and water temperatures (See Appendix 3.5.1 for more on the air-water temperature relationship), a 1.7-2.2 °C (3-4 °F) increase in air temperatures in the Roaring Fork Watershed region by the year 2030, as projected by AGCI 2006, could potentially put brook trout, cutthroat trout, and brown trout fry into suboptimal thermal ranges during the warmest portion of the year. A medium emissions scenario projection of 3.9-6.1 °C (7-11°F) warming by the end of the century would come closer to, but not exceed, the lethal limits of brook and cutthroat trout, and might approach the suboptimal ranges for rainbow and brown trout. Once the upper limit to the optimal range has been exceeded, mortality rates rise with increasing temperature (Hickman and Raleigh, 1982; Raleigh, 1982; Raleigh et al., 1986; Raleigh et al., 1984). Although many fish are capable of adapting to new thermal regimes by varying their lethal and optimal temperatures by a few degrees, this process occurs over time. The rate and degree of temperature change dictates the success of acclimatization.

The reproductive success of Roaring Fork Watershed trout populations in a warmer climate will vary greatly by species. Low overwinter temperatures, likely to be compromised by global warming, are often necessary for successful spawning of coldwater salmonids (Gerdaux, 1998), while extreme temperatures during incubation can cause mortalities. Alterations to flow during the reproductive window may affect the frequency of scouring and/or dewatering events, with implications for young survival. Brown and brook trout are fall or early winter spawners, with incubation occurring over the winter. Rainbow and cutthroat trout are spring spawners, with fry emerging in the late spring/summer in rhythm with spring runoff flows. The cumulative effects from alterations to streams' thermal regimes and flow patterns will likely affect the spawning activities of these trout species.

3.5.3 Socioeconomic Impacts

Climate-driven physical and ecological changes – both local and regional – will have financial consequences for municipal, agricultural, and recreational users in the Roaring Fork Watershed. As part of the upper Roaring Fork/Aspen climate change study, potential socio-economic impacts to the Aspen area were assessed, including those associated with alterations to the Roaring Fork River. In interviews conducted for the report, discussions with community representatives, including elected officials, ski mountain managers, resource managers, ranchers, and river-based business owners, revealed that future change to the river was consistently the greatest stakeholder concern (AGCI, 2006).

The Ski Industry and Snowmaking

Although the Aspen and Snowmass ski areas are positioned more favorably than many other U.S. and European ski resorts because of their higher elevation and colder temperatures, the local ski industry will become increasingly vulnerable to the progressive impacts of climate change in the second half of the 21^{st} century. In the watershed, lower elevation ski areas, such as Sunlight and Buttermilk, are most vulnerable.

Modeling conducted for the upper Roaring Fork/Aspen climate change study indicated that as more precipitation falls as rain rather than snow due to warming temperatures, early season snow depths will decrease (potentially delaying the opening day target date - a threat to Aspen's holiday season). An earlier spring melt will likewise shorten the ski season. In interviews, mountain managers identified several strategies for coping with shortened snow seasons and degraded conditions, including moving snowmaking to higher elevations, extending the snowmaking season, stockpiling more snow, building more water storage, and obtaining more water rights. These adaptations will require more energy, water, and money, and will put additional stress on local water resources. For example, adding snowmaking on top of Aspen Mountain is estimated to require an additional 5 million gallons of water per year; this quantity would increase at higher temperatures (AGCI, 2006). Currently, Aspen Skiing Company obtains water for snowmaking from Maroon, Castle, and Snowmass creeks. According to AGCI (2006):

> "Withdrawing water from streams in November and December prolongs normal late-summer low flows for months, and leaves streambeds and aquatic communities, like the prized trout

> fisheries in Aspen, more exposed and vulnerable to cold temperatures and freezing and drying. Anchor ice, which forms in shallow water, adheres to stream bottoms affecting egg viability…And with dewatering there are fewer deep pools for fish to overwinter. The absence of flushing flows can lead to sedimentation and problems related to algal growth."

Instream Recreation

Future growth in instream non-consumptive uses (e.g. fishing and boating) is tied to patterns of peak runoff, turbidity, and temperature. The threat of increased out-of-basin diversions in a warmer West could further complicate flow issues, potentially leaving inadequate water levels for whitewater rafting or for sufficient fish habitat to support a fishing industry. The upper Roaring Fork/Aspen climate study indicated that projected earlier peak runoff and lower flows might negatively impact whitewater rafting outfitters by forcing an abbreviated and earlier rafting season to a time of year typically not favored by tourists. Likewise, recreational fishing outfitters may need to adjust their operations to adapt to changing river conditions. As noted earlier, lower summer flows and warmer water temperatures (because of lower volumes, loss of stream cover, and warmer surface air temperatues) could adversely impact trout populations and cause shifts in the timing of trout spawning (AGCI, 2006).

Flood Risk

Climate-driven changes to the hydrological system will likely increase the frequency, magnitude, and financial costs of extreme weather events. Snowmelt-driven basins like the Roaring Fork Watershed are at especially high risk from increased flooding (Frederick and Gleick, 1999). Compounding this risk, valley-wide development has placed an increasing number of structures in the floodplain. Structures in the floodplain are costly to relocate, and vulnerabilities should be reassessed in the context of an altered hydrograph.

Municipal Supply

Future warming in the West could result in substantial water supply shortages for Colorado River Basin communities (McCabe and Wolock 2007; Steiner 1998). Notwithstanding potential climatic changes, the City of Aspen already anticipates an increased demand on municipal water that will reduce flows below instream flow designations. Although the total annual water supply available to municpal users in the watershed is not projected to change significantly under global warming, seasonal availablity will likely shift. Anticipated warmer temperatures leading to increased snowmelt in winter would alleviate surface water demand during winter months when the City of Aspen generally needs to pump water from its alluvial acquifer. However, surface water availablity would decline in June due to earlier runoff, which might require additional use of the acquifer stores. Tapping this underground source ultimately lowers the instream flow of the Roaring Fork River (AGCI, 2006).

Agriculture

The agricultural sector is likely to experience lower soil moisture content at the same time that instream water resources are reduced. Earlier peak runoff (May) is predicted to saturate soils initially but leave them desiccated by peak growing season. Therefore, more irrigation might become necessary, but water availability will likewise shift, potentially straining irrigation abilities. Higher temperatures will also have a direct impact on the transpiration rate of crops and, at the same time, create additional competition for irrigation of lawns and golf courses (AGCI, 2006).

Tourism

Alterations to the natural aesthetics of the watershed are another economic concern related to climate change. The watershed likely will become more vulnerable to beetle outbreaks because of increased overwinter insect survival rates (due to warmer winter temperatures) and weakened stands of trees experiencing drought-related stress (AGCI, 2006). Warmer summer temperatures and more frequent extreme heat waves, combined with increased tree damage from insect infestations, will make forested areas, including riparian forests, more susceptible to fires (Westerling et al., 2006; Ebi et al., 2007). Such environmental damage arising from climate-driven aggravation of natural conditions may negatively impact the tourist experience in the watershed. It should be noted, however, that Aspen's higher elevation and cooler climate relative to other popular resort destinations may work in favor of the local summertime economy.

Water Rights and Regional Demand

The recent inflation in the price of water rights in the watershed is likely to become an enduring trend in the future. Global warming will exacerbate water scarcities that drive up demand and value of water. In 2007, 200 shares of water in the Salvation Ditch were put up for sale for $1.2 million, with a final selling price of about $6,860 per acre foot (Gilman, 2008). In Summit County, water rights already sell for as much as $40,000 per acre foot (Gilman, 2008). During the summer months, a coincident decrease in supply (due to low flows) and increase in demand (due to warmer temperatures) will exert additional upwards pressure on the value of water.

In addition to local factors, changing climatic conditions beyond the watershed may impact local supply. Transmountain diversions on the upper Roaring Fork River redirect water to Front Range communities like Colorado Springs and Pueblo, where approximately 80 percent of that water is utilized for municipal and industrial uses and 20 percent for agriculture (Condon, 2005). Municipal demand for Upper Colorado River Basin water is also growing further downstream among Arizona, Nevada, and California users. Although the Bureau of Reclamation maintains that water levels in Lake Mead will be sufficient for years to come, some climate scientists contend that Lake Mead will be "operationally empty" by 2020 (Thompson, 2007). With both in- and out-of-basin municipal and agricultural water needs projected to rise due to population growth and likely to increase further with global warming, the demand for Roaring Fork Watershed water resources is expected to increase.

In very dry years, it is possible for the Cameo Call, representing a group of senior water rights holders in Grand Junction, to prevent diversions within the Roaring Fork Watershed by certain users. In August 2003, the Cameo Call prevented Twin Lake Reservoir and Canal Company (Twin Lakes) from diverting water through the Independence Pass Transmountain Diversion System. Withdrawals from the upper Roaring Fork River by the Twin Lakes reduce native flows (as measured above Aspen at the USGS stream gage station) by 40 percent (AGCI, 2006). Therefore, although the call negatively affected Front Range municipal users and Arkansas Valley farmers, the result for Roaring Fork Valley users was positive because more water remained in the river (Condon, 2003; AGCI, 2006). Projected drier summers in the future may increase the likelihood of the Cameo Call.

In contrast to the Cameo Call, the Shoshone Hydro Plant in Glenwood Springs makes a call on the Colorado River throughout most of the year (Sloan, 2004) to assure sufficient flow for the plant to operate efficiently. According to ACGI (2006): "Because the Shoshone Call results in increased flows through Glenwood Springs and down to Grand Junction, the call may delay the Cameo Call and demand for water to protect the Colorado River Endangered Fish Recovery Program. Otherwise, without the Shoshone Call in place, water from the Roaring Fork River would be required to augment flows to meet the Colorado River demands leaving more water instream. When the Roaring Fork River flows are not required to be released downstream to the Colorado River for fish habitat protection or use by Grand Valley farmers, they can be diverted elsewhere. Thus, the Shoshone Call mainly benefits Roaring Fork transmountain diversions. The resulting lower flows in the upper Roaring Fork River can negatively impact Roaring Fork instream users, such as rafters, and negatively affect fish and riparian habitat."

Climate-driven alterations to the hydrograph of the Colorado River could vary the current pattern of calls administered by the Shoshone hydroplant. For additional discussion about the Cameo and Shoshone calls, refer to Section 2.1.1.

Separate from concerns over local and regional diversions, the recent boom in biofuel production (including corn-based ethanol and soy-based biodiesel) spurred by climate-energy concerns threatens to accelerate the disappearance of groundwater reservoirs on the East Slope. Colorado corn farmers seeking prosperity from the state's $500 million ethanol industry planted 20 percent more acres of corn in 2007 than in 2006 (Moscou, 2008). Corn requires approximately 4,000 gallons of water to produce one bushel (USGS, 2007a). These growing agricultural water demands, when combined with East Slope population growth, intensify efforts to divert more West Slope water to the East Slope.

Colorado's West Slope, expanding oil and gas drilling operations are projected to require additional withdrawals from the Colorado and other rivers in the near future (Webb, 2007). Potential "in-situ" oil shale development may harbor the greatest threat to water resources. While it is not known exactly how much water would be required for full scale oil shale production, experts have projected water needs of 105 to 315 million gallons per day (Webb, 2007). This does not include water required to meet additional demands from regional population growth associated with a sizeable and growing energy industry.

Overall, competing demand from East Slope diversions, urban growth in the western part of the state, and Colorado's growing energy industries, compounded by warmer and drier conditions stemming from climate change, will further drive water prices up and availability down.

3.5.4 Watershed Management

Improved understanding of the vulnerabilities and risks associated with climate change can lead to adaptations that are anticipatory rather than reactive. Unlike many aspects of the Roaring Fork Watershed that are a product of local changes such as increased settlement and development, the climate of the watershed now responds to forces global in scope and external to local jurisdictions and institutions. This creates new challenges for local resource managers and planning efforts. In *Science's* Policy Forum, Milly and a senior group of hydrologists and climatologists caution about a tendency to base infrastructure and management decisions on past variability, a management approach they label "stationarity." They reject this as a workable approach given climate change, noting that global warming will "push [the] hydroclimate beyond the range of historical behaviors." They note that other strategies are needed, such as using probabilistic models to identify ways to optimize water systems undergoing change (Milly et al., 2008).

Although this report on the "State of the Watershed" is an important step, an in-depth integrated climate impact assessment utilizing recent developments in regional climate and hydrologic modeling could help identify and quantify potential vulnerabilities beyond the more qualitative assessment provided here. Assessments that identify vulnerabilities are a critical step toward adaptations which can reduce risks and increase resiliency to the impacts of change. Just as the impacts of human settlement in the West drove the establishment of our legal and water resource management institutions during the 19^{th} and 20th centuries, the effects of climate change will likely force a re-evaluation of infrastructure and management practices at all scales of jurisdiction within the Colorado River system. The many changing variables and interactions require dynamic systems analysis and active stakeholder involvement to help guide policies and procedures. One innovative example of this type of approach was conducted by Cohen et al. for the Okanagan region in British Columbia. The approach joins stakeholders with local experts and scientists first to assess and then to develop adaptation strategies. The general framework consists of:

1. Climate change scenarios (global to regional)
2. Hydrological scenarios (snowpack, stream flow, annual cycle)
3. Water supply and demand scenarios/land use patterns (requirements, case studies)
4. Adaptation options/case studies/costs
5. Adaptation dialogue with stakeholders

The Okanagan assessment incorporated information on regional planning and water management processes, and directly engaged local practitioners and decision makers, leaving a legacy of shared learning that should influence future planning beyond the completion of this assessment (Cohen et al., 2006; Cohen and Neale, 2006).

By the end of this century, future change in annual temperature for the Roaring Fork Watershed region could be 5.6°C (10°F) or more if global emissions follow the higher of the IPCC emission scenarios (AGCI, 2006). On the other hand, if mitigation is aggressively pursued worldwide, global average temperatures could be held at or below the 2 to 2.5°C (3.8 to 4.5°F) increase that many scientists estimate would be enough to avoid "dangerous interference" in the climate system. It is probable we have passed the point where the climate of the 21st century can be like that of the 20th century. Projections for the end of this century range from modest change to radical change. The climate of the 21st century is dependent on the path global greenhouse gas emissions take, which is a question of political will and the technical capability to dramatically reduce emissions on a worldwide scale.

Adding human-induced climate change to the list of critical factors addressed in traditional management plans and watershed assessments and plans is essential for devising sound strategies for watershed management in the future. The impact to the watershed of a changed global, regional, and local climate will be unprecedented and far-reaching. These effects will include altered hydrology, change in aquatic and riparian habitat, and a shift in species composition. The combination of natural variability with human-induced climate change will likely alter water supply and demand in ways new to existing institutions. Climate change will impact human uses of local water resources from irrigation and municipal supply to hydroelectricity generation and recreational uses like snowmaking, boating, and fishing. It will also alter riparian and instream habitat and the plant and animal communities of the entire watershed. It is important to pursue mitigation locally, thus sending the message that jurisdictions in the watershed take climate change seriously. Sound management must also face the reality of climate change. The challenge is to identify and quantify these potential changes in advance so that adaptations can be built into the planning process, management practices, and infrastructure, thereby reducing risk and building greater resilience.

3.5.5 Data and Knowledge Gaps

As noted earlier in this section, regional climate change modeling is in its early stages. Once higher resolution models become available, we will learn more about how to model at the watershed and regional scale. Along with this, resource managers will benefit from better projections of change in seasonality, timing and magnitude of runoff, and overall change in temperature and precipitation. The following points cover, more specifically, data gaps and management approaches that should be addressed in order to prepare adaptation and mitigation strategies in response to climate change.

A comprehensive climate impacts assessment for the entire Roaring Fork Watershed is needed. Although the Aspen climate impacts study completed in 2006 included snowpack runoff modeling of the upper Roaring Fork Watershed, it did not incorporate full-scale hydrological modeling, and was limited in scope to impacts on the Aspen area. A watershed-wide integrated assessment would require in-depth hydrological modeling coupled to a high resolution regional climate model. In addition to hydrologic and climate modeling, such an assessment would need to bring together stakeholders and local experts in order to develop more complete understanding and guide appropriate responses to climate change in the context of other watershed issues.

Existing watershed management plans and operational procedures should be re-evaluated to take into consideration long-term past climate variability and future climate projections related to the timing and magnitude of stream flows. Gaps identified can be incorporated in Phase II management plans.

Maintenance of existing river-related infrastructure and all new projects should incorporate future projections of stream flows based upon climate change research, and should not rely solely on interpretation of 20^{th} century historical flow variability.

Basic knowledge of how tightly coupled the economies of the watershed are to climate change is lacking. Research to assess the impact that significant global warming may have on present economic trends (real estate, tourism, recreation, and energy) in the watershed and beyond could help to fill this gap and lead to more sustainable economic strategies.

Site-specific research and modeling needs to be conducted in order to understand better the complex interactions at work within the Roaring Fork Watershed (see Figure 3.5.5) and improve projections of impacts to the overall watershed.

Gaps in the current monitoring network for physical, chemical, and biological properties of the watershed should be assessed and used to serve as the basis for developing an integrated, long-term observational database – a critical requirement for future assessments.

4. Watershed Resource Discussion by Sub-watershed

The Roaring Fork Watershed is comprised of nine sub-watersheds derived from National Resource Conservation Service 10-digit hydrologic units (Figure 4.1). The landscapes of these sub-watersheds differ in both their inherent (e.g. geology, climate, biodiversity, soils, and topography) and human (land use and ownership) characteristics. Ecoregions denote general similarities in ecosystems (Figure 4.2) (Chapman et al., 2005). Both inherent and human characteristics influence water quality and quantity as well as riparian and instream areas. The following chapter discusses the status of these various watershed resources for each sub-watershed, based on available scientific information. Each sub-watershed section concludes with a summary of key findings, a listing of data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the sub-watershed's water resources. Table 4.1 provides general physical information about each sub-watershed.

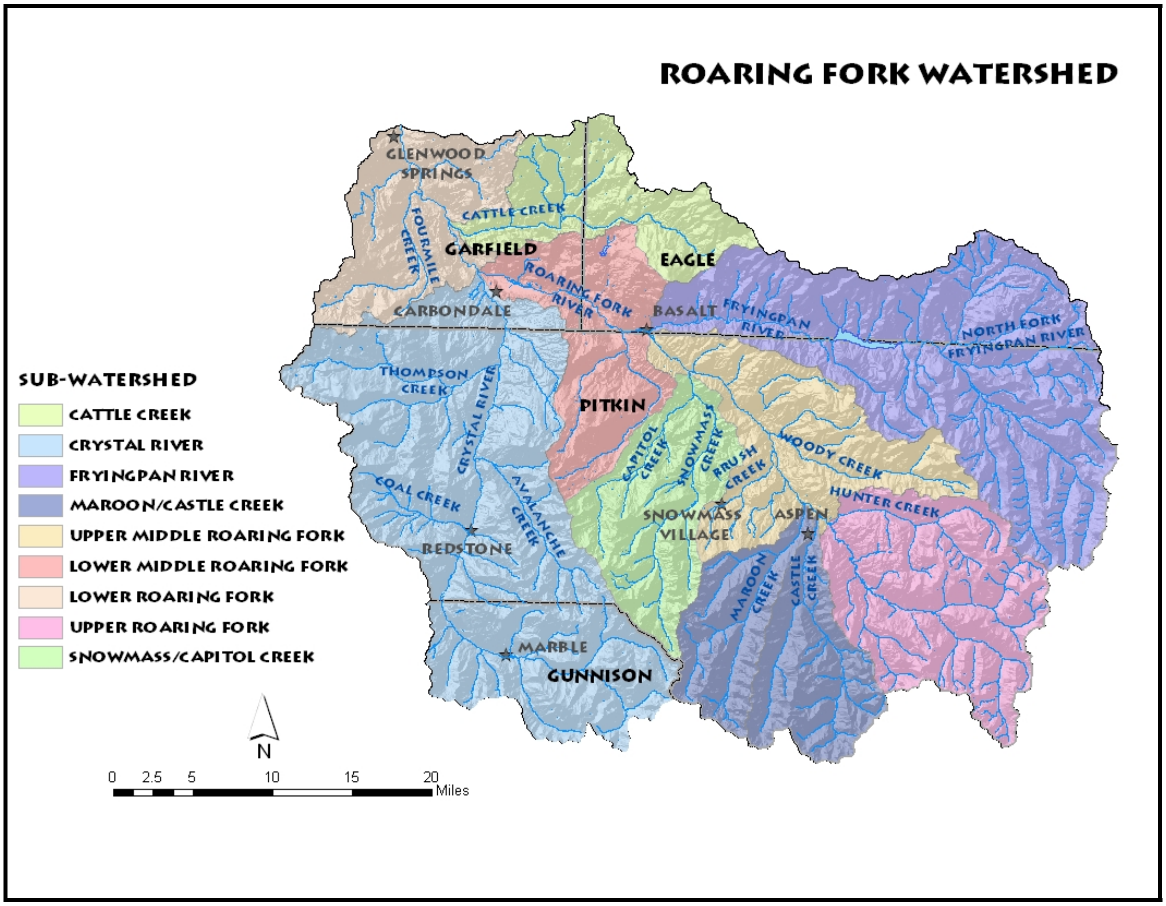


Figure 4.1. The nine sub-watersheds of the Roaring Fork Watershed (derived from National Resource Conservation Service 10-digit hydrologic units).

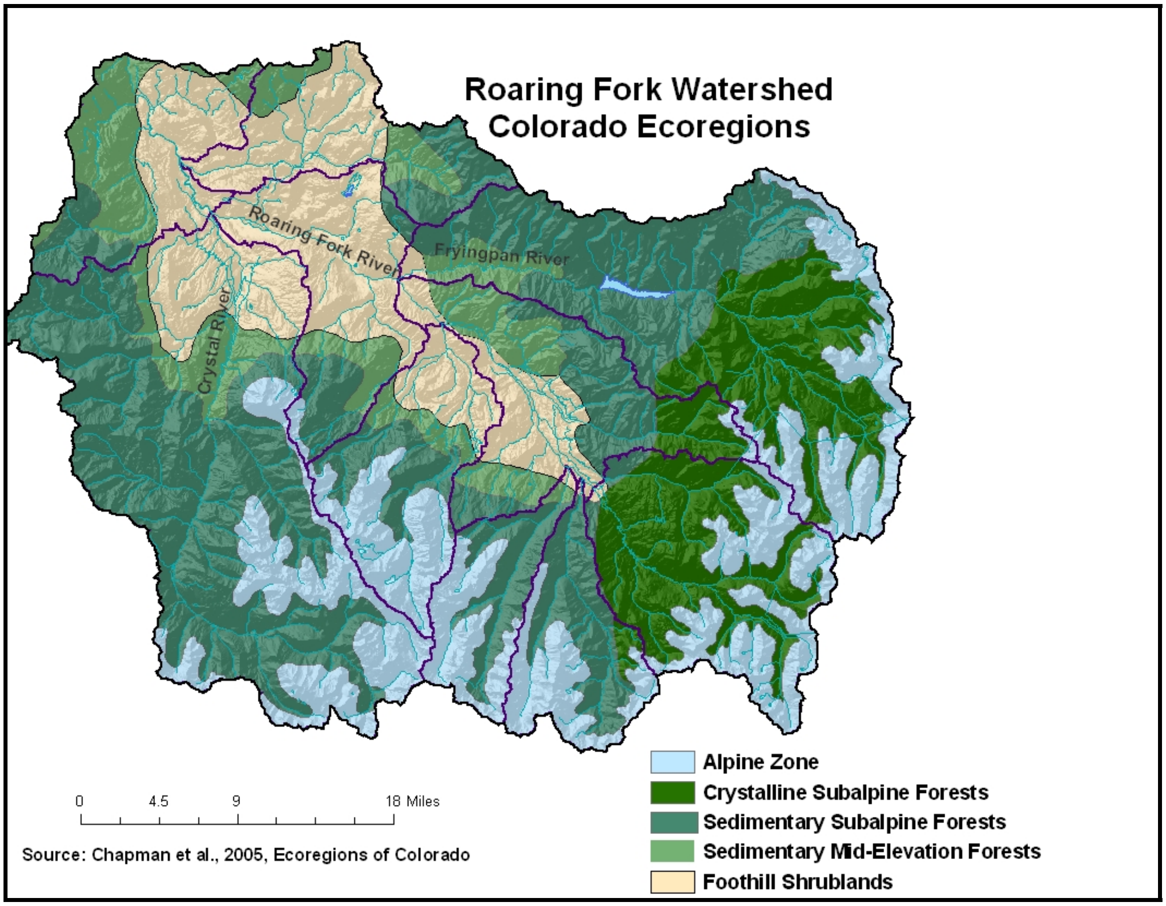


Figure 4.2. Ecoregions of the Roaring Fork Watershed.

Table 4.1. Sub-watershed characteristics.

SUB-WATERSHED	AREA (mi²)	STREAM MILES [1]	ELEVATION RANGE (ft)	ECOREGIONS [2]
4.1 Upper Roaring Fork	153	147.21	7,833 - 13,963	· Mixture of alpine zone and crystalline subalpine forests by elevational bands
4.2 Upper Middle Roaring Fork	128	162.27	6,586 - 12,572	· Crystalline subalpine forests in headwaters of Woody Creek, with elevational bands of sedimentary subalpine forests · Sedimentary mid-elevation forests and shrublands · Foothills and shrublands
4.3 Lower Middle Roaring Fork	103	88.42	6,052 - 12,333	· In the upper sub-watershed, some sedimentary subalpine forests, sedimentary mid-elevation forests and shrublands · Foothills and shrublands
4.4 Lower Roaring Fork	99	102.09	5,717 - 10,581	· Sedimentary subalpine forest with a mixture of sedimentary mid-elevation forests and shrublands; foothills and shrublands
4.5 Maroon/Castle Creek	130	102.30	7,642 - 14,235	· Mixture of alpine zone and sedimentary subalpine forests by elevational bands
4.6 Snowmass/Capitol Creek	100	105.38	6,842 - 14,111	· Elevational bands of alpine zone · Sedimentary subalpine forests · Sedimentary mid-elevation forest and shrublands · Foothills and shrublands
4.7 Fryingpan River	289	278.99	6,583 - 14,163	· Elevational bands of alpine zone · Crystalline subalpine zone · Sedimentary subalpine forests · Sedimentary mid-elevation forests and shrublands
4.8 Crystal River	363	325.28	6,052 - 13,513	· Alpine zone in the headwaters · Large extent of sedimentary subalpine forests · Short band of sedimentary mid-elevation forests and shrublands · Foothills and shrublands.
4.9 Cattle Creek	88	82.96	5,953 - 11,667	· Some sedimentary subalpine forests and sedimentary mid-elevation forest and shrublands in the upper sub-watershed · Mostly foothills and shrublands in lower sub-watershed.
TOTALS	1453	1394.90	5,717 - 14,235	

[1] Perennial streams determined from Colorado 1:100,000-scale stream data.
[2] Ecoregions of Colorado (Chapman et al., 2005).

4.1 Upper Roaring Fork Sub-watershed

4.1.1 Environmental Setting

The Upper Roaring Fork Sub-watershed, which extends from the Continental Divide downstream to Aspen, is surrounded by the Sawatch Range and the Elk Mountains with several peaks rising above 12,000 feet (Twining, Grizzly, Truro, and New York peaks, and Green and Independence mountains). Numerous small, glacial lakes are found in the headwaters, including Independence Lake at an elevation of 12,490 feet where the Roaring Fork River begins (Figure 4.1.1). The sub-watershed's ecological setting is influenced by the valley's directional trend and a stair-stepped valley floor. Stream, riparian, and upland environments are dominated by natural processes in the uppermost part of the sub-watershed with increasing development closer to Aspen and an urban setting within Aspen. Colorado State Highway 82, recently designated as a Scenic Byway from Aspen to Twin Lakes, is a significant landscape feature, cutting a route down the valley from Independence Pass. The Independence Pass Transmountain Diversion System has a significant influence on water resources in the sub-watershed. See Figure 4.1 for an overview map showing the location of this sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions. The two ecoregions in this sub-watershed are the Alpine Zone and Crystalline Subalpine Forest. The sub-watershed's general physical characteristics are summarized in Table 4.1.

Figure 4.1.1. Beginnings of the Roaring Fork: Looking south from the snowmelt ponds that are the headwaters of the Roaring Fork River.

Topography and Geology

The Upper Roaring Fork Sub-watershed is dominated by high elevation and high relief. Because the Roaring Fork Valley trends east-west, sunlight and precipitation vary from the north to the south-facing valley walls, resulting in differing runoff regimes and vegetative communities. Colder, north-facing slopes receive more snow and retain that snow well into the summer, whereas warmer south-facing slopes receive less snow that melts off more quickly, leaving snow-free areas even in winter.

In the lower part of the sub-watershed, glacial action during the late Pleistocene Epoch (ending about 11,000 years ago) formed a wide, low-gradient valley. When the glaciers retreated, they left deep deposits of glacial outwash that are important in determining stream and riparian habitat characteristics. The Roaring Fork Glacier extended down to what is now the eastern edge of Aspen. At the terminal end of the retreating glacier, morainal deposits acted as a dam that accumulated a thick deposit of alluvium consisting of glacial outwash and lake and stream sediments to a depth of more than 300 feet (Hickey et al., 2000). The stream channel developed a highly sinuous pattern due to low gradient and deep deposits of soil. Old meander scars indicate that the stream's historic shape was highly sinuous and that the stream meandered across the width of the valley (Figure 4.1.2). These channel characteristics in combination with native riparian vegetation and beaver activity enabled spring flooding flows to overbank and spread across the riparian zone. Wetlands occurred across much of the valley floor, even where the river historically did not meander due to shallow groundwater discharge from adjacent slopes.

Figure 4.1.2. 1990 Infrared aerial photograph of the historic meander pattern within the North Star Nature Preserve area.

A map of the geology of the Roaring Fork Watershed is shown in Figure 1.3. Most of the sub-watershed is underlain by granitic rocks with glacial drift along the river corridors in some areas where the stream has been scoured into a U-shape. The Lost Man Creek drainage is mostly comprised of Precambrian gneisses and schists. The Lincoln Creek drainage is a complicated mix of granitic rocks, gneisses and schists, glacial drift, extrusive igneous, and intrusive rocks that is reflected in the variety of stream types ranging from wide meadows with beaver ponds to deep, rocky gorges (Figure 4.1.3). Hunter Creek is a hanging glacial valley that drops steeply to meet the Roaring Fork River. Aspen, located near the confluence of Hunter Creek and the Roaring Fork River, sits partly on glacial outwash deposits. The Aspen Mountain Ski Area is located due south of Aspen within sedimentary rocks consisting of dolomite, sandstone, and limestone. This area was identified as a tier-two debris flow zone in "Critical Landslides in Colorado: A year 2002 review and priority list" (Rodgers, 2005). Tier-two listing is very significant but less severe than tier-one.

Figure 4.1.3. Rocky gorge in Lincoln Creek.

Weather/Climate

One Colorado Basin River Forecast Center SNOTEL site lies in the headwaters of this sub-watershed – Independence Pass (IDPC2) at 10,600 feet (http://www.cbrfc.noaa.gov/snow/snow.cgi) (Figure 4.1.8). During the 25-year period of record (1982-2007), snowpack varied considerably in both amount and timing. Average peak snowpack is 17.6 snow water equivalent (SWE) inches occurring on April 11th (Figure 4.1.4). The highest measurement recorded at this site was 27.7 inches (SWE) on May 19, 1995. The lowest peak snowpack was about 72 percent of average and occurred earlier (12.6 inches SWE on April 9, 1981 and 12.9 inches SWE on March 29, 2002).

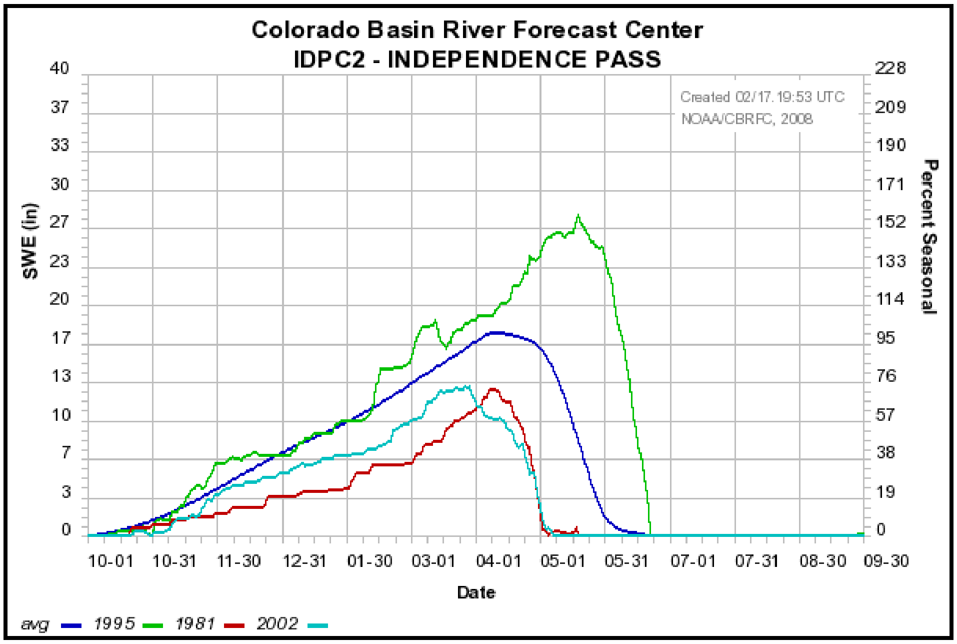


Figure 4.1.4. Highest and lowest recorded snowpack relative to average conditions (1986-2007).

According to the recently released report "Climate Change and Aspen: An Assessment of Impacts and Potential Responses" (AGCI, 2006), over the last 25 years Aspen has become warmer by about 3° F and drier with a decrease in total precipitation of about six percent. The amount of moisture falling as snow has decreased by 16 percent. Total precipitation at higher elevations (10,000 feet) at the Independence Pass SNOTEL weather station has decreased 17 percent in the past 25 years. The climate change study projected temperature and precipitation changes for 2030 and 2100 using a middle emission scenario. In 2030 average temperatures are projected to increase by 3 to 4° F over 1990 temperatures. Projections for precipitation are less clear than for temperature. By the year 2100, projections indicate a greater increase in summer versus winter temperatures, more of Aspen's annual precipitation to fall as rain rather than snow, and spring runoff very likely to be earlier with a medium probability of mid- and late winter partial thaws and rain events. Additional information about this climate change study can be found in Section 3.5.

Biological Communities

In this sub-watershed, north-facing slopes are characterized by moisture-loving plant communities such as spruce-fir forests and slope wetlands. South-facing slopes are dominated by more drought-tolerant plant communities such as lodgepole pine and oak shrublands. Aspen groves occur on each slope wherever there is adequate soil moisture (Figure 1.6). Riparian habitat in the upper part of the sub-watershed is composed of subalpine riparian willow shrublands alternating with wet meadows and open water beaver ponds. In the middle section, mixed subalpine spruce-fir and aspen forests alternate with willow carrs, alder thickets, and wet meadows. This riparian habitat then transitions into a mosaic of mixed montane aspen, cottonwood, and conifer forest; willow and non-willow shrublands; wet meadows; and open water beaver ponds. Just above McFarlane Creek, the river enters a wide floodplain where historically it meandered broadly across the wide, flat valley creating a habitat mosaic of montane willow carrs, cottonwood-blue spruce forests, sedge and rush wetlands, and open water ponds and backwaters. Where the gradient increases above Aspen, riparian habitat is characterized by a mix of cottonwood-blue spruce forests, willow carrs, and non-willow shrublands.

On the steep valley walls of the sub-watershed, soils are thin and the ability to retain and conserve soil moisture is largely dependent on soil condition and vegetation characteristics such as a dense root system. In associated riparian areas, vegetation recruitment is dependent on sufficient soil, soil quality and moisture for seed germination, and rooting. The bases of these steep-gradient stream reaches often open onto wide floodplains with deep soils that provide important water storage and purification functions.

In the upper part of the sub-watershed that is dominated by public lands, wildlife potential is high due to the presence of large, undeveloped landscapes in combination with a diversity of high-quality habitats. Ecosystem diversity results from the local climate differences between north- and south-facing slopes, habitat patchiness that stems from high topographic relief, natural disturbance factors, and the variety of riparian habitats created by the stair-stepped topographic character of the valley (Figure 4.1.5). The diversity of habitats provides a year-round supply of cover and forage for large and small mammals, amphibians, and resident and Neotropical migrant bird species. Common mammals such as American elk, mule deer, black bear, pine marten, and mountain lion are abundant. Several wildlife species that are threatened, endangered, or considered as species of special concern at the state and/or federal level (http://wildlife.state.co.us/WildlifeSpecies/SpeciesOfConcern) are documented in this sub-watershed, including Canada lynx and boreal toad (Appendix 1.3). Breeding boreal toad populations occur in the Lincoln Creek drainage and Canada lynx activity has been documented in the Independence Pass area (CDOW, 2007c). Additionally, several Colorado Natural Heritage Program elements, sensitive species designated by the U.S. Forest Service, and Audubon watch-listed bird species are found frequently in stream reaches in the upper sub-watershed. Bird species include great blue heron, white-tailed ptarmigan, Northern pygmy owl, Northern goshawk, rufous hummingbird, Williamson's sapsucker, three-toed woodpecker and brown-capped rosy finch. Also listed are the olive-sided, cordilleran and willow flycatcher, and Virginia's, orange-crowned, Wilson's, and MacGillivray's warbler.

In the lower part of the sub-watershed, where the valley floor flattens, increased stream meandering decreases stream gradient and energy, slows flow velocity, and creates ideal environmental conditions for beaver. Deep soils and abundant moisture in combination with beaver activity have created a variety of habitats from mesic meadows to open water ponds that historically provided refugia for a large diversity of native wildlife. In remaining natural areas, the wetlands, side channels, backwater ponds, and riparian habitat support chorus frogs and boreal toads; shorebirds and waterfowl such as sora, Virginia's rail, and green-winged teal; and mammals such as Western jumping mouse, mink, muskrat, and beaver. Great blue herons nest in stands of cottonwood and conifers, and riparian-dependent songbirds such as willow flycatcher, yellow warbler, and fox sparrow find protected habitat in willow carrs. Aspen groves are used by black bear, mule deer, elk, and numerous bird species including Cooper's and sharp-shinned hawk, and red-naped sapsucker. Adjacent slopes are dominated by oak shrublands that provide nest habitat for bird species like MacGillivray's warbler and black-headed grosbeak, and small mammals such as masked shrew, montane vole, and least chipmunk. In the fall an abundance of berries and nuts provides high quality forage for many of these wildlife species. Development in this lower part of the sub-watershed has affected habitat diversity and quality, reducing wildlife potential.

Figure 4.1.5. A wide diversity of ecosystems occurs in the Upper Roaring Fork Sub-watershed due to varied topography and the east-west trending valley (North Star Nature Preserve).

With regard to fish, the Colorado Division of Wildlife (CDOW) has identified occurrence of the following species in the sub-watershed: Colorado River Cutthroat, rainbow, brook, and brown trout; mottled sculpin; speckled dace; mountain whitefish; and bluehead sucker (Harry Vermillion, CDOW, personal communication, March 3, 2008). Two great blue heron nesting colonies and foraging areas are located in the sub-watershed (Figure 3.3.4). Appendix 1.3 provides a thorough listing of riparian-related and instream species as well as communities of concern in the sub-watershed.

4.1.2 Human Influences

Land Ownership and Use

Figure 4.1.6 is a map of the Upper Roaring Fork Sub-watershed showing ownership and protection status. Much of the sub-watershed is in the White River National Forest, which is managed by the U.S. Forest Service (USFS), and most of the forest is either in the Hunter-Fryingpan or Collegiate Peaks Wilderness Area. The conservation organization Wilderness Workshop is proposing that several other areas in the sub-watershed be reviewed for wilderness status, including Hunter, Ruby Lakes, and North Independent (http://www.whiteriverwild.org/aspen-region.php).There are several open space parcels along the Roaring Fork River and lower Hunter Creek (Appendix 4.1). Pitkin County Open Space and

Trails has management plans in place for two of these properties – North Star Nature Preserve (North Star) and the James H. Smith North Star Open Space (James H. Smith) (Pitkin County, 2000 and 2001).

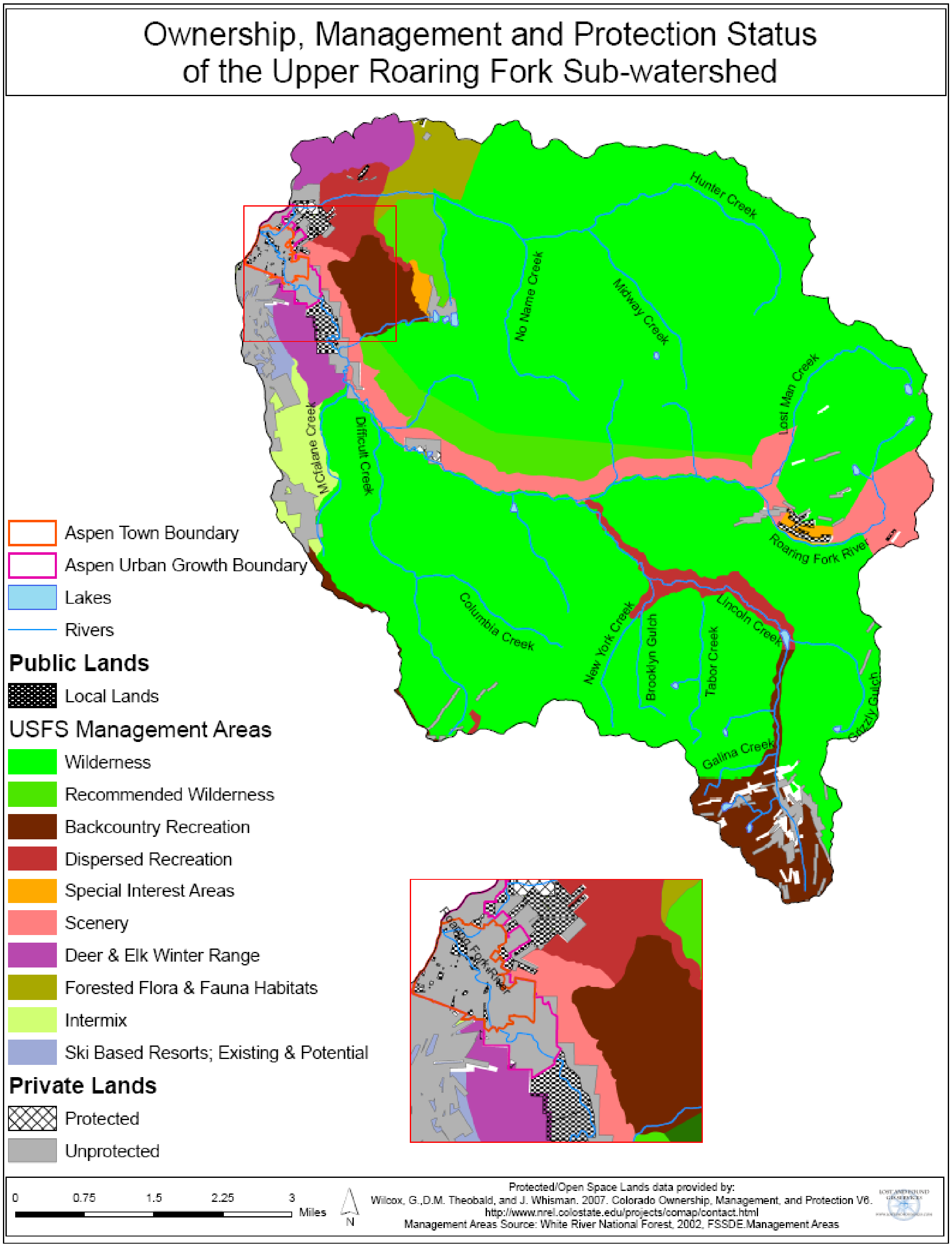


Figure 4.1.6. Ownership and protection status of the Upper Roaring Fork Sub-watershed.

The sub-watershed is located entirely within Pitkin County. The East of Aspen/Independence Pass Caucus (http://www.aspenpitkin.com/depts/77/east_aspen.cfm) was formed to make recommendations to the county concerning land use, and the East of Aspen/Independence Pass Master Plan was adopted in 2003. One of the goals of the caucus is to “maintain and enhance the quality of wildlife habitat within the East of Aspen/Independence Pass planning area.” It is also interested in working with the USFS to address issues with Warren Lakes and Warren Creek (Figure 4.1.8). In the spring of 2003, Warren Creek overflowed its banks and caused significant damage to private property as well as to Highway 82.

Generally, Highway 82 parallels the Roaring Fork River. It is closed for the winter at Mile Marker 45, so road sand and salts do not affect the river above the closure, and winter recreation access above the closure is restricted to snowmobilers or those pursuing non-motorized activities such as skiing or snowshoeing. Most of the roads in this sub-watershed are in the Aspen and its immediate surroundings (including the lower part of the Hunter Creek Valley). Figure 4.1.7 shows the roads in the sub-watershed and identifies roads within 150 feet of second order and higher streams (approximately nine percent of the streams). Aspen and Pitkin County do not use magnesium chloride for deicing and try to minimize the use of sand. For application of magnesium chloride as a dust suppressant, Pitkin County adheres to caucus requests (Lutz, 2007). An unimproved USFS road parallels Lincoln Creek; for the most part, the other streams in this sub-watershed do not have roads near them.

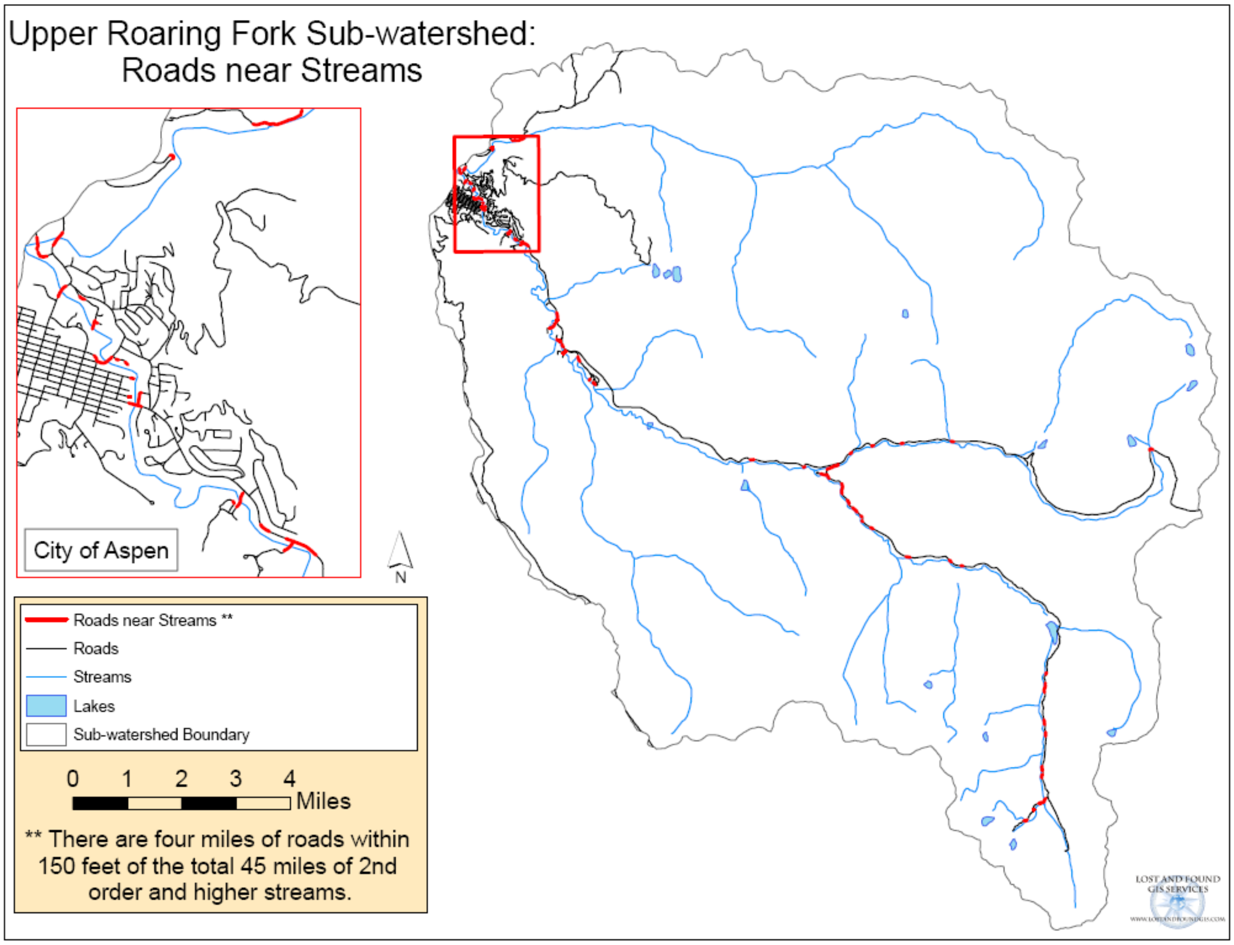


Figure 4.1.7. Roads adjacent to streams in the Upper Roaring Fork Sub-watershed.

Aspen is partly located in this sub-watershed and extends into the Maroon/Castle Creek and Upper Middle Roaring Fork sub-watersheds. It occupies an area of four square miles, and the Urban Growth Boundary increases this footprint to almost eight square miles (Figure 4.1.6). Historically, Aspen has obtained the majority of its municipal water supply by diversion from Castle Creek. The city diverts water from Maroon Creek primarily for the generation of hydroelectric power, and also diverts water from several alluvial wells tributary to the Roaring Fork River. Untreated irrigation water is used to supply open space areas, parks, and golf courses. This water is obtained from Castle, Maroon, and Hunter creeks, the Roaring Fork River, and several wells. Water for snowmaking on Aspen Mountain is obtained from Maroon and Castle creeks.

Discussion of water supply and demand issues as they influence Maroon and Castle creeks is provided in Section 4.5. The Aspen Consolidated Wastewater Treatment Plant serves this sub-watershed. More information about this treatment plant can be found in the 2002 Roaring Fork Watershed Plan done by the Northwest Colorado Council of Governments.

Cities with populations above 10,000 are required by the Clean Water Act to have a comprehensive storm water management system that captures and treats runoff before it enters waterways. Although Aspen does not fall under this mandate, stormwater runoff can be an issue. A particular need for sediment removal stems from the sand put on icy roads in the winter and other soil disturbing activities such as construction. In late winter and spring, streets start to thaw and sand is carried into the stormwater system, directly entering the Roaring Fork River in areas without treatment. The amount of total suspended solids in this runoff has been measured at levels as high as 55 times the national average.

To address this issue Aspen installed a sediment removal vault and water sampling device at Rio Grande Park in 2006. In 2007 another vault was added at the restored Jenny Adair Pond, along with the creation of wetlands that provide natural filtration and purification of stormwater runoff. Together, these two projects treat water draining from about 15 percent of the city's area, meaning that runoff from 85 percent of the city still drains directly to the river. In 2007, Referendum 2B was passed to further improve stormwater management and will raise $800,000 annually through a property tax mill levy to support capital projects and operational activities, including sediment removal, creation of wetlands and other storm water management areas, educational and outreach programs, master planning, and stormwater monitoring.

Mining

Table 4.1.1 lists the permitted, active mines in this sub-watershed. Throughout the sub-watershed the legacy of mining continues to affect the river system. The historic Independence Townsite is a popular tourist attraction located on uplands just above and on the north bank of the Roaring Fork River. Historic buildings still stand and the old ore crusher remains about one-half mile downstream of the town. The old town site and associated upland mine sites have not been successfully revegetated and are a source of stream sediment. Also in the upper part of the watershed, the abandoned Ruby Mine discharges mine drainage into Lincoln Creek. Mine dumps are scattered across Aspen Mountain and throughout the Hunter Creek Valley on hillslopes above Hunter Creek. Smuggler Mine, on the flank of Smuggler Mountain, was designated by the Environmental Protection Agency as a Superfund site because of elevated lead and cadmium levels on the mine dump and surrounding soils. Cleanup and remediation activities at the Smuggler site were completed in 1996 but ongoing mitigation activities are required. Although contaminated soils and dumps may not be located directly adjacent to a stream, runoff can carry elevated levels of heavy metals into receiving streams. In the lower part of the sub-watershed, just north of North Star Nature Preserve, two gravel mines are located about 1,000 feet from the Roaring Fork River. Peat was mined from a portion of a fen (wetland) at Warren Lakes until about 20 years ago. The USFS and the Aspen Center for Environmental Studies are collaborating on restoration of this area.

Table 4.1.1. Mine sites in the Upper Roaring Fork Sub-watershed. Source: Colorado Division of Reclamation Mining and Safety. No date.

SITE NAME	STREAM	SIZE	COMMODITY	STATUS	PERMIT ISSUED
Stillwater Sand Pit	Roaring Fork River	29 acres	Sand and gravel	Application withdrawn	n/a
Smuggler Mine	Roaring Fork River	9.9 acres	Silver and lead	Active	1/14/1997
Independence Pass	Roaring Fork River	8.7 acres	Sand and gravel	Active	7/2/1984

Recreation Activities

Outdoor recreation dominates land management throughout this uppermost sub-watershed. The Aspen Mountain Ski Area is partially located within the sub-watershed, and the magnificent scenery of the upper Roaring Fork Valley draws large numbers of sightseers and outdoor enthusiasts. Most USFS trails follow water courses. There are five USFS campgrounds in the upper sub-watershed – three on the Roaring Fork River (Weller, Difficult, and Lost Man) and two along Lincoln Creek (Lincoln Gulch and Portal).

Although listed as boatable, the upper Roaring Fork River is not a draw for kayakers or rafters because of the high gradient in the upper sections and the flat water in the lower section. Both the Southwest Paddler (www.southwestpaddler.com) and American Whitewater (http://www.americanwhitewater.org) websites list the section of the Roaring Fork River from Weller Lake to Difficult Campground as boatable, with several stipulations about the level of difficulty and ability required. The river drops 900 feet in 3.2 miles – an average gradient of 5 percent. The flatwater section in the North Star area does attract some kayakers and canoeists seeking an experience in calm water. In the early 1990s Aspen obtained a "Recreational In-channel Diversion" water right for a channel on the Roaring Fork River adjacent to Rio Grande Park. The channel helps to prevent flooding and was ultimately turned into a kayak park. To increase the length of time it can be used for kayaking, Aspen has allocated money to remove sediment from the channel (Phil Overeynder, the City of Aspen's Public Works Director, personal communication, September 16, 2008).

There are numerous places to access the upper Roaring Fork River for fishing in the sub-watershed. According to Shook (2005): "This section is characterized by fast moving pocket water in its upper stretches and slow-moving runs in the (North Star) 'Preserve' water just above town." Rainbow and brook trout inhabit this section, which is regularly stocked by the CDOW (Shook, 2005). North Star and USFS managed lands are open to the public.

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams and lakes in the sub-watershed have been stocked with the species listed (Table 4.1.2).

Table 4.1.2. Species stocked by the CDOW in streams and lakes of the Upper Roaring Fork Sub-watershed.

STREAM/LAKE	SPECIES
Lincoln Creek	Colorado River cutthroat trout, rainbow trout
Roaring Fork River	Colorado River cutthroat trout, Pikes Peak cutthroat trout, rainbow trout
Anderson Lake	Colorado River cutthroat trout, rainbow trout
Upper Brooklyn Gulch Lake	Colorado River cutthroat trout, Pikes Peak cutthroat trout
Lower Brooklyn Gulch Lake	Colorado River cutthroat trout
Grizzly Lake	Colorado River cutthroat trout, Pikes Peak cutthroat trout
Grizzly Reservoir	Colorado River cutthroat trout, Snake River cutthroat trout, rainbow trout (including Tasmanian)
Hallam Lake	Colorado River cutthroat trout
Independence Lake	Colorado River cutthroat trout
Jack Lake	Colorado River cutthroat trout, Pikes Peak cutthroat trout
Linkins Lake	Colorado River cutthroat trout, rainbow trout
Lost Man Lake	Colorado River cutthroat trout
Lost Man Reservoir	Rainbow trout
Midway Lake	Rainbow trout
New York Lake	Colorado River cutthroat trout
Petroleum Lake	Colorado River cutthroat trout, rainbow trout
Scott Lake	Colorado River cutthroat trout
Sioux Lake	Colorado River cutthroat trout, Pikes Peak cutthroat trout
Tabor Lake	Colorado River cutthroat trout, Pikes Peak cutthroat trout
Truro Lake	Colorado River cutthroat trout, Pikes Peak cutthroat trout
Weller Lake	Colorado River cutthroat trout, rainbow trout

4.1.3 Resource Information

Several research studies and syntheses of information have been done in the Upper Roaring Fork Sub-watershed, providing data on stream flows, groundwater sources, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in this sub-section. For background information on the data sources, please refer to Chapter 3.

Water Quantity

Surface Water

There are four stream gages in the sub-watershed (Figure 4.1.8 and Appendix 3.1.1). In 1964 the Roaring Fork River near Aspen gage began operation and the three others began operation around 1980. None of these gages can be used to establish a pre-impact flow regime because water was diverted through the Twin Lakes Tunnel beginning in 1935. Fifteen years of data prior to 1935 exist for the Roaring Fork at Aspen gage that was located about a mile downstream of the Roaring Fork near Aspen gage. The Hunter Creek near Aspen gage started operation in 1950, before diversions began for the Fryingpan-Arkansas Project (Fry-Ark Project). Flow alteration was assessed using the Upper Colorado River Basin Water Resource Planning Model dataset

(CWCB and CDWR, 2007a). The modeling accounts for diversions over 10 cfs. Modeled stream flow data are available for four nodes in the sub-watershed: Lincoln Creek at the transmountain diversions, the Roaring Fork near Aspen gage, the Hunter Creek gage, and the Hunter Tunnel diversions (Figure 4.1.8 has the locations of the nodes, shown with the symbol for "flow altered"). Appendix 3.1.2 and figures 3.1.4-3.1.6 show how much the flows in the Roaring Fork River and Lincoln and Hunter creeks have been altered.

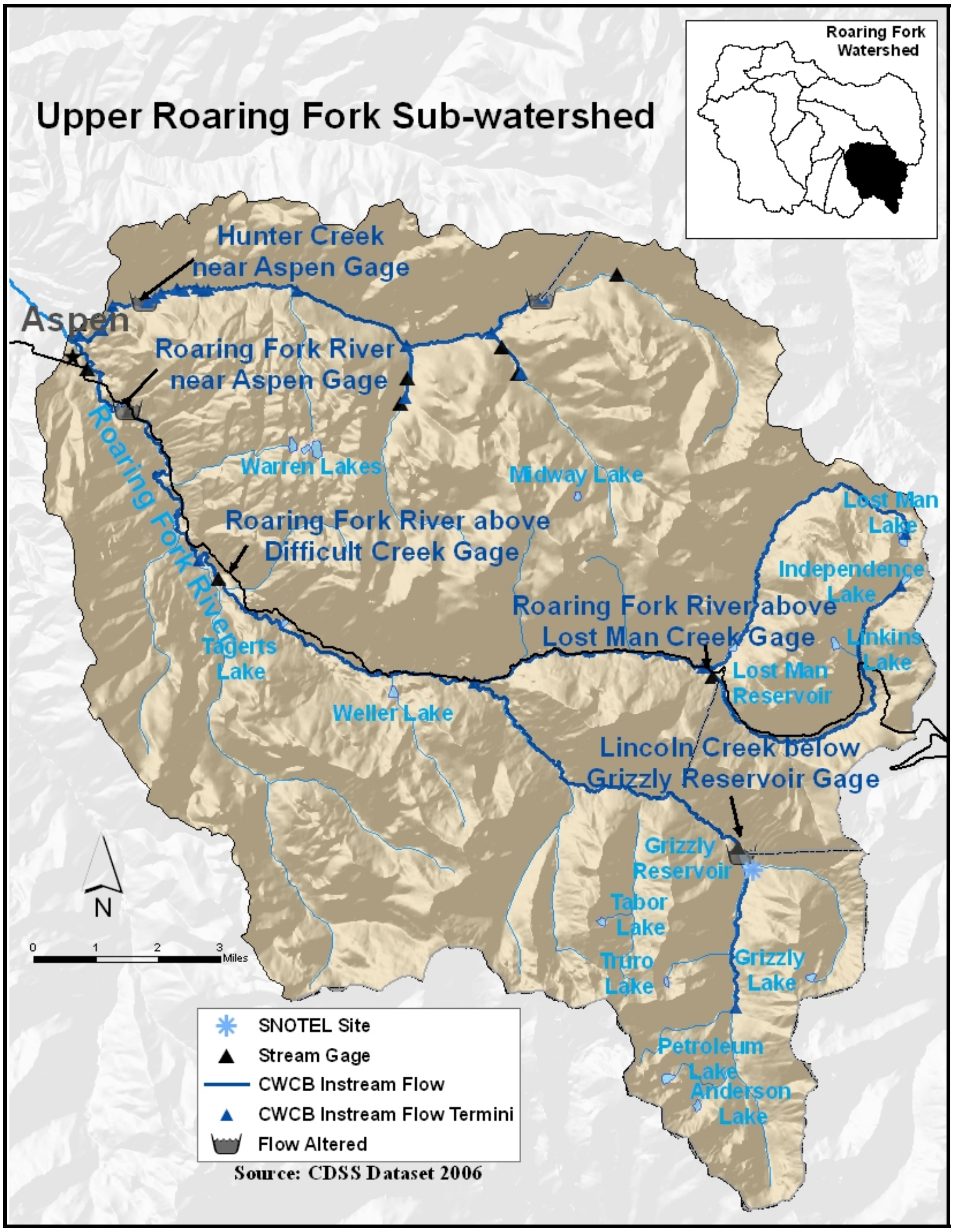


Figure 4.1.8. Water features in the Upper Roaring Fork Sub-watershed.

Almost all of the major headwaters streams of Roaring Fork River are heavily influenced by transmountain diversions, with Difficult Creek being the exception. The two major transmountain diversions in the sub-watershed are the Independence Pass Transmountain Diversion System (IPTDS) and the Fryingpan-Arkansas (Fry-Ark) Project's Hunter Creek diversions (Figures 2.6 and 2.4). The latter is part of a larger collection system that diverts water from the Upper Fryingpan Sub-watershed. More discussion of the IPTDS and the Fry-Ark Project can be found in section 2.1.3. The IPTDS diverted an annual average of 37,221 acre-feet (37 percent) of the Upper Roaring Fork Sub-watershed from 1997-2005. From 1971 to 2005, the maximum amount diverted was 62,656 acre-feet in 1993 and the minimum amount was 8,790 acre-feet in 1984. Annually, 3,000 acre-feet are bypassed as a result of a Fry-Ark Twin Lakes Exchange Agreement. Section 2.1.3 contains more information on this agreement and its implementation. Inbasin diversions affect the Roaring Fork River and Hunter Creek in the lower portion of the sub-watershed.

The magnitude, frequency, duration, and year-to-year variation in the natural flow regime has been dramatically altered in the sub-watershed. As expected, the severity of hydrologic alteration is greatest closer to the diversions.

Appendix 3.1.2 shows to what degree Lincoln Creek's stream flows are affected below the transmountain diversion when compared with pre-developed flow patterns. Flows are most greatly altered from May through August. In addition, the creek has seen a shift in the timing of the lowest flow from February to April. Overall, Lincoln Creek has more extreme low flow conditions and fewer occurrences of high flows and associated floods when compared with its predeveloped flow regime. Under pre-developed flow conditions small floods would be expected to occur in four out of 10 years, but such small floods would be expected in less than one out of 10 years with developed flow conditions. Figure 4.1.9 compares pre-developed to developed daily flows for the period of record.

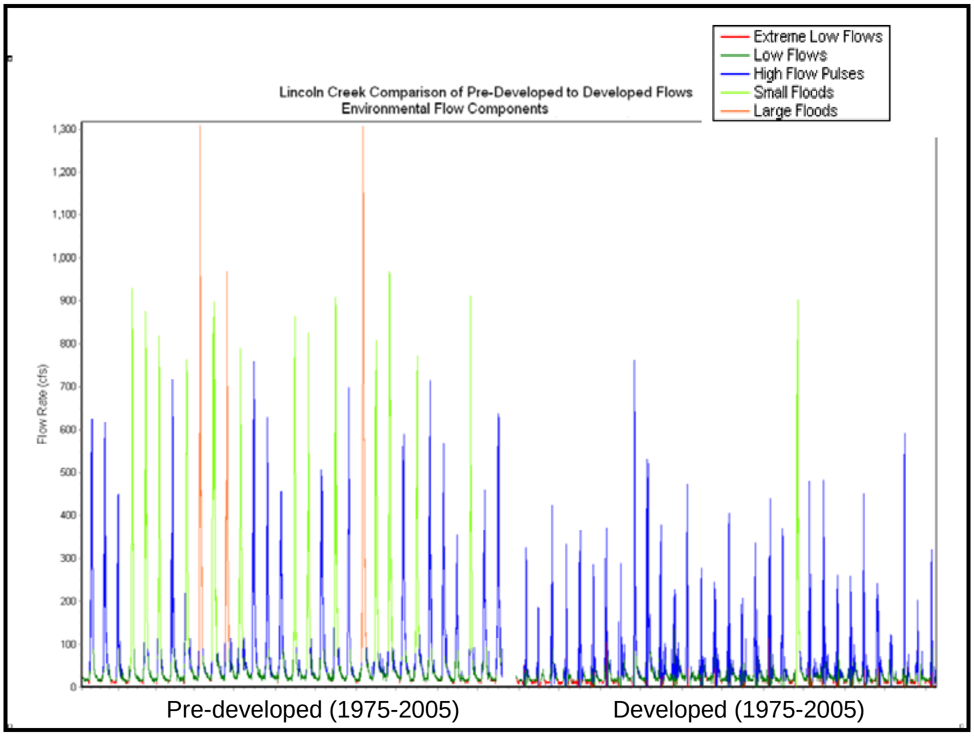


Figure 4.1.9. Comparison of modeled pre-developed flows to developed flows on Lincoln Creek. There are more extreme low flows and fewer high flow events under current conditions.

The influence of the transmountain diversion on the Roaring Fork River is most severe directly below the IPTDS diversion dam. Within a half-mile, because of the geology and groundwater recharge, flows show a moderate improvement. The contribution from relatively unaltered tributary reaches such as Difficult Creek help improve downstream flows. Flows modeled for the Roaring Fork River near Aspen node indicate the best conditions for the Roaring Fork River in the sub-watershed. Flow alteration increases both upstream and downstream from there – upstream due to transmountain diversions and downstream from inbasin diversions. This node is located just upstream of the Salvation Ditch, a major inbasin diversion on the Roaring Fork River, and although this node represents the best conditions, it is still highly altered. Appendix 3.1.2 shows to what degree the upper Roaring Fork River's stream flows are affected below the transmountain diversion and above Aspen, respectively, when compared with pre-developed flow patterns. Flows are most altered from May through August. The significant alterations in May and June correspond to significant decreases in spring runoff flows. Under pre-developed flow conditions, small floods would be expected to occur in four out of 10 years; small floods would be expected in less than one out of 10 years with developed flow conditions. Figure 4.1.10 compares pre-developed to developed daily flows for the period of record.

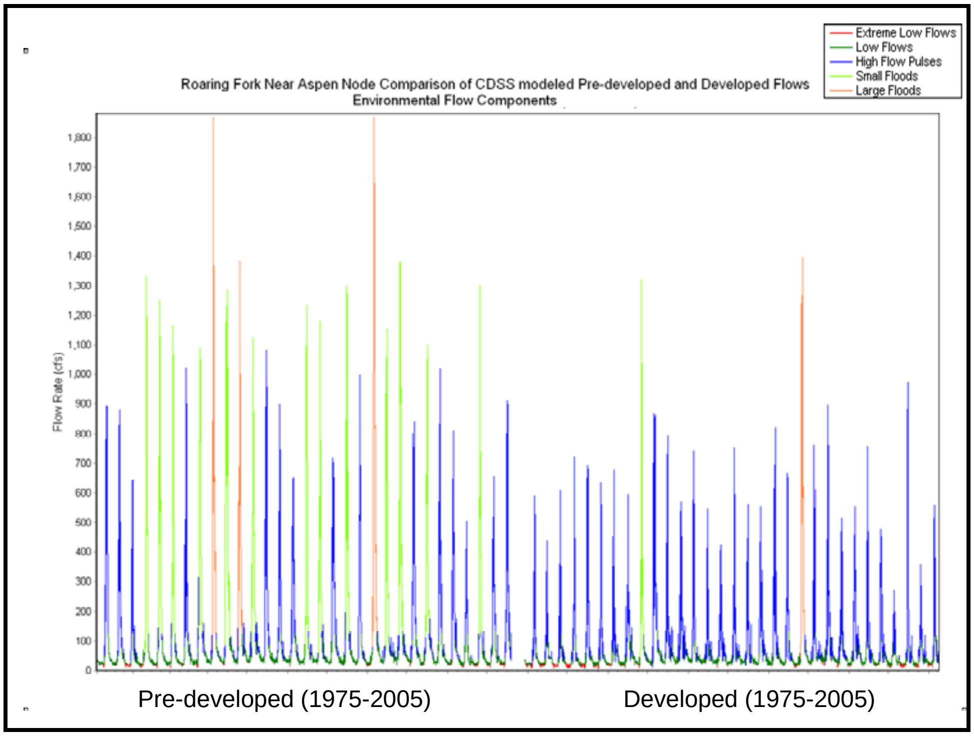


Figure 4.1.10. Comparison of modeled pre-developed flows to developed flows on the upper Roaring Fork River. There are more extreme low flows and fewer small and large floods under current developed conditions.

Below the Roaring Fork near Aspen node, the combined impact of the transmountain and inbasin diversions (including the senior 1904 Salvation Ditch diversions and several smaller inbasin diversions) (See Figure 4.1.11 and Table 4.1.3) creates low flows in the late summer and early fall. The Salvation Ditch is an earthen 11-mile-long ditch system drawing flow from the Roaring Fork River two miles above Aspen. The ditch's water is used to irrigate the lands of more than 25 major shareholders. It is managed by the Salvation Ditch Company, which issues share certificates to its shareholders, entitling them to use the comingled Salvation Ditch water rights in proportion to their share ownership interests. The typical diversion season is from mid-May to mid-October. Over the last 20 years, the average maximum amount diverted has been approximately 25 cfs.

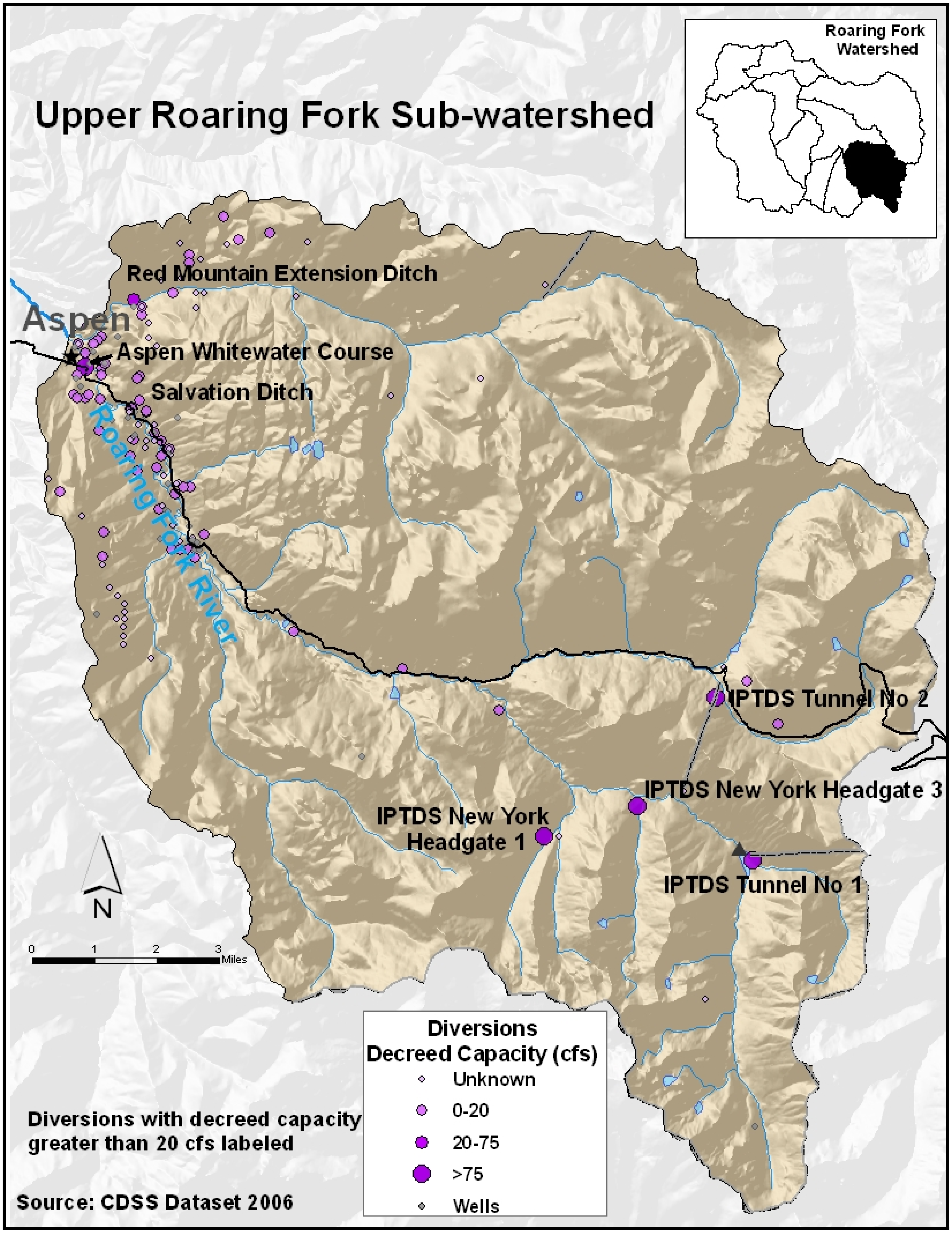


Figure 4.1.11. Diversions and wells in the Upper Roaring Fork Sub-watershed.

Table 4.1.3. Diversions in the Upper Roaring Fork Sub-watershed greater than 10 cfs. Source: CDSS GIS Division 5 diversion data, 2006.

STREAM	DITCH/TUNNEL	DECREED CAPACITY (cfs)
Lincoln Creek	IPTDS Tunnel No. 1*	625.00
Lincoln Creek	IPTDS New York Headgate No. 3*	210.00
Lincoln Creek	IPTDS New York Headgate No.1	76.61
Roaring Fork River	IPTDS Tunnel No. 2	486.16
Roaring Fork River	Salvation Ditch*	59.00
Roaring Fork River	Aspen Whitewater Course	653.00
Hunter Creek	Red Mountain Extension Ditch*	24.96
Hunter Creek	Hunter Creek Flume and Pipeline*	15.00

* Used in CDSS modeling.

The Colorado Water Conservation Board's (CWCB) instream flow water rights (ISF) (Figure 4.1.8 and Appendix 2.2) often are not met because they are junior to the Twin Lakes Reservoir and Canal Company's IPTDS water rights and to many of the inbasin diversions. According to the Stream Flow Survey Report (Clarke, 2006), the ISFs were met less than 50 percent of the time from June to October on the upper Roaring Fork River above Lost Man Creek and for most months with the exception of August for Lincoln Creek. In August this ISF was met just over 50 percent of the time, most likely due to Twin Lake's water rights being called out by the senior Cameo Call in some years.

The CWCB ISF on the river through Aspen is 32 cfs. An assessment made for the 2002 water year by the Colorado River Water Conservation District (River District) determined when and for how long the ISF was not met. This was accomplished by subtracting the flow diverted by the Salvation Ditch from the flow recorded at the Roaring Fork River at Aspen gage (Figure 4.1.12). This calculation slightly overestimated flow according to Aspen's Public Works Director Phil Overeynder, who observed times of no flow through Aspen (Personal communication, September 16, 2008). Figure 4.1.13 shows that the flow dropped below the ISF in early July and stayed below for most of the rest of the year. Water rights owned by Aspen are typically senior to ISF rights. Although the city could legally deplete the stream flow to an amount less than the ISF, it seeks to protect the environment below all of its diversion facilities, and has adopted a policy to bypass sufficient water to maintain these junior ISF rights downstream of all city facilities (City of Aspen, 1993).

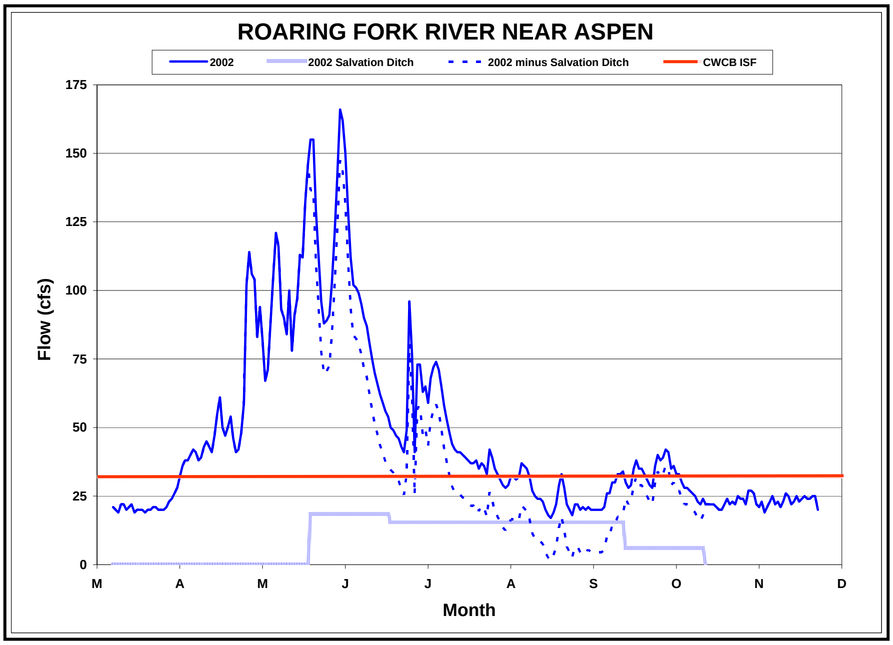


Figure 4.1.12. CWCB instream flow right was not met for the Roaring Fork River in Aspen for most of the summer of 2002. Source: River District.

To address instream flow issues in the Upper Roaring Fork Sub-watershed, a 2007 report by Grand River Consulting studied alternatives that would:

- Meet flow recommendations for the Roaring Fork River above Difficult Creek as established in the Fry-Ark operating principles,
- Maintain the instream flow water right through the City of Aspen,
- Support viable aquatic ecosystems below key Twin Lakes Project points of diversion with year-round bypasses, and
- Provide additional flushing flows in the sub-watershed.

The study estimated that meeting these objectives would require an additional 11,000 to 12,000 acre-feet of water per year in addition to the 3,000 acre-feet bypassed for the Fry-Ark/Twin Lakes Exchange Agreement. Six alternatives were studied that respected the water supply of the IPTDS and Salvation Ditch and that might provide additional water yield for stream flow enhancement in the upper Roaring Fork River. It was concluded that the cumulative water demands are large and will be difficult to supply in their entirety. Three alternatives were determined to represent a potentially viable source of water to satisfy a portion of the identified demand:

- Use of River District water in Grizzly and Twin Lakes reservoirs,
- Reduction of Fry-Ark Project stream flow bypass requirements for the Thomasville Gage, and
- Acquisition of Arkansas River Basin water.

In Hunter Creek, a major tributary to the Roaring Fork River in the sub-watershed, flows are also altered. There are three Fry-Ark Project diversions in the Hunter Creek drainage: Hunter, Midway, and No Name creeks. An average of 29 percent of Hunter Creek was diverted annually from 2002-2006 by the Fry-Ark Project (BOR, 2002-2006). The maximum amount diverted was 12,573 acre-feet in 2005 and the minimum was 2,793 acre-feet in 2002. The two major inbasin diversions on Hunter Creek are the Red Mountain Extension Ditch and Hunter Creek Flume. Similar to the upper Roaring Fork River, the cumulative impact of the transmountain and inbasin diversions result in lower flows in May, June, and July (Appendix 3.1.2). This is reflected in lower maximum flows and shorter duration high flows. However, bypass requirements and CWCB instream flow rights lessen flow alteration in this basin.

There was no provision in the 1959 Fry-Arkansas Project Operating Principles for minimum flows for the upper Hunter Creek Basin. In 1975 the CWCB acquired five ISFs, three on the mainstem of Hunter Creek and one each on Midway and Hunter Creek (Appendix 2.2). A 1977 study conducted by Boaze and Fifer for the USFS recommended bypass flows at the three Fry-Ark Project diversions on Hunter Creek to protect aquatic resources and to satisfy downstream water needs of White River National Forest, including recreation, aesthetics, wildlife, and riparian ecosystem maintenance. The specific bypass flow recommendations are:

Hunter Creek - 12 cfs or natural flow, whichever flow is less;
Midway Creek - 5 cfs or natural flow, whichever is less; and
No Name Creek - 4 cfs or natural flow, whichever is less.

In 1978, Congress amended the original authorizing legislation for the Fry-Ark Project to incorporate minimum bypass requirements for the diversion structures on Hunter, No Name, and Midway creeks (P.L. 95-586). In addition, P.L. 95-586 required that the Fry-Ark Project be operated in a manner that complies with both CWCB's Instream Flow Program and the Fry-Ark's 1975 Final Environmental Impact Statement. In 1979, CWCB ISF amounts were increased on Hunter, Midway, and No Name creeks. Seventeen additional CWCB instream flow rights on Hunter Creek are either donated or acquired rights (Figure 4.1.8 and Appendix 2.2). With one exception the appropriation dates of these rights are prior to 1970, including the Hunter Creek Flume and Pipeline, the largest (15 cfs) and oldest (1886) ISF in the Hunter Creek basin.

Two studies were prepared for the City of Aspen by Enartech, Inc. (1994 and 1997) to consider water availability. Some of the findings of the 1997 study addressed the city's water supply derived from wells that influence the Roaring Fork River. The study concluded that:

- Pumping of the city's existing wells reduces stream flow of the Roaring Fork River through town. Very little lag time occurs between the time of pumping and the time of river depletion. The effect of pumping from the city's best producing well (the Little Nell Well) on stream flows in the Roaring Fork River comes very fast. Within the first month of pumping, stream flow of the Roaring Fork is reduced by about 75 percent of the well pumping rate.
- Stream flow of the Roaring Fork River through Aspen is commonly less than the 32 cfs instream flow right decreed to the CWCB. Shortages on the Roaring Fork typically occur for about nine months (from August through April) in all but the wettest years. Late summer shortages are primarily the result of Salvation Ditch diversions. Non-irrigation shortages occur when natural flow is less than 32 cfs.

- Existing well pumping by the city diminishes flow of the Roaring Fork River during the winter months when stream flow is less than the CWCB instream flow right. The impact of the city's pumping is very minor compared to the impact of Salvation Ditch diversions.
- Expanded well pumping could reduce or eliminate dry-year instream flow right shortages on Castle or Maroon Creek. However, the expanded pumping would additionally deplete flow of the Roaring Fork River at times when an instream flow shortage occurs on the river.
- Well-pumping impacts to the Roaring Fork River during periods of instream flow shortages are relatively minor, and probably average less than 200 acre-feet per year. Total annual shortages to Roaring Fork instream flow rights downstream of the Salvation Ditch average between 5,000 and 6,000 acre-feet per year. In a dry year, Roaring Fork River instream flow right shortages exceed 10,000 acre-feet.

Groundwater

Groundwater modeling that has been done for the North Star area indicates that shallow groundwater from surrounding slopes is the main water source that sustains wetlands along the northeast and southwest margins of North Star, and that flows move from the hill slopes through the wetland areas across North Star to the Roaring Fork River (Hickey et al., 2000). The interaction of unique topographical, environmental, and biological conditions created a complex ecosystem that also enabled the development of a deep aquifer underlying North Star and probably also under similar upstream reaches. Aquifer recharge comes primarily from infiltration of precipitation that flows through surface layers of unconsolidated upland deposits (Glover and Kolm, 1999). Precipitation that does not infiltrate to bedrock runs off by shallow subsurface flow or overland flow to streams. This shallow subsurface flow is one of the most significant components of runoff in this upper part of the Roaring Fork Watershed and is an important component of the North Star hydrologic system. As indicated by modeling, both infiltration that recharges the aquifer and shallow groundwater discharge that sustains North Star's wetlands are important to the long term sustainability of North Star (Glover and Kolm, 1999). The hydrologic system is part of a larger regional system that sustains flows in the Roaring Fork River during late summer and early fall low-flow seasons, as well as during drought (Hickey et al., 2000).

Groundwater movement within the upper Roaring Fork Watershed occurs within a two-aquifer framework (Kolm and van der Heijde, 2006). An upper system consists of thick, unconsolidated sediments of glacial outwash, lake-bed materials, and modern stream deposits overlying crystalline bedrock. It is found mainly within the valley bottom subsystem. A deeper, regional aquifer includes the fractured crystalline bedrock. Local scale groundwater flow occurs in the upper permeable sediments and movement within these sediments is relatively rapid. Groundwater is recharged to the system from precipitation as well as the underlying crystalline bedrock regional aquifer.

Water Quality

Author: U.S. Geological Survey

Within the Upper Roaring Fork Sub-watershed, data have been collected at 35 water-quality sites, dating as far back as 1957. Water-quality data summarized for this sub-watershed are from 1996 to 2005. Thirty of the water-quality sites were stream sites, two were from lakes/reservoirs, and the other three were groundwater sites. Streams with at least some historical water-quality data include Hunter, Lincoln, No Name, Midway, Lost Man, and Difficult Creeks and a reach of the Roaring Fork River from above Lost Man Creek to the confluence with Hunter Creek in Aspen. Stream reaches with recent data are Hunter Creek near Aspen and the Roaring Fork River from Difficult Campground to Mill Street in Aspen. Data from the following six sites were used to summarize recent water-quality conditions in the Upper Roaring Fork Sub-watershed:

- Roaring Fork River at Difficult Campground (Site 1)
- Roaring Fork River above Difficult Creek near Aspen, CO (Site 2)
- Roaring Fork River above Aspen, Colorado (Site 3)
- Roaring Fork River near Aspen, Colorado (Site 4)
- Roaring Fork River at Mill Street Bridge (Site 5)
- Hunter Creek near Aspen, Colorado (Site 6)

These sites are shown in Figure 4.1.14, along with locations and information about water and wastewater treatment facilities. For each site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

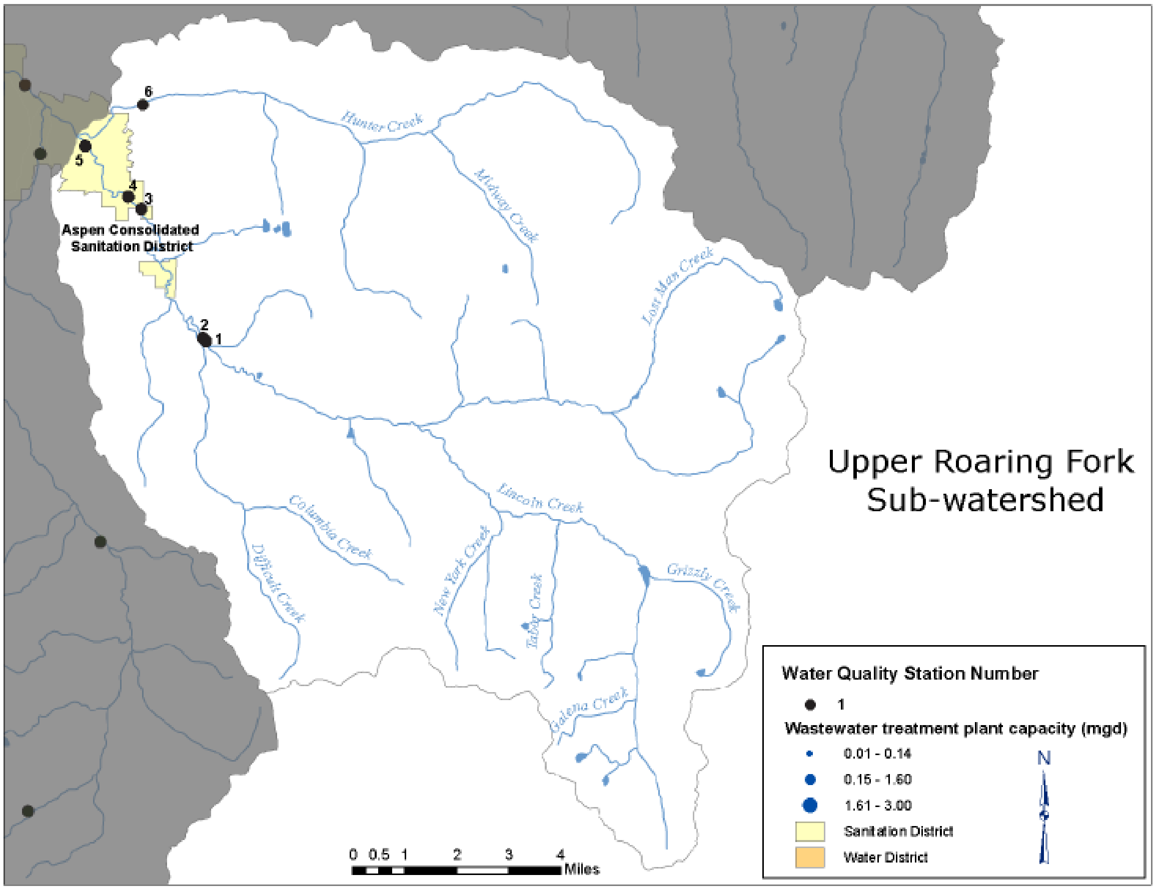


Figure 4.1.13. Water-quality sites and wastewater treatment providers in the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and CDOLA, No date b.

Currently through the Colorado River Watch Program, water quality data are being collected at sites 1 and 5 every other month. Previous water quality studies indicate that water quality conditions in the sub-watershed are generally good (Britton, 1979; NWCCOG, 2002; Roaring Fork Conservancy, 2006a). The following summary of recent water quality results supports this finding, although it should be noted that no recent data were available upstream from Site 1, leaving much of the upper part of the sub-watershed without recent water-quality data.

Field parameters were collected at all six sites during water-quality sampling. Two of the 69 pH results exceeded water-quality standards (exceedances occurred in October 1996 at sites 3 and 4). Water temperature was within water-quality standards. Specific conductance generally was low and indicated dilute, snowmelt-dominated source water, which would be expected in the mountainous headwaters like the Roaring Fork watershed (Hem, 1985). Dissolved oxygen concentrations indicated well-oxygenated conditions typical of high-gradient headwater streams.

Major ions indicate a predominately calcium bi-carbonate water type (Appendix 3.2.2), which is generally consistent with the overall geology in the sub-watershed (Apodaca et al., 1996). Chloride concentrations ranged from <0.1 mg/L to 7.31 mg/L and sulfate concentrations ranged from 0.8 mg/L to 21.9 mg/L. Total dissolved solids concentrations at these sites were low (19-74 mg/L) and are indicative of snowmelt-source water. Total dissolved solids concentrations were comparable to conditions found in previous studies (NWCCOG, 2002) and have similar concentrations to that of precipitation (10-40 mg/L) (Hem, 1985). Median hardness concentrations indicated soft water with low buffering capacity.

Nutrient data were not sufficient to provide detailed characterization of seasonal or spatial trends. Sites 2, 3, and 4 had recent nutrient concentration data. Available nutrient constituents include: ammonia, nitrate, nitrite, total nitrogen, total phosphorus, orthophosphorus, and un-ionized ammonia. There were no exceedances of ammonia or nitrate standards. There was one nitrite water quality standard exceedance (0.052 mg/L at Site 4) in 1998, although there were only two nitrite samples for this site. One of 83 total phosphorus samples collected had a concentration (0.37 mg/L at Site 3 in August, 1998) greater than the 0.1 mg/L recommended concentration (established by the U.S. Environmental Protection Agency) although there has only been one additional total phosphorus sample since that time, collected in February, 1999.

Trace elements were rarely detected in the sub-watershed, and few concentrations exceeded water quality standards. Because table value standards (TVS) for trace elements are based on hardness concentrations, the low hardness concentrations in the sub-watershed result in low TVS for trace elements in this area as compared to streams with higher hardness concentrations. Of 155 cadmium-concentration results, a single exceedance (2.8 µg/L) occurred at Site 4 (Roaring Fork River near Aspen). This cadmium concentration exceeded the chronic, acute, and acute trout TVS in April 1997. Out of 154 copper concentration results, a single concentration exceeded the chronic TVS in April, 2002. Only one of the 96 total recoverable aluminum concentrations had a concentration greater than 750 µg/L (941 µg/L), occurring at Site 5 (Roaring Fork River at Mill St. Bridge) in April 2003. Lead and zinc each had concentrations that exceeded the chronic TVS. Two lead concentrations exceeded the chronic TVS, one exceedance occurred at Site 5 in September 2002 and the other at Site 1 in April 2002. A single zinc concentration exceeded the chronic TVS at Site 1 in September 2002. Selenium was detected in 25 of 140 results. Two concentrations (6.2 µg/L and 6.1 µg/L) exceeded the chronic selenium water-quality standard (4.6 µg/L) at Site 5, once in January and once in July of 2004.

There were insufficient microorganism data for detailed characterization, with most of the data being collected at Site 2 (Roaring Fork River above Difficult Creek). One *E. coli* concentration exceeded the 126 CFU/100 mL standard in April 2001 (180 CFU/100 mL). Total suspended solid (TSS) and suspended sediment data also were inadequate for analysis purposes. One site (Site 3) had 15 TSS samples with concentrations ranging from <10 mg/L to 20 mg/L, with a median value of <10 mg/L.

Riparian and Instream Areas

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed the Roaring Fork River and Lost Man Creek in this sub-watershed. Figure 4.1.14 shows specific riparian and instream information, by habitat quality category, for each reach assessed. The habitat quality categories are shown in the riparian and instream assessment charts in Section 3.3 and Section

3.4. Appendix 3.3.1 contains the actual percentage values for each of these categories by sub-watershed and how they were determined. The sub-watershed has one stream segment: Roaring Fork River from just below the Highway 82 cut to the confluence with Hunter Creek (SHI reaches RF1-1 through RF3-15), and Lost Man Creek from the confluence with Jack Creek to the Roaring Fork River (reaches LM1-1 to LM1-2), 22.52 miles.

What follows is a brief description of results. The SHI report contains detailed narrative description. “Right bank” and “left bank” refer to the orientation of the riparian zone when facing downstream.

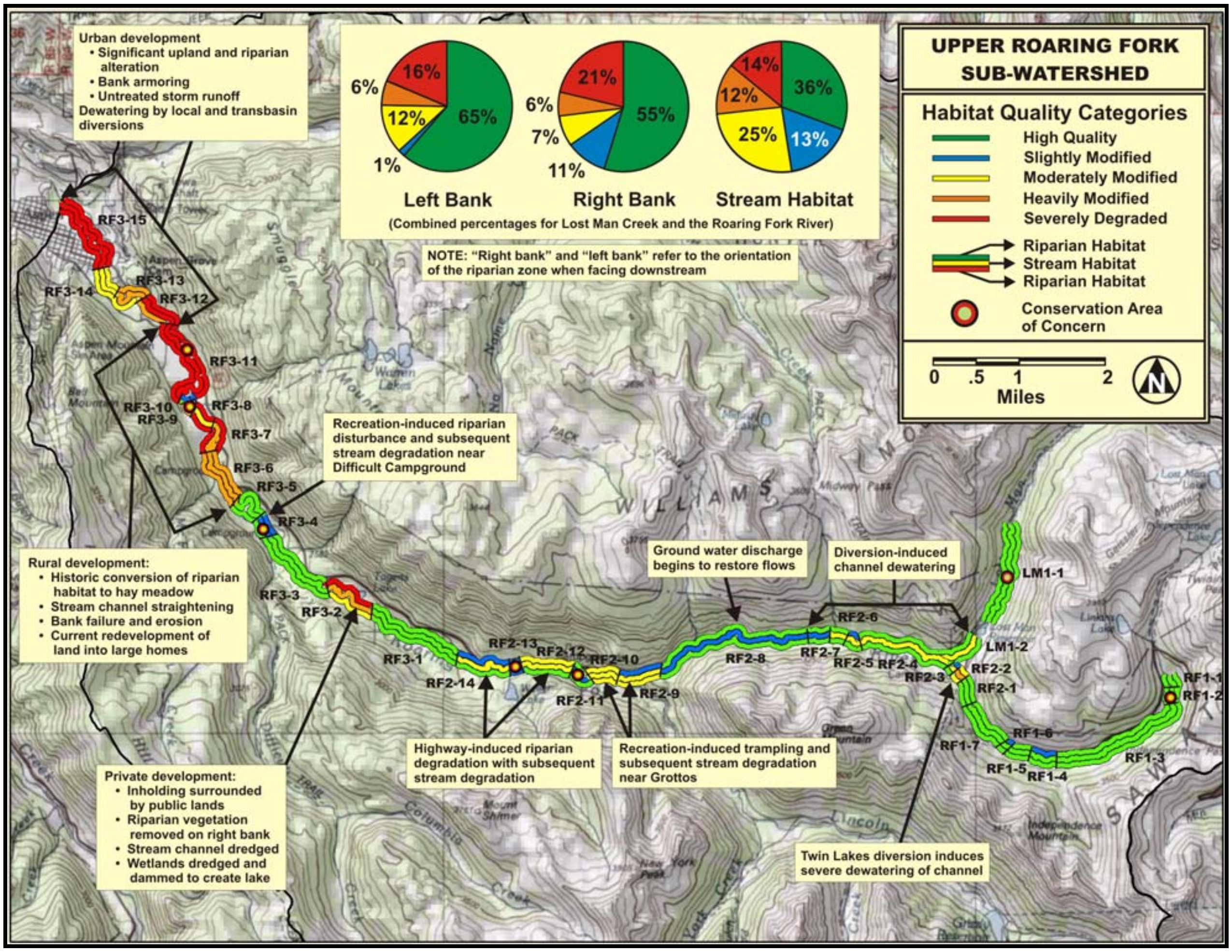


Figure 4.1.14. Riparian and instream habitat quality in the Upper Roaring Fork Sub-watershed.

Uplands

Upland habitat from RF1-1 through RF 3-11 and LM1-1 to LM1-2 is mostly in excellent condition and contributes positively to stream flow and water quality (Figure 4.1.15). Exceptions include those areas impacted by Highway 82 roadcuts, mining roads and un-reclaimed mine sites, recreational trails, residential development, and the Aspen Mountain Ski Area. Roadcuts have resulted in fragmented upland and riparian habitat, and eroding slopes that impact streams through introduction of sediment and pollutants. Mine sites on steep surrounding slopes continue to impact headwater streams with excess sediment and an altered infiltration/runoff regime. Recreational trails that traverse fragile alpine riparian and wetland ecosystems, such as the Lost Man Loop Trail, have resulted in vegetation damage and loss, soil degradation, and wildlife disturbance. Residential development on south-facing slopes has caused loss of critical winter habitat for wildlife, and ski area-induced deforestation has brought loss of breeding and foraging habitat. These activities also have altered plant communities, promoted weed invasion and soil erosion through soil disturbance, and have altered runoff patterns through increased presence of impermeable surfaces. Upland habitat from RF3-12 to RF3-15, in the vicinity of Aspen, has been altered by historic and recent development including mining, residential and commercial development, ski area development, and road building – all have significantly increased impervious surfaces such as roads, parking lots, and roof tops. Consequently, precipitation runoff has increased and infiltration has decreased, leading to hydrologic alteration and increased delivery of chemical pollutants, sediment, and nutrients to receiving streams.

Figure 4.1.15. Upland habitat adjacent to RF3-1 contributes to stream flows, water quality, and wildlife values.

Riparian Habitat and Wildlife

Overall the riparian habitat quality in this sub-watershed is high. On the left bank 65 percent of riparian habitat is high quality, 1 percent slightly modified, 12 percent moderately modified, 6 percent heavily modified, and 16 percent severely degraded. On the right bank 55 percent of riparian habitat is high quality, 11 percent slightly modified, 7 percent moderately modified, 6 percent heavily modified, and 21 percent severely degraded.

Throughout the sub-watershed, a variety of activities have altered riparian zone width and vegetation quality. Types and extent of habitat-altering impacts vary from headwater reaches where land is mostly publicly owned to downstream reaches where land is mostly in private ownership. Table 4.1.4 summarizes the types and extent of impacts to riparian and instream habitat. Riparian habitat in the upper reaches downstream to RF3-5 is generally in good condition. Threats to riparian ecosystem sustainability and function come primarily from road and recreation-induced habitat alteration (Figure 4.1.16), dewatering (Figure 4.1.17), and, where private residential development occurs, from habitat loss. From RF3-6 through RF3-11, historic agricultural and recent rural development has resulted in the conversion of riparian habitat to hay meadows and non-native grass lawns over much of the segment (Figure 4.1.18). Over much of the area from RF3-12 through RF3-15, urban development has replaced native riparian and streambank habitat with lawns and riprapped banks (Figure 4.1.19). In general, riparian habitat in headwater reaches is of high quality, becoming progressively more modified and degraded in the downstream direction.

Table 4.1.4. Summary of land development impacts and threats to riparian and instream habitat in the Upper Roaring Fork Sub-watershed's surveyed reach.

UPPER ROARING FORK SUB-WATERSHED	TRAILS AND RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	WEEDS COMMON-ABUNDANT (5-10%) RIGHT BANK
Total Stream Miles: 22.52	28%	13%	26%	37%	23%	23%

Figure 4.1.16. Trampling of vegetation as a result of recreation activities at the Lincoln Creek Campground (RF2-9) has eliminated herbaceous vegetation and resulted in bank erosion.

Figure 4.1.17. When flows are diverted, dewatering affects stream flows and riparian habitat well below the Twin Lakes diversion tunnel.

Figure 4.1.18. Historic agricultural development in reach RF3-11 resulted in severe down-cutting and changes to riparian plant communities.

Figure 4.1.19. In this location, riparian vegetation has been removed and replaced with a lawn. Resulting erosion has necessitated bank riprapping.

Along stream reach RF3-10, the James H. Smith open space property (Figure 4.1.20), riparian habitat is sustainable because there is a sufficiently wide riparian zone with dense cover, complex habitat structure, and diverse composition of native riparian plant species with a good distribution of all age classes of trees and shrubs. High quality riparian habitat in this reach has diminished the negative impacts of hydrologic alteration by maintaining a stable channel that is not downcut, enabling spring flooding flows to overbank and replenish groundwater.

Figure 4.1.20. Riparian vegetation at the James H. Smith open space property (RF3-10) stabilizes the stream channel and provides high quality riparian habitat.

Riparian wildlife potential corresponds to habitat quality and level of disturbance. In general, wildlife potential is high in headwater reaches and decreases downstream commensurate with habitat alteration and increasing levels of human disturbance. Wildlife potential is optimal in 56 percent of the riparian area, suboptimal in 19 percent, marginal in 19 percent, and poor in 5 percent. Reaches with optimal potential correspond to high quality riparian habitat with complex structure and vigorous native riparian vegetation. Examples include reaches RF1-1 through RF2-1, LM1-1, RF3-1, 3-3, 3-5, and 3-10. Wildlife potential is reduced in reaches RF1-4, RF2-9 and 2-10, and RF3-2 and 3-4 due to trails, campgrounds, and roadcuts that have introduced a variety of disturbances and limit the availability or quality of wildlife resources. Historic conversion of native habitat to pastures has simplified habitat and degraded breeding and foraging resources, thus reducing wildlife potential in reaches RF3- 7, 3-8, 3-9, and 3-11. Residential development has altered native habitat so that the majority of wildlife values have been lost in reach RF3-2, and reaches 3-12 through 3-15. Throughout the majority of this sub-watershed, Highway 82 is a lethal barrier to daily and seasonal wildlife migration. During summer the road affects daily wildlife migration between upland and riparian habitats, and in the fall and spring it affects seasonal migration between summer and winter habitats.

Several studies have assessed biodiversity in the sub-watershed including: the Roaring Fork Biological Inventory conducted by the Colorado Natural Heritage Program (CNHP) (Spackman et al., 1999); the SHI (Malone and Emerick, 2007a); the Elk Mountain Biological Survey (PanJabi, 1995); a hydrologic study by the Colorado School of Mines that included vegetation, bird, and small mammal surveys (Hickey et al., 2000); and Pitkin County management plans for the North Star and James H. Smith open space properties, which include wildlife and vegetation surveys that confirm the wildlife diversity and values of the areas (http://www.aspenpitkin.com/depts/21).

CNHP has identified the majority of the Roaring Fork River in this sub-watershed, from the headwaters through North Star Nature Preserve in reach RF3-11, as a Potential Conservation Area (PCA) (Figure 3.3.2 and Appendix 3.3.2). The Upper Roaring Fork PCA received a rank of "B2," indicating very high biodiversity significance. CNHP justified the ranking because of the occurrence of numerous globally or state rare and vulnerable plant species and communities, and mammal, fish, amphibian, and bird species. CNHP also assigned this segment a Protection Urgency Rank of P3 because of the presence of a definable threat to biodiversity, and a Management Urgency Rank of M2, indicating that new management action is needed within five years to prevent the loss of biodiversity. Specifically, CNHP cited recreational pressure and exotic plants as biodiversity threats and recommended recreational restrictions and exotic plant eradication programs.

CNHP identified five other riparian/instream PCAs in this sub-watershed: Lost Man Creek, New York Creek, and The Grottos PCAs have high biodiversity significance, and Hunter Creek and Grizzly Creek PCAs have moderate biodiversity significance (Figure 3.3.2 and Appendix 3.3.2).

The Elk Mountain Biological Survey (PanJabi, 1995) conducted breeding bird surveys of the upper Roaring Fork and Lincoln and Castle Creek drainages. PanJabi found the highest bird diversity on Castle and Lincoln creeks and the lowest on the Roaring Fork River. Reduced biodiversity on the Roaring Fork survey sites was attributed to reduced habitat diversity and habitat degradation stemming from the highway's road cut. On Lincoln Creek, several rare and sensitive bird species were documented in addition to numerous migrant bird species. The presence of migrant species such as Swainson's hawk suggested the potential importance of the Roaring Fork corridor as a migratory route with critical stopover habitats. The SHI identified seven Conservation Areas of Concern (CAC) in this segment along the Roaring Fork River and on Lost Man Creek. Table 4.1.5 summarizes wildlife values and threats to these areas.

Table 4.1.5. SHI Conservation Areas of Concern in the Upper Roaring Fork Sub-watershed.

LOCATION	JUSTIFICATION
LM1-1	High quality willow carr wetlands support abundant wildlife. Disturbance and trampling of vegetation by recreationists and pack horses threatens sustainability by causing vegetation damage, trail erosion, and weed invasion.
RF1-2	High quality willow carr wetlands support abundant wildlife. Sediment from roadcuts is harming vegetation and resulting in stream sedimentation.
RF2-11	Riparian and upland habitat is sustainable and provides high quality wildlife values. Threats come from social trails and disturbance from recreationists using the Grotto's day-use area, including trampling of vegetation and damage to beaver dams.
RF2-13	Wildlife potential is high but is greatly reduced by high levels of human disturbance associated with the Weller Lake Trail. Social trails, disturbance to vegetation, and streambank destabilization diminish wildlife values and stream habitat.
RF3-4	Riparian cottonwood-spruce forest provides high wildlife potential but campground-related impacts degrade wildlife value. Social trails cause impacts including trampling of vegetation, and introduction of noxious weeds.
RF3-9 (Aspen Valley Land Trust)	A diverse mosaic of riparian habitats characterizes this reach and provides high wildlife potential. Because the property is managed for wildlife, human disturbance is minimal, thus providing undisturbed environment needed for sensitive species. Additionally stream, riparian, and upland habitat are intact and unfragmented, thus provide wildlife with a protected migratory corridor. Threats to habitat sustainability come from severe downcutting and ensuing hydrologic alteration.
RF3-11 (North Star Nature Preserve)	A diverse mosaic of plant communities with an uninterrupted connection between upland slopes provides high wildlife potential. Threats come from severe, historic channelization with consequent downcutting, hydrologic alteration, and degradation of riparian plant communities.

Although historic and recent development activities have generally reduced wildlife potential below stream reach RF3-5, the North Star and adjacent James H. Smith open space properties (RF3-11 and 3-10) continue to provide essential breeding, foraging, migratory, and winter habitat for a large diversity of native wildlife (Figure 4.1.21). Because of the area's importance to breeding and migratory birds, North Star has been designated as an Important Bird Area by Audubon Colorado (http://www.auduboncolorado.org/birdcon_iba.html). Designation was based on breeding bird surveys conducted from 1997-1999 that documented as many as 691 individuals per breeding season across 63 species (Hickey et al., 2000). The diversity of plant communities, relative solitude, and lack of human presence are primary reasons for the area's high wildlife value. Vegetation surveys at North Star identified 10 plant community types, including coniferous forest, riparian shrublands, wet meadows, and open water (Hickey et al., 2000). Currently, habitat on the west side of the river is managed for wildlife and prohibits recreational use, while limited recreation is permitted on the east side. The SHI also conducted vegetation and breeding bird surveys in this area. Surveys documented several vulnerable bird species including willow and olive-sided flycatcher.

Figure 4.1.21. Backwaters and side channels at the North Star and adjacent James H. Smith open space properties provide high value wildlife habitat.

Instream Habitat and Wildlife

In this sub-watershed, stream morphology and type vary in the landscape, and rapids alternate with slow-flowing streams. Where streams drain steep valley walls the channel is characterized by a high gradient Type A stream with plunge pools and steep riffles. Where the valley gradient decreases to a moderate slope, stream type changes accordingly to Type B. On valley floors where the floodplain widens and valley gradient decreases further, the stream channel becomes more sinuous with a wide variety of pool, riffle, and run habitat and is characterized as either Type C or E. Channel stability in both of these stream types is sensitive to disturbance and upstream watershed conditions, and is dependent on bank stability (Rosgen and Silvey, 1996). Please refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of these different types of streams.

Instream habitat quality has been altered by historic and recent development including mining-related activities; installation and operation of a dam and other water diversion structures; the Highway 82 roadcut; degradation of riparian and streambank vegetation related to trails, campgrounds, and residential development; and agricultural development that has included channel straightening, drainage of wetlands, irrigation diversions, and conversion of native habitat to hay meadows (Figure 4.1.22). Consequently, instream habitat quality, as measured by the ability of the stream to sustain aquatic wildlife, has diminished over much of the sub-watershed: 36 percent of stream habitat is high quality, 13 percent is slightly modified, 25 percent moderately modified, 12 percent heavily modified, and 14 percent severely degraded.

Figure 4.1.22. Removal of native vegetation and bank riprapping has degraded riparian and stream habitat. Fish habitat has consequently been degraded.

Aquatic wildlife potential varies with riparian and stream habitat quality and stream flows. In headwater reaches, above the IPTDS and above Lost Man Reservoir, aquatic wildlife potential is high. Below this diversion and dam, aquatic wildlife is limited by dewatering, bank instability, sedimentation, reduced instream habitat diversity, and a reduction in overhanging and bank vegetation. See Figure 4.1.23 for photos of stream conditions above and below the dam. Diversions cause dramatically reduced flows as well as fluctuating flows. Subsequent impacts include decreased habitat diversity and abundance, increased water temperatures, and isolated, disconnected pools of water. In reaches RF2-3 through 2-7 (below the IPTDS), when flows were being diverted, American dippers were rarely observed due to lack of aquatic habitat and macroinvertebrates. Fish kills have been frequently observed in the small isolated pools that are all that remain of the river in the fall and winter. In diverted streams, flow alteration has reduced the potential for self-sustaining fish populations. Although high quality aquatic habitat is present in headwater reaches of the Roaring Fork River and in some tributaries, diminished flows fragment the aquatic ecosystem and hinder fish migration, thereby inhibiting genetic exchange.

Figure 4.1.23. Upper photo: Lost Man Creek above the dam. Lower photo: Lost Man Creek below the dam. Very little water is left in the stream to maintain the channel or flush sediment from the stream.

The mainstem Roaring Fork River and most tributaries are dominated by non-native, naturally reproducing brook trout, brown trout, and hatchery-stocked rainbow trout. Five streams in the sub-watershed contain native Colorado River cutthroat trout (CRCT) (Figure 3.4.6). Some potential exists in the Upper Roaring Fork River Sub-watershed for reclamation and/or expansion of stream miles of existing populations of CRCT. Historically, CRCT were the only native trout in the Rocky Mountains (including in the Roaring Fork Watershed). Many of the alpine lakes historically did not have fish, but were stocked with brook, rainbow, and cutthroat trout many years ago for recreational fisheries, a practice that altered the food web. In recent years, CDOW has been primarily stocking CRCT into these lakes for anglers. Most of the lakes are stocked every other year with fingerling trout given the lack of natural reproduction in these lakes. Section 3.4 contains additional information about the Roaring Fork Watershed's aquatic species.

Although transmountain diversions that have been in existence since the 1930s pose a major challenge for aquatic species in this sub-watershed, some instream restoration work using large unanchored wood has been done in Lincoln Creek downstream of Grizzly Reservoir (Mark Lacy, USFS Fish Biologist, personal communication, March 17, 2008) (Figure 4.1.24). Beavers are beginning to do some dam building in Lincoln Creek, which will also help maintain complex diverse aquatic habitats. A good example of the dynamic relationships between beaver, wood, and aquatic habitats is found in the upper Roaring Fork River above the old Independence townsite. This site can serve as a reference for restoration activities that can be replicated in appropriate reaches within this sub-watershed and other reaches throughout the entire watershed.

Figure 4.1.24. Large wood replacement project Lincoln Creek, 2004. Upper photo: Before large wood was placed. Lower photo: Wood being placed in stream. Photo credits: Mark Lacy.

Boreal toads have been documented in several locations in this sub-watershed and there is one known breeding population (Figure 3.4.5) (Mark Lacy, USFS Fish Biologist, personal communication, March 17, 2008). Additional surveys need to be conducted to find additional breeding populations/sites within the sub-watershed. Boreal toad populations have been impacted primarily by chytridiomycosis, a disease that has decimated boreal toad populations in the Rocky Mountains and amphibian populations worldwide (Muth et al., 2008). One boreal toad breeding pond restoration project was completed in 2007 by the USFS, CDOW, and Twin Lakes Reservoir and Canal Company (Figure 4.1.25). Additional possibilities exist for other restoration projects to expand the population to habitats where toads once occurred. Chorus frogs and tiger salamanders are the two other amphibian species occurring in the sub-watershed and their populations appear to be stable (Mark Lacy, USFS Fish Biologist, personal communication, March 17, 2008).

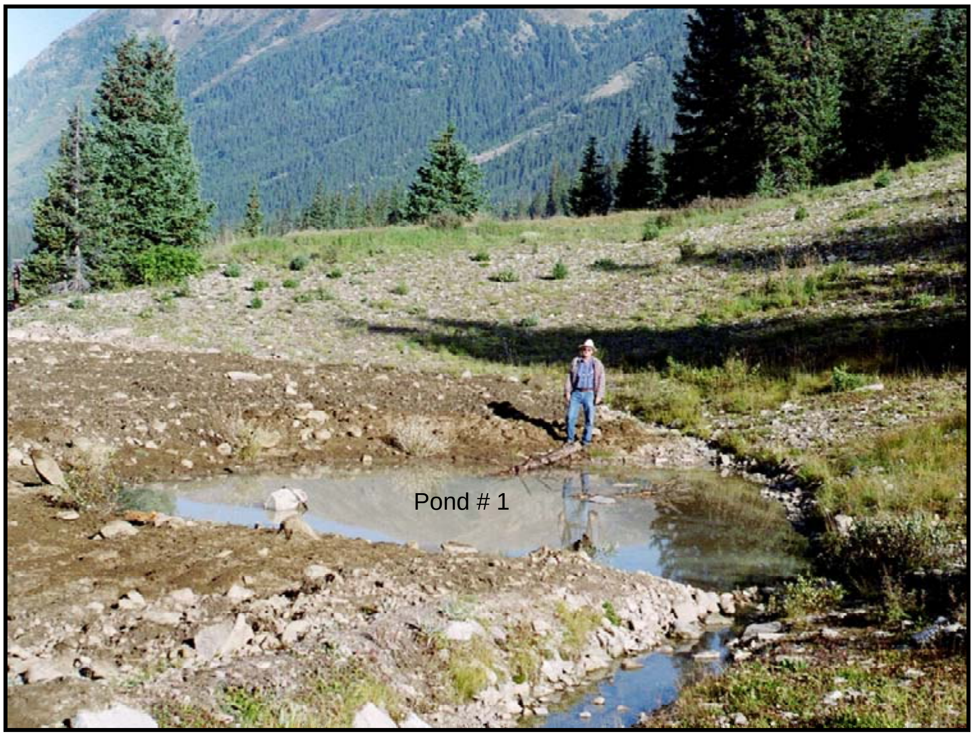


Figure 4.1.25. Boreal toad breeding pond construction in Lincoln Creek, September 2007. Photo credit Mark Lacy.

Although groundwater discharge replenishes the channel a few miles below the IPTDS diversion, several other diversions farther downstream dewater the channel, resulting in unsustainable flows during late summer and times of drought. Channelizing activities have simplified channel structure and decreased sinuosity, thereby reducing the variety and abundance of pools and riffles that provide critical fish habitat. Vegetation degradation has destabilized overhanging banks that provide cover for aquatic organisms, and has also reduced canopy shade.

Macroinvertebrate species provide the prey base for aquatic species and thus serve as an excellent indicator of stream health. In 2005, the USFS (Brian Healy, USFS Fish Biologist, personal communication, June 5, 2006) sampled macroinvertebrates at sites above and below the diversion structure for Twin Lakes Tunnel Number 2 on the Roaring Fork River, shown in Figure 4.1.26. According to Ward et al. (2002) in "An Illustrated Guide to the Mountain Stream Insects of Colorado," Plecoptera (stoneflies) are often severely reduced immediately below dams, whereas dipterans (especially true midges) increase in relative abundance. The USFS data followed this pattern, showing a decrease in the number of stoneflies and an increase in the percentage of true midges below the diversion. As shown below in Table 4.1.6, the percent EPT (see Section 3.4 for explanation of this biological indicator) decreased from above the diversion to below the diversion and the number of intolerant taxa decreased. As also highlighted in the table, the Benthic Condition Index, an index of sedimentation, was higher below the diversion (a higher score indicates more impaired stream conditions).

Figure 4.1.26. The Roaring Fork River directly above (upper photo) and below (lower photo) the IPTDS Tunnel Number 2 diversion.

Table 4.1.6. Comparison of 2005 USFS macroinvertebrate data from above and below IPTDS Tunnel Number 2 diversion, on the Roaring Fork River (Source: Brian Healy, USFS Fish Biologist, personal communication, June 5, 2006).

	NUMBER OF STONEFLIES	PERCENT OF TRUE MIDGES	PERCENT EPT TAXA	NUMBER OF INTOLERANT TAXA	BENTHIC CONDITION INDEX
Above Transmountain Diversion	8	19%	72%	21	4.5
Below Transmountain Diversion	5	39%	31%	19	7.9

4.1.4 Important Issues

Below is a summary of key findings from available scientific information, a listing of data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the sub-watershed's water resources

Key Findings

- The Independence Pass Transbasin Diversion System (IPTDS) affects all of the major headwater streams within the sub-watershed except Difficult Creek. The upper Roaring Fork River's hydrologic regime – including flow magnitude, duration, and inter-annual variation – has been dramatically changed, with an average of 37 percent of the sub-watershed's yield diverted to the East Slope annually.
- The cumulative impact of the Fryingpan-Arkansas Project and inbasin diversions on Hunter Creek results in lower flows in May, June, and July. However, bypass requirements for the Project and Colorado Water Conservation Board instream flow rights lessen flow alteration in this basin.
- The CWCB's instream flow rights on Lincoln Creek, the upper Roaring Fork River, and Hunter Creek, often are not met, depending on the season, because they are junior to the Twin Lakes Reservoir and Canal Company's water rights and/or those of local inbasin water diversions.
- Shallow subsurface flow is one of the most significant components of runoff in the sub-watershed, and is an important part of North Star's hydrologic system.
- There are seven direct-flow conditional water rights greater than 10 cubic feet per second in this sub-watershed.
- In the sub-watershed, Hunter Creek and the Roaring Fork River had sufficient water quality data to provide a summary of water quality conditions. Compared with current state and national water quality standards and previous studies, these streams have good water quality, suitable for all uses.
- More than 25 percent of the surveyed section within the sub-watershed is impacted by trails and development, and on 23 percent weeds are common to abundant.
- Across the areas surveyed, there is high quality riparian habitat along 55 percent of the right bank and 65 percent of the left bank. Riparian wildlife potential is rated as optimal

in 56 percent of the riparian area, suboptimal in 19 percent, marginal in 19 percent, and poor in 5 percent.

- In general, wildlife potential in riparian areas is high in headwater reaches and decreases in the downstream direction with increased habitat alteration and levels of human activity.
- Several Colorado Natural Heritage Program (CNHP) elements, species designated sensitive by the U.S. Forest Service, and Audubon watch-listed bird species are also frequently found in stream reaches in the upper sub-watershed, including great blue heron, white-tailed ptarmigan, Northern pygmy owl, Northern goshawk, rufous hummingbird, Williamson's sapsucker, three-toed woodpecker, and brown-capped rosy finch. Also listed are the olive-sided, cordilleran and willow flycatcher and Virginia's, orange-crowned, Wilson's, and MacGillivray's warbler.
- CNHP has identified the Roaring Fork River Corridor from the headwaters through North Star Nature Preserve as a Potential Conservation Area (PCA). The area is considered by CNHP to have very high biodiversity significance and therefore carries a high ranking for urgency of protection. The Stream Health Initiative (SHI) identified seven Conservation Areas of Concern (CAC) in this segment along the Roaring Fork River and on Lost Man Creek. CNHP identified five other riparian/instream PCAs in this sub-watershed: Lost Man Creek, New York Creek, and The Grottos PCAs have high biodiversity significance, and Hunter Creek and Grizzly Creek PCAs have moderate biodiversity significance.
- For those areas surveyed, instream habitat quality, as measured by the ability of the stream to sustain aquatic wildlife, has diminished over much of the sub-watershed: 36 percent of instream habitat is high quality, 13 percent slightly modified, 25 percent moderately modified, 12 percent heavily modified, and 14 percent severely degraded.
- Riparian and instream data are not available for all headwater streams that are part of the IPTDS; however, two stream reaches surveyed by the SHI are directly affected by the IPTDS, with moderate modification of instream habitat resulting from dewatering. These reaches include several miles of the Roaring Fork River below the IPTDS dam and Lost Man Creek below the Lost Man Reservoir dam.
- The North Star Nature Preserve area provides essential breeding habitat for a large diversity of native wildlife (including birds, leading to its classification by Audubon as an Important Bird Area), an important groundwater hydrologic system, and a popular location for outdoor recreation activities.
- The James H. Smith open space property (reach RF3-10) provides an important example of historic channel conditions with optimal sinuosity, intact native riparian vegetation, stable stream banks, and resulting healthy riparian and aquatic habitat. This reach provides an important contrast to the rest of the lower part of the sub-watershed, which generally has been degraded through development activities.
- Boreal toads have been documented in several locations in this sub-watershed, with one known breeding population.
- Five streams in the sub-watershed contain native Colorado River cutthroat trout (CRCT). There is some potential in the sub-watershed for reclamation and/or expansion of stream miles of existing populations of CRCT.

Data Gaps

There are a number of gaps in information for the sub-watershed that limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Modeled pre-developed and developed stream flow data on the Roaring Fork River directly below IPTDS Tunnel Number 2 and the Salvation Ditch;
- Accurate gage data for the Roaring Fork above Lost Man stream gage;
- Groundwater quantity data and in-depth subsurface geology information;
- Water-quality monitoring of groundwater and lakes/reservoirs;
- Recent monitoring /water-quality data that is sufficient to adequately characterize water-quality conditions on Hunter, Lincoln, No Name, Midway, Lost Man, and Difficult creeks;
- Water-quality data for the following constituent groups:
  - Microorganisms (collected to establish potential for water-born disease)
  - Suspended sediments (to evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals)
  - Emerging contaminants (establish a baseline to better understand occurrences in the rest of the watershed);
- Riparian and instream habitat survey data for Hunter, Lincoln, and Difficult creeks;
- Breeding bird data for Hunter, Lincoln, and Difficult creeks; and
- Information about upland and riparian mammal community diversity, amphibian and reptile populations, and population sustainability.

Relevant Local Initiatives, Plans, and Studies

- One of the goals of the East of Aspen/Independence Pass Caucus Master Plan is to "maintain and enhance the quality of wildlife habitat within the East of Aspen/Independence Pass planning area." The Caucus is also interested in working with the U.S. Forest Service to address issues with Warren Lakes and Warren Creek.
- Grand River Consulting Corp. (2007) worked with several interest groups to identify four specific stream flow objectives:
  - meet flow recommendations for the Roaring Fork River above Difficult Creek as established in the Fryingpan-Arkansas Project Operating Principles,
  - maintain the Colorado Water Conservation Board instream flow water right through the City of Aspen,
  - support viable aquatic ecosystems below key Twin Lakes Project points of diversion with year-round bypasses, and
  - provide additional flushing flows in the upper Roaring Fork Sub-watershed.

The following three alternatives were concluded to be potentially viable source of water to satisfy a portion of the identified demands:

  - use of water controlled by the Colorado River Water Conservation District in Grizzly and Twin Lakes reservoirs;

  - reduce Fryingpan-Arkansas Project stream flow bypasses for the Thomasville Gage; and
  - acquisition of Arkansas River Basin water.
- The report "2006 Climate Change and Aspen: An Assessment of Impacts and Potential Responses" by the Aspen Global Change Institute assessed the impacts of climate change for the Aspen area. The report covers potential climate change impacts to, and vulnerabilities of, the area's climate patterns, ecosystems, and socioeconomic conditions.

4.2 Upper Middle Roaring Fork Sub-watershed

4.2.1 Environmental Setting

The Upper Middle Roaring Fork Sub-watershed covers the area from the Roaring Fork River's confluence with Hunter Creek to its confluence with the Fryingpan River. The Roaring Fork River flows through distinct, scenic canyons in this sub-watershed, including along Red Butte, Shale Bluffs, and Snowmass Canyon. Ecoregions range from Foothills and Shrublands to Crystalline Subalpine Forests. The western portion of Aspen, including Buttermilk Ski Area and the airport, is located within this sub-watershed, as is Snowmass Village, Snowmass Ski Area, the southeastern outskirts of Basalt, and the rural enclave of Woody Creek. State Highway 82 receives major use in this sub-watershed as people commute from Basalt and further down valley to Aspen. The highway affects the river corridor through road improvement and maintenance activities. The sub-watershed is subject to water quantity issues, due to transmountain diversion influences in the headwaters and several large agricultural diversions near Basalt. In addition, the urbanized areas of Aspen and Snowmass Village create water-quality issues for the stretch of the Roaring Fork River in this sub-watershed, which is located fairly high in the watershed and thus has less dilution potential than downstream reaches. See Figure 4.1 for an overview map showing the location of this sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions, and the sub-watershed's general physical characteristics are summarized in Table 4.1.

Topography and Geology

The sub-watershed includes the drainages of Woody, Brush, Owl, and Red Canyon creeks. High peaks to the west of Snowmass Village, such as Mount Daly and Capitol Peak, are made of a stable, granite-like rock called granodiorite (Huggins, 2004). The southwest part of the sub-watershed, including the Owl and Brush Creek drainages, is comprised mainly of Mancos Shale with some pockets of glacial drift and sandstone at higher elevations. These shales, which are very susceptible to erosion and slope instability problems, are prevalent in the Brush Creek headwaters above Snowmass Village. According to a report on the critical landslides of Colorado (Rogers, 2005), the Snowmass Village area is listed as a tier three (the least severe priority area) for landslides, slumps, and earthflows affecting ski slopes and potential residential areas. The 1970s and 1980s saw numerous landslide problems. However, there have been no reports of serious new occurrences since 1988. According to the landslide report's year 2002 evaluation, "Local governments, ski area managers, and developers and their consultants are aware of the problems and appear to have been successful in dealing with them in the last 12 years." A large area of granitic rocks is located in the upper Woody Creek drainage, and glacial drift is found in a section along the creek. The rest of the Woody Creek and Little Woody Creek drainages are made up of Pennsylvanian siltstones, shales, limestones, and dolomites and the Maroon Formation. Several small tributaries of the Roaring Fork River in the lower section of this sub-watershed, including Bionaz, Wheatley, Cerise, and Arbaney gulches, and Red Canyon Creek, have their headwaters in the State Bridge Formation. This formation is relatively stable with some drainage problems due to impermeable clay or carbonate cement. Gravels and alluvium are found along the Roaring Fork River in this sub-watershed. Much of this is glacial outwash that is found in terraces that mark various glacial periods. Please refer to Figures 1.3 and 1.4 for maps of the geology and slope of the Roaring Fork Watershed.

Weather/Climate

The Snowmass Water and Sanitation District records temperature and the amount of rain and snow at their water treatment plant in the Brush Creek drainage. General weather/climate information for the watershed can be found in Chapter 1.

Biological Communities

North-facing upland habitat slopes in both the Roaring Fork and Brush Creek drainages are characterized by aspen forests, spruce-fir forests, and moist meadows and slope wetlands. South-facing slopes are covered by a mixture of Gambel oak-serviceberry, sage shrublands, and Douglas fir forests. Aspen occur in moist ravines and pinyon-juniper woodlands are found in the Upper Sonoran Life Zone. Large areas of north-facing slopes have been deforested for ski area and related development. South-facing slopes have long been impacted by domestic livestock grazing and more recently by residential and recreational development.

Highly variable topography has resulted in a complex mosaic of forests, woodlands, shrublands, and meadows with varying associations of plant and animals species. In deeper canyons along the Roaring Fork River, riparian vegetation is characterized by a narrow band of mixed cottonwood-conifer forests and woodlands. On flatter-gradient floodplains, stream meandering has resulted in the development of wider riparian zones with a greater variety of riparian plant communities including narrowleaf cottonwood, mixed cottonwood-blue spruce forests, tall willow and non-willow shrublands, and wet and moist meadows. Riparian habitat at the headwaters of Brush Creek is a mixture of quaking aspen and mixed aspen-conifer riparian forests, tall willow shrublands, and wet and moist meadows. Historic native riparian habitat in lower reaches consisted of wide willow carrs sustained by a broadly meandering stream that frequently overflowed its banks.

Appendix 1.3 lists the riparian-related and instream species and communities of concern in the sub-watershed. Figure 3.3.5 provides a map showing bald eagle wintering range for the watershed, including areas of the Roaring Fork and Woody Creek corridors within this sub-watershed. The bald eagle is designated at the state level as threatened. In terms of fish, the Colorado Division of Wildlife (CDOW) has identified occurrence of the following species: brook, brown, and rainbow trout; and mottled sculpin (Harry Vermillion, CDOW, personal communication, March 3, 2008). There are no populations of Colorado River cutthroat trout in this sub-watershed.

4.2.2 Human Influences

Land Ownership and Use

Figure 4.2.1 shows ownership and protection status for the Upper Middle Roaring Fork Sub-watershed. With the exception of Brush Creek, the headwaters of all of the creeks in the sub-watershed are found in the White River National Forest which is managed by the U.S. Forest Service (USFS). Woody Creek starts in the Hunter Fryingpan Wilderness. Land adjacent to lower Little Woody Creek, most of Brush and Owl creeks, and the Roaring Fork River is mainly in private ownership. Some BLM land is found along the Roaring Fork River as it flows through Snowmass Canyon, and there are several open space parcels (Appendix 4.1).

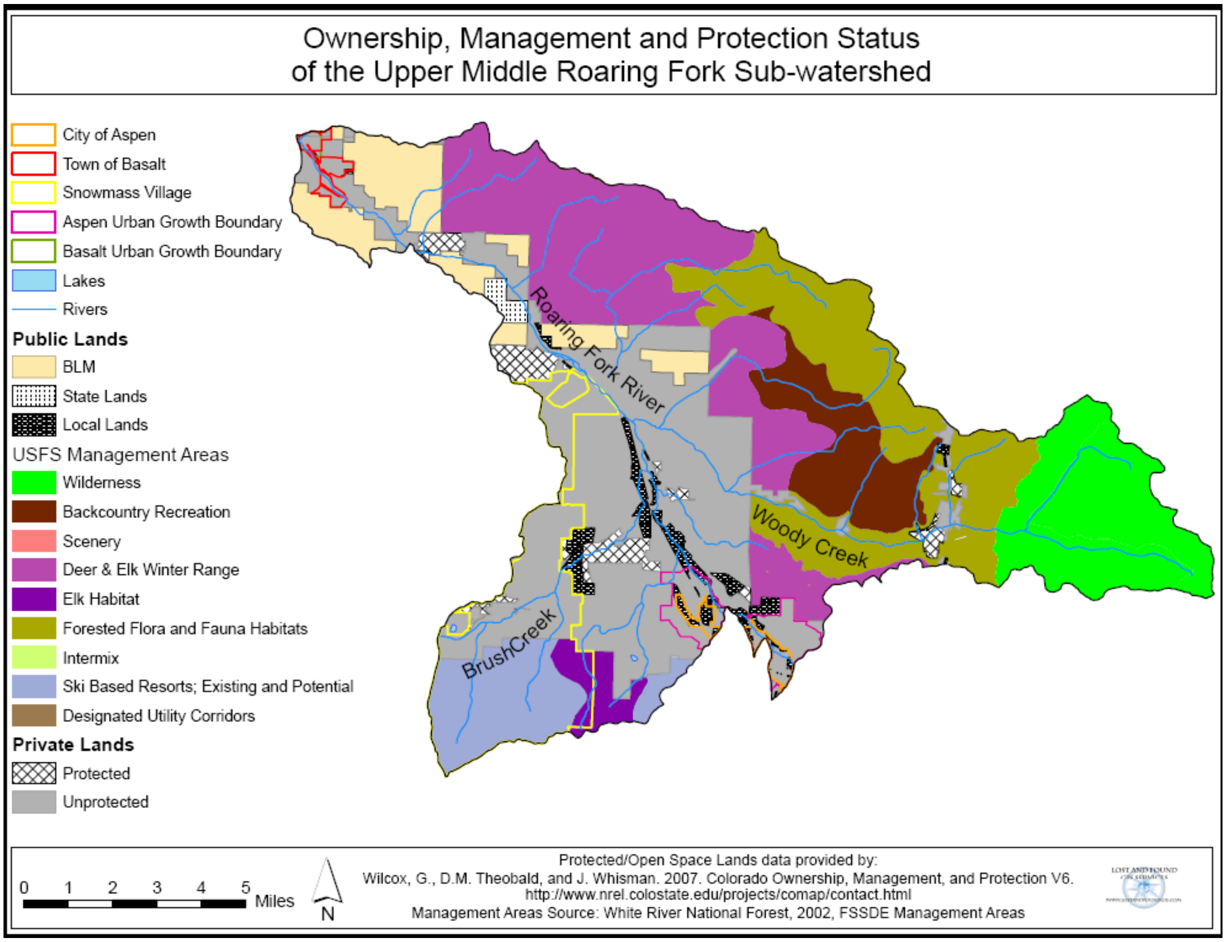


Figure 4.2.1. Ownership and protection status for the Upper Middle Roaring Fork Sub-watershed.

The sub-watershed is located almost entirely in Pitkin County and has two active neighborhood groups: the Woody Creek Caucus (http://www.aspenpitkin.com/depts/77/woody_creek.cfm) and Owl Creek Caucus http://www.aspenpitkin.com/depts/77/owl_creek.cfm). The Woody Creek Caucus Master Plan was submitted in 1991 (http://www.aspenpitkin.com/pdfs/depts/7/woodycreekcaucusmp.pdf). Although the plan is not organized by topics, a few comments point to the importance of stream and riparian areas in the caucus area. The Statement of Consensus includes the following comments: "We, better than anyone else, ... know what a privilege it is to walk by a river where things still work as they should..." and: "We want to preserve and enhance wildlife habitats, open space, trails, parks, and agricultural uses." Several recommendations for parks, open space, and trails concern river access; riparian restoration; and protection of riparian wildlife habitat, through zoning and conservation easements.

The Owl Creek Caucus Master Plan was completed in September, 2003. In the water/sewer and natural environment sections, the plan identifies several issues and concerns relating to existing conditions. These include ensuring that an adequate, reliable water supply be available for new development; that water conservation measures are developed and implemented; that water-quality issues associated with magnesium chloride and gravel use on roads, irrigated agriculture, and individual septic systems are addressed; and that mapping of wetlands and riparian areas is undertaken along with identification of impacts to these areas. Specific objectives and actions for identified issues can be found in Appendix 1.5 and in the Master Plan itself (http://www.aspenpitkin.com/pdfs/depts/7/finalowlcreekplan.pdf).

Figure 4.2.2 shows roads within the sub-watershed and identifies roads within 150 feet of second order and higher streams (approximately 13 percent of the streams). Upstream of Basalt, Highway 82 crosses the Roaring Fork River and parallels the southwest bank of the Roaring Fork River through most of the sub-watershed. On the northeast side of the river Lower River Road, a busy county road, parallels the river from above Woody Creek to Old Snowmass. County roads follow Owl, Woody, and Little Woody creeks, and the county road along Brush Creek is the main access to Snowmass Village and the Snowmass Ski Area. A dirt road parallels Lower Collins Creek.

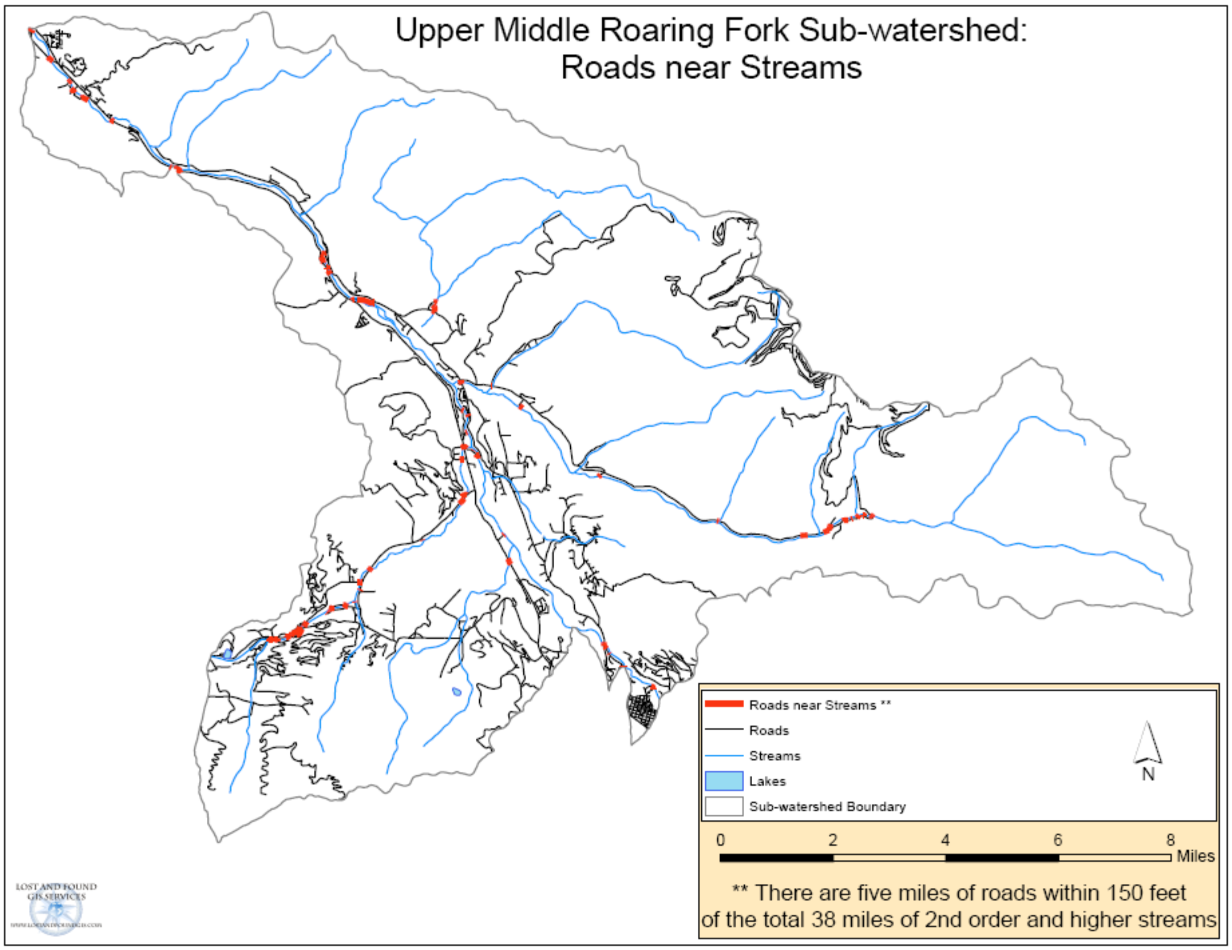


Figure 4.2.2. Roads near streams in the Upper Middle Roaring Fork Sub-watershed.

Some irrigated agriculture is found along parts of Brush, Woody, and Owl creeks and the mainstem of the Roaring Fork River (Figure 1.16). The amount of irrigated agriculture has declined significantly from 1993 to 2000. Zoning and parcel information for unincorporated areas in this sub-watershed can be found on the Pitkin County GIS website at:

(http://www.aspenpitkin.com/depts/46/GISMOdisclaimer_parcels.cfm and http://www.aspenpitkin.com/depts/46/GISMOdisclaimer_zoning.cfm).

The Town of Snowmass Village, the unincorporated area of Lenado, and parts of the Town of Basalt and City of Aspen are located in this sub-watershed. In the Brush Creek drainage, Snowmass Village occupies almost 26 square miles (approximately 20 percent of the sub-watershed). The Town of Snowmass Village (2007) has a Greenway Master Plan with the following five goals:

1. Reconnect the stream to the community.
2. Restore stream stability, function, aquatic habitat, and associated riparian habitat.
3. Establish passive park settings along stream corridors near the population concentrations in the Community and Village study areas.
4. Enhance pedestrian trail connections to the stream.
5. Increase public awareness, education, and stewardship of riparian, aquatic, and animal habitat.

The report describes existing conditions and recommended improvements for each of the four segments of Brush Creek running through Snowmass Village.

The Snowmass Water and Sanitation, Brush Creek Metropolitan, White Horse Springs Water and Sanitation, Starwood Water, and Aspen Consolidated districts are the water suppliers in this sub-watershed. Appendix 3.1.3 provides more information about these water suppliers. Discussion of water supply for Snowmass Village is found in Section 4.6 (the Snowmass/Capitol Creek Sub-watershed) since Snowmass Creek is its primary water source. The Basalt Water Conservancy District (BWCD) serves the unincorporated areas in the lower part of the sub-watershed (Figure 2.1). More information about the BWCD can be found in Chapter 2. In addition to the water and sanitation districts, wastewater treatment plants serving this sub-watershed are: Aspen Village, Woody Creek, and Lazy Glen. More information about these water and sanitation districts and treatment plants can be found in the 2002 Roaring Fork Watershed Plan by Northwest Colorado Council of Governments. Figure 4.2.5 shows the location of water and sanitation districts and wastewater treatment plants in the sub-watershed.

Mining

Table 4.2.1 lists the permitted, active, and inactive mines in the sub-watershed.

Table 4.2.1. Mine sites in the Upper Middle Roaring Fork Sub-watershed. Source: Colorado Division of Reclamation Mining and Safety. No date.

SITE NAME	STREAM	SIZE (ACRES)	COMMODITY	STATUS	PERMIT ISSUED
Fiou Ranch	Roaring Fork River	8	Borrow material	Terminated	4/6/1987
Woody Creek Quarry	Roaring Fork River/Woody Creek	16.5	Sand and gravel	Application withdrawn	n/a
Vagneur Site	Roaring Fork River	105	Sand and gravel	Active	2/17/1981
Elam Gravel Pit	Roaring Fork River	5	Sand and gravel	Application withdrawn	n/a
Lenado Site	Woody Creek	0	Silver	Not mining	n/a
Jaffee Pit	Roaring Fork River	47.5	Sand and gravel	Terminated	6/19/1978

Recreation Activities

There are no campgrounds in this sub-watershed. USFS trails follow Woody, Spruce, and Hannon creeks. The conversion of the Rio Grande railroad grade into a recreational trail has promoted increased use of the river corridor.

Most of the Snowmass ski area and part of Buttermilk ski area are located within this sub-watershed. Table 1.5 provides information on water use for these two ski areas and water use for snowmaking is discussed in Section 4.6 (Snowmass)and Section 4.5 (Buttermilk).

Both the Southwest Paddler (www.southwestpaddler.com) and American Whitewater (http://www.americanwhitewater.org) websites describe boating opportunities within this sub-watershed. The section of the Roaring Fork River from Aspen to the Upper Woody Creek Bridge (Slaughterhouse) is designated Class IV-V. A milder Class III section is found from the Lower Woody Creek Bridge to the Highway 82 Bridge (Toothache). A third run starts at the Aspen Music School on Castle Creek and ends at Slaughterhouse Bridge on the Roaring Fork River. According to the Southwest Paddler: "The prime season for the Upper and Lower Woody Creek run on the Roaring Fork River is May through July, depending upon winter snowpack, spring rainfall, and the amount of water being diverted." A popular commercial rafting stretch on the Roaring Fork extends from Wink Jaffee Park (upstream from Woody Creek) to Wingo. According to the Colorado River Outfitters Association (2007), the number of commercial user days on the upper Roaring Fork River ranged from none in 2002 to a high of 5,074 in 1997 with an average of 2,612 (Figure 1.12). See Figure 1.11 for a map of commercial rafting and kayaking reaches in the Roaring Fork Watershed. A listing of the reaches, with their classes and minimum, maximum, and optimum flow levels, is in Appendix 3.1.6.

According to the "Flyfishing Guide for the Roaring Fork Valley" (Shook, 2005), this section of the Roaring Fork River offers a wide variety of water types including turbulent water with large eddies, some excellent riffles, large pocket water, and classic drops. This diversity of water supports a healthy brown trout fishery and offers high quality angling conditions. The section of the Roaring Fork River from above Aspen (McFarlane Creek) downstream to the Upper Woody

Creek Bridge is designated as a "Wild Trout Water," which signifies that it has self-sustaining populations of trout and is not stocked with hatchery fish. This stretch has catch-and-release fishing regulations.

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams and lakes in the Upper Middle Roaring Fork Sub-watershed have been stocked with species listed (Table 4.2.2).

Table 4.2.2. Species stocked by the CDOW in streams and lakes of the Upper Middle Roaring Fork Sub-watershed.

STREAM/LAKE	SPECIES
Roaring Fork River	Colorado River rainbow trout and rainbow trout (Tasmanian cross)
Bionaz Gulch	Rainbow trout

4.2.3 Resource Information

Several research studies and syntheses of information have been done in the Upper Roaring Fork Sub-watershed, providing data on stream flows, groundwater sources, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in this sub-section. For background information on the data sources, refer to Chapter 3.

Water Quantity

Surface Water

There are two active stream gages in this sub-watershed: the Roaring Fork River above Basalt/Fryingpan and the Roaring Fork River below Maroon Creek. The former gage began operation in 2006 and the latter in 1988. The other two stream gages in the sub-watershed, on Owl Creek and the Roaring Fork River below Aspen, only operated for short time periods (15 and five years, respectively). Specific information about these gages can be found in Figure 4.2.3 and Appendix 3.1.1

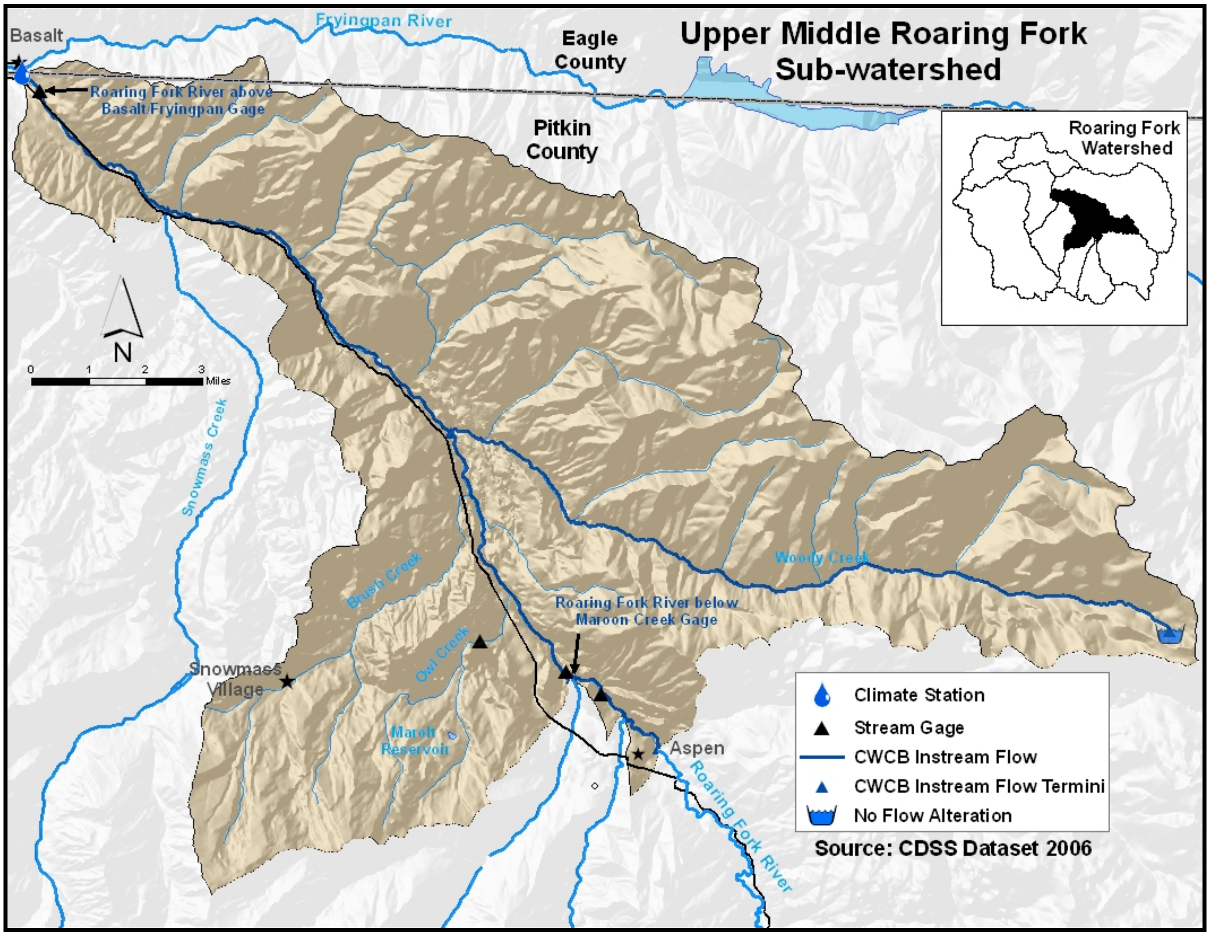


Figure 4.2.3. Water features in the Upper Middle Roaring Fork Sub-watershed.

Flow alteration assessment using the Upper Colorado River Basin Water Resource Planning Model dataset (CWCB and CDWR, 2007a) was very limited in this sub-watershed, with data available only for one node on upper Woody Creek. Because this node is located above most of the diversions, no flow alteration was detected (Figure 4.2.3 has the location of the node, shown with the symbol for "no flow alteration"). Figure 4.2.4 shows the locations of all of the diversions in the sub-watershed, 10 of which have a decreed capacity greater than 10 cfs (Table 4.2.3). According to Bill Blakeslee (CDWR, Division 5, Water Commissioner, personal communication, March 20, 2008), lower Woody Creek has been dried up downstream of the Walthen Ditch for the past six years for 60-90 days starting around July 10th. Two tributaries of Woody Creek are also dried up due to irrigation ditch diversions: Little Woody Creek below the Waco Ditch and Collins Creek below the Collins Creek Ditch. All three of these streams are cut off from the Roaring Fork River for a majority of the summer and into the fall (Michael Craig, past CDWR Division 5, Water Commissioner, personal communication, March 20, 2008). Owl Creek does not have a lot of natural stream flow because of its small drainage area and lower elevation headwaters (Bill Blakeslee, CDWR, Division 5, Water Commissioner, personal communication, May 24, 2008).

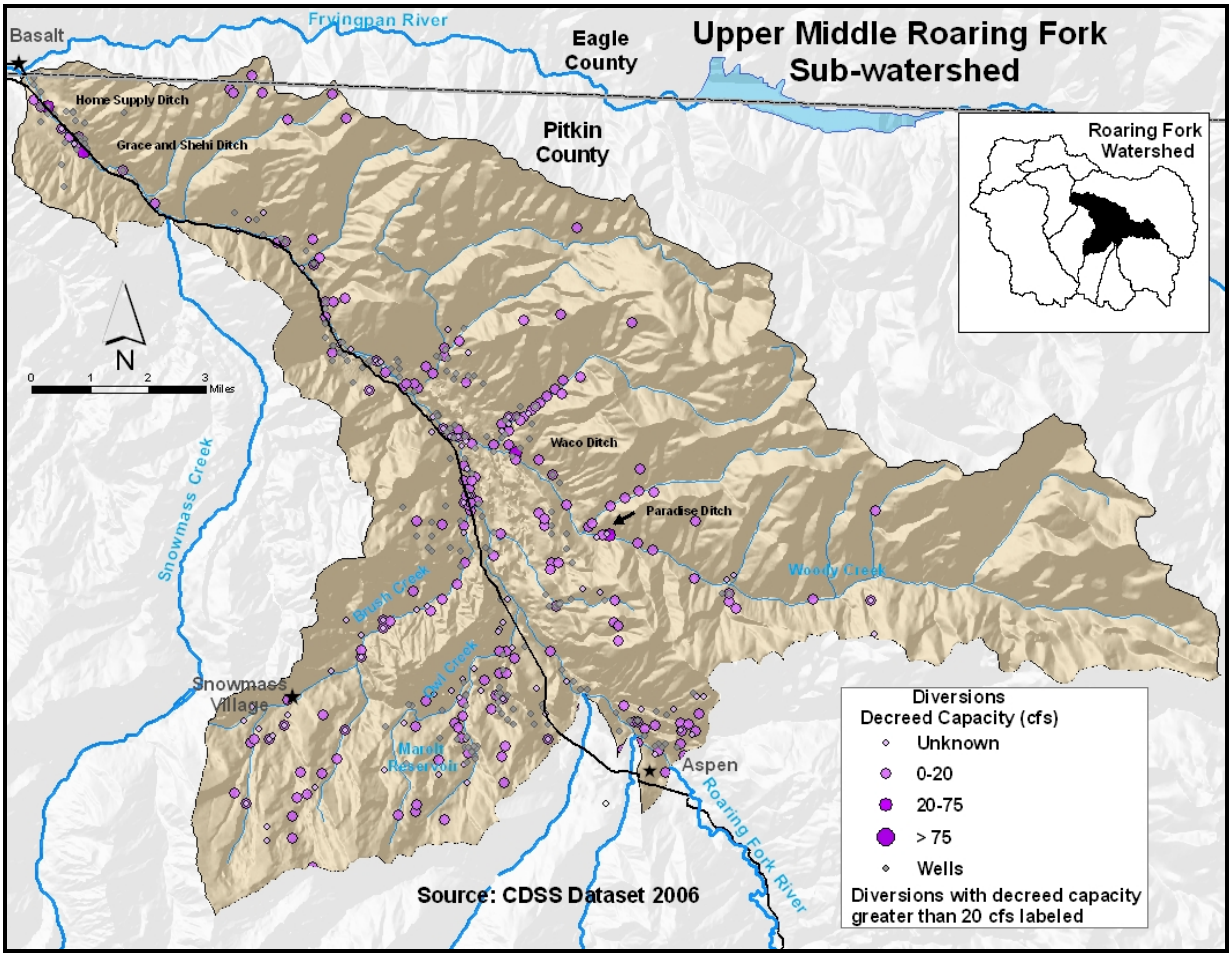


Figure 4.2.4. Diversions and wells in the Upper Middle Roaring Fork Sub-watershed.

Table 4.2.3. Diversion in the Upper Middle Roaring Fork Sub-watershed greater than 10 cfs. Source CDSS GIS Division 5 diversion data, 2006.

STREAM	DITCH	DECREED CAPACITY
Woody Creek	Salvation Ditch Vagneur Extension*	15.00
Woody Creek	Paradise Ditch*	25.00
Collins Creek	Collins Creek Ditch*	15.70
Woody Creek	Waco Ditch*	38.20
Woody Creek	Walthen Ditch*	16.77
Roaring Fork River	Eli Cerise Ditch*	14.99
Roaring Fork River	Kester Ditch*	16.55
Roaring Fork River	Grace and Shehi Ditch*	20.74
Roaring Fork River	Home Supply Ditch*	59.00
Brush Creek	West Fork Brush Creek Pipeline	11.50

* Used in CDSS modeling.

There are three direct-flow conditional water rights greater than 10 cfs in the sub-watershed: two on the mainstem of the Roaring Fork River (RFC and John Cerise ditches) and one on Brush Creek (Brush Creek hydro) (Table 2.4). One conditional storage right greater than 1,000 acre-feet is located on Brush Creek (Snowmass Reservoir) (Table 2.5).

Two Colorado Water Conservation Board instream flow rights (ISFs) are within the sub-watershed, one on the Roaring Fork from the confluence of Maroon Creek to the confluence with the Fryingpan River and the other on Woody Creek (see Figure 4.2.3). According to the Stream Flow Survey Report (Clarke, 2006), the ISF on the Roaring Fork River below Maroon Creek gage was met throughout the year from 1988-2005.

Groundwater

The Upper Middle Roaring Fork Sub-watershed area has four distinct geologic units affecting groundwater storage and flow. These include three bedrock units and one unconsolidated ("loose" sediments rather than rock) unit made up of Quaternary- and Tertiary-age sediments (Kolm and van der Heijde, 2006). For the sub-watershed, no overall regional groundwater system has been identified; rather, it is dominated by local-scale groundwater flow systems that in some cases are isolated, small, and have limited capacity to support development.

The three bedrock units consist of Mancos shale, Dakota sandstone, and Lower Bedrock. Mancos shale acts as a confining layer when present, primarily occurring in the western half of the sub-watershed; this layer restricts groundwater movement. Wells on property located on Mancos shale must be deep enough to penetrate to Dakota sandstone. Fracture permeability provides the most significant source of water supply in the Dakota sandstone unit. This unit typically is found at depths greater than 200 feet and underlies most of the area west of Aspen. The Lower Bedrock areas are primarily limestone and are located at depths greater than 1,000 feet under the majority of the area west of Aspen. Groundwater is available from fractures in the Lower Bedrock unit, although it is often hard and requires treatment.

The unconsolidated unit, broadly speaking, is a permeable aquifer. Quaternary unconsolidated materials are recharged from precipitation as well as upward recharge in some locations from the faulted, saturated Dakota sandstone. Otherwise, the predominant Mancos shale does not allow for the upward movement of recharge. These unconsolidated local aquifers exist primarily in upper Brush Creek, in the river bottom systems, and on the disconnected terraces of the sub-watershed's east side. Water quality from these deposits is usually good, although groundwater reservoirs are often small.

A report by Kolm and van der Heijde (2006) describes a groundwater resources evaluation procedure for the Upper and Middle Roaring Fork Valley and presents three examples. The examples for two sites in the Middle Roaring Fork Valley illustrated: 1) the variability of drinking water supplies, both in availability and sustainability, for sites located near each other, and 2) the vulnerability to groundwater pollution. Additionally, the groundwater for the well at the second site near McLain Flats Road was recharged from precipitation and irrigation return flows. Seasonal fluctuations in the well would be directly related to ditch flow.

Water Quality

Author: U.S. Geological Survey

The Upper Middle Roaring Fork Sub-watershed has had water quality data collected at 35 sites since 1973. Of these sites, 29 were stream sites, one a groundwater site, and five were mine or effluent sites. Water quality data summarized for this sub-watershed are from 1976 to 2007. Streams with at least some historical water quality data include Woody Creek, Spring Creek, Brush Creek, and the Roaring Fork River from below Hunter Creek to above the confluence with the Fryingpan River. Available recent data from one site on Brush Creek and seven sites along the Roaring Fork River were used to represent the sub-watershed's water quality conditions:

- Roaring Fork River at Slaughterhouse (Site 7)
- Roaring Fork River below Aspen Metro Plaza below Aspen, Colorado (Site 8)
- Brush Creek at mouth near Snowmass (Site 9)
- Roaring Fork River at Gerbaz Bridge (Site 10)
- Roaring Fork River at Snowmass Bridge in Snowmass (Site 11)
- Roaring Fork River near Basalt, Colorado (Site 12)
- Roaring Fork River below Roaring Fork Club (Site 13)
- Roaring Fork River at 7-11 Bridge (Site 14)

These sites are shown in Figure 4.2.5, along with locations and information about water and wastewater treatment facilities. For each site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

The Colorado River Watch Program is currently collecting water quality data at three sites on the Roaring Fork River (sites 7, 10, and 14) and four sites on Brush Creek, including Site 9 as well as three new sites not included in this analysis. Previous summaries of water quality data by the Roaring Fork Conservancy have identified Brush Creek as having high pH values and high total phosphorus concentrations (Roaring Fork Conservancy, 2006a). Brush Creek is currently targeted for stream habitat improvement projects aimed at restoring stream stability, aquatic and associated riparian habitat, and community access (Town of Snowmass Village, 2007). These improvements may also act to improve water quality. The Roaring Fork Conservancy conducted a targeted study along Brush Creek to establish baseline water quality conditions and to characterize pH and phosphorus concentrations (Roaring Fork Conservancy, 2007). Further sampling will occur after the restoration activities are completed to assess changes in conditions.

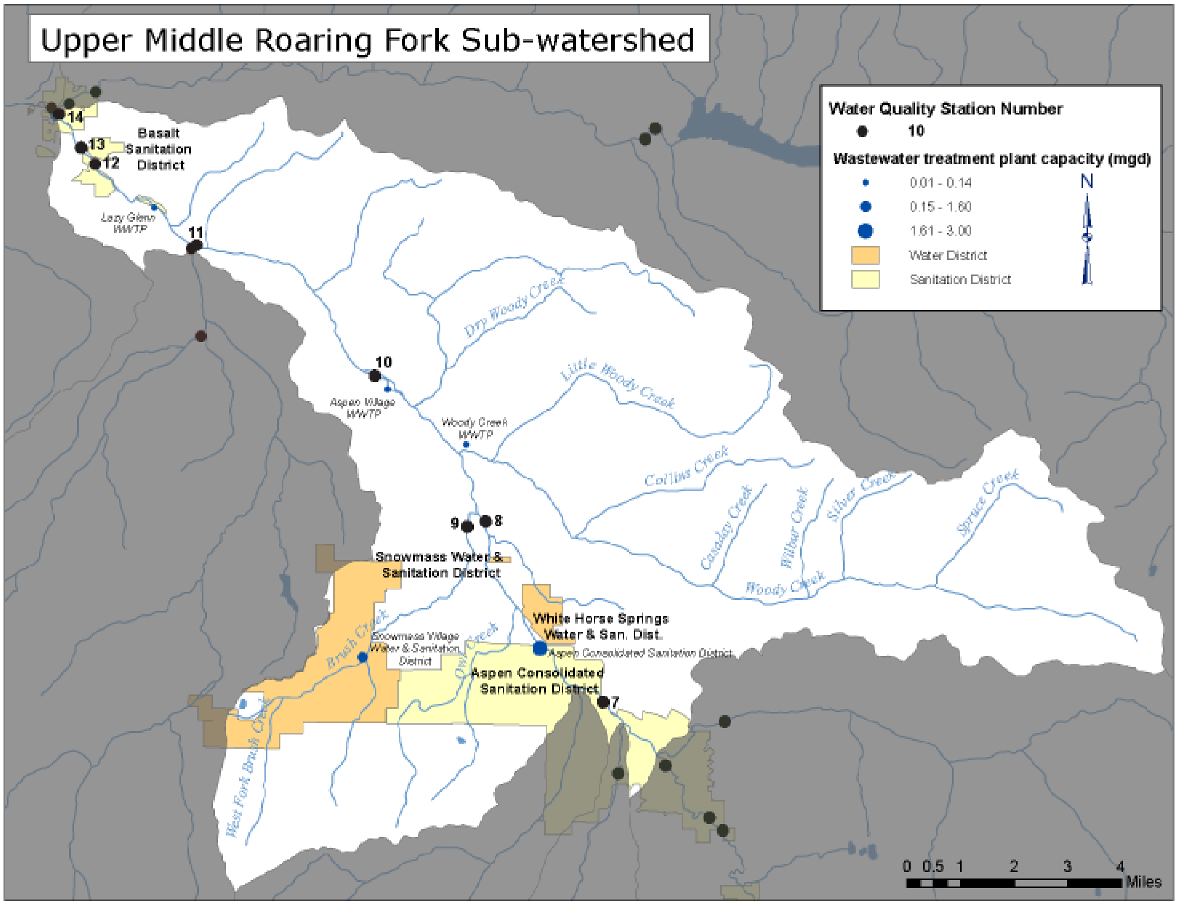


Figure 4.2.5. Water-quality sites and wastewater treatment providers in the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and CDOLA, No date b.

pH ranged from 5.6 to 9.58, and median pH ranged from 8.24 to 8.65. Twenty-one of 345 pH results exceeded the water quality standard at sites 9, 10, 11, and 14. Nine of the 22 exceedances occurred at Site 9. All other exceedances occurred downstream from where Brush Creek joins the Roaring Fork River. Nine of the 22 exceedances occurred at Site 14, the most downstream site in the sub-watershed, where results exceeded the minimum and maximum standards for pH. For sites 10, 11, and 14, exceedances were found from 1997 to 2004, mainly during winter and spring, suggesting a seasonal effect on pH along this stretch of the Roaring Fork River. Exceedances for Site 9 occurred from late summer to late fall of 2000 through 2003, suggesting a completely different process than that observed on the Roaring Fork River. Roaring Fork Conservancy monitored pH on Brush Creek and concluded that high pH levels occur during low stream flow conditions (Roaring Fork Conservancy, 2007); however, concurrent pH and stream flow information are needed in order to clarify this relationship.

Water temperatures generally are within water quality standards. Across a total of 334 water temperature samples, results ranged from -2°C (28.4°F) to 21°C (69.8°F) with median temperatures ranging from 4.2°C (39.6°F) to 8.5°C (47.3°F). One exceedance of the temperature standard occurred in August 2000 at Site 14, and one exceedance in July 2004 at Site 9. Specific conductance results were limited to sites 11 and 12. Sixty-three results ranged from 158 to 523 µS/cm across both sites, with median specific conductance values of 420 µS/cm at Site 11 and

472 µS/cm at Site 12. These results indicate a relatively high amount of dissolved material as compared to the Upper Roaring Fork Sub-watershed, which is the result of a change in geology from igneous and metamorphic to sedimentary rocks. Previous studies suggest that the source of this dissolved material is likely related to the occurrence of geologic units like the Maroon formation, the Eagle Valley evaporite (Maroon and Castle creeks), and the Mancos shale (Snowmass Creek) that outcrop and underlie streams throughout the Roaring Fork Watershed (Warner et al., 1985; Kirkham et al., 1999).

Dissolved oxygen concentrations ranged from 4.3 to 18.3 mg/L. Four concentrations were below the 6 mg/L standard. Three of 82 dissolved oxygen values exceeded the standard at Site 14 in January, September, and October of 1996-97. These three exceedances do not reflect the overall condition at Site 14 where the median dissolved oxygen value was 9.55 mg/L, indicating well-oxygenated conditions. One of 39 dissolved oxygen values at Site 11 was below the standard during March 1998.

Sites 9 and 12 had the majority of available major ion data. Fifty-seven total dissolved solid concentrations ranged from 92 mg/L to 340 mg/L, and the median total dissolved solids ranged from 240 mg/L to 260 mg/L. Median hardness concentrations (ranging from 168 mg/L to 231 mg/L) indicate hard to very hard water.

Nutrient data were limited to Site 9 (Brush Creek at the mouth) and Site 11 (Roaring Fork River at Snowmass Bridge in Snowmass), which had nine and 42 samples, respectively. Total phosphorus exceeded the USEPA recommended concentration at Site 9 six times out of nine samples. Most exceedances occurred in February and May, suggesting that these elevated concentrations could be associated with both high and low stream flow. Typically, February would be the winter base flow period and May would be a period with high snowmelt runoff. However, due to the lack of recent stream flow data at this site, these relationships between stream flow and total phosphorus concentrations cannot be examined in detail. February exceedance concentrations ranged from 0.428 to 1.1 mg/L and May exceedance concentrations from 0.13 to 0.33 mg/L. The exceedances observed in February may be related to anthropogenic sources, including Snowmass Village's wastewater treatment plant (WWTP), upstream of the site. Exceedances observed during May could be related to more natural processes including the suspension of sediments containing phosphorus during early stream runoff events (Wynn et al., 2001). Total phosphorus exceeded the recommended standard three times at Site 11, in February of 2001, 2003, and 2007. It should be noted that four WWTPs are located upstream of Site 11: Aspen Consolidated Sanitation District, Snowmass Village WWTP (which is upstream of Site 9 on Brush Creek), Woody Creek WWTP, and Aspen Village WWTP (Figure 4.2.5). Un-ionized ammonia and nitrate concentrations were generally low, and no water quality standard exceedances were observed for these constituents.

Total recoverable iron and selenium are trace elements that occasionally exceeded table value standards (TVS) in the sub-watershed. Nine of 293 total recoverable iron concentrations exceeded the chronic standard (1,000 µg/L). Exceedances occurred at sites 9, 10, and 14 in March, April, and May 1996-97, 1999, and 2002-03. Spring snowmelt acts to mobilize sediments in streams and is the most likely source of total recoverable iron concentrations that exceed the TVS. Site 14 (Roaring Fork River at 7-11 Bridge) had five of the nine exceedances, all of which occurred from 1996 through 1999. Seven of the 179 selenium concentrations exceeded the chronic standard at sites 7, 9, 10, and 14. These exceedances occurred during various months from 2001 to 2004, indicating that these exceedances are not primarily associated with a seasonal source (e.g. irrigation adjacent to streams or snowmelt). None of the TVS were exceeded for cadmium, copper, lead, manganese, or zinc.

Riparian and Instream Areas

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed the Roaring Fork River and Brush Creek in this sub-watershed. Figure 4.2.6 shows specific riparian and instream information, by habitat quality category, for each reach assessed. The habitat quality categories are shown in the riparian and instream assessment charts found in Section 3.3 and Section 3.4. Appendix 3.3.1 contains the actual percentage values for each of these categories by sub-watershed and how they were determined. In the sub-watershed are two stream segments:

- Roaring Fork Segment – the Roaring Fork River from Hunter Creek to the Fryingpan River, SHI reaches RF4-1 through RF5-3, 18.71 miles.
- Brush Creek Segment – Brush Creek from the headwaters to the confluence with the Roaring Fork River, SHI reaches BR1-1 through BR1-6, 7.6 miles.

A brief description of results follows. The SHI report contains detailed narrative description. “Right bank” and “left bank” refer to the orientation of the riparian zone when facing downstream.

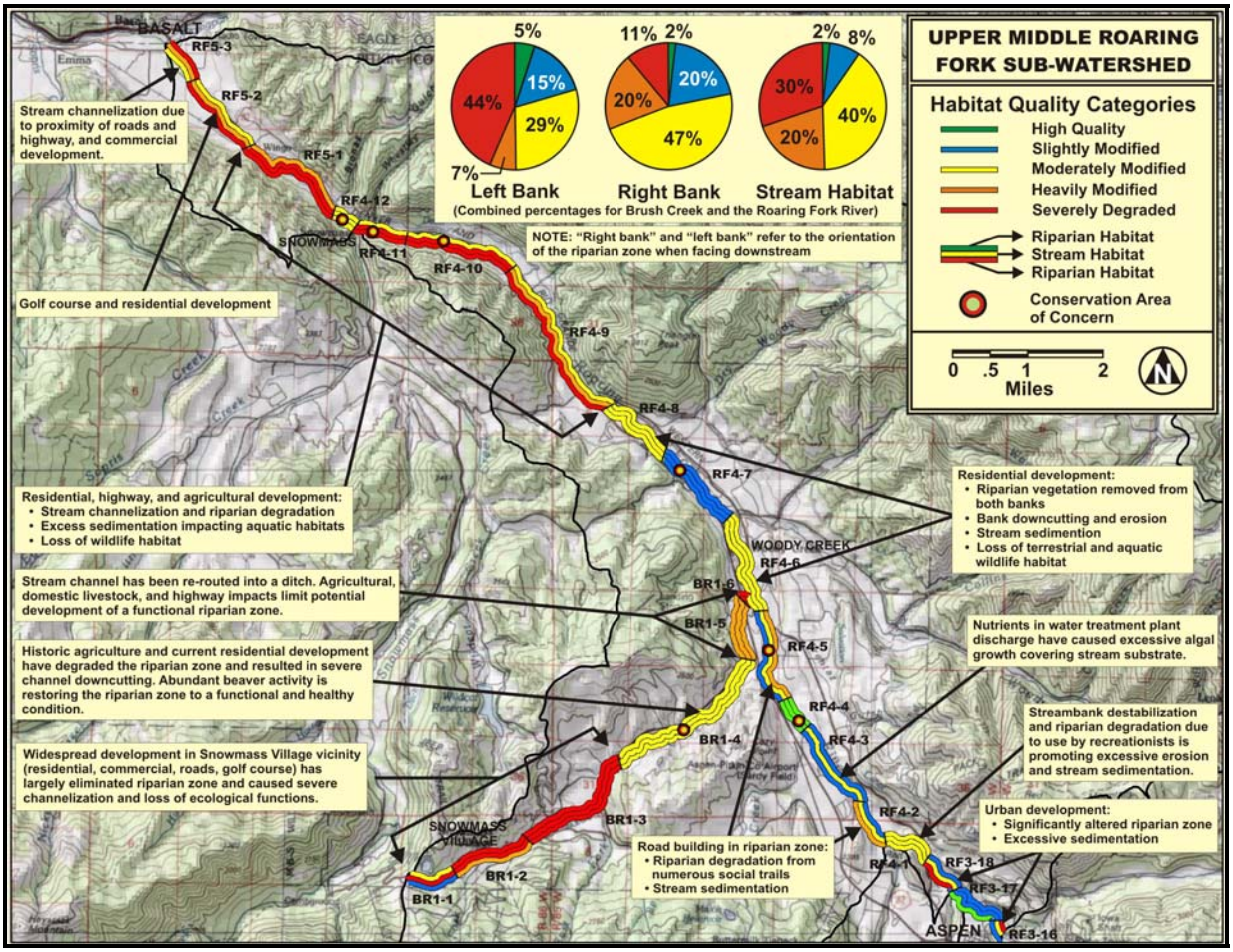


Figure 4.2.6. Riparian and instream habitat quality in the Upper Middle Roaring Fork Sub-watershed.

Roaring Fork Segment – Uplands

Upland landscapes in this segment have been fragmented and habitat quality reduced by agricultural, residential, and recreational development. Associated infrastructure such as roads, power lines, and trails increase the area of impact. Recreational development is well-established on public lands with commercial ski areas and a dense network of hiking, biking, ski, and horse pack trails, and all-terrain vehicle and snowmobile routes. On public and private lands, historic agricultural uses continue. Livestock grazing has occurred on much of the public lands with consequent vegetation and soil degradation and loss of wildlife habitat. On private land, conversion of native habitat to ranch pastures has been common, although many of these ranches are now being sold for residential development. Only a few developments, such as Wildcat Ranch, have preserved and protected the majority of habitat in a natural condition. Also, several organizations, such as the Aspen Valley Land Trust and Pitkin County Open Space and Trails, have protected several thousand acres of ranchland from development in this sub-watershed (Figure 4.2.1 and Appendix 4.1). Colorado Natural Heritage Program (CNHP) has identified three upland areas as Potential Conservation Areas (PCAs) due to their biodiversity significance: Light Hill, Williams Hill, and Cerise Gulch. However, ecosystem sustainability at each of these areas is threatened with noxious weeds (Figure 3.3.2 and Appendix 3.3.2). In addition, Williams Hill faces impacts from residential and recreational development, Light Hill has erosion issues, and unmanaged recreation and historic grazing activities are found at Cerise Gulch.

Roaring Fork Segment – Riparian Habitat and Wildlife

Less than 10 percent of the riparian habitat along the Roaring Fork River segment in this sub-watershed is high quality. On the left bank, 7 percent of the habitat is high quality, 22 percent is slightly modified, 23 percent is moderately modified, 4 percent is heavily modified, and 44 percent is severely degraded. On the right bank, 3 percent of the habitat is high quality, 25 percent is slightly modified, 52 percent is moderately modified, 17 percent is heavily modified, and 5 percent is severely degraded.

Table 4.2.4. Summary of land development impacts and threats to riparian and instream habitat in the Upper Middle Roaring Fork Sub-watershed's surveyed reach.

UPPER MIDDLE ROARING FORK: ROARING FORK SEGMENT	TRAILS AND RELATED DISTURBANCES	ROADCUTS	DEVELOPMENT (Residential, commercial, agricultural)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	WEEDS COMMON-ABUNDANT (5-10%) RIGHT BANK
Total Stream Miles: 18.71	24%	21%	32%	19 %	47%	52%

Table 4.2.4 summarizes impacts to riparian and instream habitat for this segment. In reaches RF4-1, 2, and 5, recreational trails adjacent to and through the riparian zone have eliminated habitat, and caused formation of numerous undesignated social and angler trails that have eliminated or damaged streambank vegetation. On 32 percent of this segment, native riparian habitat has been converted to pastures, golf courses, and residential development. In areas with residential and golf course development, as occur on RF3-16 and 18, RF4-6 and 8, and RF5-2 and 3, the functional width of the riparian zone has been reduced and native shrubs and herbaceous plants have been removed and replaced with non-native grass lawns, leaving a simplified and dysfunctional habitat (Figure 4.2.7). Domestic livestock grazing and pastures in reaches RF4-10 and 11 have caused the replacement of native vegetation with pasture grasses and have decreased vegetative protective cover on streambanks. Where soils have been disturbed along trails, roads, eroding streambanks, and developments, noxious weeds have displaced native vegetation. Highway construction on the left bank of reaches RF4-9 through RF5-2 has eliminated much of the native riparian and upland vegetation (Figure 4.2.8).

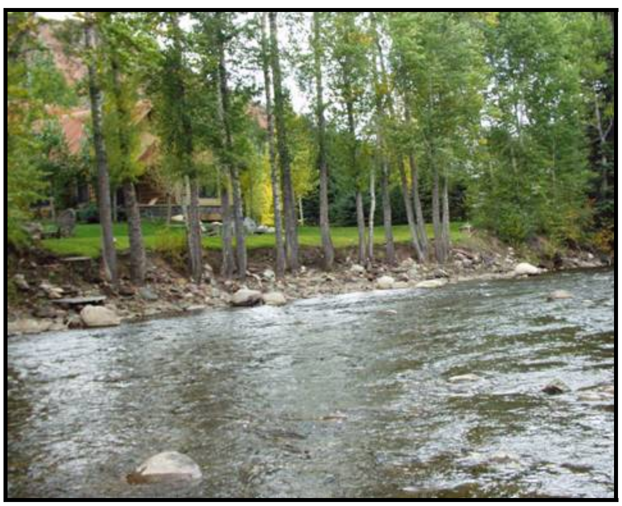


Figure 4.2.7. Understory riparian vegetation at this residence on reach RF3-18 has been removed, resulting in streambank erosion.

Figure 4.2.8. Highway 82 construction has channelized the river and contributed to instability.

Bank erosion and channel downcutting are common in reaches RF3-16, RF4-6, 7, 8, and 9 inhibiting the out-of-bank flows that sustain native riparian vegetation (Figure 4.2.9). Narrowleaf cottonwood-blue spruce forests, which are a defining riparian plant community along this stretch of the Roaring Fork, are declining due to the cumulative effects of channel straightening, stream flow alteration, noxious weed invasion, and domestic livestock grazing.

Figure 4.2.9. Reach RF4-7: Removal of native understory shrubs and herbaceous plants have resulted in bank erosion (see upper photo). On the opposite bank, landowners have conserved native vegetation (lower photo), resulting in stable banks and high wildlife value.

Wildlife potential has diminished due to a reduction in the amount and quality of riparian habitat, habitat fragmentation, and human disturbance. A few reaches remain in good to fair condition and provide wildlife with protected breeding and foraging habitat. The SHI identified five Conservation Areas of Concern (see Table 4.2.5): reaches RF4-4 and 4-7 (Figure 4.2.10), and areas within reaches RF4-10, RF4-11, and RF4-12. Each has good wildlife potential provided by diverse plant communities with numerous layers of native shrubs and trees of all age classes. RF4-4 is threatened by recreational disturbance, and residential development could impact RF4-7. In reaches RF4-10, 4-11, and 4-12, only small, isolated patches of good quality riparian habitat remain. These patches provide some wildlife species, especially songbirds and small mammals, with good breeding and foraging resources.

Figure 4.2.10. Riparian and stream habitat in reach RF4-7 is in functional condition and provides high wildlife value.

Several studies have assessed biological diversity in this sub-watershed including the SHI, CNHP (Spackman et al., 1999), and the Roaring Fork Valley Bird Monitoring Project (Vidal and Fidel, 1997). Breeding bird surveys conducted by the SHI found that throughout this sub-watershed breeding bird diversity was greater in higher quality riparian areas compared to lower quality areas. CNHP identified four riparian areas within this sub-watershed as Potential Conservation Areas (PCA) due to their biodiversity significance: Roaring Fork River at Brush Creek PCA (RF 4-4 and RF4-5); Roaring Fork at Old Snowmass PCA, located on the Roaring Fork upstream of Snowmass Creek (RF4-9, 10 and 11); Woody Creek at Horseshoe Draw; and Woody Creek Headwaters (Figure 3.3.2 and Appendix 3.3.2). The Brush Creek and Woody Creek at Horseshoe Draw PCAs have good occurrences of a globally-vulnerable plant community. Several vulnerable and rare plant communities as well as several other elements of concern were identified in the Old Snowmass PCA. Several globally secure plant communities exist within the Woody Creek Headwaters PCA. CNHP identified residential development, recreational disturbance, and highway construction-related erosion as threats to the Brush Creek PCA; noxious weeds as a threat to both the Snowmass Creek and Woody Creek Headwaters PCAs; and residential development and agricultural development, and noxious weeds as threats to Woody Creek at Horseshoe Draw PCA. Breeding bird surveys conducted on the Rio Grande Corridor (RF4-2 through RF4-4) in riparian and adjacent upland habitat identified numerous breeding bird species, including some species of conservation concern such as the Northern goshawk (Vidal and Fidel, 1997), olive-sided flycatcher, Brewer's sparrow, Virginia's warbler, Cooper's hawk, lark sparrow, and wintering bald eagles (Malone and Emerick, 2002 and 2007a).

Table 4.2.5. SHI Conservation Areas of Concern in the Roaring Fork segment of the Upper Middle Roaring Fork Sub-watershed.

LOCATION	JUSTIFICATION
RF4-4	Riparian and instream habitat provide high terrestrial and aquatic wildlife potential. Good connectivity with upland habitat further enhances wildlife value. Social trails with associated vegetation disturbance threaten wildlife values. Stream habitat is threatened by excessive sedimentation and nutrient loads.
RF4-7	Riparian and instream habitat provide high terrestrial and aquatic wildlife potential. Bald eagles use this area for winter roosting habitat and a high diversity of Neotropical migrant songbirds breed here. Development threatens wildlife value.
RF4-10, 4-11, 4-12	Isolated patches of good quality native habitat are embedded in developed areas. Although these patches are disconnected and small they still provide wildlife species such as songbirds and small mammals good quality breeding habitat. Threats include disturbance and encroaching development.

Roaring Fork Segment – Instream Habitat and Wildlife

In this segment, stream morphology and type varies with the landscape, with Type A streams in steep-walled canyons, Type B streams where the valley has a less steep gradient, and Type C streams where the valley is wider and flatter. Refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of these different types of streams. In many reaches within this sub-watershed, development-induced channelization combined with hydrologic modification has altered the natural, pre-development characteristics that determine stream type.

The Roaring Fork and Fryingpan Rivers Multi-objective Planning Project (Multi-Objective Study) identified unstable streambanks, damage to riparian vegetation, stream channel straightening, and excessively steep stream slopes (due to decreased sinuosity) as causes of instability in this segment (BRW, Inc. et al., 1999). Land development has exacerbated natural instability by altering channel characteristics and morphology. Development in the stream corridor has included channelizing activities such as stream straightening; bridge building, bank riprapping, shoring, and riparian vegetation alteration − all of which lead to unstable stream banks and bank erosion. Bank erosion has caused downcutting and widening, thus changing the shape of the channel.

Development has impacted instream habitat to the point where only 3 percent of instream habitat in this segment is high quality, 11 percent is slightly modified, 42 percent moderately modified, 23 percent heavily modified, and 22 percent severely degraded. Impacts from development include channelizing alterations that have modified much of the river channel. In stream reaches RF4-9, 10, 11, and RF5-1, 2 and 3, highway and road runoff, construction, and streambank devegetation have increased erosion. Newly constructed wildlife underpasses in these reaches act as funnels that direct eroding upland sediments into the stream (Figure 4.2.11). Road sanding material is carried with precipitation runoff into culverts and then to the river. Housing and agricultural development in or adjacent to the riparian zone on reaches RF3-16 and 18, on the right bank of RF4-6, 8, 9, 10, and 11, and on RF5-1, 2, and 3, has damaged vegetation, destabilized hillslopes and streambanks, and increased runoff.

Figure 4.2.11. Wildlife underpasses funnel eroding upland sediment into the river.

Although urbanization and highway construction have caused significant channel alteration and riparian degradation along this segment of the Roaring Fork River, it still maintains a robust population of brown trout very popular with anglers. High wildlife potential occurs in reaches RF3-17 and RF4-3, 4, and 7. In these reaches channel habitat diversity is high, substrate is stable and diverse, sedimentation and embeddedness are not excessive, and year-round flows provide sufficient habitat quantity and quality. In the remaining reaches, wildlife habitat has been degraded by activities that have caused channelization, which in turn has reduced instream habitat variety and resulted in a suboptimal distribution of pools, riffles, and runs. In addition, drop structures, diversions, and culverts inhibit fish movement; excessive sedimentation is filling pools and embedding cobbles; alteration to riparian and streambank vegetation has reduced the amount of overhanging bank vegetation and destabilized undercut streambanks; and flow alteration has reduced the habitat available to fish and aquatic insects. A reduction in beaver populations from historic levels has negatively affected stream habitat and wildlife diversity.

Non-native naturally reproducing rainbow trout populations in this segment have been severely affected by whirling disease. As determined in the Multi-Objective Study (BRW Inc. et al., 1999), whirling disease has resulted in high mortality of rainbow trout fry and young-of-the-year recruits, resulting in changes in abundance, population structure, and community assemblage. Fish surveys conducted from 1970 to 1980 indicated that wild rainbow trout, followed by brown and brook, were the most abundant species in the river in all age categories. By the mid-1990s, rainbow trout were virtually eliminated from this reach and currently, brown trout dominate in the system because they are more resistant to whirling disease (Kendall Ross, CDOW, aquatic biologist, personal communication, April 10, 2008).

Brush Creek Segment - Uplands

Ski area development and residential and infrastructure development have altered the precipitation infiltration-runoff regime throughout this segment's Brush Creek drainage. On north-facing slopes, 3,132 acres of forested habitat have been converted into ski slopes. Widespread residential development occurs on south-facing slopes. The bottom of the valley is dominated by a golf course, commercial development, condominiums, and hotels. Aspen forests that still dominate north-facing slopes are rich with native plants and provide lush breeding habitat for large and small mammals including elk, mule deer, black bear, pine marten, Southern red-backed vole, and water shrew, and for bird species such as Northern goshawk, Western screech owl, brown creeper, and Williamson's sapsucker (Malone and Emerick, 2002). Oak-sage shrublands dominating south-facing slopes provide critical winter habitat for deer and elk and their predators, including mountain lion. The migration route between these summer and winter habitats is interrupted by roads and development in the valley bottom. Native oak and sage shrublands provide high-quality breeding habitat for Brewer's sparrow, vesper sparrow, green-tailed towhee, and blue-gray gnatcatcher, and year-round habitat for many species such as badger, coyote, bobcat, rock squirrel, montane vole, and dwarf shrew.

Brush Creek Segment - Riparian Habitat and Wildlife

With the unstable geology that characterizes much of this drainage, a well-vegetated, naturally wide riparian zone is essential to maintaining stream stability. Over the majority of the drainage, riparian habitat has been severely degraded. Much of the native riparian vegetation has been eliminated. Weed infestation is severe on much of the segment, and due to upland land development, groundwater flow to riparian and stream habitat is altered and soil condition is degraded. Consequently, high quality, unmodified habitats are present only on a few reaches or in small, isolated patches. On the left bank no high quality or slightly modified habitat remains. Forty-five percent of left bank riparian habitat is moderately modified, 13 percent is heavily modified, and 42 percent severely degraded. On the right bank, 9 percent of riparian habitat is slightly modified, 36 percent moderately modified, 28 percent heavily modified, and 27 percent severely degraded.

Table 4.2.6. Summary of land development impacts and threats to riparian and instream habitat on Brush Creek in the Upper Middle Roaring Fork Sub-watershed.

UPPER MIDDLE ROARING FORK: BRUSH CREEK SEGMENT	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	WEEDS COMMON-ABUNDANT (5-10%) RIGHT BANK
Total Stream Miles: 7.6	8%	17%	38%	64%	100%	91%

Table 4.2.6 summarizes impacts to riparian and instream habitats. In natural areas such as the right bank of BR1-1 and small isolated areas of BR1-2 and 3, plant species diversity and cover is high, habitat structure is complex, all age classes of trees and shrubs are well-represented, and ecological functions are intact. However, impacts from adjacent urban areas are encroaching into these healthy areas. For instance, weeds that have gained a foothold in disturbed areas have invaded natural areas and are out-competing and displacing native plants. Development in the riparian zone has had widespread, destabilizing effects on the sustainability of the riparian-instream ecosystem. Construction of Brush Creek Road in reaches BR1-1 and 1-2 has damaged

riparian vegetation, resulted in bare and eroding soils, and allowed the invasion of noxious weeds. Residential and commercial development throughout much of BR1-2 and the majority of BR1-3 (Figure 4.2.12) has led to replacement of native riparian vegetation with non-native grass lawns. Additional effects of these development practices include introduction of weeds, channel instability, and loss of ecological functions. Vegetation and channel structure along a small area of BR1-2, the Mayfly Trail, has been restored, but restoration efforts have been degraded by road runoff and erosion from adjacent upland development. Effects of grazing in the riparian zone of reaches BR1-4 and 5 continue to degrade riparian plant communities and the stream channel. However, in the majority of BR1-4 and the upper half of 1-5 beaver damming activity has enabled out-of-bank flows, resulting in decreased stream energy, increased soil moisture, and re-establishment of native riparian vegetation. In areas where beaver activity is high, plant species diversity and protective cover is also high, habitat structure is complex, and riparian functions are being restored.

Figure 4.2.12. Reach BR1-3: Riparian vegetation has been removed on the majority of the Snowmass Golf Course.

Terrestrial wildlife potential has been dramatically reduced throughout a majority of the segment in response to land development and disturbance. A few areas with large patches of natural habitat remain, such as BR1-1 and BR1-4. These natural habitats are rich in plant species, structurally complex, and provide good wildlife potential. For example, native wildlife documented in BR1-4 include beaver, bobcat, mink, great blue heron, belted kingfisher, and fox sparrow. In comparable but developed landscapes, such as BR1-3, these native species are mostly absent. Riparian habitat in urbanized areas is structurally simple due to the removal of understory plants, with most natural habitat limited to small, isolated patches. The Stream Health Initiative identified one riparian Conservation Area of Concern – BR1-4 – in this segment (Table 4.2.7).

Table 4.2.7. SHI Conservation Area of Concern in the Brush Creek segment of the Upper Middle Roaring Fork Sub-watershed.

LOCATION	JUSTIFICATION
BR1-4	Historic grazing by domestic livestock resulted in severe downcutting. Abundant beaver activity is restoring the riparian zone and stream channel to a functional condition. Current residential development threatens recovery.

Brush Creek Segment - Instream Habitat and Aquatic Wildlife

Stream type in this segment varies with topography and human alteration to the channel. Refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of the stream types. The headwater reach of Brush Creek is a Type G stream that transitions to a Type E where the gradient decreases and the valley opens. In reach BR1-2, the stream again becomes a Type G type stream, but where channel restoration has occurred along the Mayfly Trail, the stream is Type C. In reach BR1-3, human-induced channel alteration has resulted in a Type G stream, but historically, it was likely a Type E stream. In reach BR1-4 beaver activity has begun to restore the channel, which currently is a Type C stream. In reach BR1-5 and 1-6, the stream channel has been diverted into a constructed irrigation ditch and is classified as Type G; however, there are signs of establishment of a functional floodplain.

The entire stream segment has been altered by both historical and current land uses. The channel has been moved, straightened, riprapped, and put into culverts. Numerous culverts direct road and parking lot runoff to the stream. Grazing and development-related alteration or removal of streambank vegetation has resulted in extreme channel downcutting and loss of ecological function. In a few places, the stream channel and functions are being restored largely due to the presence of beavers and their dam-building. The Town of Snowmass Village has initiated channel restoration in one small area (the Mayfly Trail) of reach BR1-2. However, these efforts are impacted by upland development-induced erosion, which delivers high sediment loads to the channel.

Land development has resulted in the disappearance of unmodified high quality, or even slightly modified stream habitat; 36 percent of stream habitat is moderately modified, 13 percent heavily modified, and 51 percent is severely degraded. Residential and commercial development in some of BR1-2 and the majority of BR1-3 has included extensive vegetation alteration that has destabilized the channel and led to bank erosion, downcutting, and the necessity for riprapping of the channel. Grazing in BR1-4 and 1-5 has caused erosion and channel downcutting. In some reaches, including areas of BR1-2 and all of BR1-5 and 1-6, the stream has been completely diverted into a newly constructed channel, the majority of which is severely downcut.

Anecdotal accounts from local ranchers indicate that native Colorado River cutthroat trout once existed in Brush Creek. Currently there is little potential for native aquatic wildlife except in reach BR1-4 and the lower half of BR1-1 (Figure 4.2.13). In reach BR1-4 beaver activity has improved instream conditions. Beaver dams have created deep pools where sediment drops out of the water column. These pools also provide excellent fish habitat and foraging habitat for mink, great blue heron, and waterfowl, all observed in the reach.

Figure 4.2.13. Reach BR1-1: At the headwaters of Brush Creek, dewatering and downcutting is severe (upper photo). In the lower photo, groundwater slope discharge sustains riparian vegetation. Further downstream in reach BR1-1, enough groundwater has discharged and accumulated in the channel to create sustainable flows.

4.2.4 Important Issues

Below is a summary of key findings from available scientific information, a listing of data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the sub-watershed's water resources.

Key Findings

The following bullet points refer to the sub-watershed:

- Woody, Little Woody, and Collins creeks are often dried up downstream of large diversion structures in the summer and fall, disconnecting them from the Roaring Fork River.
- The sub-watershed contains local permeable groundwater systems that can be influenced by surface and/or other groundwater sources. The groundwater in some areas of the sub-watershed is vulnerable to pollution and partially recharged from irrigation return flows.
- There are three direct-flow conditional water rights greater than 10 cfs and one conditional storage right greater than 1,000 acre-feet in this sub-watershed.
- The Colorado Natural Heritage Program identified four riparian areas as Potential Conservation Areas due to their biodiversity significance: Roaring Fork River at Brush Creek, the Roaring Fork at Old Snowmass, Woody Creek at Horseshoe Draw, and Woody Creek Headwaters.
- The sub-watershed has several Stream Health Initiative Conservation Areas of Concern (CAC) with riparian and instream habitats that support high terrestrial and aquatic wildlife potential (RF 4-4 and RF 4-7). RF 4-10, 11, and 12 provide good quality native habitat within developed areas. Beaver activity in the BR 1-4 reach along Brush Creek, also a CAC, is helping to restore the stream channel and riparian zone to a functional condition.

The following bullet points refer to the Roaring Fork River:

- The Colorado Water Conservation Board's instream flow right on the Roaring Fork River between the confluence with Maroon Creek and the Fryingpan River is met throughout the year in the upper section (measured at the Roaring Fork River below Maroon Creek gage). The new stream gage located on the Roaring Fork River above Basalt will help administer this right and determine how often it is met in the lower section.
- pH results that fell both below and above the water quality standards were observed primarily on Brush Creek and on the Roaring Fork River below Brush Creek. Brush Creek pH levels are potentially associated with low flow conditions, while on the Roaring Fork, there appears to be a seasonal effect on pH.
- Total phosphorus exceeded water-quality standards at two sites: Brush Creek at the mouth and the Roaring Fork River at the Snowmass Bridge. The exceedances in phosphorus may be attributed to a combination of anthropogenic (wastewater treatment plant discharges) and natural sources.
- Thirty-two percent of the Roaring Fork River segment is impacted by development, 24 percent is affected by trails, and almost 50 percent of the segment has a common to abundant presence of weeds.
- On the Roaring Fork segment, less than 10 percent of the riparian habitat is high quality due to impacts from highway construction, recreational trails, and residential, commercial, and agricultural development. On the left bank, 44 percent of the habitat is severely degraded. Weeds are common to abundant on about 50 percent of both the left and right banks.
- Breeding bird surveys conducted on the Roaring Fork River above Brush Creek in riparian and adjacent upland habitat identified numerous breeding bird species, including some species of conservation concern such as the Northern goshawk, olive-sided

flycatcher, American dipper, Brewer's sparrow, Virginia's warbler, and lazuli bunting. Bird surveys also documented wintering bald eagles and a great blue heron colony on Woody Creek.

- Fifty-five percent of the Roaring Fork segment's instream habitat is either heavily modified or severely degraded.
- Although significant channel alteration and riparian degradation has occurred along the Roaring Fork mainstem from urbanization and highway construction, the river still maintains a robust population of brown trout very popular with anglers. Non-native, naturally reproducing rainbow trout populations in this segment have been severely affected by whirling disease.

The following bullet points refer to Brush Creek:

- There were frequent observations of pH levels either below or above water-quality standards on Brush Creek. These pH levels are potentially associated with low flow conditions.
- Total phosphorus is a water-quality concern at the Brush Creek site. The exceedances in phosphorus could be attributed to a combination of anthropogenic (wastewater treatment plant discharges) and natural sources.
- Thirty-eight percent of the surveyed Brush Creek segment is impacted by development, and almost the entire segment has a common to abundant presence of weeds.
- Brush Creek's riparian corridor has significant amounts of severely degraded habitat – 27 percent of the right bank and 42 percent of the left bank.
- Much of the Brush Creek segment's stream channel has been altered through straightening, moving, riprapping, and location into culverts. As a result, instream habitat is severely degraded in 51 percent of the segment.
- Beaver activity has improved instream habitat in some areas. Beaver dams have created deep pools where sediment drops out of the water column. These pools also provide excellent fish habitat and foraging habitat for mink, great blue herons, and waterfowl.

Data Gaps

There are a number of gaps in information for the sub-watershed that limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Stream gage data for Woody and Brush creeks;
- Stream flow data for the Roaring Fork River and Woody, Brush, and Owl creeks to determine flow alteration;
- Continuous stream flow data at sites such as Site 9 (Brush Creek at the mouth) to aid in characterizing water-quality conditions;
- Information about groundwater quantity;
- Groundwater-quality monitoring;
- Water-quality data for Woody and Owl creeks (to determine current status and trends);
- Water-quality data for the following constituents and constituent groups:
    - Microorganisms (collected to establish potential for water-born disease)
    - Suspended sediments (to evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals)

  - Emerging contaminants (to determine occurrence and relation to WWTPs, septic leachate, industrial discharges, recreation, and/or agriculture);
- Information about upland habitat condition;
- Information about upland and riparian mammal community diversity, amphibian and reptile populations, and population sustainability;
- Data on bird community diversity and population sustainability;
- Assessment of effectiveness of wildlife underpasses to enable migration;
- Riparian and instream habitat condition for Woody Creek; and
- Breeding bird data for Woody and Brush creeks.

Relevant Local Initiatives, Plans, and Studies

The Woody Creek and Owl Creek caucuses have master plans that reflect goals and priorities for various water-related resources within their respective areas of concern.

The Town of Snowmass Village has created a Greenway Master Plan that focuses on improving the environmental quality of and public interface with the Brush Creek corridor.

4.3 Lower Middle Roaring Fork Sub-watershed

4.3.1 Environmental Setting

The Lower Middle Roaring Fork Sub-watershed extends from the confluence of the Fryingpan River to the confluence of the Crystal River. Its ecoregions are primarily Foothill Shrublands, with some Sedimentary Mid-elevation Forests, and Sedimentary Subalpine Forests. The town of Basalt which is experiencing a large increase in population and development is the largest community within the sub-watershed. It has two distinct sections – the old town, located where the Fryingpan River joins the Roaring Fork, and a newly developing area a few miles down valley that includes part of El Jebel. Additional residential areas in the sub-watershed include Emma, The Ranch at Roaring Fork, and parts of both Missouri Heights and the town of Carbondale. This sub-watershed has the challenging circumstance of falling within three county jurisdictions, making collaborative efforts especially important. A changing landscape from rural to more developed land uses, represents a key issue for this sub-watershed especially in relation to protection of riparian habitat and water quality. See Figure 4.1 for an overview map showing the location of this sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions; the sub-watershed's general physical characteristics are summarized in Table 4.1.

Topography and Geology

East and West Sopris creeks drain the Elk Mountains and flow in a northerly direction to Sopris Creek, which meets the Roaring Fork River just below Basalt. A few smaller tributaries, including Blue Creek, drain Basalt Mountain, the northeast boundary of the sub-watershed.

As shown in Figure 1.3 (the surface geology of the Roaring Fork Watershed), the Maroon Formation is found in the headwaters of East Sopris Creek where most of the sub-watershed's slopes greater than 30 percent also are found (Figure 1.4). As evidence of this area's glacial history, large areas of glacial drift occur in upper East and West Sopris creeks. The majority of the Sopris Creek drainage is comprised of highly erodible Mancos Shale. The northern half of the sub-watershed is underlain primarily by basalt flows, which form the distinctive lava-capped Basalt Mountain. Below the lava cap an outcropping of Pennsylvanian evaporites is prone to unstable slopes and subsidence problems. A large landslide deposit is found on an unnamed tributary in the northeast corner of the sub-watershed. Two large areas of ancient alluviums exist, one near the divide with the Cattle Creek sub-watershed and the other extending into the part of the lower Crystal River Sub-watershed. Gravels and alluviums are along the length of the Roaring Fork River.

Weather/Climate

The one climate station in the sub-watershed operated in Basalt (050514), at 6,620 feet, from 1965 to 1972 (http://www.wrcc.dri.edu/). For the period of record, average total precipitation was about 15 inches. The highest monthly precipitation, on average, occurred in August and September, each of which received just less than two inches. March received the lowest precipitation (.58 inches). The probability of a half-inch of rain in one day was greatest in late summer/early fall. Additional climate data exists for the one active site on Sopris Creek associated with the Colorado Collaborative Rain, Hail, and Snow Network (Appendix 1.2) (http://www.cocorahs.org/).

Biological Communities

Within this sub-watershed, surrounding native upland habitats are characterized by a mosaic of pinyon-juniper woodlands and mountain shrublands dominated by sage, Gambel oak, and other shrubs, grasses, and herbs. Between the confluences with the Fryingpan and Crystal rivers, the Roaring Fork River traverses a broad, flat valley only twice interrupted in places where the river has deeply incised into adjacent river terraces. Historically the river meandered widely across its floodplain, replenishing the land with soil, nutrients, and water. Prior to development the riparian plant community was characterized by an expansive mosaic of lower montane riparian forest and woodlands, wetland meadows, cattail marshes, willow carrs, non-willow shrublands, and open water ponds. This diversity of vegetation supported a tremendous abundance and diversity of native wildlife. Remnants of these native habitat conditions and plant communities can still be observed in a few areas of this sub-watershed.

Wildlife potential in the sub-watershed has been reduced by extensive riparian and upland habitat alteration and disturbance. Those few riparian and upland landscapes that still provide sufficient resources and are disturbance-free are essential to long-term wildlife sustainability. In these areas large mammals such as American elk, mule deer, black bear, and mountain lion are common. Extensive channelization and riparian and hydrologic alteration have reduced the quantity and quality of fish habitat. The cumulative impact has been to lessen the long term sustainability of aquatic wildlife populations (BRW, Inc. et al., 1999).

Appendix 1.3 lists the riparian-related and instream species and communities of concern in the sub-watershed. Winter range, roost sites, and an active bald eagle nest site, (Colorado state threatened species), occur in this sub-watershed (Figure 3.3.5), along with foraging areas and nests for great blue herons and foraging areas for osprey (Figure 3.3.3). According to Colorado Division of Wildlife (CDOW) records, Colorado River cutthroat, brook, brown, and rainbow trout; bluehead and flannelmouth suckers; mountain whitefish; and mottled sculpin have been recorded in this sub-watershed (Harry Vermillion, CDOW, personal communication, March 3, 2008). Brown trout are the sub-watershed's dominant salmonid species.

4.3.2 Human Influences

Land Ownership and Use

Figure 4.3.1 shows ownership and protection status for the Lower Middle Roaring Fork Sub-watershed. The upper East and West Sopris creek drainages and the northeast corner of the sub-watershed are located within the White River National Forest which is managed by the U.S Forest Service (USFS). Headwaters of both East and West Sopris creeks fall within the Maroon Bells-Snowmass Wilderness. The conservation organization Wilderness Workshop is proposing that two other areas in the sub-watershed be reviewed for wilderness status – Hay Park (http://www.whiteriverwild.org/carbondale-region.php) and Basalt Mountain (http://www.whiteriverwild.org/aspen-region.php). Also within the sub-watershed is the 4,807-acre Basalt State Wildlife Area, managed by CDOW. In 2007, CDOW did major work on Lake

Christine, including rebuilding the dam and spillway, and restoring wetlands. The rest of the sub-watershed contains a mixture of private land and land managed by the Bureau of Land Management (BLM), the latter including a large area (approximately 7,000 acres) called "The Crown." Part of this area ("The Crown Ridge") has been proposed by the BLM as an Area of Critical Environmental Concern (http://www.blm.gov/rmp/co/kfo-gsfo/documents/ACEC-Report-FINAL.pdf). The list of open space parcels in this sub-watershed can be found in Appendix 4.1. Conservation easements and some of the public lands have been essential to maintaining high quality upland habitats and their functions. Colorado Natural Heritage Program has identified The Crown and Christine State Wildlife Area (Basalt State Wildlife Area) as Potential Conservation Areas due to their biodiversity significance (Figure 3.3.2 and Appendix 3.3.2).

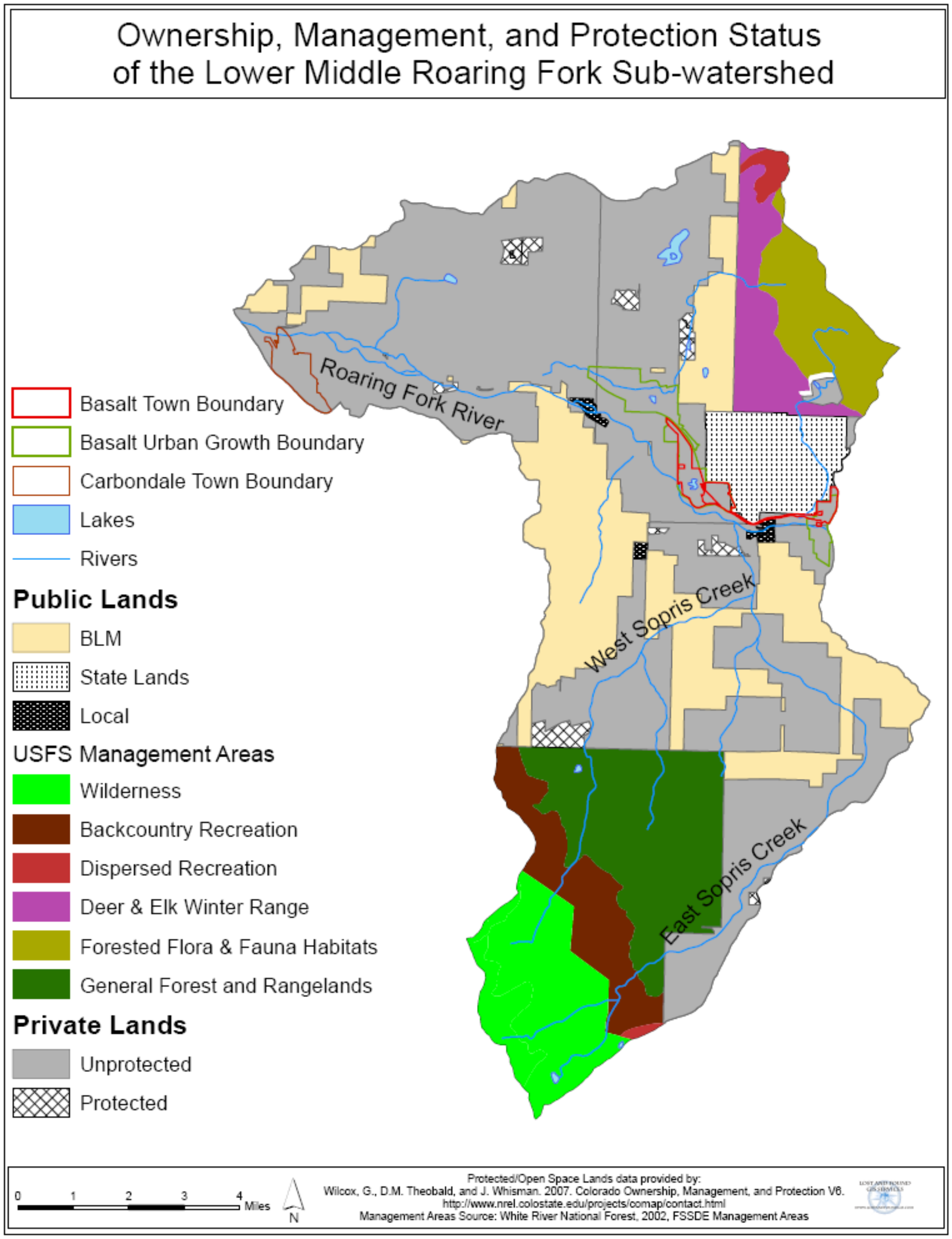


Figure 4.3.1. Ownership and protection status for the Lower Middle Roaring Fork Sub-watershed.

As noted earlier the sub-watershed is bisected by three counties: Garfield and Eagle counties split the northern areas and most of the Sopris Creek drainage is in Pitkin County. The Emma Caucus represents most of the Sopris Creek drainage (http://www.aspenpitkin.com/depts/77/emma.cfm). The Emma Caucus Area Master Plan Draft Existing Conditions Report was submitted in 2007 (http://www.aspenpitkin.com/pdfs/depts/77/Draft_existing_cond.pdf). This report is the first step in a five-part process of preparing a master plan and future land use strategy for the caucus area. The report describes existing conditions for the natural environment (topography, soils, and geology; hydrology - water resources; vegetation; wildlife; visual quality; air quality; and wildfire); existing land use, zoning, and build-out estimate; roads and transportation; trails and recreation; and special districts, adjacent jurisdictions, and utilities.

Figure 4.3.2 shows roads within the sub-watershed and identifies roads within 150 feet of second order and higher streams (approximately 10 percent of the streams). Colorado Highway 82 parallels the northern bank of the Roaring Fork River through all of this sub-watershed. County roads follow East and West Sopris creeks and the Missouri Heights area has a network of roads.

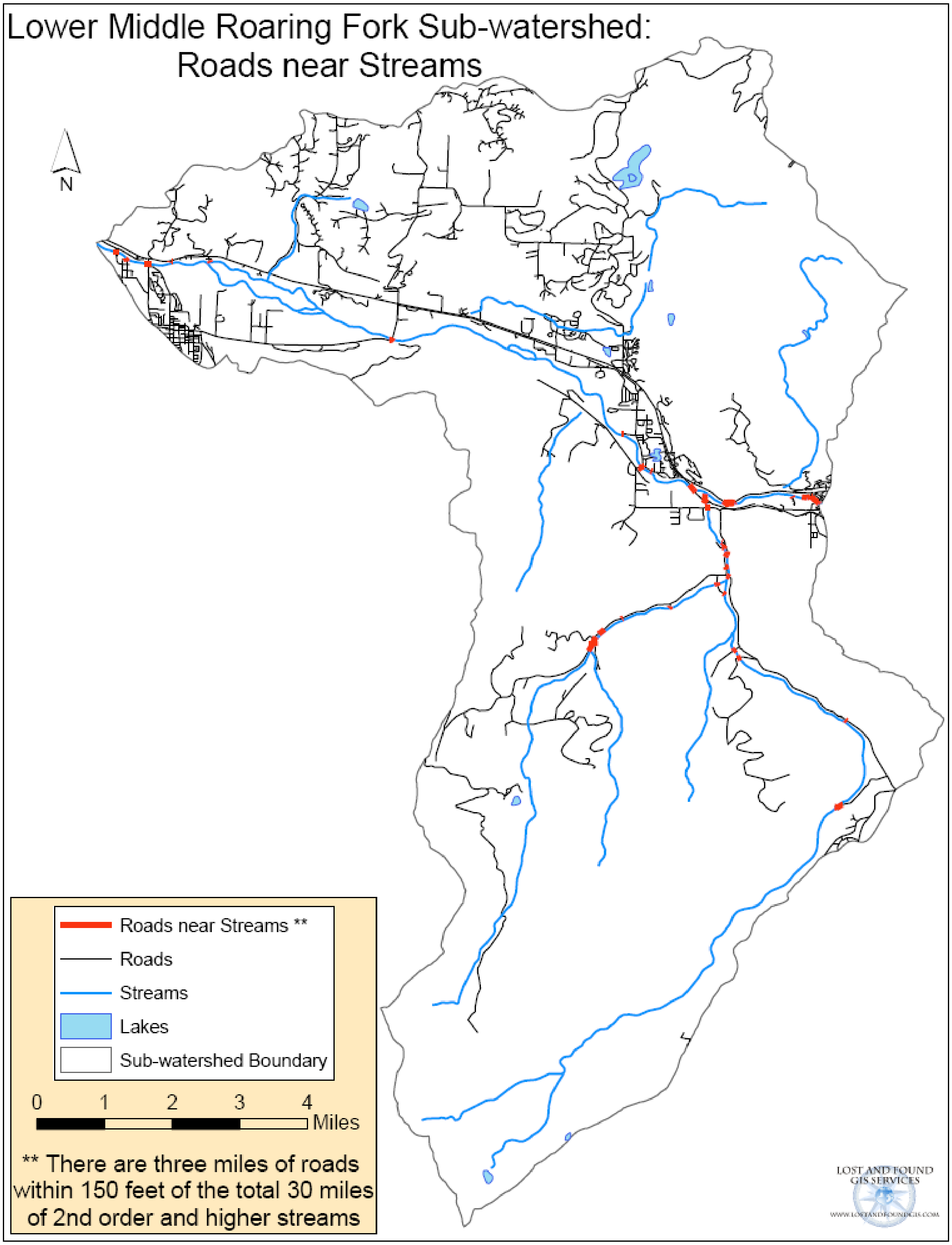


Figure 4.3.2. Roads near streams in the Lower Middle Roaring Fork Sub-watershed.

Irrigated agriculture is found along parts of East and West Sopris creeks, the mainstem of the Roaring Fork River, and throughout the Missouri Heights area (Figure 1.16). The amount of irrigated agriculture declined from 1993 to 2000, with significant portions of the Roaring Fork River corridor no longer in agricultural land uses. Within this sub-watershed, the number of subdivisions along the Roaring Fork River corridor and on Missouri Heights can be seen on county zone district/parcels maps (Garfield County, http://www.garfield-county.com/Index.aspx?page=991; Pitkin County, http://www.aspenpitkin.com/depts/46/GISMOdisclaimer_parcels.cfm and http://www.aspenpitkin.com/depts/46/GISMOdisclaimer_zoning.cfm; and Eagle County, http://gisweb.eaglecounty.us/website/ecgis/viewer.htm).

Most of the town of Basalt (2.19 square miles) and El Jebel (6.74 square miles) are located in this sub-watershed. The town of Basalt's Urban Growth Boundary extends the area to 2.5 square miles. The town currently obtains its municipal water supply from wells and springs. See Appendix 3.1.3 for information about the town's water usage.

In 2001, a project resulting in the "Stormwater Evaluation and Recommendations Report" was completed for the town of Basalt (Matrix Design Group, 2001). The report evaluates and describes existing stormwater runoff conditions in the town, focusing on discharges into the three-mile stretch of the Roaring Fork River between the Upper and Lower Bypass bridges. For the town's stormwater runoff and management, the project described runoff sources, assessed existing programs and ordinances, recommended Best Management Practices, proposed a monitoring plan, and proposed activities for expanded stormwater education and awareness.

Section 5 of the report contains information on existing ordinances and regulations relating to stormwater and drainage issues, such as river setbacks, construction site erosion measures, post construction drainage criteria, and water quality protection standards promoted by the Northwest Colorado Council of Governments (NWCCOG). Recommendations for improved stormwater management are found in Section 6, and fall into five categories:

- Erosion control
- Improvement of stormwater conveyance
- Integration of detention facilities into land use planning
- Installation of water-quality treatment controls
- Education of the community on management of stormwater runoff

To help Basalt plan future river management strategies and improvements, the Roaring Fork River Stewardship Master Plan was completed in 2002. Appendix 3.1.7 lists the seven master plan goals. For the eight sections of the Roaring Fork River that flow through the town (Southside Flooding, Upper Bypass Bridge, Fisherman's Park to Emma Bridge, Emma Bridge, Emma Bridge to Midland Bridge, Midland Avenue to Pan and Fork Mobile Home Park, Levinson Property to Spring Creek, and Downstream of Basalt), specific management objectives and action recommendations can be found at: http://www.basaltriverinfo.net/master_plan.htm. Two examples of projects that have been undertaken based on these recommendations are noted in Section 3.1.7 (Flood Control Issues).

Looking at public opinion in relation to water resources, a 2005 Town of Basalt Community Survey conducted by NWCCOG found that more than 90 percent of both surveyed homeowners and registered voters said that water quality/quantity was an important issue.

The Mid-Valley Metropolitan District and Basalt are the two municipal water suppliers in this sub-watershed. Basalt has a tiered water rate structure, provides online water conservation information (http://www.basalt.net/water_conservation.pdf), and has a watering pamphlet (http://www.basalt.net/water_pamphlet.pdf). Appendix 3.1.3 provides more information about these water suppliers. The Basalt Water Conservancy District (BWCD) serves all of the unincorporated areas in the sub-watershed outside of the White River National Forest (Figure 2.1), and is discussed in more detail in Chapter 2. Several wastewater treatment plants (WWTP) and a metropolitan district serve the area. WWTP are located at Basalt, Carbondale, The Ranch at Roaring Fork, Sopris Village, El Jebel Mobile Home Park, and the Mid-Valley Metropolitan District (Figure 4.3.5). More information about these treatment plants can be found in the 2002 Roaring Fork Watershed Plan done by NWCCOG.

Mining

Table 4.3.1 lists the permitted active and inactive mines in the sub-watershed, including two active sand and gravel mines.

Table 4.3.1. Mine sites in the Lower Middle Roaring Fork Sub-watershed. Source: Colorado Division of Reclamation Mining and Safety. No date.

SITE NAME	STREAM	SIZE	COMMODITY	STATUS	PERMIT ISSUED
Powers Pit	Roaring Fork River	93.9 acres	Sand and gravel	Active	11/19/1980
Blue Pit	Roaring Fork River	82.69 acres	Sand and gravel	Active	3/8/1982
Blue Lake Development	Roaring Fork River	2 acres	Gravel	Application withdrawn	n/a
Blue Lake Pit	Roaring Fork River	31 acres	Sand and gravel	Terminated	5/14/1984
Grants Pit	Roaring Fork River	35.4 acres	Sand and gravel	Application withdrawn	n/a
El Jebel-BLM Site	Roaring Fork	6 acres	Sand and gravel	Terminated	6/18/1987
Gravel Pit	Roaring Fork River	70 acres	Sand and gravel	Application withdrawn	n/a

Recreation Activities

According to the Southwest Paddler website, the prime rafting season in this section of river is April to August, depending on the snowpack (http://www.southwestpaddler.com/). A quote from the website states: “This section of the Roaring Fork does not roar as much as it purrs” (http://southwestpaddler.com/docs/roaring5.html). It is popular for commercial raft trips, which put in at the boat ramp upstream of Hook’s Bridge. See Figure 1.11 for a map of commercial rafting and kayaking reaches in the Roaring Fork Watershed. For each reach, Appendix 3.1.6 lists the classes, and minimum, maximum, and optimum flow levels. Basalt is currently discussing the location of a whitewater park in the Basalt area (Urquhart, 2008).

The Roaring Fork River in this middle part of the valley is classified by CDOW as "Gold Medal" water, linking the Gold Medal waters of the Fryingpan River and lower Roaring Fork. According to the "Flyfishing Guide for the Roaring Fork Valley" (Shook, 2005), this section of river has very few public access points but offers a great float trip. It contains large concentrations of good-sized rainbow and brown trout, as well as mountain whitefish.

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams and lakes in the sub-watershed have been stocked with the species listed (Table 4.3.2).

Table 4.3.2. Species stocked by the CDOW in streams and lakes of the Lower Middle Roaring Fork Sub-watershed.

STREAM/LAKE	SPECIES
Roaring Fork River	Colorado River cutthroat trout, rainbow trout, brown trout, and Tasmanian rainbow trout
Sopris Creek	Brook trout
East Sopris Creek	Colorado River cutthroat trout, and Pikes Peak cutthroat trout
Lake Christine	Rainbow trout
Dinkle Lake	Rainbow trout
Hardscrabble Lake	Colorado River cutthroat trout and Pikes Peak cutthroat trout
Williams Lake	Brook trout and Colorado River cutthroat trout

4.3.3 Resource Information

Several research studies and syntheses of information have been done in the Lower Middle Roaring Fork Sub-watershed, providing data on stream flows, groundwater sources, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in this sub-section. For background information on the data sources, please refer to Chapter 3.

Water Quantity

Surface Water

The single active stream gage in this sub-watershed, the Roaring Fork River at Emma gage, began operation in 1998. A gage once operated in the sub-watershed on West Sopris Creek. Specific information about these gages can be found in Figure 4.3.3 and Appendix 3.1.1.

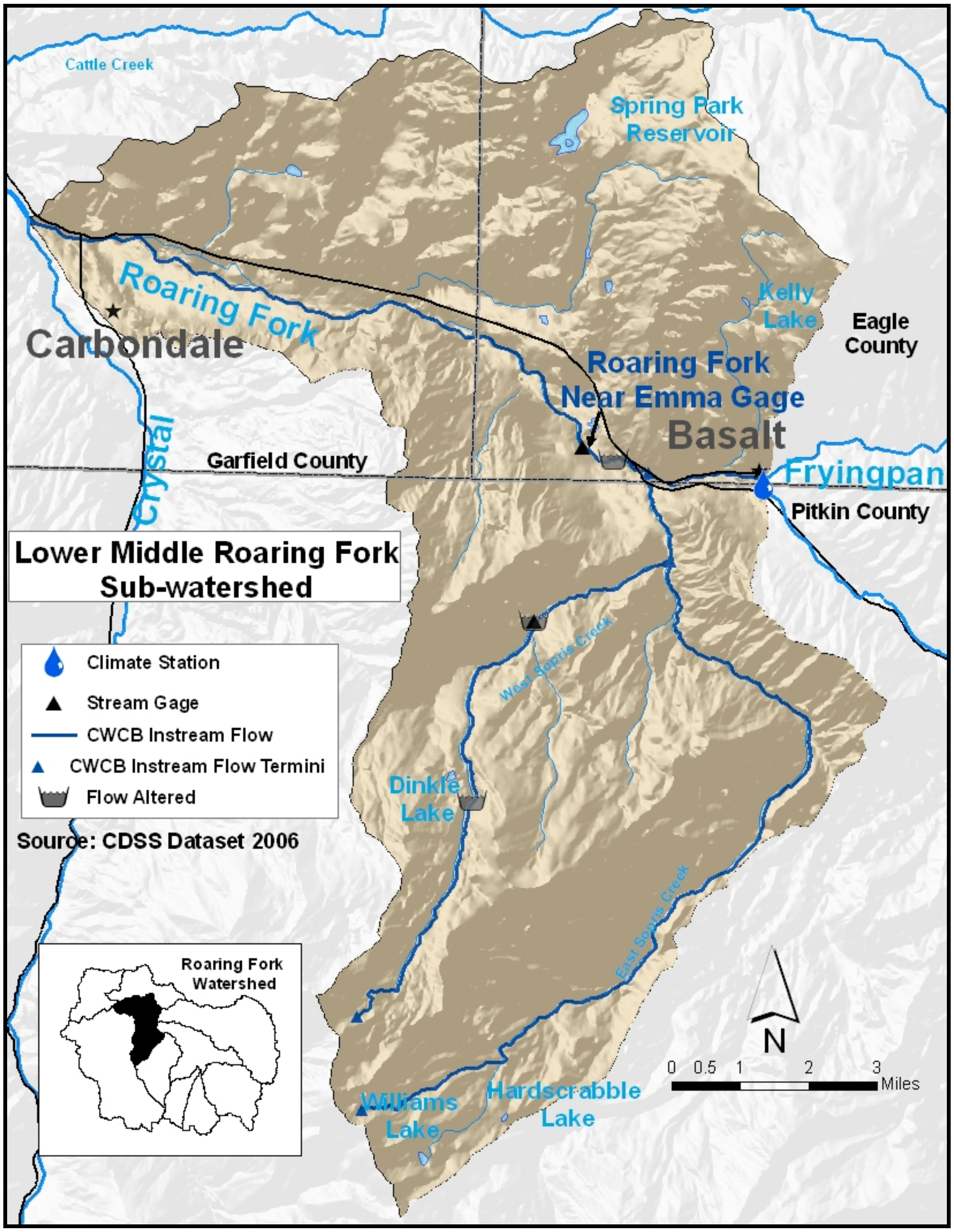


Figure 4.3.3. Water features in the Lower Middle Roaring Fork Sub-watershed.

Flow alteration was assessed using the Upper Colorado River Basin Water Resource Planning Model dataset (CWCB and CDWR, 2007a). The modeling accounts for diversions over 10 cubic feet per second (cfs). These data are available for three nodes in the sub-watershed: Roaring Fork River/Robinson Ditch, West Sopris Creek/Mount Sopris Ditch, and West Sopris Creek near Basalt (Figure 4.3.3 shows the locations of these nodes, depicted with the symbol for “flow altered”). Appendix 3.1.2 and figures 3.1.4 - 3.1.6 show to what extent flows at nodes in the sub-watershed have been altered.

Figure 4.3.4 shows the locations of the diversions and wells in the sub-watershed. Thirteen of the diversions have a decreed capacity greater than 10 cfs (Table 4.3.3).

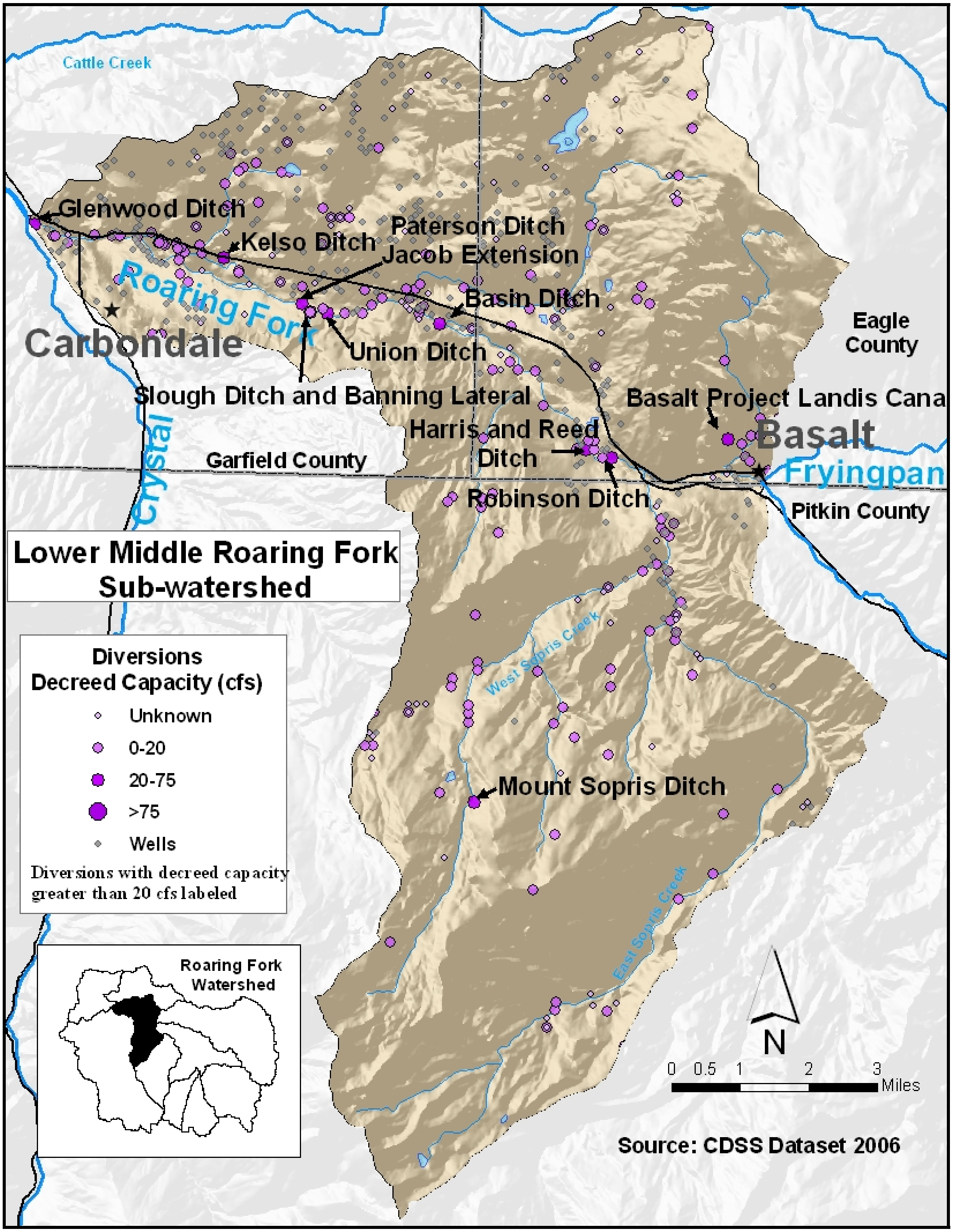


Figure 4.3.4. Diversions and wells in the Lower Middle Roaring Fork Sub-watershed.

Table 4.3.3. Diversions in the Lower Middle Roaring Fork River Sub-watershed greater than 10 cfs. Source CDSS GIS Division 5 diversion data, 2006.

STREAM	DITCH	DECREED CAPACITY
West Sopris Creek	Mount Sopris Ditch*	41.00
West Sopris Creek	Sloss Ditch*	12.66
West Sopris Creek	Shippee Ditch*	13.46
Roaring Fork River	Robinson Ditch*	49.30
Roaring Fork River	Harris and Reed Ditch*	23.55
Roaring Fork River	Basin Ditch*	45.00
Roaring Fork River	Union Ditch*	31.00
Roaring Fork River	Slough D and Banning Lateral*	49.26
Roaring Fork River	Paterson D Jacob Ext*	63.00
Roaring Fork River	Bailey BC P&PL	15.00
Roaring Fork River	Oxford No 1 Ditch*	12.00
Roaring Fork River	Crane and Peebles Ditch*	11.18
Blue Creek	Johnson Blue Cr Ditch*	12.00

* Used in CDSS modeling.

The Roaring Fork/Robinson Ditch node is located on the Roaring Fork River below its confluence with the Fryingpan River and above many of the large diversion structures in the sub-watershed. At this node, flows were significantly reduced in May, June, and July and increased from November to March. The flow reduction in spring and early summer translates to a decrease in small flood frequency. Under pre-developed flow conditions small floods would be expected to occur in four out of 10 years; such small floods would be expected in less than two out of 10 years with developed flow conditions.

At both nodes on West Sopris Creek, reduced flows occurred from April through October, with a small reduction in the number of small floods. At the lower node, small floods would be expected to occur in about four out of 10 years with pre-developed conditions compared to three out of 10 years under developed flow conditions. Water from the Mount Sopris Ditch is stored in Dinkle Lake and subsequently delivered to Prince Creek.

There are two direct-flow conditional water rights greater than 10 cfs (Table 2.4), both on the Roaring Fork River (Crane and Peebles Ditch and Glenwood Ditch).

Four Colorado Water Conservation Board (CWCB) instream flow rights (ISFs) are within this sub-watershed, one each on East Sopris, West Sopris, and Sopris creeks and one on the mainstem of the Roaring Fork River from the confluence of the Fryingpan River to the confluence of the Crystal River. According to the Stream Flow Survey Report (Clarke, 2006), the ISF on the Roaring Fork River was met throughout the year.

Groundwater

The Eagle Basin Bedrock Aquifer underlies all of this sub-watershed. The Roaring Fork River Alluvial Aquifer is found in areas adjacent to the Roaring Fork River and lower Sopris Creek. Figure 4.3.4 shows the locations of decreed and other wells in the sub-watershed. A number of wells are located along the Roaring Fork River and in the Missouri Heights area.

Graham Gilbert of Resource Engineering, Inc. (personal communication, December 11, 2007) provided key conclusions from Phase I of the BWCD's Missouri Heights Groundwater Monitoring Program. Although existing data were sufficient to draw the following conclusions about the regional aquifer, data limitations precluded more detailed conclusions. Phase I conclusions include:

- Trans-basin diversions from Cattle Creek play a significant role in maintaining the Missouri Heights aquifer;
- Irrigated agriculture acreage decreased by about 16 percent between 1993 and 2000 and, as a result, diversions from Cattle Creek ditches may be decreasing1.
- Variations in the regional groundwater table are strongly correlated to natural climatic fluctuations; and
- Water levels in the regional Missouri Heights aquifer have not shown a distinct downward trend in response to steady development, but may show a slight decrease in average water level.

More information about these conclusions can be found in Appendix 4.3.1. The BWCD plans to initiate Phase II in the spring of 2008. The objectives of this phase are to address data limitations identified in Phase I and to develop a more detailed understanding of the Missouri Heights aquifer. To accomplish this, BWCD plans to establish six new well study sites and install a remote precipitation gage. Data will be collected at these sites for five years and, at the end of the study period it will be analyzed and summarized in a report that will provide a technical basis for water rights administration and land use planning on Missouri Heights (Graham Gilbert, Resource Engineering, Inc., personal communication, March 17, 2008).

[1] According to Bill Blakeslee (CDWR, Division 5, Water Commissioner, personal communication, May 5, 2008) irrigated acreage has increased dramatically in the last six to eight years, so diversions are not decreasing.

Water Quality

Author: U.S. Geological Survey

Within the Lower Middle Roaring Fork Sub-watershed, data have been collected at 38 water quality-sites dating as far back as 1963. There are 19 stream sites, 15 groundwater sites, and 4 point source (mine or effluent) sites. Streams with at least some historical data include Sopris Creek (East and West Fork and mainstem) and the Roaring Fork River from the confluence with the Fryingpan River to the confluence with the Crystal River. Stream reaches with recent data were Sopris Creek and sites along the Roaring Fork. Data from 1996 to 2006 from the following sites were used to represent water-quality conditions in the sub-watershed:

- Roaring Fork River at Midland Ave Bridge (Site 15)
- Sopris Creek (Site 16)
- Roaring Fork River at Emma (Site 17)
- Roaring Fork River near Emma, CO (Site 18)
- Roaring Fork River at Catherine Bridge (Site 19)
- Roaring Fork River at Ranch (Site 20)

These sites are shown in Figure 4.3.5 along with locations and information about water and wastewater treatment facilities. For each site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

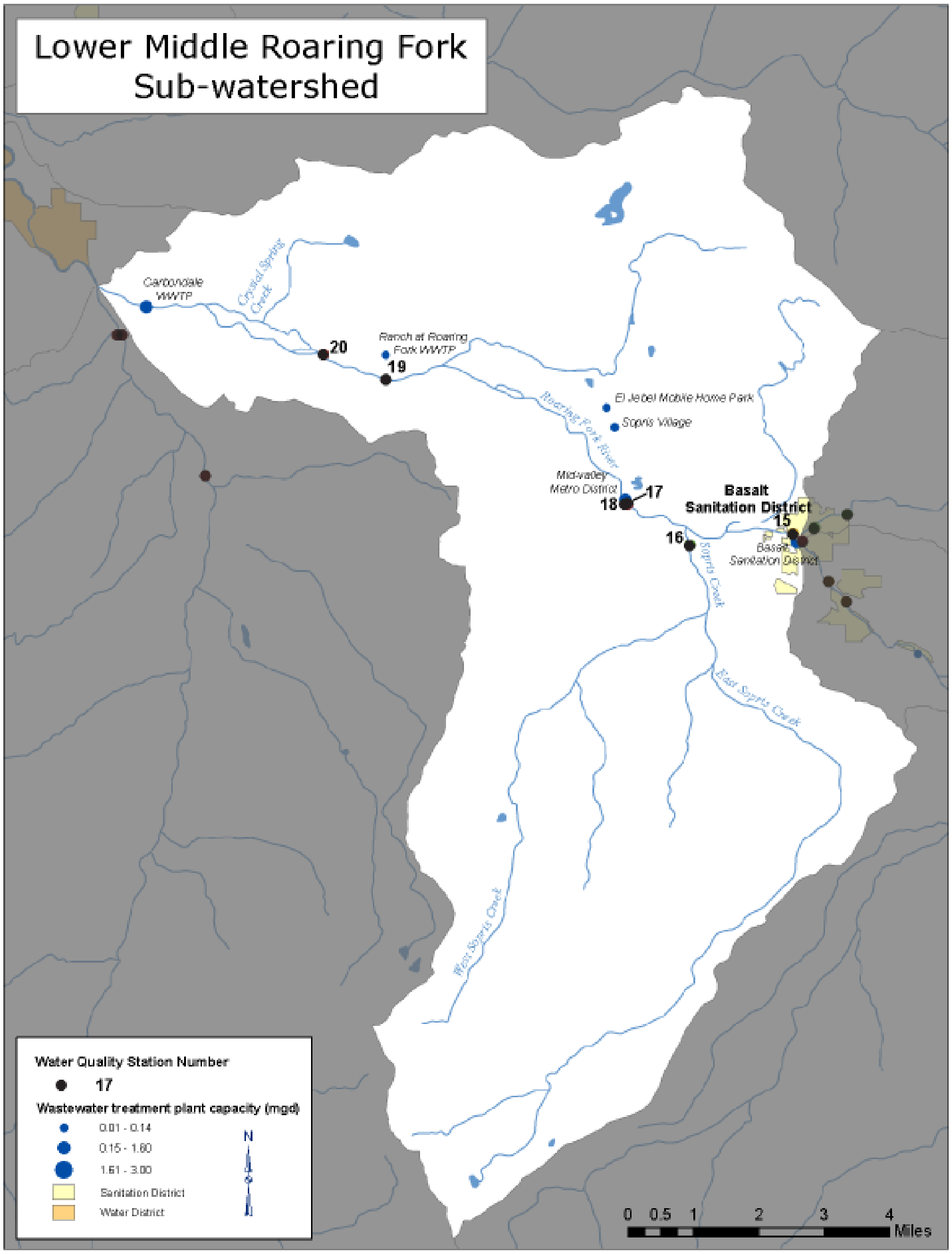


Figure 4.3.5. Water-quality sites and wastewater treatment providers within the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and CDOLA, No date b.

Site 18 is currently being monitored by the U.S. Geological Survey for both water quality and continuous stream flow. The Colorado River Watch Program is currently monitoring water quality at Site 17. For the purposes of analysis, sites 17 and 18 were not combined; however, given their close proximity, water-quality conditions observed for one of these sites suggests similar water-quality conditions for the other.

All six sites had field parameters collected during water-quality sampling. pH results exceeded the water quality standard at sites 17 and 20. Eleven of 101 pH results exceeded water quality standards at these two sites, with most exceedances occurring in March from 2001 to 2004. The median pH value at Site 17 was 8.44 and the median pH value at Site 20 was 8.51. pH results that exceeded the standard ranged from 9.04 to 9.39. The higher pH results are probably either related to pH results observed upstream in the Upper Middle Roaring Fork Sub-watershed or to the sub-watershed's geology.

As mentioned previously, a more restrictive chronic water temperature standard (18.2°C) (64.8°F) is in effect for the Roaring Fork River from the confluence with the Fryingpan River to the confluence with the Colorado River. In this sub-watershed, only Site 17, Roaring Fork River at Emma, had water temperatures in exceedance of this standard. Four exceedances were observed in June and July of 2001 through 2003.

Specific conductance concentrations were limited to Site 18, ranging from 200 to 435 mg/l with a median concentration of 356 mg/L. Geologic structures like the Carbondale collapse center, a large-scale evaporite-related collapse near Carbondale, can in part be delineated by observed increases in specific conductance in this area of the Roaring Fork Watershed and increases in salt loads are attributed to groundwater discharge into the river (Kirkham et al., 1999). These factors probably contribute significantly to the median specific conductance observed at Site 18 as well as total dissolved solids and hardness concentrations in the sub-watershed.

Site 19, Roaring Fork River at Catherine Bridge, had 23 dissolved oxygen concentrations that ranged from 3 mg/L to 8 mg/L, with a median of 5 mg/L. Data collected at site 19 are from 1996 to 1997 and additional data would be needed to establish current dissolved oxygen concentration conditions. Aside from Site 19, dissolved oxygen concentrations indicate well-oxygenated conditions at all other sites. Dissolved oxygen concentrations (a total of 193 values) at all other sites ranged from 6 mg/L to 14.9 mg/L, and median concentrations ranged from 8.8 mg/L to 10 mg/L.

Major ion data at Site 18 indicate a predominately calcium bicarbonate water type (see Appendix 3.2.2, Figure 2, tri-linear plot), which is generally consistent with the geology in the sub-watershed (Apodaca et al., 1996). Thirty-eight chloride concentrations ranged from 0.94 mg/L to 4.5 mg/L and 38 sulfate concentrations ranged from 35.5 mg/L to100 mg/L. Hardness concentrations indicate hard to very hard water (Hem, 1985) with values ranging from 91 mg/L to 316 mg/L and median concentrations ranging from 157 mg/L to 230 mg/L. Site 16, Sopris Creek, had the highest median hardness.

Nutrient data were limited to Site 18. From 1998 to 2006, 56 nutrient samples for ammonia, nitrate, nitrite, total nitrogen, total phosphorus, and orthophosphate were observed to be generally low and did not exceed nutrient water quality standards or criteria. Nitrate concentrations were less than 0.325 mg/L, nitrite concentrations were less than 0.01 mg/L, and total phosphorus was less than 0.06 mg/L.

Trace element concentrations did not exceed Table Value Standards (TVS). Because TVS for trace elements are based on hardness concentrations, the high hardness concentrations observed in the sub-watershed result in high TVS for trace elements. In 151 cadmium concentrations, no exceedances occurred. Of the 153 copper concentrations, 95 were censored, and uncensored copper concentrations ranged from 0.43 µg/L to 3 µg/L. Total recoverable iron was detected in 179 of the 180 results, with concentrations ranging from <10 µg/L to 740 µg/L. Median total recoverable iron ranged from 41 µg/L to 272 µg/L. Of the 153 lead concentrations, 140 were censored. Of the 155 manganese concentrations, 116 were censored, and manganese concentrations ranged from <10 µg/L to 18.8 µg/L. Of the 152 selenium concentrations, 108 were censored, and selenium concentrations ranged from 0.21 µg/L to 4.6 µg/L. Of the 151 zinc concentrations, 136 were censored.

Microorganism data were available for Site 18. The fecal coliform standard was exceeded by an order of magnitude for a single fecal coliform concentration (1000 CFU/100 mL) in November 2000.

Riparian and Instream Areas

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed the Roaring Fork River in this sub-watershed. Figure 4.3.6 shows specific riparian and instream information, by habitat quality category, for each reach assessed. The habitat quality categories are shown in the riparian and instream assessment charts found in Section 3.3 and Section 3.4. Appendix 3.3.1 contains the actual percentage values for each of these categories by sub-watershed and how they were determined. In the sub-watershed there is one stream segment:

- Roaring Fork Segment – Roaring Fork River from the Fryingpan River to the Crystal River, SHI reaches RF5-4 through RF6-1; 13.07 miles.

What follows is a brief description of results. The SHI report contains detailed narrative description. “Right bank” and “left bank” refer to the orientation of the riparian zone when facing downstream.

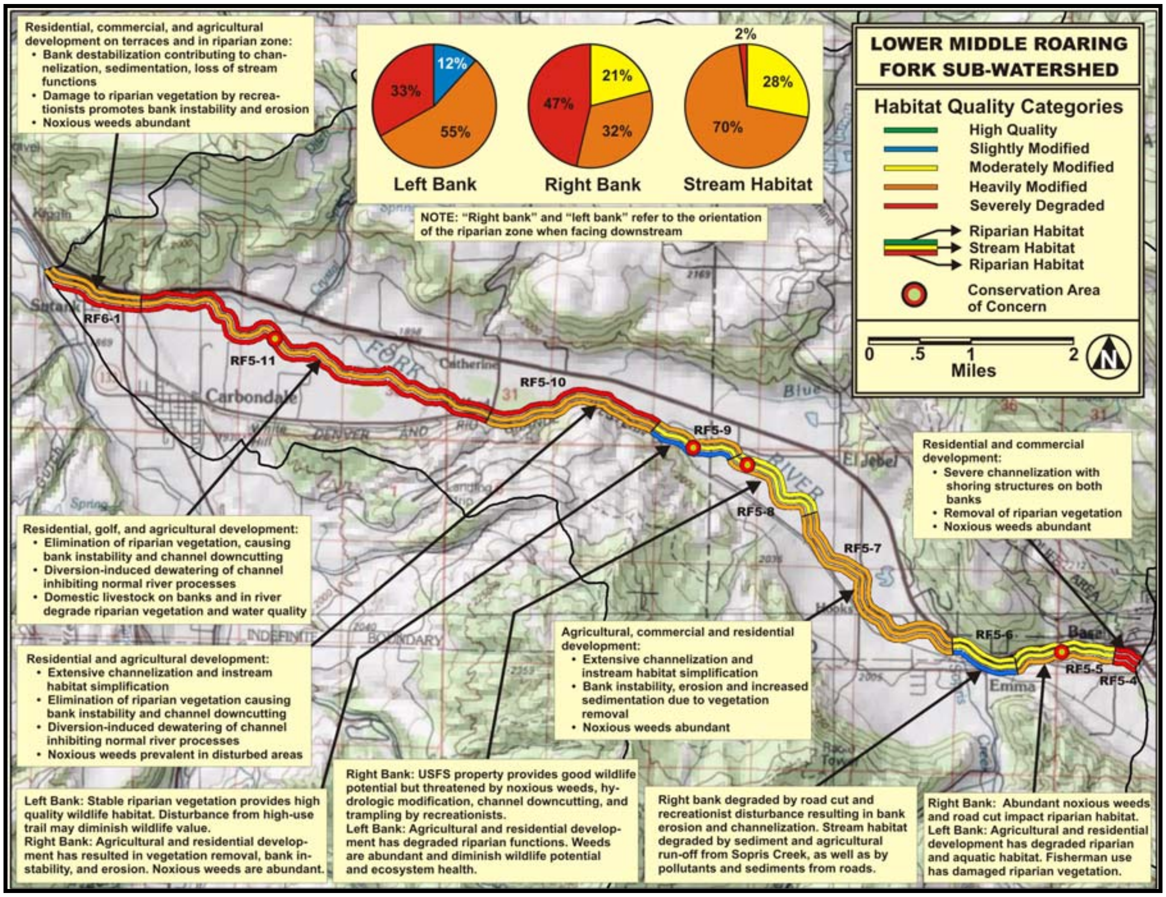


Figure 4.3.6. Riparian and instream habitat quality for the Lower Middle Roaring Fork Sub-watershed.

Uplands

Within the sub-watershed's upland areas large areas of natural meadows, woodlands, and forests have been replaced with pastures, roads, housing, and commercial development. Results include loss of ecosystem functions such as precipitation absorption and storage, and soil conservation. Grazing by domestic livestock on surrounding hills and in floodplains has degraded native habitat by altering native vegetation structure and composition, and compacting soils. Gambel oak and pinyon-juniper woodlands still have good representation on the surrounding hillsides, however those areas that are not protected with conservation easements or designated as protected public lands are rapidly being replaced with housing developments. Several bird surveys done within the sub-watershed have documented important bird communities and vulnerable species in high quality upland habitat areas within the sub-watershed, including pinyon jay (Vidal and Fidel, 1997), Brewer's sparrow (Vidal and Fidel, 1997; Malone and Emerick, 2007a), and Virginia's warbler (Malone and Emerick, 2007a).

Riparian Habitat and Wildlife

In this sub-watershed, no high quality riparian habitat remains. On the right bank of the river, 21 percent is moderately modified, 32 percent heavily modified, and 46 percent severely degraded. On the left bank 12 percent is slightly modified, 55 percent heavily modified, and 33 percent severely degraded.

Riparian areas have been used extensively for domestic livestock grazing, transportation corridors, recreation, and residential development. Most of the native riparian habitat has been altered, replaced, or covered over with pastures, lawns, buildings, and roads (Figure 4.3.7). Table 4.3.4 summarizes various impacts to the sub-watershed's riparian and stream habitats.

Figure 4.3.7. Removal and replacement of native riparian vegetation.

Table 4.3.4. Summary of land development impacts and threats to riparian and instream habitat in the Lower Middle Roaring Fork Sub-watershed's surveyed reach.

LOWER MIDDLE ROARING FORK SUB-WATERSHED	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	RIGHT BANK
Total Stream Miles: 13.07	24%	3%	58%	8%	57%	53%

More than 50 percent of the Roaring Fork River segment in this sub-watershed is impacted by development. In many areas historic agricultural land has been replaced with rural or urban housing development. Small ranchettes and subdivisions with golf courses border much of the river. Higher housing density has increased impacts to riparian and stream habitat. Lawns often go to the river's edge, and most of the understory has been removed in many reaches including RF5-4, 5-7, 5-9, 5-11, and 6-1. In reaches RF5-4, 5-5, and 6-1, road-based pollutants and sediment move into the river unfiltered by riparian vegetation, and culverts drain road runoff directly into the river. In developed areas, riparian zone width and percentage of native vegetative cover typically has been reduced. In residential areas the composition of the plant community has been altered through the replacement of native plants with non-native plants. Riparian and stream habitat in reaches RF5-5, 5-6, 5-10, and 5-11 continue to be impacted by livestock grazing in the riparian zone and on streambanks. In some areas, plant diversity has been reduced because cattle select palatable plants like willow over unpalatable ones such as snowberry. Vegetation damage by anglers and boaters is common in the few areas of natural habitat that remain on this segment, including parts of stream reaches RF5-5, 5-6, 5-9, and 5-11.

Narrowleaf cottonwood trees are a dominant structural component of native riparian woodland habitat throughout the Roaring Fork segment. Channel alteration in combination with diversion-induced flow alteration has reduced cottonwood recruitment to replace the ageing stand. Only remnant stands of mostly old and dying cottonwood remain along most of the segment. In areas where the water table has been lowered due to land use changes and channel and flow alterations, drought-tolerant and upland plant species have invaded. Weeds are abundant and have typically invaded disturbed areas where native vegetation is damaged or bare soil is present.

The degraded condition of woodlands and shrublands along much of this segment, including both banks of reaches RF5-4, 5, 7, and 11, and 6-1, also greatly diminishes wildlife potential. Essential terrestrial wildlife resources are reduced or eliminated wherever development has removed or degraded native plant species and reduced the diversity of the habitat structure (horizontal layers of shrubs and vertical patch diversity). Additional loss of wildlife potential results from roads, noxious weeds, lack of tree and shrub regeneration, and recreational disturbance. Scattered throughout the river corridor are a few remnant natural areas where native vegetation is healthy. These natural patches provide good potential for native wildlife not needing large landscapes, especially birds, small mammals, amphibians, and reptiles. They can be found on the left bank of reaches RF5-6, and 5-9, and on the right bank of RF5-8 and parts of RF5-5 (Figure 4.3.8) and 5-11. Additional high quality habitat is present on mid-channel islands. The left bank of RF5-10 is recovering from channelization that occurred with the building of the railroad grade, as shown by the development of well-vegetated riparian benches within the incised channel. These higher quality areas are threatened by noxious weeds and recreational disturbance.

Figure 4.3.8. Riparian habitat at the USFS Tree Farm on the right bank of reach RF5-5 provides good wildlife potential.

Several studies have assessed biological diversity in this sub-watershed including the Colorado Natural Heritage Program (CNHP), the SHI, and the Roaring Fork Valley Bird Monitoring Project. CNHP identified two riparian Potential Conservation Areas (PCAs) (Figure 3.3.2 and Appendix 3.3.2) because of their biodiversity significance: The Ranch at Roaring Fork (RF5-11), and several reaches on the Roaring Fork near the unincorporated neighborhood of El Jebel (RF5-7, 8, and 9). The Ranch at Roaring Fork was cited as having “one of the largest good condition riparian areas observed in the lower Roaring Fork Watershed,” as well as other elements of concern. A globally-vulnerable riparian plant community occurs in the El Jebel PCA (narrowleaf cottonwood/thinleaf alder). This area is referred to as the USFS “Tree Farm” and restoration activities began in 2007 by constructing 90 feet of boardwalk to protect wetland habitats (USFS,

2006) (Figure 4.3.9). Additionally, a great blue heron nesting colony occurs in reach RF5-9. Because great blue herons are known to abandon nests in response to increased human presence, road building, and logging activity, CNHP has recommended a minimum buffer zone of 300 meters (1000 feet.) where no human activity would take place during the heron courtship and nesting season (Spackman et al, 1999), which in this sub-watershed, typically begins in mid-April and extends through the end of July. CNHP also identified noxious weeds and residential and recreational development as threats to both areas and recommended weed control and restricted recreation access to preserve their biodiversity. In 2006 Audubon Colorado designated Spring Park Reservoir as an Important Bird Area, based on its impressive concentrations of migratory waterfowl. Roaring Fork Audubon Society member Linda Vidal, who nominated the site, wrote in the application: “The reservoir is one of the most important migratory stop-over, resting, and feeding sites on the Western Slope” (Roaring Fork Audubon Society, 2007).

Figure 4.3.9. Boardwalk construction at the USFS Tree Farm to protect wetland habitats (Photo credit: Mark Lacy).

SHI identified four Conservation Areas of Concern (CAC) (Table 4.3.5), three of which correspond with CNHP PCAs - reaches RF5-8, RF-9, and areas within RF5-11. The fourth CAC is located on reach RF5-5, downstream of Basalt. As indicated by vegetation assessments and breeding bird surveys, each of these areas has good wildlife potential, diverse layers of native shrubs and trees of all age classes, and a relatively high diversity of breeding Neotropical migrant songbirds. However, SHI found habitat sustainability threatened by hydrologic modification, noxious weeds, and recreational disturbance.

Table 4.3.5. SHI Conservation Areas of Concern in the Lower Middle Roaring Fork Sub-watershed.

LOCATION	JUSTIFICATION
RF5-5	Mid-channel islands and adjacent upland habitat provide good wildlife potential. On the right bank, threats include abundant weeds, a roadcut, vegetation trampling by boaters and fishermen. On the left bank agricultural and residential development threaten wildlife values.
RF5-8	Diverse riparian habitat on the right bank provides good wildlife potential. Recreational disturbance to vegetation, hydrologic modification, channel downcutting, and weeds threaten wildlife values.
RF-9	The left bank has mostly recovered from historic railroad grade disturbance and, in combination with adjacent upland habitat, provides excellent wildlife potential. A high use, paved recreational trail and weeds threaten wildlife values.
RF5-11	Numerous undeveloped areas within this reach with stable banks harbor healthy riparian vegetation and provide high wildlife potential. Residential development, domestic livestock grazing, recreational disturbance, and weeds threaten wildlife values.

In high-quality riparian areas within this sub-watershed olive-sided and cordilleran flycatcher, osprey, great blue heron, and wintering bald eagles are important bird species that have been identified through bird surveys by the CDOW and SHI.

Instream Habitat and Wildlife

The stream morphology and type for the Roaring Fork segment (Rosgen and Silvey, 1996) is characterized by a Type C stream with two exceptions: where the river has cut into the river terrace in reach RF5-6 and 6-1, the river is a Type B stream; and in RF5-10 the stream is a Type F. Refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of these stream types.

According to the Roaring Fork and Fryingpan Rivers Multi-objective Planning Project (Multi-Objective Study) (BRW, Inc. et al., 1999), the lower Roaring Fork Valley is characterized by an alluvial floodplain through which the river widely meanders. The alluvium is derived from the collapse of surrounding geologic formations, and is thus unstable and adds to the river's instability. Active subsidence related to the dissolution of evaporitic rock promotes disequilibrium of the river channel. In these circumstances, native riparian vegetation is essential to channel stability. Numerous areas of channel instability were identified by the Multi-Objective Study. In the majority of these areas, channel instability has been exacerbated by alterations to bank stabilizing vegetation and channel morphology. Seventy percent of the stream channel in the Roaring Fork segment has been heavily modified by cumulative impacts of riparian and flow alterations, and hydrologic modifications. Natural river flows have been altered by diversions and wells (within the sub-watershed and upstream), by a reduction in beaver activity, and by a dramatic increase in the extent of impervious surfaces that has resulted from upland and riparian development. Agricultural, residential, and commercial development in the riparian corridor and floodplain has contributed to extensive channel alteration throughout the sub-watershed. Development-related vegetation removal has caused destabilized and eroding streambanks that have downcut, widened, and straightened the stream channel. Levees, streambank shoring structures, instream drop structures, bridge abutments, and roads adjacent to the river are common. These channel-altering activities have further simplified stream habitat and diminished stream functions, including its ability to dissipate energy. This has led to increased bank erosion downstream. Sediment transport and sedimentation is excessive due to an imbalance between the amount of water and sediment in the stream. Because of the large contribution of sediment and the flow reduction caused by diversions, flow is insufficient to transport the sediment.

Higher quality aquatic wildlife habitat is found in areas where riparian vegetation and channel structure are intact, such as in reaches RF5-5, RF5-6, and RF5-9. In other reaches, aquatic wildlife habitat has been degraded by excessive sedimentation and embeddedness, inadequate availability and reduced quality of stream substrate, bank degradation, and flow alteration. Riparian degradation has reduced the amount of overhanging vegetation and destabilized undercut streambanks – habitat features that provide fish with protective cover. Channel alterations have resulted in a deficiency of stream substrate available for cover and colonization, excessive sedimentation and embeddedness, and channel simplification with suboptimal distribution of pools, riffle, and run habitat. Channel alterations such as drop structures and culverts have created barriers to fish migration. Flow modification has reduced the amount of habitat available to aquatic wildlife. The population of brown trout from Ruedi Dam to Glenwood Springs of which this sub-watershed stretch of the Roaring Fork River is a part, comprises the longest Gold Medal Fishery in the State.

Chorus frogs are abundant in wetland habitats in this sub-watershed.

4.3.4 Important Issues

Below is a summary of key findings from available scientific information, a listing of data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the sub-watershed's water resources.

Key Findings

- Compared with pre-developed flow patterns, the lower middle segment of the Roaring Fork River has a reduction in summer-month flows (May through July) and the number of small floods.
- Reduced flows occur in West Sopris Creek from April to October.
- The Colorado Water Conservation Board’s instream flows are met on the sub-watershed’s stretch of the Roaring Fork River throughout the year.
- Ruedi Reservoir releases increase late summer, fall, and winter flows, moderate water temperatures, and enhance fishing opportunities in the lower middle stretch of the Roaring Fork River.
- There are two direct-flow conditional water rights greater than 10 cfs in the sub-watershed.

- Compared with current state and national water quality standards, Sopris Creek has good water quality suitable for all uses.
- The sub-watershed generally has good water quality. pH was observed to exceed water-quality standards on the mainstem of the Roaring Fork River, specifically observations at The Ranch at Roaring Fork and Roaring Fork at Emma. Further analysis would be needed to understand the significance of these exceedances.
- More than 50 percent of the Roaring Fork River's riparian and instream habitats in this sub-watershed have been directly impacted by developed land use activities and the spread of weeds.
- Due to impacts of livestock grazing, transportation corridors, and recreational and residential development, no high quality riparian habitat was found in the surveyed parts of this sub-watershed. On the right bank, 78 percent of the riparian corridor is classified as either severely degraded or heavily modified, and 88 percent of the left bank is so classified.
- Olive-sided and cordilleran flycatcher, osprey, great blue heron, American dipper, and a wintering bald eagle population represent important species identified in high quality riparian areas in this sub-watershed.
- Throughout much of the sub-watershed, lack of sufficient flooding flows has resulted in a decline in cottonwood regeneration and, in combination with drying soils, has enabled the invasion of plants from adjacent upland communities including conifers such as Douglas fir, juniper, and shrubs like serviceberry and Gambel oak. Patches of healthy native riparian habitat can be found along the Roaring Fork River near El Jebel.
- The Colorado Natural Heritage Program (CNHP) identified two riparian Potential Conservation Areas (PCAs) based on their biodiversity significance: The Ranch at Roaring Fork, considered one of the largest good-condition riparian areas in the entire watershed; and several reaches near El Jebel, that include a great blue heron nesting colony and a globally-vulnerable riparian plant community (narrowleaf cottonwood/thin-leaf alder). Both of these areas are threatened by invasive weeds and residential and recreation development. The Stream Health Initiative identified four Conservation Areas of Concern (CAC), three of which correspond with CNHP PCAs. The fourth CAC is located downstream of Basalt.
- Spring Park Reservoir has been designated as an Important Bird Area by Audubon Colorado.
- Seventy percent of the stream channel assessed in this sub-watershed has been heavily modified because of hydrologic alteration and the effects of agricultural, residential, and commercial development within the riparian and flood plain zones. Higher quality aquatic habitat is found in those areas with intact riparian habitat and channel structure.
- The longest Gold Medal Fishery in the state occurs from Ruedi Dam to Glenwood Springs, including the Roaring Fork River segment in the sub-watershed. It is comprised mainly of brown trout. Brown trout populations have replaced rainbow trout because they are not susceptible to whirling disease.

Data Gaps

A number of gaps in information for the sub-watershed limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Stream flow gage data for East Sopris Creek, Sopris Creek, and the Roaring Fork River downstream of the Robinson Ditch;
- Information on the relationship between domestic wells and irrigation recharge in the Missouri Heights area;
- Recent water-quality data for the following constituents and constituent groups:
    - Dissolved oxygen for Site 19, Roaring Fork River at Catherine Store Bridge
    - Specific conductance – to aid in establishing sources of dissolved material and to help describe other water-quality conditions
    - Microorganisms – expand collection to other sites to establish potential for water-born disease (currently monitored at Site 18)
    - Suspended sediment – to evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals.
    - Emerging contaminants – to determine occurrence and relation to wastewater treatment plants, septic leachate, industrial discharges, recreation, and/or agriculture
- Recent groundwater-quality data;
- Upland habitat condition;
- Riparian and instream habitat condition in those areas not surveyed by SHI, including East Sopris, West Sopris, and mainstem Sopris creeks;
- Population status of breeding birds; and
- Information about upland and riparian mammal community diversity, amphibian and reptile populations, and population sustainability.

Relevant Local Initiatives, Plans, and Studies

- Prompted by significant flooding within the sub-watershed (as well as upstream of it) in 1995, the Roaring Fork and Fryingpan Rivers Multi-Objective Study (BRW, Inc., et al., 1999) was done to locate areas of high flood hazards, areas and causes of instability, and infrastructure at risk along the Roaring Fork River below Aspen and on the Fryingpan River below Ruedi Reservoir.
- A "Stormwater Evaluation and Recommendations Report" has been done for the Town of Basalt (Matrix Design Group, 2001), and contains recommendations for stormwater management improvements important for protecting water quality. The largest of the proposed actions, the Levinson Pond renovation (now known as Old Pond), has been completed.
- The Town of Basalt's River Master Plan process resulted in recommendations to address issues including public safety, infrastructure protection, river stability, and protection and restoration of the river environment.
- The Emma Caucus Area Master Plan Draft Existing Conditions Report is the first step in a five-part process of preparing a Master Plan and future land use strategy for the caucus area. Existing conditions are described for the natural environment (topography, soils, and geology; hydrology - water resources; vegetation; wildlife; visual quality; air quality; and wildfire); existing land use, zoning, and build-out estimate; roads and transportation; trails and recreation; and special districts, adjacent jurisdictions, and utilities.

4.4 Lower Roaring Fork Sub-watershed

4.4.1 Environmental Setting

The Lower Roaring Fork Sub-watershed extends from the Roaring Fork River's confluence with the Crystal River to its confluence with the Colorado River. Its elevation ranges from 5,717 to more than 10,000 feet, covering Foothill Shrublands, Sedimentary Mid-elevation Forests, and some Sedimentary Subalpine Forest ecoregions. It includes the wide river bottomland and terraces in the lower part of the Roaring Fork Watershed. A significant portion of the land adjacent to the river has existing or planned residential development. Golf courses and active or reclaimed gravel mining operations are also located on the terraces that parallel the river's course. Historically, the valley bottomlands were irrigated for livestock pasture and hay crops. The sub-watershed also includes the watershed's largest municipality, Glenwood Springs, situated in a narrow strip of the lower Roaring Fork Valley. Glenwood Springs is one of Colorado's oldest tourist towns; its hot springs, mild climate, and access to many surrounding attractions have drawn visitors for well over a century and close by is the Sunlight Mountain Resort. Given the sub-watershed's population growth and land use development, both encouraged by adequate buildable land and development- oriented zoning, the most immediate water resource issues are the effects of development on the availability and quality of water, and on riparian and instream habitat. See Figure 4.1 for an overview map showing the location of this sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions, and the sub-watershed's general physical characteristics are summarized in Table 4.1.

Topography and Geology

In addition to the Roaring Fork River, the sub-watershed includes several drainages. Fourmile Creek drains Sunlight Peak and Bald Mountain, both just over 10,000 feet; and Landis and Threemile creeks flow into the lower Roaring Fork River.

As shown in Figure 1.3 (the surface geology of the Roaring Fork Watershed), the geology of upper Fourmile Creek is comprised of Tertiary sedimentary rocks that extend into the upper Thompson Creek drainage. To the southwest of the Roaring Fork River, parallel ridges of the Maroon Formation and Mancos Shale, among other sedimentary deposits, comprise the Grand Hogback. This is where the small portion of the sub-watershed with slopes greater than 30 percent are found (Figure 1.4). According to a report on the critical landslides of Colorado (Rogers, 2005), the area adjacent to the lower Roaring Fork River near Glenwood Springs is listed as a tier one (the most severe) debris flow area. Glenwood Springs has been impacted by debris flows throughout its history, with more than twenty damaging events since 1900. Soils of the debris fans are generally subject to moderate to severe subsidence when saturated. The Bureau of Land Management designated parts of this area as the Glenwood Springs Debris Flow Hazard Zone Area of Critical Environmental Concern because of natural hazards (BLM, 2007). The headwaters of Landis Creek also contain a very large landslide deposit. Gravel and alluvium deposits are found along much of the lower Roaring Fork River where several gravel mines are located (Table 4.4.1).

Weather/Climate

The longest operating climate station in the Roaring Fork Watershed is in this sub-watershed. The Glenwood Springs #2 station (053359), at 5,750 feet in elevation, started collecting data in 1900 (http://www.wrcc.dri.edu/) (Figure 4.4.3). According to these data, average total annual precipitation during the period of record was 16.6 inches. Monthly precipitation amounts did not vary drastically. On average, April and September each received 1.6 inches of precipitation, and June and November each received about 1.1 inches of precipitation. Additional precipitation data exist for the seven active sites associated with the Colorado Collaborative Rain, Hail, and Snow Network in the sub-watershed (Appendix 1.2) (http://www.cocorahs.org/).

Biological Communities

Looking at the overall sub-watershed's wildlife communities, according to the Colorado Division of Wildlife (CDOW), Colorado River cutthroat (CRCT), brown, and rainbow trout; bluehead, white, and flannelmouth suckers; mountain whitefish; and mottled sculpin have been recorded in the sub-watershed (Harry Vermillion, CDOW, personal communication, March 2, 2008). It also contains distributions for two species designated by the state as threatened: the bald eagle and Northern river otter (Figures 3.3.5 and 3.3.3) although no confirmed records exist of otters in the lower Roaring Fork River in the recent past (John Groves, CDOW, personal communication May 2, 2008). Foraging and nesting areas for great blue heron and osprey are also located in this sub-watershed (Figures 3.3.4 and 3.3.3). Appendix 1.3 lists the riparian-related and instream species and communities of concern in the sub-watershed.

With specific focus on the lower Roaring Fork River corridor, native plant communities are characteristic of those found in the Upper Sonoran Life Zone. Uplands are dominated by a habitat of pinyon-juniper woodlands, sagebrush shrublands, and, on moister sites, Gambel oak shrublands.

Pre-development native riparian habitat is characterized by a mosaic of plant communities, each in a different successional stage. Along the banks of the river, narrow bands of cottonwood woodlands and shrub thickets border the stream at the base of canyon walls. On the occasional wide riparian bench, dense thickets of hawthorn, willow, and silver buffaloberry are interspersed with backwater ponds and sedge meadows. Mid-channel islands and point bars are dominated by dense willow carr stands that stabilize newly deposited soil. In wider canyon openings, overbanking flows and beaver activity combine to create diverse habitat mosaics of mixed ponderosa-cottonwood woodlands, cattail marshes, and sedge meadows. On sites with drier soils, non-willow riparian shrubs such as river hawthorn and silver buffaloberry form dense thickets. In this part of the sub-watershed, because of the impacts from various development activities, only a few small fragments of pre-development native riparian habitat remain. As with plant communities, wildlife communities within the lower Roaring Fork drainage have also been altered by development impacts. Over time, the river has cut down through upland geology to create the canyon in which it is confined, leaving behind fertile river terraces. Historically, these upland terraces provided winter range for herds of elk, summer habitat for mule deer, and breeding habitat for a large diversity of upland songbirds. Conversion to agriculture altered the environmental conditions and diminished wildlife potential, but still provided habitat for some native wildlife species. Recent conversion of the agricultural land to golf courses, residential development, shopping centers, and roads has eliminated most wildlife potential. In developed areas, human-tolerant mammal species such as raccoon and non-native bird species like the European starling have replaced native wildlife species.

Fourmile Creek traverses a wide range of life zones, ecosystems, and land use types. Headwater ecosystems are characteristic of the Lower Subalpine Life Zone. A mosaic of spruce-fir and aspen forest densely covers upland habitat, and riparian habitat here is characterized by wide willow carrs comprised of willow, bog birch, alder, and dogwood. Downstream, at an elevation of about 8,600 feet, the valley narrows and the riparian plant community is made up of a cascade of beaver ponds bordered by willow and alder thickets. A narrow zone of mixed spruce-fir and aspen forest occurs at the stream's edge. Adjacent upland habitat continues to be characterized by mixed aspen and spruce-fir forests

Further downstream in the Fourmile Creek drainage at elevations starting around 7800 feet, montane and lower montane ecosystems characterize plant communities. Upland habitats are dominated by aspen and mixed aspen-conifer forests on north-facing slopes and Gambel oak-serviceberry shrublands on south-facing slopes. Riparian habitat is comprised of narrowleaf cottonwood-blue spruce woodlands and riparian shrub thickets with homogenous patches of willow, alder, hawthorn and dogwood. In the lowest reaches, starting at elevations of about 7,200 feet down to the confluence with the Roaring Fork River at an elevation of approximately 5,850 feet, plant communities are characteristic of those in the Upper Sonoran Life Zone. Riparian habitat is narrowleaf cottonwood woodlands interspersed with riparian shrub thickets and beaver pond complexes bordered by willow and alder. Uplands are a patchwork of pinyon-juniper forests with sage and oak shrublands. Each of these areas and habitats has been altered, some more severely than others.

4.4.2 Human Influences

Land Ownership and Use

Figure 4.4.1 shows ownership and protection status for the Lower Roaring Fork Sub-watershed. The upper Fourmile Creek drainage is located within the White River National Forest, which is managed by the U.S. Forest Service (USFS). The rest of the sub-watershed contains a mixture of private land and public land managed by the Bureau of Land Management. A list of open space parcels in this sub-watershed can be found in Appendix 4.1.

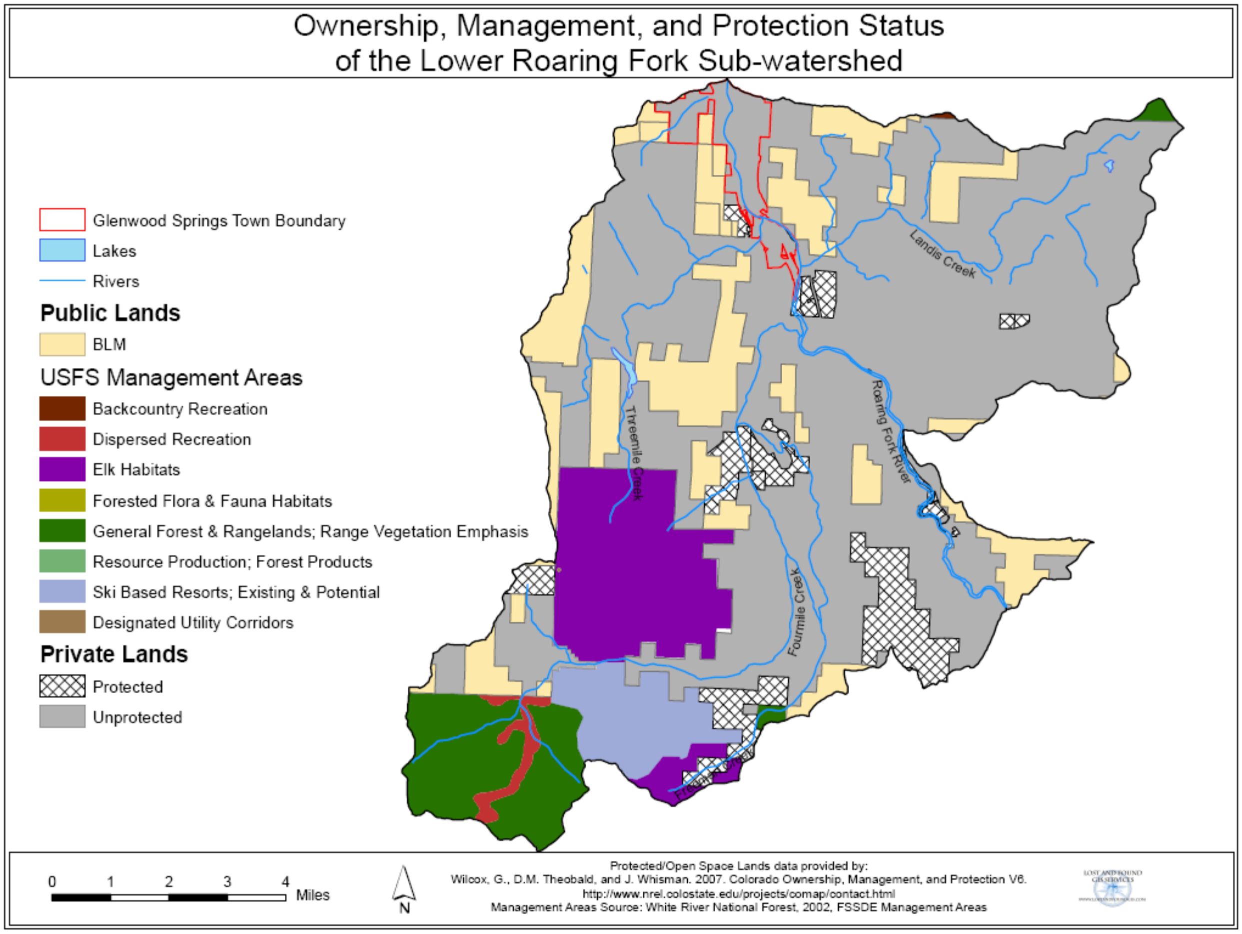


Figure 4.4.1. Ownership and protection status for the Lower Roaring Fork Sub-watershed.

Almost the entire sub-watershed is located within Garfield County, with a very small part of the headwaters of Fourmile Creek in Pitkin County. A map of zone districts in Garfield County found on the county's website (http://www.garfield-county.com/Index.aspx?page=991) highlights the development pressure facing lands adjacent to the Roaring Fork River and Fourmile Creek, as well as above the valley floor on Missouri Heights. For much of its length in this sub-watershed, the Roaring Fork River is flanked by planned developments or planned unit developments (PUDs) or is adjacent to the urban development of the Glenwood Springs. Several PUDs are also located along Fourmile Creek, as is a proposed expansion of the Sunlight Ski Area, which is discussed in more detail in the recreation section. Irrigated agriculture is found along parts of the lower Roaring Fork River, and Fourmile and Landis creeks (Figure 1.16). Most of the decline in irrigated agriculture from 1993 to 2000 has occurred along the Roaring Fork.

Figure 4.4.2 shows roads within the sub-watershed and identifies roads within 150 feet of second order and higher streams (approximately 25 percent of these streams). Colorado Highway 82 parallels the northeast bank of the Roaring Fork River through all of this sub-watershed. County roads follow Landis, Fourmile, and Threemile creeks. Along Fourmile Creek, above Sunlight Mountain Resort, the road becomes a USFS road.

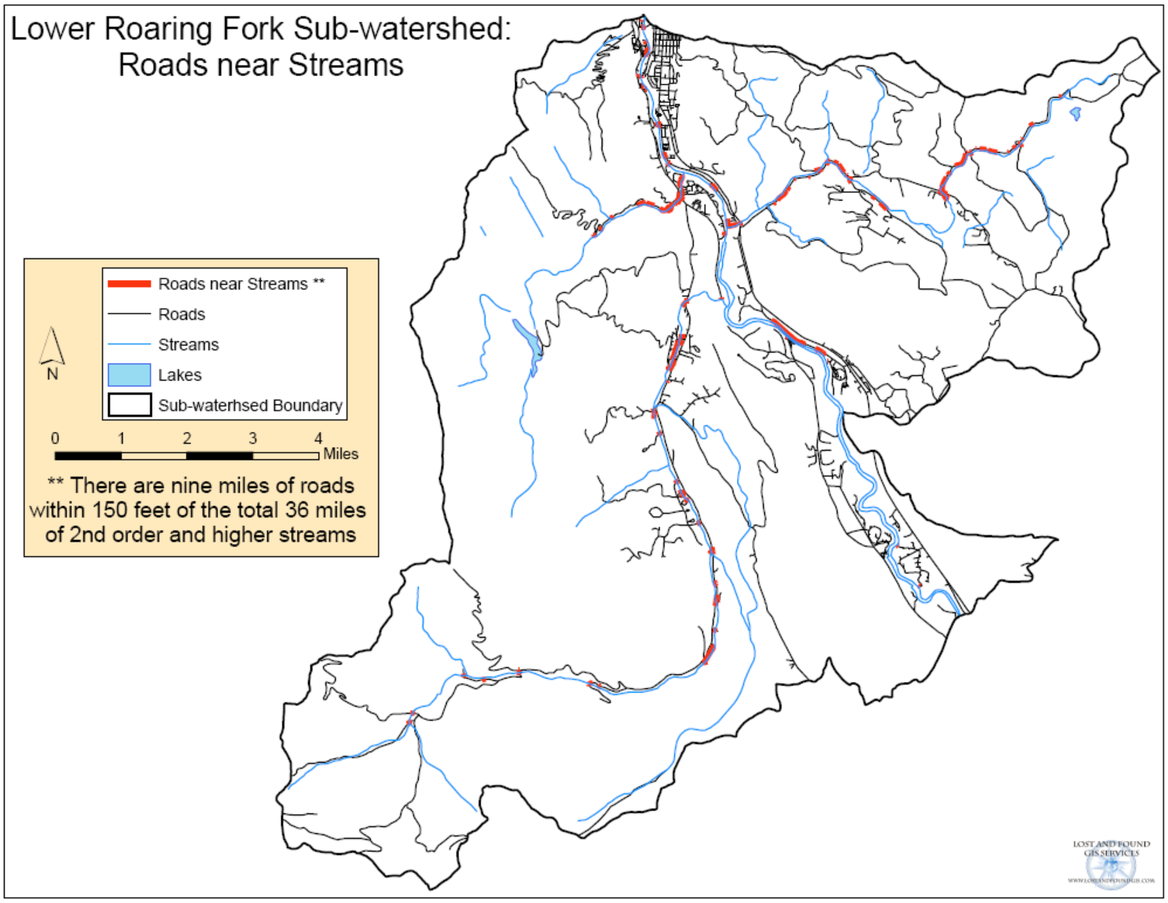


Figure 4.4.2. Roads near streams in the Lower Roaring Fork Sub-watershed.

Situated at the confluence of the Roaring Fork and Colorado rivers, Glenwood Springs occupies an area of just over 4.8 square miles. It obtains the majority of its municipal water supply from sources outside the Roaring Fork Watershed, including No Name and Grizzly creeks which are tributaries of the Colorado River. If these primary systems are out of service, the city has an emergency pump station on the Roaring Fork River near the 7th St. Bridge with a maximum design flow of five million gallons per day. The Roaring Fork Water and Sanitation District provides water and wastewater services for the Aspen Glen, Coryell Ranch, Midland Point, and Ironbridge developments. This water is obtained from five wells in the Roaring Fork Aquifer. More information about this water provider can be found in Appendix 3.1.3. For the unincorporated section of the sub-watershed, the Basalt Water Conservancy District serves the eastern part and the West Divide Water Conservancy District the western part (Figure 2.1). More information about these conservancy districts can be found in Chapter 2. Glenwood Springs, Aspen Glen, H Lazy F Mobile Home Park, Spring Valley Sanitation District, El Rocko Mobile Home Park, and Ski Sunlight all have wastewater treatment plants in the sub-watershed (Figure 4.4.7). More information about these treatment plants can be found in the 2002 Roaring Fork Watershed Plan done by Northwest Colorado Council of Governments.

In 2003, Glenwood Springs implemented a Water Conservation Plan to promote the efficient use of water through education, example, incentive, and innovation. The plan states that: “water conservation is a must in deferring major upgrades at the water and wastewater treatment facilities." To accomplish the plan's objectives, the city has created water conservation pamphlets outlining conservation measures that customers can implement to reduce their water bills. It also offers tours of the water treatment plant to classes in grades K-12 and at the college level. More information about the plan and other accomplishments can be found on the city's web site (http://www.ci.glenwood-springs.co.us/departments/publicworks/water/files/wtrconserv.pdf).

In 2003 a stormwater assessment and education report was completed for Glenwood Springs (Matrix Design Group, 2003). The report was prepared at the request of Roaring Fork Conservancy in cooperation with the Colorado Department of Public Health and Environment's Water Quality Control Division. The objective of the report was to evaluate nonpoint-source pollution to waterways, and develop an education project on the stormwater impacts to water quality in the Glenwood Springs area. The project provided the following tools to the city for management of stormwater runoff:

- GIS database of stormwater infrastructure,
- Electronic mapping of drainage basins,
- Identification and inventory of major storm drain outfalls,
- Field confirmation of stormwater outfalls,
- Recommendations for stormwater improvements and educational materials on nonpoint-source pollution.

In 1990 a River Management Plan was completed by Glenwood Springs' River Advisory Committee. The plan recommends specific actions under four topic areas: river awareness and education; river management policies; river rehabilitation and preservation; and river corridor recreation and open space development. The plan can be found in Appendix 4.4.1. The Glenwood Springs Comprehensive Plan (1998) recommends implementing the River Management Plan to re-establish a river system that provides balanced resources for the community and the environment, and improves the amount, quality, and accessibility of river access points.

Mining

Table 4.4.1 lists the permitted, active, and terminated mines in the sub-watershed.

Table 4.4.1. Mine sites in the Lower Roaring Fork River Sub-watershed. Source: Colorado Division of Reclamation Mining and Safety, No date.

SITE NAME	STREAM	SIZE	COMMODITY	STATUS	PERMIT ISSUED
Sievers Pit	Roaring Fork	122.9 acres	Sand and gravel	Active	6/30/1980
Jammaron Pit	Roaring Fork	35.4 acres	Sand and gravel	Terminated	11/5/1977
Otto Zinko Gravel Pit	Roaring Fork	5 acres	Sand and gravel	Terminated	9/5/1985
Sunlight-Archived Box 229	Fourmile Creek	unknown	Coal	Terminated	unknown
Sunlight Mine	Fourmile Creek	180 acres	Coal	Revoked	5/20/1985

Recreation Activities

No developed USFS campgrounds are in the sub-watershed.

Due to its modest gradient, the lower Roaring Fork River is most popular for boaters seeking a more leisurely type of experience, as well as for boaters who are also angling. The Southwest Paddler website (http://www.southwestpaddler.com/) attributes some of the popularity of the lower Roaring Fork to its longer season and its close proximity to Glenwood Springs. According to the Colorado River Outfitters Association (2007), the number of commercial user days on the lower Roaring Fork ranged from none in 2002 to 5,000 in 1995, with an average of 1,474 (Figure 1.12). See Figure 1.11 for a map of commercial rafting and kayaking reaches in the Roaring Fork Watershed. Appendix 3.1.6 lists the reaches and classes along with minimum, maximum, and optimum flow levels for each.

Many rafts and drift boats carry anglers seeking trophy-sized fish. The lower Roaring Fork River is the downstream end of the longest continual stretch of 'Gold Medal Water' in the state. The "Flyfishing Guide for the Roaring Fork Valley" (Shook, 2005) noted that the water is full of brown trout with some large rainbow trout and "thousands" of mountain whitefish. Shook also notes that the Crystal River sometimes blows out, leading to muddying of the lower Roaring Fork.

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams in the sub-watershed have been stocked with the species listed (Table 4.4.2).

Table 4.4.2. Species stocked by the CDOW in streams of the Lower Roaring Fork Sub-watershed.

STREAM/LAKE	SPECIES
Fourmile Creek	Brook trout
Threemile Creek	Rainbow trout
Roaring Fork River	Colorado River cutthroat trout, rainbow trout, and brown trout

Sunlight Mountain Resort, which includes a ski area, is located in the upper Fourmile Creek drainage. It currently obtains its water for snowmaking from Fourmile Creek. Plans are being discussed for an on-mountain development proposing 750 housing units, 100,000 square feet of commercial space, 10 acres of irrigated lawn and landscaping, and a snowmaking system to cover approximately 120 acres of skiable terrain. For reference, in 2004/2005 the resort made snow on approximately 20 acres. In order to provide water for this development, the resort has applied to Division 5 Water Court, requesting the court to: 1) confirm its conditional surface water rights for a diversion from the Roaring Fork River; 2) confirm its conditional storage water rights for the resort's five existing reservoirs and ponds; 3) approve its plan for augmentation; and 4) confirm exchanges of effluent discharges, irrigation return flows, and snowmaking runoff accruals to Fourmile Creek from water produced by the proposed diversions from the Roaring Fork River.

4.4.3 Resource Information

Several research studies and syntheses of information have been done in the Lower Roaring Fork Sub-watershed, providing data on stream flows, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in this sub-section. For background information on the data sources, refer to Chapter 3.

Water Quantity

Surface Water

The one active stream gage in this sub-watershed also has the longest period of record in the entire Roaring Fork Watershed (Figure 4.4.3). The Roaring Fork at Glenwood Springs gage has operated almost continuously since 1906. The other three stream gages in the sub-watershed are no longer in operation and operated for various time periods. Specific information about these gages can be found in Figure 4.4.3 and Appendix 3.1.1.

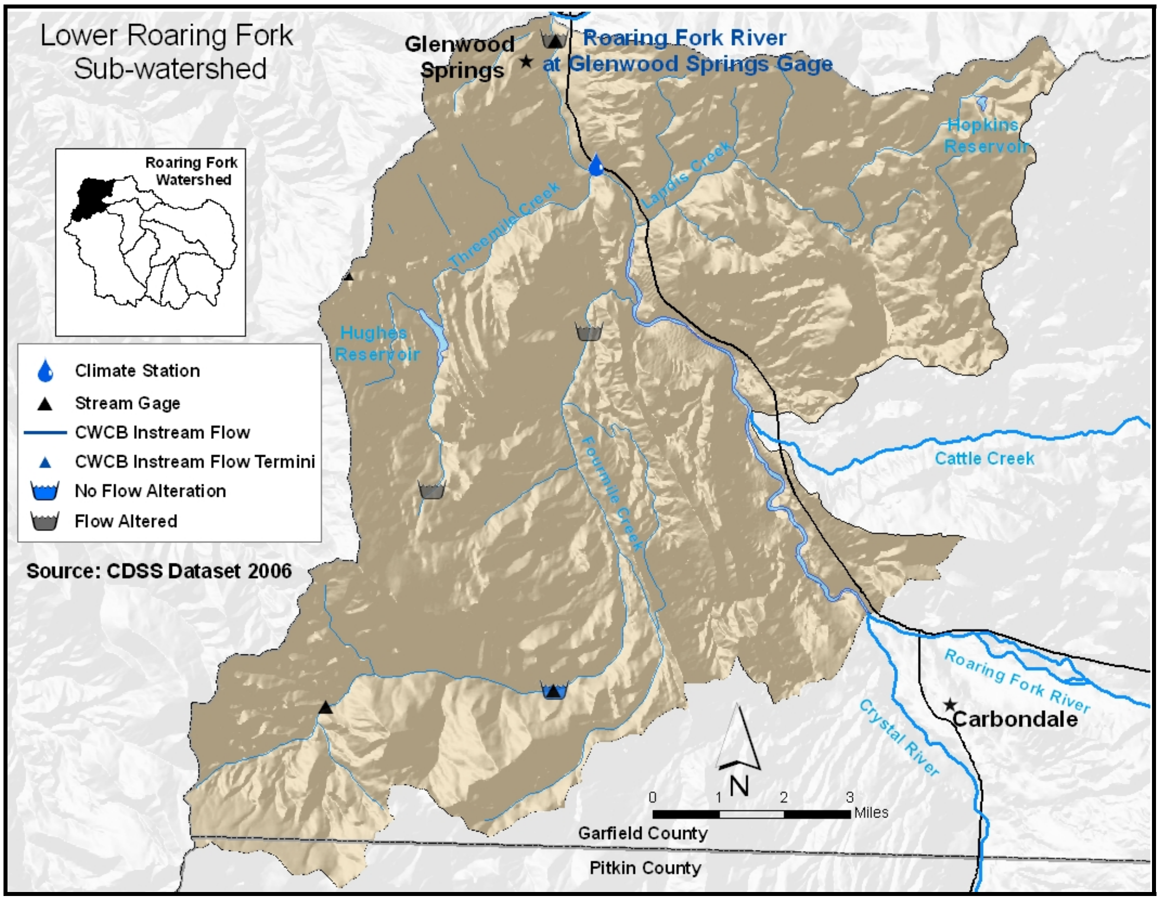


Figure 4.4.3. Water features in the Lower Roaring Fork Sub-watershed.

Flow alteration was assessed using the Upper Colorado River Basin Water Resource Planning Model dataset (CWCB and CDWR, 2007a). The modeling accounts for diversions over 10 cfs. These data are available for four nodes in this sub-watershed: Roaring Fork River at Glenwood Springs, Fourmile Creek near Glenwood, Fourmile Creek/Fourmile Ditch, and Threemile Creek.

Figure 4.4.3 shows the locations of these nodes, depicted by the symbols for "no flow alteration" and "flow altered". Appendix 3.1.2 and figures 3.1.4 - 3.1.6 show to what extent the flows on the Roaring Fork River, Fourmile Creek, and Threemile Creek have been altered compared with pre-developed conditions.

Figure 4.4.4 shows the locations of the diversions in the sub-watershed. Eight of the diversions have a decreed capacity greater than 10 cfs (Table 4.4.3).

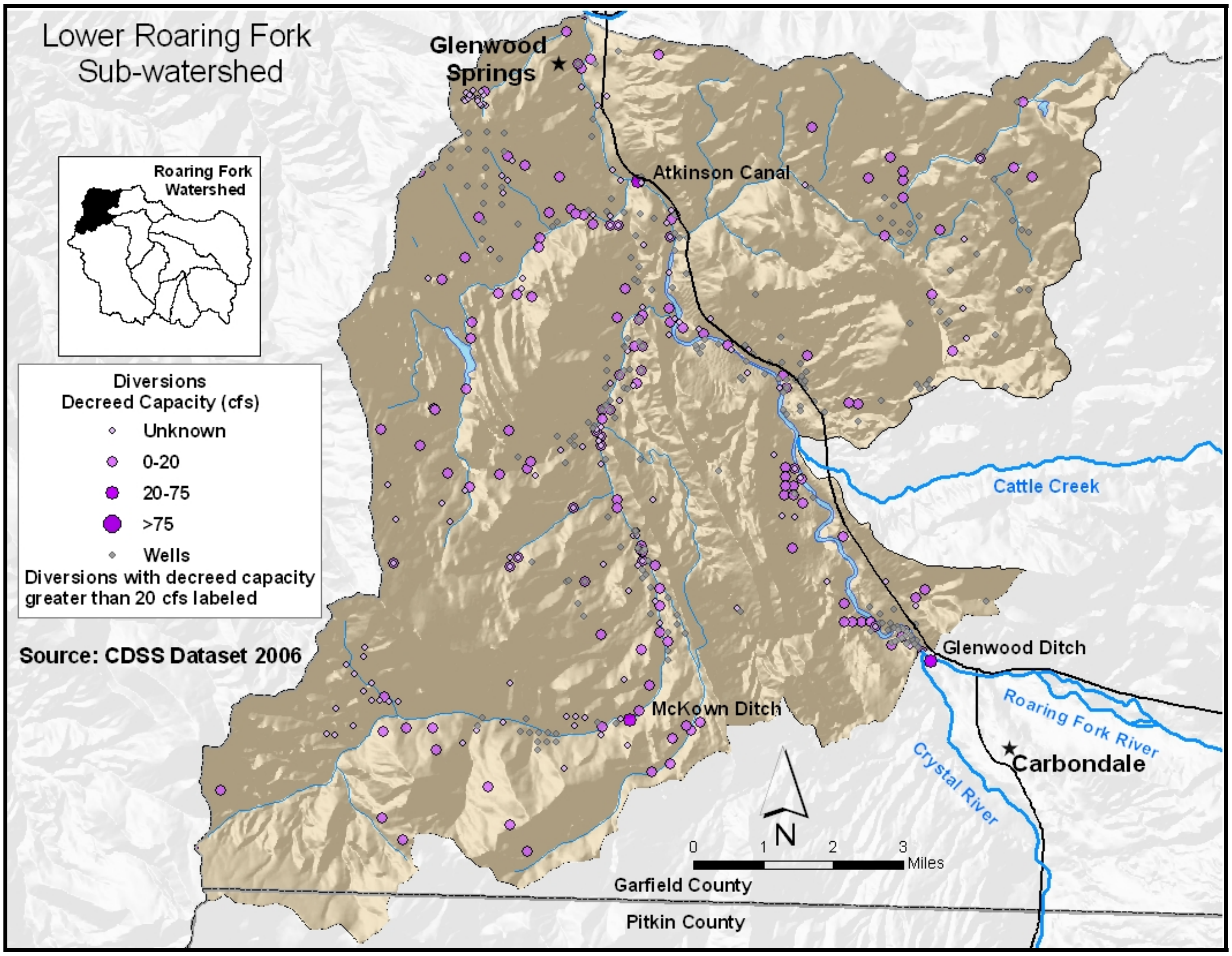


Figure 4.4.4. Diversions and wells in the Lower Roaring Fork Sub-watershed.

Table 4.4.3. Diversions in the Lower Roaring Fork Sub-watershed greater than 10 cfs. Source CDSS GIS Division 5 diversion data, 2006.

STREAM	DITCH	DECREED CAPACITY (cfs)
Roaring Fork River	Glenwood Ditch*	45.88
Roaring Fork River	Atkinson Canal*	26.33
Roaring Fork River	Red Acres Ditch	10.20
Fourmile Creek	McKown Ditch	20.50
Fourmile Creek	Lignite Ditch*	15.00
Fourmile Creek	Atkinson Ditch*	17.20
Fourmile Creek	Fourmile Ditch*	12.64
Three Mile Creek	Three Mile Ditch	14.40

* Used in CDSS modeling.

The Glenwood Ditch diverts from the Roaring Fork River just upstream of the confluence with the Crystal River. Although it is located in the Lower Middle Roaring Fork Sub-watershed, it is included here because of its location just upstream of the sub-watershed boundary (Figure 4.4.4). The Glenwood Ditch crosses Cattle Creek, mixing ditch and creek water (Figure 4.4.5). The largest diversion in the sub-watershed, the Atkinson Canal, no longer diverts water, instead serving to provide augmentation water for more junior water rights downstream when there is a senior downstream call (Brian Epstein, Colorado Division of Water Resources Division 5 Water Commissioner, personal communication, January 8, 2008).

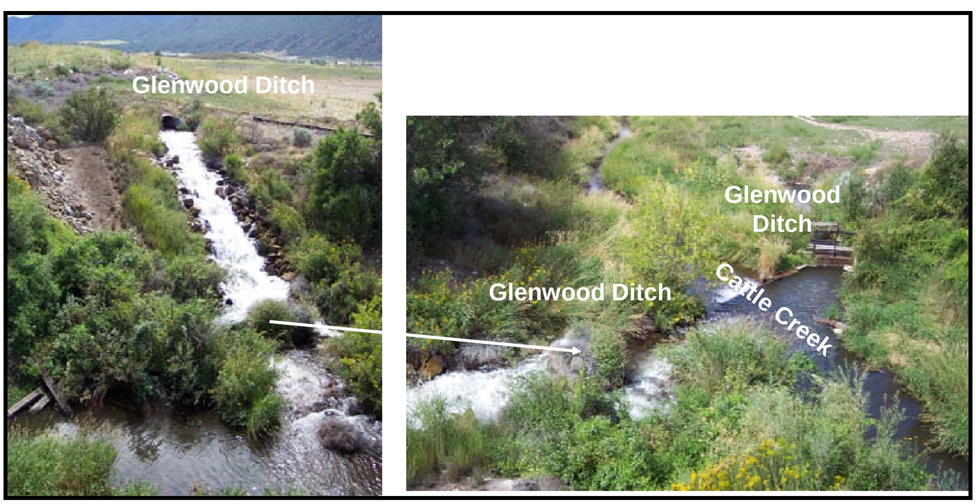


Figure 4.4.5. Glenwood Ditch mixing with/crossing Cattle Creek. Photo location is between Highway 82 (to left of photos) and old railroad trestle. (Photo credits: Chad Rudow, August 29, 2007).

At the Roaring Fork at Glenwood Springs node, flows were significantly reduced in May and June and increased from November to March. The flow reduction in May and June translates to a decrease in small flood frequency. Under pre-developed flow conditions, small floods would be expected to occur in four out of 10 years, but such small floods would be expected in two out of 10 years with developed flow conditions. Flow alteration at this node represents the cumulative response of flow alteration throughout the Roaring Fork Watershed.

Since the CDSS modeling only accounts for diversions over 10 cfs, no flow alteration was detected at the Fourmile Creek near Glenwood node. At the downstream node on Fourmile Creek, flows were reduced from April through October. Water is mainly used for irrigation, hydropower generation, and snowmaking. The number of small and large floods occurring under developed conditions is similar to the number occurring under pre-developed conditions (Figure 4.4.6).

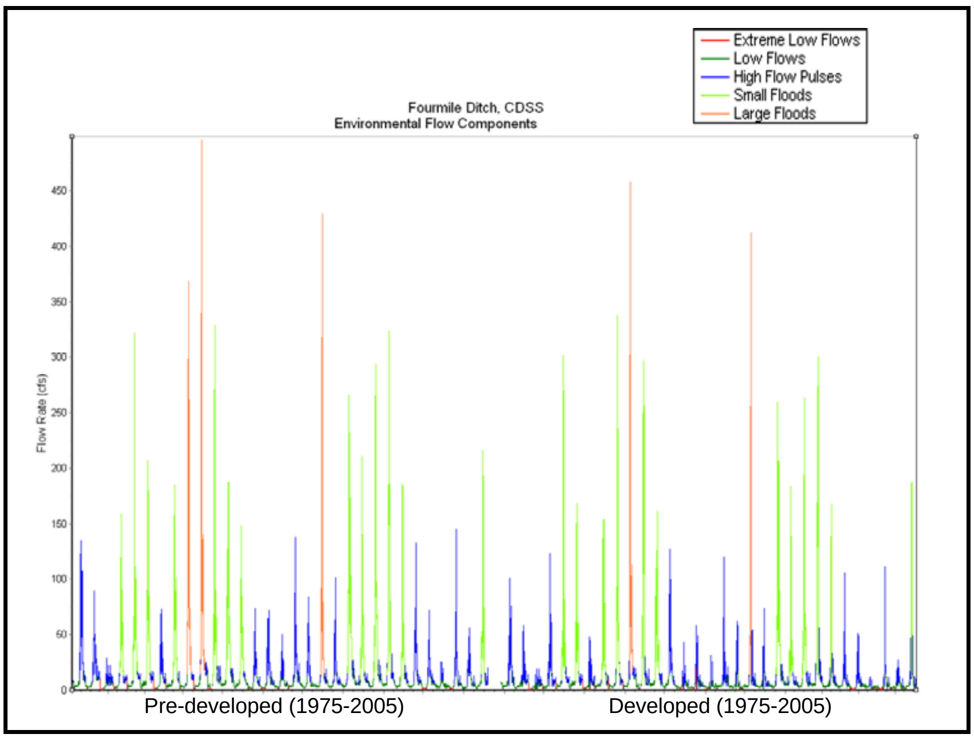


Figure 4.4.6. Comparison of modeled pre-developed flows to developed flows for the period 1975-2005 at the Fourmile Ditch node.

At the node in upper Threemile Creek, flows were reduced in May and June. Water from upper Threemile Creek is diverted by the West Threemile Ditch to a tributary of the Colorado River.

Three direct-flow conditional water rights are greater than 10 cfs in this sub-watershed (Table 2.4). Two of these are owned by the Glenwood Springs and the third is in the headwaters of Threemile Creek. Appendix 2.7 contains maps of the River District’s conditional water rights for Yank Reservoir and Fourmile Canal Projects; and West Divide Project.

No Colorado Water Conservation Board (CWCB) instream flow rights (ISFs) exist within the sub-watershed, although discussions have occurred between local interests and CWCB staff for Fourmile Creek. In response, CWCB did some preliminary measurements to determine flow requirements. It found that a new junior ISF would not improve flows because existing senior water rights could dry up the stream, and instead recommended exploration of opportunities to acquire more senior water rights for ISF purposes (Linda Bassi, CWCB, personal communication, October 22, 2007).

Groundwater

The edge of the Piceance Basin Bedrock Aquifer lies in the upper parts of Fourmile and Threemile creeks. The Eagle Basin Bedrock Aquifer extends into the western section of the sub-watershed, and the Roaring Fork River Alluvial Aquifer is found in areas adjacent to sections of the lower Roaring Fork River. No specific groundwater hydrology studies have been done in this sub-watershed.

Water Quality

Author: U.S. Geological Survey

Within the Lower Roaring Fork Sub-watershed, data have been collected at 22 water quality sites dating back to 1949. Fifteen of these sites were stream sites, six were groundwater sites, and one was an effluent site. Streams with at least some historical water quality data include Threemile, Landis, and Fourmile creeks and the Roaring Fork River from the confluence with the Crystal River to the confluence with the Colorado River. Water quality data covered for this sub-watershed are from 1996 to 2007 for sites on Fourmile Creek and the Roaring Fork River from above the confluence with Cattle Creek to the mouth. The five sites with recent data are:

- Roaring Fork River, Westbank Ranch, Sanders Ranch (Site 21)
- Fourmile Creek at Bershenyi Ranch (Site 22)
- Roaring Fork River at Park East (Site 23)
- Roaring Fork River at Glenwood Springs, CO (Site 24)
- Roaring Fork River at 7th St Bridge (Site 25)

These sites are shown in Figure 4.4.7 along with locations and information about water and wastewater treatment facilities. For each site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

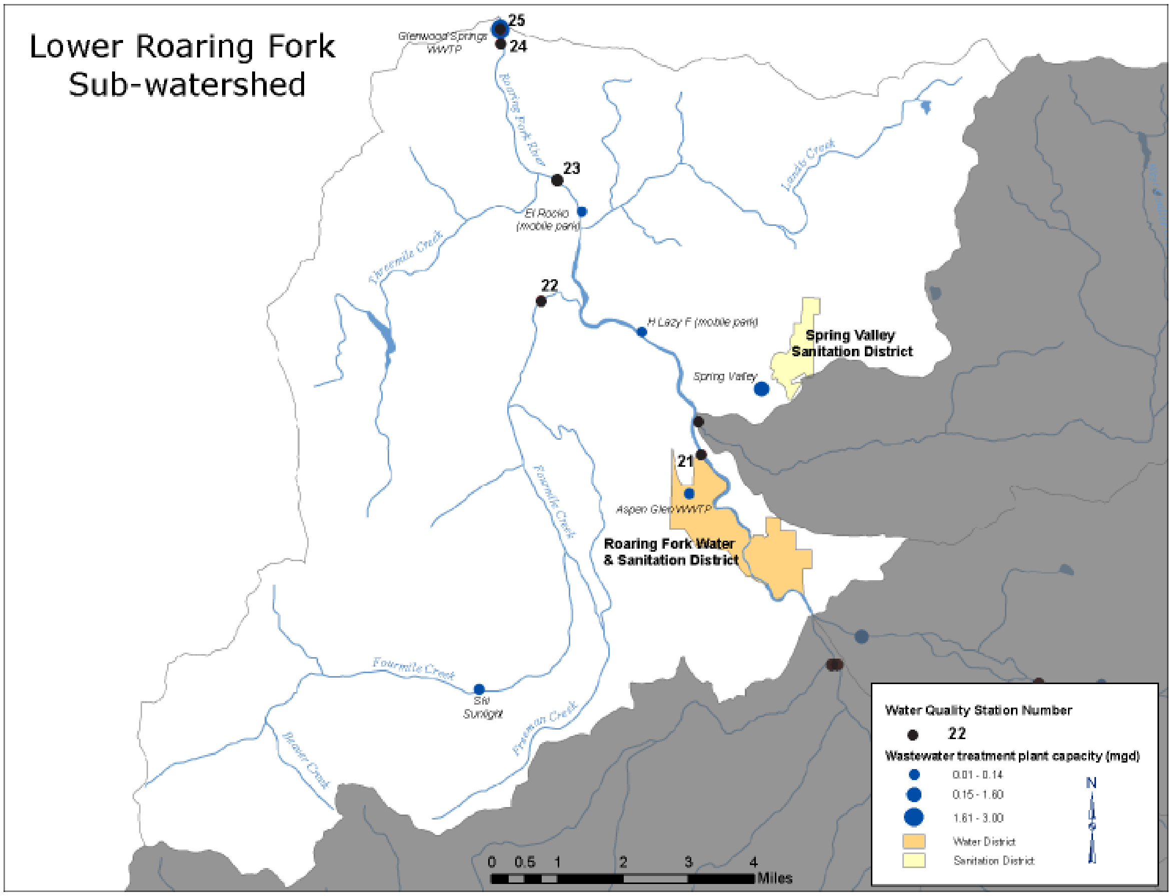


Figure 4.4.7. Water-quality sites and wastewater treatment providers in the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and CDOLA, No date b.

Site 24, Roaring Fork River at Glenwood Springs, is currently being monitored by the U.S. Geological Survey for water quality, continuous stream flow, and temperature. The Colorado River Watch Program is currently monitoring water quality at sites 21, 23, and 25 on the Roaring Fork River, Site 22 on Fourmile Creek, and, since 2006, a site below Sunlight Ski Area. Seven wastewater treatment plants are located within the sub-watershed and include Aspen Glen Wastewater Treatment Plant (capacity 0.107 MGD), Spring Valley (capacity 0.499 MGD), H Lazy F (capacity 0.04 MGD), El Rocko (capacity 0.01 MGD), Ski Sunlight (capacity 0.03 MGD), and Glenwood Springs Wastewater Treatment Plant (capacity 2.30 MGD) (O'Keefe and Hoffman, 2005).

Nine of 363 pH values exceeded the water quality standard at four of five sites in the sub-watershed. pH values ranged from 7.01 to 9.3 and median pH values ranged from 8.41 to 8.675. A single exceedance was observed during July; however, most exceedances occurred during the months of February, March, and November of 1997, 2001-02, 2004, and 2006. Site 23 had five of the nine exceedances.

Water temperatures occasionally exceeded the applicable water temperature standard for streams designated as Gold Medal fisheries (18°C or 65°F) at all sites on the Roaring Fork within this sub-watershed. Seven exceedances occurred during the months of June, July, and August over the period from 2000 to 2006. Fourmile Creek (Site 22) had two temperature values at the 20°C (68°F) standard in July of 2003 and 2006.

Only Site 24 had recent specific conductance data. Concentrations ranged from 173 µS/cm to 703 µS/cm, with a median of 536 µS/cm. Site 24, which is situated at the mouth of the entire watershed, would reflect the cumulative effects of the geology, as well as agricultural and urban land uses. Dissolved oxygen concentrations at all sites ranged from 6 mg/L to 17.2 mg/L, with median concentrations ranging from 9.2 mg/L to 11 mg/L, indicating well-oxygenated conditions for all sites.

Site 24, Roaring Fork at Glenwood Springs, is generally a calcium and bicarbonate/sulfate water type. Calcium is the dominate cation, accounting for more than 60 percent of all cations in all samples and bicarbonate and sulfate are the dominant anions (Appendix 3.2.2, Figure 3). For all sites, 87 chloride concentrations ranged from 1.64 mg/L to 57.2 mg/L and 115 sulfate concentrations ranged from 18.9 mg/L to 190 mg/L. Total dissolved solid concentrations were limited to Site 24, which had 70 total dissolved solids concentrations ranging from 108 to 430 mg/L, and a median value of 320 mg/L. Hardness concentrations among five sites ranged from 80 mg/L to 320 mg/L, with median concentrations ranging from 210 mg/L to 258 mg/l, indicating very hard water according to the categories presented by Hem (1985).

All sites in the sub-watershed had nutrient concentration data. Of the 104 nitrate concentrations, values ranged from 0.013 mg/L to 1.27 mg/L, and the median nitrate concentrations ranged from 0.1165 mg/L to 0.836 mg/L. Of the 48 un-ionized ammonia concentrations, 16 values were censored and measurable concentrations ranged from 0.0008 mg/L to 0.87 mg/L. Of the 62 nitrite concentrations at Site 24, 18 values were censored and concentrations ranged from <0.0009 mg/L to 0.04 mg/L. No water quality exceedances occurred for un-ionized ammonia, nitrite, or nitrate. These low concentrations indicate that point and nonpoint sources within the sub-watershed are not adversely affecting water quality. Of the 121 total phosphorus concentrations, values ranged from <0.006 mg/L to 0.64 mg/L. All sites had total phosphorus concentrations that exceeded the recommended criteria (a total of 12 exceedances). Because most of the elevated total phosphorus concentrations occurred in the spring (specifically in May), these concentrations could be related to naturally occurring phosphorus that adheres to suspended sediments flushed from streams during snowmelt runoff events (Wynn et al., 2001).

Total recoverable iron exceeded the chronic standard at all five sites within the sub-watershed. Of the 281 total recoverable iron concentrations, 19 concentrations exceeded the chronic standard. Exceedances generally occur during April and May and concentrations generally increased from upstream to downstream. The maximum total recoverable iron concentration (10,500 µg/L) was observed at Site 24 in August of 2000, and several total recoverable iron concentrations have subsequently exceeded the chronic standard at this site. Quaternary and Tertiary igneous rocks consisting primarily of basalt lava flows occur in the sub-watershed and are a significant source of iron (Green, 1992); however, some of the iron concentrations observed may originate upstream in the Crystal River Sub-watershed (discussed in Section 4.8). Of the 202 selenium concentrations, values ranged from 0.24 µg/L to 9.6 µg/L and 14 concentrations exceeded the chronic standard. Exceedances occurred at four of the five sites, with no distinct seasonal pattern evident. Arsenic, cadmium, copper, manganese, and zinc were collected and there were no Table Value Standard exceedances.A single exceedance of the acute standard for lead was observed at Site 23, Roaring Fork River at Park East, in November of 2003.

The majority of the microorganism data were collected at Site 24, resulting in a limited understanding of spatial patterns and sources within the sub-watershed. Forty-seven fecal coliform and 48 *E. coli* samples were collected at Site 24. Fecal coliform and *E. coli* standards (200 CFU/100 mL and 126 CFU/100 mL, respectively) were exceeded at this site on three occasions:
- August 2000 (fecal coliform was 670 CFU/100 mL and *E. coli* was 630 CFU/100 mL),
- August 1995 (fecal coliform was 420 CFU/100 mL and *E. coli* was 460 CFU/100 mL), and
- July 1998 (fecal coliform was 250 CFU/100 mL and *E. coli* was 180 CFU/100 mL).

Both constituents were collected until September/October of 2003, with no exceedances observed after August of 2000. Collection of these constituents has been discontinued at this site; therefore, monitoring of microorganism data would need to be re-established to determine the current status of these constituents.

Total suspended solids were collected at four of the five sites. A total of 44 total suspended solids concentrations ranged from 1.4 mg/L to 160 mg/L, where higher concentrations are typically associated with higher stream flows.

Riparian and Instream Areas

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed the Roaring Fork River and Fourmile Creek in this sub-watershed. Figure 4.4.8 shows specific riparian and instream information, by habitat quality category, for each reach assessed. The habitat quality categories are shown in riparian and instream assessment charts found in Section 3.3 and Section 3.4. Appendix 3.3.1 contains the actual percentage values for each of these categories by sub-watershed and how they were determined. In the sub-watershed are two stream segments:

- Roaring Fork Segment – the Roaring Fork River from the confluence with the Crystal River to the confluence with the Colorado River, SHI reaches RF6-2 through RF6-6; 12.58 miles.
- Fourmile Segment – Fourmile Creek from Fourmile Park to the confluence with the Roaring Fork River, SHI reaches 4M1-1 through 4M1-5; 12.14 miles.

The following is a brief description of results. The SHI report contains detailed narrative description. “Right bank” and “left bank” refer to the orientation of the riparian zone when facing downstream.

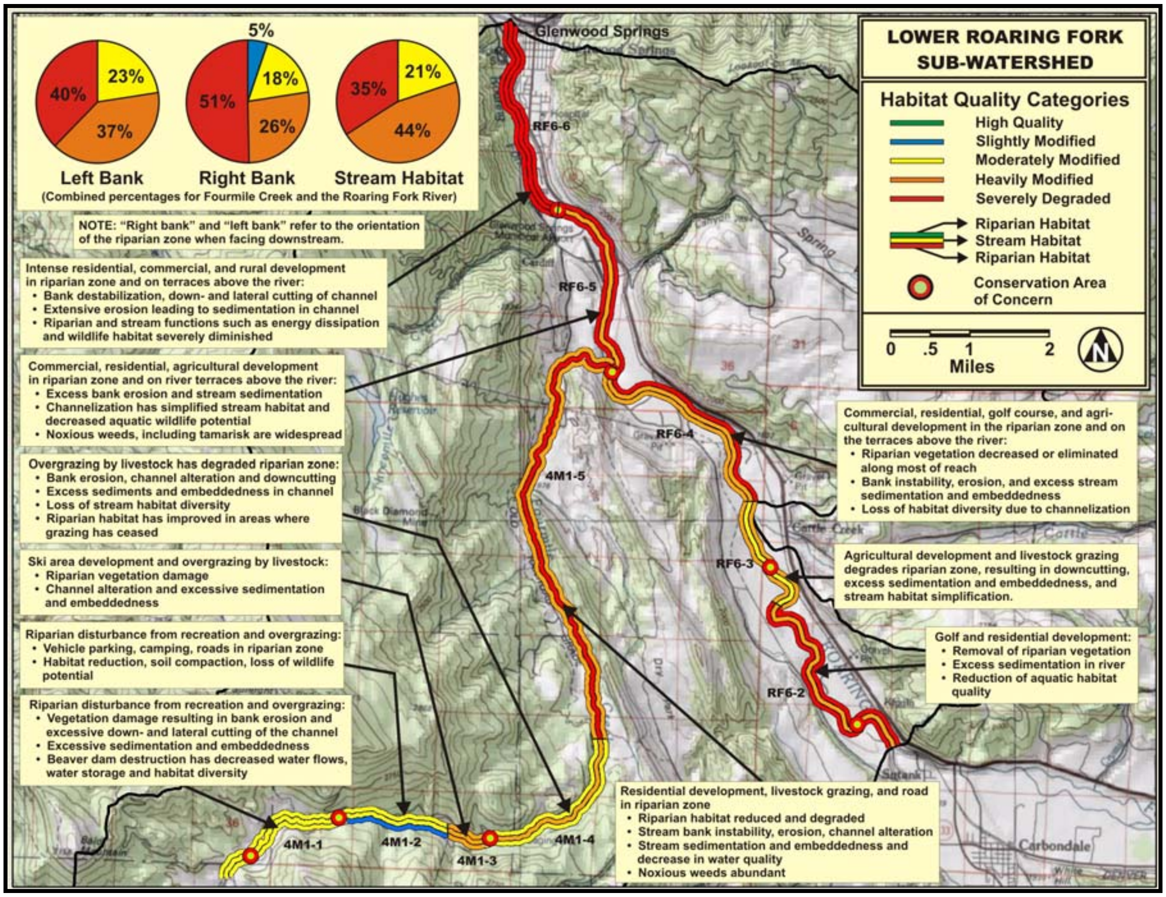


Figure 4.4.8. Riparian and instream habitat quality for the Lower Roaring Fork Sub-watershed.

Roaring Fork Segment - Uplands

Grazing is widespread throughout the Roaring Fork segment and has impacted native vegetation, contributing to an increase in bare and eroding soil where noxious weeds have invaded. Large natural areas in both sage and pinyon-juniper habitats have been cleared and replanted with pasture grasses. Many of these ranchlands are now being converted into housing developments, a trend that brings a different set of impacts to riparian and stream ecosystems. Sage shrublands are especially at risk and are considered one of the most imperiled ecosystems in the United States due to habitat conversion, primarily agriculture (Thompson, 2007). In western Colorado a conservative estimate of between 13 and 30 percent of sage shrublands have been lost to agricultural conversion, (Figure 4.4.9) with the remainder highly fragmented and infested with weeds (Boyle and Reeder, 2005). This trend is prevalent in the lower Roaring Fork Valley as manifested by the local extirpation of the greater sage grouse (*Centrocercus urophasianus).* This bird is a sagebrush obligate species, and was historically common in the watershed up to elevations of about 10,000 feet wherever healthy sagebrush and healthy riparian habitats were present together (Kingery, 1998; USGS, 2007b).

Figure 4.4.9. Reach RF 6-3: In the foreground a remnant of native sage shrubland persists, and in the middleground pasture replaces sage habitat, in the background residential/golf development has replaced ranchland.

Roaring Fork Segment - Riparian Habitat and Wildlife

Impacts from agriculture and associated hydrologic alteration have fundamentally altered the riparian ecosystem along the majority of this segment. These historic impacts have been exacerbated and increased by residential and commercial development. A few remnant pre-development plant communities persist wherever human disturbances are minimized and river processes (such as overbanking flows and meandering) can maintain appropriate soil moisture and redistribute sediment and nutrients. Cumulative impacts of development have modified riparian habitat throughout the segment. On the left bank, 22 percent of riparian habitat is heavily modified and 78 percent is severely degraded; on the right bank, 100 percent of the riparian habitat is severely degraded.

Table 4.4.4 summarizes various impacts to riparian and stream habitats in the Roaring Fork segment. Historic agricultural impacts coupled with residential and commercial development have severely reduced riparian zone width, vegetation quality, and ecosystem function on the majority of reaches RF6-2, 6-3, 6-4, and 6-5, and all of 6-6. Along most of the segment the native cottonwood woodlands that historically lined the river banks are dying and are not being replaced. Cottonwood recruitment is low due to grazing, presence of non-native grass lawns that extend to the river's edge, and downcut and riprapped banks that inhibit seedling establishment. In addition, recruitment is impacted by the constraint on river processes such as out-of-bank flows and meandering that are essential to cottonwood establishment. One consequence of these impacts is drier riparian soils which have enabled the invasion of upland plant species like oak, juniper, and sage into riparian habitat.

Table 4.4.4. Summary of land development impacts and threats to riparian and instream habitat in the Roaring Fork segment of the Lower Roaring Fork Sub-watershed.

LOWER ROARING FORK: ROARING FORK SEGMENT	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	RIGHT BANK
Total Stream Miles: 12.6	15%	3%	78%	45%	100%	63%

In contrast to developed areas, plant communities in remaining natural areas are characterized by a wide riparian zone, a diversity of native riparian plant species, structurally complex habitat, and a more even-age class distribution of trees and shrubs. However, noxious weeds have invaded from adjacent degraded habitats and are common throughout the segment. Remaining natural areas include parts of reach RF6-2, 6-3, and 6-4. These three areas have been identified by the Stream Health Initiative as Conservation Areas of Concern (Table 4.4.5 and Figure 4.4.8). On the left bank of RF6-2 small areas of riparian wetlands have been conserved as natural areas. Although these areas are surrounded by golf course and home development, they still provide high wildlife values. A great blue heron nesting colony, bald eagle's nest and a cattail marsh occur in these natural areas (Figure 4.4.10). The marsh is a remnant of a habitat type that once was common and supports numerous bird species including white-faced ibis, sora rail, yellow-headed blackbird, Bullock's oriole, and great blue heron. Because the surrounding landscape is severely altered, these remaining natural areas have become critical to wildlife.

Figure 4.4.10. A cattail marsh receives treated sewage and removes nutrients before flowing into the Roaring Fork River. A great blue heron nesting colony can be seen in the ponderosa pine tree.

Urbanized landscapes provide little wildlife value – especially for those species sensitive to human disturbance. Thus, conversion of native habitat to a human-dominated landscape has also altered the community of wildlife. Human-tolerant and disturbed-habitat wildlife species dominate along most of the reach and alter natural communities. For example, a breeding pair of Lewis's woodpeckers was observed in a small stand of cottonwood on reach RF6- 4. The Lewis's woodpecker is a native species that is on Audubon's and Colorado Natural Heritage Program's "watch lists" due to population declines. At the same site, eight brown-headed cowbirds and three European starlings were also observed – neither is native. Starlings displace Lewis's from their nest cavities and cowbirds parasitize the nest, thus reducing nesting success and contributing to population declines.

Table 4.4.5. SHI Conservation Areas of Concern in the Roaring Fork segment of the Lower Roaring Fork Sub-watershed.

LOCATION	JUSTIFICATION
RF6-2 at the Golf Course	Riparian wetlands have been conserved as wildlife habitat in a few small areas of this golf/home development. Wetlands provide high wildlife values but potential is degraded by high levels of human disturbance, noxious weeds, and high nutrient loads.
RF6-3 at Cattle Creek	Steep canyon walls on the right bank provide nest sites for hundreds of swallows. A great blue heron rookery and an active osprey nest are present on the left bank of the river and a cattail marsh provides good breeding habitat for numerous songbird species. Threats come from a large residential development on the uplands of the right bank of the river which has bulldozed vegetation to within a few feet of the edge of the slope.
RF6-4 at Fourmile Creek and RF6-5 at Threemile Creek	Fourmile and Threemile creeks are trout-spawning streams. Threats come from diversions that dewater the streams, and residential development that has destabilized slopes and degraded channel habitat.

Roaring Fork Segment - Instream Habitat and Wildlife

For most of this segment the river is confined to a narrow canyon that is occasionally interspersed with wide openings. Stream gradient is fairly steep with occasional stretches of flat water where deep, quiet pools alternate with shallow riffles. Stream habitat in steeper sections is characterized by fast, deep water with a substrate of large boulders alternating with fast, shallow water with cobble riffles. Both of these stream environments help dissipate energy and provide resources for aquatic wildlife. Stream types vary between Type B in steeper sections, C in flatter sections, and G in deeply incised canyons. Refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of these various types of streams.

Extensive channel alteration occurs throughout the reach and is due to a variety of human changes to upland, riparian, and stream ecosystems. Irrigation diversions dewater the stream and habitat alterations are primarily related to agricultural and residential development. Upland development has severely impacted canyon walls, causing eroding banks and changes to channel morphology (Figure 4.4.11). Replacement of riparian vegetation by pastures, lawns, and golf courses that extend to the edge of streambanks, along with grazing in the riparian zone (Figure 4.4.12), have resulted in destabilized streambanks, loss of streambank soil, channel widening, downcutting, reduced pool numbers, and increased stream sedimentation. A common response to bank erosion has been to riprap banks with boulders. Although this solution solves the immediate erosion problem at that specific site, riprapping also contributes to channelization, which leads to such negative effects as degraded fish habitat, increased stream energy, and increased erosion further downstream.

Figure 4.4.11. In reach RF6-5, upland development-induced bank destabilization and erosion affects the river. In the foreground, tamarisk has invaded point bars.

Figure 4.4.12. In reach RF6-3, grazing in the riparian zone and on streambanks has damaged vegetation, compacted soil, and degraded water quality.

Due to the impact of development, no high quality or slightly modified instream habitat remains in this segment. Thirteen percent of the instream habitat is moderately modified, 66 percent heavily modified, and 21 percent severely degraded.

Numerous small areas of natural instability were identified by the Roaring Fork and Fryingpan Rivers Multi-objective Planning Project, including the floodplain throughout the Aspen Glen residential/golf course development (RF-2 through RF6-3), and areas at the confluences of Fourmile Creek and Threemile Creek with the Roaring Fork River (BRW, Inc. et al., 1999). Various land uses have exacerbated these geologically unstable areas. Impacts from development include channel straightening, bank riprapping, and removal of bank vegetation with subsequent channel downcutting and stream habitat simplification.

Aquatic wildlife potential has been diminished by instream habitat alteration. Channelizing activities have reduced the variety and quality of instream habitat. The removal of bank and overhanging vegetation has reduced protective cover and resulted in bank erosion that contributes to excess sedimentation. Sedimentation has caused both the number and habitat quality of pools to decline. The brown trout is the dominant salmonid in the lower Roaring Fork River and provides a valuable recreational fishery. Colorado River cutthroat trout are rarely found in any reach in the Roaring Fork River and any fish observed have moved downstream from tributary habitats (CDOW surveys). Brown and rainbow trout travel up the Roaring Fork River and into Threemile and Fourmile creeks where they spawn. Excessive sedimentation degrades habitat for aquatic macroinvertebrates that are a food resource for fish, and excess nutrient loads have resulted in thick algal blooms that degrade water quality. American dippers are good indicators of stream habitat quality, but these birds were rarely observed throughout this segment, suggesting impaired habitat.

Fourmile Segment - Uplands

In the Fourmile segment, large areas of native forests and shrublands have been used for grazing, and cleared for pastures (Figure 4.4.13), ski slopes, roads, and residential and commercial development. Recreation and agriculture dominate land uses in upper reaches while residential and agricultural land uses dominate lower reaches. Upland and riparian habitat upstream of Sunlight Mountain Resort is in much better condition than habitat below this ski area. Fourmile Creek has been dewatered for hydropower and irrigation diversions. Conversion of native habitat into pastures and a ski area has altered precipitation infiltration-runoff regimes, increased sediment-laden runoff, compacted soils, and reduced wildlife potential by simplifying habitat structure and decreasing the diversity of plant species. Over-grazed sage meadows have been invaded by pinyon-juniper woodlands with an understory dominated by noxious weeds, especially cheatgrass. Roads and trails crisscross upland habitat, even in designated roadless areas, causing erosion and spread of weeds. Noxious weeds are abundant wherever upland or riparian is degraded or soils have been disturbed. Fourmile Road separates upland from riparian habitat, creates a lethal barrier to wildlife migration, and has destabilized upland and riparian hillslopes along the length of the road. On private lands throughout the Fourmile Creek Valley, land use is transitioning from agriculture to sprawling residential development. Impervious surfaces have increased due to new roads, houses, and non-native grass lawns.

Figure 4.4.13. Native shrublands have been cleared for agriculture.

Fourmile Segment - Riparian Habitat and Wildlife

Overgrazing and agricultural, residential, and recreational development have degraded riparian habitat and functions (figures 4.4.14 and 4.4.15). In this segment, along those stretches of stream where the riparian zone is intact or where grazing has ceased, riparian vegetation is in good condition and provides channel stability and wildlife value. Overall, cumulative effects of development here modified riparian habitats thereby reducing function and wildlife potential. On the left bank, high quality and slightly modified riparian habitat is absent, 47 percent of the riparian habitat is moderately modified, and 53 percent heavily modified. On the right bank, high quality riparian habitat is absent, 11 percent is slightly modified, 37 percent moderately modified, and 53 percent heavily modified.

Figure 4.4.14. Residential development and roads in the riparian zone in reach 4M1-5 have altered vegetation and channelized the stream.

Figure 4.4.15 Grazing in the riparian zone in 4M1-5 has negatively impacted riparian and instream habitat.

Habitat quality has been altered by development impacts that have reduced the width of the riparian zone and quality of riparian vegetation. Table 4.4.6 summarizes impacts and their linear extent.

Table 4.4.6. Summary of land development impacts and threats to riparian and instream habitat on Fourmile Creek in the Lower Roaring Fork Sub-watershed.

LOWER ROARING FORK: FOUR MILE CREEK SEGMENT	TRAILS & RELATED DISTURBANCES	ROADCUT AND BRIDGES	DEVELOPMENT (Residential, commercial agricultural)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	WEEDS COMMON-ABUNDANT (5-10%) RIGHT BANK
Total Stream Miles: 12.14	5%	30%	59%	89%	71%	71%

Grazing, dewatering, and recreation activities currently have the greatest impact on riparian habitat in stream reaches 4M1-1 and 4M1-2, and have reduced the functional width of the riparian zone and vegetation quality. Grazing in riparian areas has trampled streambank vegetation; reduced plant vigor, species diversity, and habitat structure; eliminated seedlings and saplings and the potential for regeneration; and impacted beaver dams. In areas not affected by grazing or recreation, habitat quality is high and ecosystem functions are intact. Overgrazing in some areas has reduced or eliminated favored plants, such as willow and cottonwood seedlings and saplings, leaving undesired species and an aging cottonwood forest with little regenerative ability.

In Fourmile Creek from Sunlight Mountain Resort (reach 4M1-3) to the confluence with the Roaring Fork River, the combined impacts of residential, commercial, and agricultural development have degraded ecosystem functions by reducing both the width and quality of the riparian habitat. In the majority of 4M1-5, road-induced channelization has reduced and sometimes eliminated the riparian zone. Housing and commercial development in 4M1-3 and 1-5 has typically included clearing native riparian shrubs and replacing them with non-native grass lawns. Throughout the drainage, ecosystem functions such as pollution filtration and streambank stabilization are degraded, weed invasion is extensive, and erosion is common. Riparian areas are in better condition where there is beaver activity (Figure 4.4.16).

Figure 4.4.16. Beaver pond complexes are present in two areas of reach 4M1-5. Directly below the beaver ponds(right photo) stream flows are restored and riparian habitat is in good condition.

Terrestrial wildlife potential is fairly high on the upper two reaches of this segment, but is limited below Sunlight Mountain Resort. In the upper two reaches, a high diversity of plant species and a complex habitat structure provide a variety of foraging and breeding resources and good protective cover. Threats that undermine wildlife potential in 4M1-1 and 1-2 include off-road vehicle recreation, grazing, and roads. Wildlife is abundant; numerous elk, mule deer, coyotes, red foxes, and snowshoe hares were observed. Beavers were seen and their activity was prolific. Canada lynx have been documented in this area by satellite tracking devices.

Starting at Sunlight Mountain Resort and going downstream, wildlife occurrence matches the level of development. In areas recovering from grazing, a variety of native tree and shrub species and a structurally complex habitat provide abundant and good quality wildlife resources. Although historic grazing very likely altered the plant community assemblage, in recovering areas the shrubs less palatable to cattle, such as alder and hawthorn, now dominate streambank habitat. These shrubs are good streambank stabilizers and provide high quality resources for mammals and birds. Conversely, wildlife potential is severely limited by the habitat simplification and human disturbance that accompany residential and commercial developments. Human-tolerant wildlife species thrive with the urbanization of agricultural lands, but many native species cannot survive the new environmental conditions and invading competitors that habitat alteration brings.

The Colorado Natural Heritage Program has identified riparian and upland habitat near Sunlight Mountain Resort as a Potential Conservation Area (PCA) because of good quality mixed mountain shrubland. Threats to the PCA are similar to those in the riparian area, including residential development, roads, and recreational disturbance. The Stream Health Initiative identified three Conservation Areas of Concern in Fourmile Creek (Table 4.4.7).

Table 4.4.7. SHI Conservation Areas of Concern on Fourmile Creek in the Lower Roaring Fork Sub-watershed.

LOCATION	JUSTIFICATION
4M1-1	High elevation willow carrs provide good quality wildlife potential for mammals, birds, and amphibians. Wildlife values are threatened by grazing, motorized recreation, (snowmobiles and all-terrain vehicles) and stream dewatering.
4M1-2	Beaver-controlled wetlands stabilize the stream channel and provide excellent wildlife habitat. Habitat is threatened by grazing, beaver dam destruction, and dewatering.
4M1-3	Historic ranching impacts still affect this reach but natural restoration is occurring and is increasing wildlife value. Restoration and wildlife values are threatened by ski area expansion with related commercial and residential development.

Fourmile Segment - Instream Habitat and Wildlife

Stream types in Fourmile Creek vary from a widely meandering Type E stream in 4M1-1 to a Type B beaver dam controlled stream in the steeper reaches of 4M1-2, 3, and 5, and a Type C stream in 4M1-4 where the gradient is less steep. Refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of these types of streams.

Alteration to channel condition and function results from vegetation degradation and channel and hydrologic alteration (Figure 4.4.17). Cumulative grazing and development impacts have resulted in moderate modification to 29 percent of the stream habitat in the drainage, heavy modification to 23 percent, and severe degradation to 48 percent. No high quality or slightly modified habitat remains in the survey area. Native habitats in Fourmile Creek suffer from a legacy of overgrazing in sensitive riparian habitat. Current residential and commercial development continues this pattern of riparian degradation and consequent channel alteration. Impacts to the stream channel include channelization, habitat simplification with a reduction in flow diversity, and excessive sedimentation. Grazing and development-related vegetation removal have destabilized streambanks, which then eroded, downcut, and widened, ultimately contributing to channel straightening, habitat simplification, and sedimentation. Roads, culverts, drop structures, and bank riprap have altered channel morphology, leading to further channelization, reduction in flow diversity, and loss of stream functions. In numerous areas, with grazing cessation and consequent recovery of riparian vegetation, and presence of beaver activity, channel condition is improving.

Figure 4.4.17. Channel downcutting in 4M1-1 has resulted from domestic livestock grazing.

Throughout the majority of drainage, flows are inadequate to maintain a functioning stream system (Figure 4.4.18). Sufficient flows are necessary to maintain channel shape and structure, and to transport sediment and provide fish habitat. Diminished flows have resulted because of the cumulative effect of numerous diversions, channel and riparian alteration, reduced beaver activity, and destruction of beaver dams. Excessive sediment and dewatering have resulted in sediment covering the stream bottom, filling pools, and embedding cobble and gravel. Consequences include impaired stream functions and reduced wildlife potential.

Figure 4.4.18. Stream dewatering in 4M1-1 has left little suitable fish habitat.

Beaver are an integral part of stream and riparian ecosystems throughout the majority of Fourmile Creek (Figure 4.4.19). From reach 4M1-1 through 4M1-5 (to where the stream turns east through a narrow canyon), historic beaver activity was high. Wherever beaver are still active and stable dams occur, stream flows are increased, riparian vegetation is in good condition, and the condition of the stream channel is improved. However, beaver activity at present is sparse and sporadic with consequences that include decreased instream flows, channel instability, and increased sedimentation.

Figure 4.4.19. Beaver dams in 4M1-2 conserve water and stabilize the channel.

Aquatic wildlife is limited in the majority of the segment. Only one American dipper was observed in the drainage, indicating impaired aquatic habitat. Protected sites for fish are limited due to the rarity of deep pools, backwater pools, or stable, undercut banks. Cobbles are armored with mineral deposits that are covered with a thick coat of periphyton and heavily embedded with fine sediment. This embedded stream environment limits macroinvertebrate habitat and fish resources. Brook trout are the dominant salmonid species in upper Fourmile Creek and brown trout are the dominant salmonids species in lower Fourmile Creek. One Colorado River cutthroat trout was observed in Fourmile Park (USFS surveys 2005, 2006). Fourmile and Threemile creeks are important tributaries for brown trout spawning as brown trout move into lower tributaries from the lower Roaring Fork and Colorado rivers for spawning (CDOW fish surveys).

Maintaining adequate fall flows is important to maintain spawning habitat for brown trout in both Threemile and Fourmile Creeks. Lower Threemile Creek also provides spawning for rainbow trout in the spring (Alan Czenkusch, retired fish biologist, CDOW, personal communication, 2004).

4.4.4 Important Issues

Below is a summary of key findings from available scientific information, a listing of data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the sub-watershed's water resources.

Key Findings

The following bullet points refer to the overall sub-watershed:

- No designated CWCB instream flow reaches are in this sub-watershed.
- The sub-watershed contains three direct-flow conditional water rights greater than 10 cfs.
- Total recoverable iron concentrations exceeded the chronic Table Value Standards at all five monitoring sites in the sub-watershed.
- Selenium, total phosphorus, water temperature, and pH exceeded water-quality standards on occasion. All five sites had total phosphorus exceedances. Because most of the elevated total phosphorus concentrations occurred in the spring (specifically in May), these concentrations could be related to naturally occurring phosphorus that adheres to suspended sediments flushed from streams during snowmelt runoff events.

The following bullet points refer to the lower Roaring Fork River:

- Compared with pre-developed flows, the frequency of small floods has been reduced and base flows have increased on the lower Roaring Fork River.
- Ruedi Reservoir releases increase late summer, fall, and winter flows, moderate water temperatures, and enhance fishing opportunities in the lower Roaring Fork River.
- Microorganism data results showed exceedances for fecal coliform and *E. coli* at Site 24 three different times from 1995 to 2000. No exceedances occurred between August 2000 and October 2003, at which time sampling was discontinued. .
- More than 75 percent of the Roaring Fork River's riparian and instream habitat in this sub-watershed has been directly impacted by developed land use activities and the related spread of weeds.
- Due to historic agricultural development and more recent residential and commercial development, all riparian habitat on the right bank and 78 percent on the left bank is severely degraded. The remaining 22 percent on the left bank is heavily modified.
- Along most of this segment, the native cottonwood woodlands that historically lined the riverbanks are dying and are not being replaced because of channel downcutting, riprap, and flow alteration. Upland plant species such as oak, juniper and sage have invaded these riparian habitats.
- Small areas of riparian wetlands have been protected in some locations, and provide high wildlife values. In these areas, good nest sites are available for birds such as bald eagle, osprey, great blue heron, sora, yellow-headed blackbird, Bullock's oriole, and Lewis's

woodpecker. These areas serve as migratory stopovers for species such as white-faced ibis. Because the surrounding landscape is severely altered, these remaining natural areas are critical to wildlife.

- The Stream Health Initiative identified several Conservation Areas of Concern, including riparian wetlands in the Aspen Glen area; the Cattle Creek confluence area, which has important nesting habitat for birds including swallows, great blue heron, osprey, and songbirds; and trout-spawning areas at the confluences of Fourmile and Threemile creeks.
- Because of impacts to instream habitat from development, no high quality or slightly modified habitat exists; 13 percent of instream habitat is moderately modified, 66 percent heavily modified, and 21 percent severely degraded.
- The brown trout is the dominant trout in the lower Roaring Fork River and provides a valuable recreational fishery. The longest Gold Medal Fishery in the state occurs from Ruedi Dam to Glenwood Springs, including the lower Roaring Fork River.

The following bullet points refer to Fourmile Creek:

- Reduced flows occur in Fourmile Creek from April through October due to irrigation diversions, and from November through March from hydropower diversions.
- Total recoverable iron exceeded water-quality standards, with observed exceedances of chronic Table Value Standards.
- Selenium, total phosphorus, water temperature, and pH exceeded water-quality standards on occasion.
- Fourmile Creek (Site 22) had two temperature values at the 20°C (68°F) standard in July of 2003 and 2006.
- Fifty-nine percent of Fourmile Creek's surveyed riparian and instream habitat has been directly impacted by developed land use activities and 71 percent has been impacted by the spread of weeds.
- Due to overgrazing and agricultural, residential, and recreational development, no high quality riparian habitat exists on either bank. On the left bank, 100 percent is moderately or heavily modified, as is 89 percent of the right bank.
- No high quality or slightly modified instream habitat is in the survey area. Cumulative grazing and development impacts have resulted in moderate modification to 29 percent of the instream habitat, heavy modification to 23 percent, and severe degradation to 48 percent.
- Aquatic wildlife is limited over the majority of the segment. Only one American dipper was observed in the drainage, indicating impaired aquatic habitat.
- Brook trout is the main salmonid species in upper Fourmile Creek while brown trout dominate lower Fourmile Creek. Fourmile and Threemile creeks are important tributaries for brown trout spawning.
- The Stream Health Initiative identified three contiguous reaches as Conservation Areas of Concern that have important wildlife value (extending from Fourmile Park to approximately two miles past the Sunlight Mountain Resort). Colorado Natural Heritage Program designated the upland and riparian habitat in the area near the Sunlight

Mountain Resort as a Potential Conservation Area because of its good quality mixed mountain shrubland.

Data Gaps

A number of gaps in information for the sub-watershed limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Stream flow data for Fourmile, Threemile, and Landis creeks;
- Recent water-quality data for tributaries of the Roaring Fork River within the sub-watershed (including upper Fourmile Creek);
- Recent water-quality data for the following constituent groups:
  - Specific conductance – could aid in establishing sources of dissolved material as well as help describe other water-quality conditions
  - Suspended sediment – to evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals
  - Emerging contaminants – to establish a baseline for understanding occurrence in the rest of the watershed
  - Microorganisms – to establish potential for water-born disease (some recent data exists, but continued monitoring is needed to understand changing conditions);
- Recent groundwater-quality data;
- Riparian and instream habitat condition for Threemile Creek;
- Riparian and upland breeding bird data;
- Information about upland habitat condition and animal populations in areas not surveyed by Colorado Natural Heritage Program; and
- Information about upland and riparian mammal community diversity, amphibian and reptile populations, and population sustainability.

Relevant Local Initiatives, Plans, and Studies

- The Roaring Fork and Fryingpan Rivers Multi-Objective Study (BRW, Inc., et al., 1999), done to locate areas of high flood hazards, areas and causes of instability, and infrastructure at risk, contains information for the Roaring Fork part of this sub-watershed.
- A "Stormwater Assessment & Education Report" for the City of Glenwood Springs (Matrix Design Group, 2003) contains recommendations for stormwater management improvements to protect water quality, and educational materials on nonpoint source pollution.
- The City of Glenwood Springs River Advisory Committee completed a River Management Plan in 1990. The plan recommends specific actions for four topic areas: river awareness and education, river management policies, river rehabilitation and preservation, and river corridor recreation and open space development.
- In 2003 the Glenwood Springs implemented a Water Conservation Plan to promote the efficient use of water through education, example, incentive, and innovation.

4.5 Maroon/Castle Creek Sub-watershed

4.5.1 Environmental Setting

The Maroon/Castle Creek Sub-watershed has many spectacular mountain peaks, including several that exceed 14,000 feet. Three "fourteeners" are found in the headwaters of Maroon Creek (North Maroon, Maroon, and Pyramid peaks), and two in the headwaters of Castle Creek (Castle and Conundrum peaks). The Maroon Bells represent what is arguably one of the most-photographed natural features in the country, and draw more than 200,000 visitors annually. The sub-watershed's primary ecoregions are Sedimentary Subalpine Forests and Alpine Zone. The old silver mining town of Ashcroft, in upper Castle Creek Valley is now a ghost town. Land use within the lower parts of the Maroon and Castle creek drainages is primarily residential with a majority of the sub-watershed composed of public lands, including wilderness. Given the sub-watershed's generally pristine character, an important issue for preserving its overall hydrologic and ecologic integrity is adequate stream flows in the lower creeks – flows that are affected by local diversions. See Figure 4.1 for an overview map showing the location of this sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions; the sub-watershed's general physical characteristics are summarized in Table 4.1.

Topography and Geology

Figures 1.3 and 1.4, maps of the geology and slope of the Roaring Fork Watershed, highlight the dominant characteristics of this sub-watershed. A preponderance of slopes exceed 30 and 45 percent. These coincide with the Maroon Formation, which dominates the sub-watershed's surface geology, especially in the Maroon and Willow creek drainages. Tertiary intrusive rocks, forming some of the dominant mountain peaks in this sub-watershed, are found in the headwaters of Maroon and Castle creeks. The western edge of the Castle Creek drainage is a mixture of Pennsylvanian siltstones, sandstones, limestones, and dolomites; Mississippian and Cambrian rocks; Precambrian gneisses and schists; and granitic rocks. An extensive area of glacial drift extends along Castle Creek and lower Conundrum Creek, with smaller areas along upper Maroon Creek and at the lower end of the sub-watershed. Some Mancos Shale and gravels and alluviums are also found near the confluences of Maroon and Castle creeks with the Roaring Fork River.

Weather/Climate

The one active climate station within the sub-watershed is at Aspen 1SW (050372), located at 8,160 feet. It began operation in 1980 (http://www.wrcc.dri.edu/) (Figure 4.5.5). Based on data for the period of record, average total annual precipitation was about 24 inches, and the three wettest months were March, April, and November (2.6, 2.4, and 2.6 inches). June was the driest month, averaging just over 1.3 inches of precipitation. Two other climate stations have collected data in this sub-watershed: the Lift station recorded snow data from 1957 to 1989, and the Aspen station recorded data for temperature, precipitation, frost dates, and snow from 1949-1979. Additional precipitation and snow data can be found for the site near Maroon Creek (Aspen 1.7 WSW) that is associated with the Colorado Collaborative Rain, Hail, and Snow Network (Appendix 1.2) (http://www.cocorahs.org/).

Biological Communities

Both Castle and Maroon creeks begin in the Alpine Life Zone in the Maroon Bells-Snowmass Wilderness Area. The headwaters of Maroon Creek rise at about 12,000 feet at the base of Pyramid Peak, and those of Castle Creek start from the base of Castle Peak at about 12,240 feet. These two creeks flow northward through steep, glacially carved valleys to their confluences with the Roaring Fork River, traversing Subalpine and Montane Life Zones along the way. Plant communities in these life zones are characteristic of those on the West Slope of the Southern Rocky Mountains. At their beginning in the alpine tundra, the streams coalesce from snowmelt areas where a rich mosaic of alpine wet meadows and willow carrs has developed (Figure 4.5.1). As the streams cascade down steep slopes, they enter subalpine ecosystems where a mosaic of spruce-fir forests, aspen forests, herbaceous meadows, and sage shrublands provide high quality habitat and the potential for a rich wildlife community. In shadier environments the shrub layer is dominated by plant species such as Colorado currant, gooseberry, and twinberry with mosses providing bank stability. Riparian habitats in the subalpine include willow carrs and sedge meadows in wider, flatter floodplains. The steeper reaches, where the stream plunges down boulder-lined channels, are bordered by a narrow band of conifer and mixed aspen-conifer forests and riparian shrub communities. Further downstream, as the streams enter the Montane Life Zone, riparian plant communities transition to narrowleaf cottonwood and mixed narrowleaf cottonwood-blue spruce forests interspersed with willow carrs, non-willow riparian shrublands, and wet meadows. Surrounding uplands are a patchwork of aspen and conifer forests, sage and oak shrublands, and wet and dry herbaceous meadows.

Figure 4.5.1. Upper photo: Maroon Creek, MA1-1: High quality willow carr habitat and healthy, forested upland habitat provide excellent summer range for wildlife. Lower photo: Castle Creek: High elevation riparian and upland habitats provide wildlife with excellent summer range.

From the Subalpine through the Montane Life Zones, beaver damming activity is a major feature of the sub-watershed's riparian landscape. Beaver dams have created abundant and diverse resources through the development of open water ponds bordered by broad willow carrs and wetlands (Figure 4.5.2). Ponds provide high quality and protected rearing habitat for fish, breeding and resting habitat for waterfowl, feeding areas for great blue herons, and breeding sites for amphibians such as boreal toads. Willow habitat provides elk and deer with high quality forage and protective cover for their young. It also supports songbirds with undisturbed nesting and foraging sites. Surrounding uplands provide good resources for elk, deer, bighorn, snowshoe hare, mountain lion, lynx, pine marten, and coyote.

Figure 4.5.2. MA1-1: Beaver dams were a major stream-structuring feature of the pre-development landscape.

Appendix 1.3 lists the riparian-related and instream species and communities of concern in the sub-watershed. Figure 3.3.4 provides a map showing great blue heron activity within the overall watershed which includes Maroon Creek within this sub-watershed. The Colorado Division of Wildlife (CDOW) has identified occurrence of the following fish species: Colorado River cutthroat, rainbow, and brook trout; mottled sculpin, speckled dace, and bluehead sucker (Harry Vermillion, CDOW, personal communication, March 3, 2008). Two breeding populations of boreal toads have been documented in the sub-watershed (Figure 3.4.5) (Mark Lacy, USFS Fish Biologist, personal communication, March 17, 2008). The Colorado Natural Heritage Program identified one of these areas as a Potential Conservation Area (Conundrum Creek) (Figure 3.3.2 and Appendix 3.3.2).

Historic and current land uses on both public and private lands within Castle Creek and Maroon Creek drainages have had variable impacts on habitat and wildlife values. Impacts from past grazing activities within the upper reaches of Maroon Creek and historic mining and grazing activities within Castle Creek Valley have been repaired with time and, in some areas wilderness designation. In lower reaches, where private lands are more common and extractive uses occur on public lands, upland and riparian habitats have been affected by recreation, residential, and agricultural land uses.

4.5.2 Human Influences

Land Ownership and Use

Figure 4.5.3 shows ownership and protection status for the sub-watershed. The majority of this sub-watershed is within the White River National Forest, which is managed by the U.S. Forest Service (USFS). A majority of both the Maroon Creek and Conundrum Creek drainages are within the Maroon Bells-Snowmass Wilderness Area. The history of mining in this area is reflected in the private in-holdings found scattered throughout the sub-watershed, especially in upper Conundrum and Castle creeks. The lower part of Castle Creek is a mixture of private and public land. The sub-watershed has several open space parcels located mainly in the lower section. Most of these parcels are owned by the City of Aspen Parks and Recreation Department (Appendix 4.1).

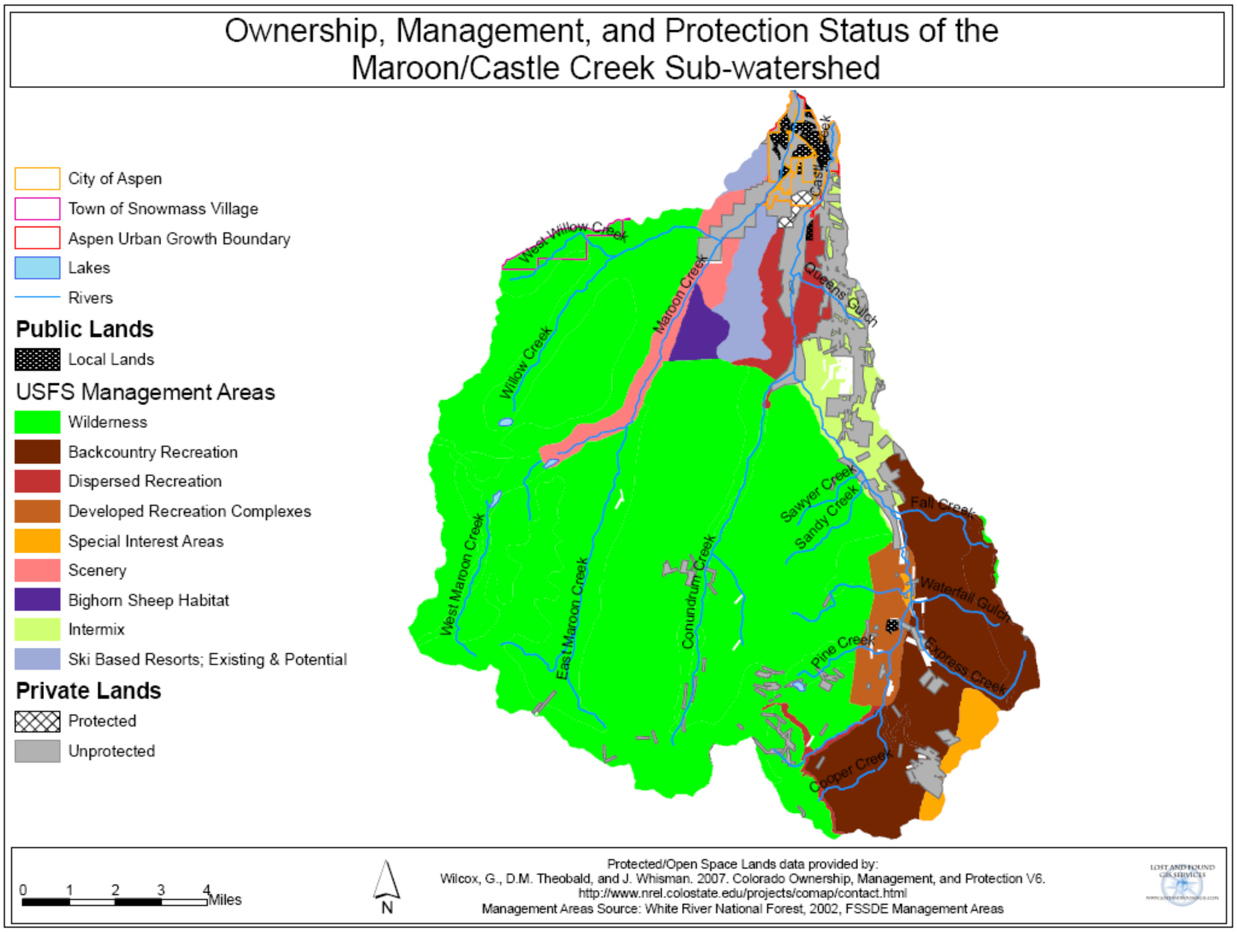


Figure 4.5.3. Ownership and protection status for the Maroon/Castle Creek Sub-watershed.

This sub-watershed is located entirely in Pitkin County. The Maroon/Castle Creek Caucus (http://www.aspenpitkin.com/depts/77/maroon_castle_creek.cfm) represents a large part of the sub-watershed. The Maroon/Castle Creek Master Plan was submitted in 2003 (http://www.aspenpitkin.com/pdfs/depts/7/mccmarooncastleplan.pdf). Two topic areas are directly relevant to this report: The "Water Use, Quantity, and Quality Objective" has as a priority the protection of creeks, wetlands, and riparian areas, and also states that all development proposals are to be evaluated for their effects on this priority. This objective also highlights the importance of preservation of water quantity/stream flows, water quality, and aquatic habitat. The "Natural Environment Objective" focuses on the importance of protecting open space, drainage ways, plant species, and cover and corridors for native wildlife species in the Castle and Maroon Creek valleys. Major riparian and wetland species are identified in the plan's discussion of existing conditions, and some implementation measures directly involve riparian and wetland areas. Existing conditions and implementation measures for these objectives are noted in Appendix 1.5.

Figure 4.5.4 shows roads within the sub-watershed and identifies those roads within 150 feet of second order and higher streams (approximately 11 percent of the streams). County Road 13

(Maroon Creek Road) parallels Maroon Creek and turns into USFS Road 125. Maroon Creek Road traverses upland habitat parallel to the creek for most of its length from Maroon Lake to Highway 82. It is typically more than 300 feet from the creek, with a dense cover of riparian vegetation between the road and creek helping to filter out road-based pollutants before they can enter the water. Winter sanding on Maroon Creek Road delivers large amounts of sediment to some sections of the creek during spring runoff. To minimize traffic impacts from thousands of visitors to Maroon Lake each summer, this road has restricted motor vehicle acess, with a shuttle bus operation during the day in summer. County Road 15 (Castle Creek Road) parallels Castle Creek, eventually turning into USFS Road 102.

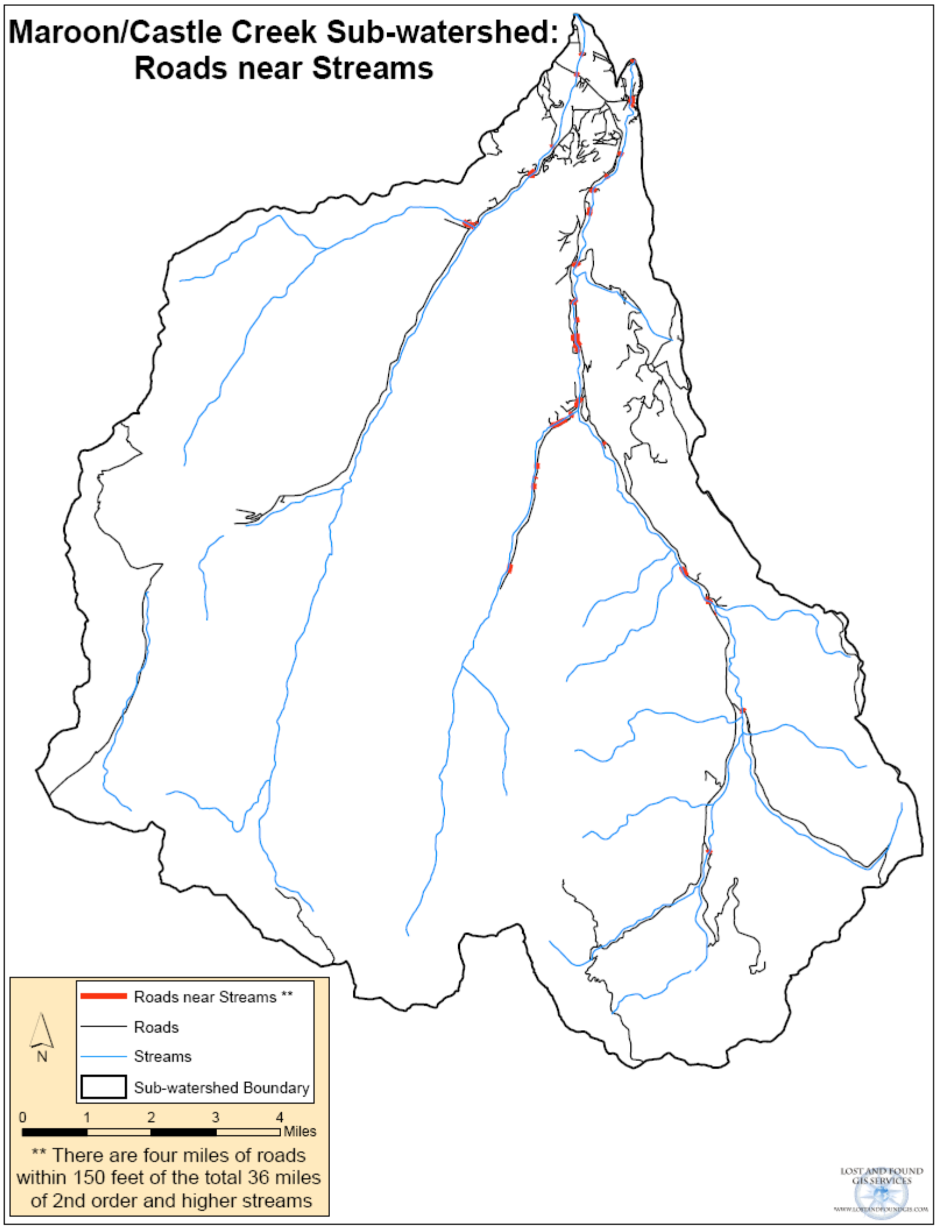


Figure 4.5.4. Roads near streams in the Maroon/Castle Creek Sub-watershed.

The City of Aspen extends into this sub-watershed, with Maroon and Castle creeks providing the primary water supply for the city. Appendix 3.1.3 contains more information about this water supply. The Aspen Consolidated Sanitation District serves properties along the lower end of Maroon Creek Road. Figure 4.5.7 shows the location of the sanitation districts in the sub-watershed.

The City of Aspen has a small hydroelectric facility at Maroon Creek, and plans are underway to revamp a 19th-century facility at the base of Castle Creek Bridge. In 2007, the City passed Resolution No 69 (Series 2007), which approves constructing and equipping a new hydroelectric facility on Castle Creek. When completed, the 1.05 megawatt facility is expected to increase electric production by 5.5 million kilowatt-hours annually, equating to the average electricity consumed by 655 typical homes in Aspen. More information about this proposed hydroelectric facility can be found at: http://www.aspenpitkin.com/pdfs/depts/38/cc.res.069-07.pdf.

Mining

Table 4.5.1 has information about recent, permitted mines in the sub-watershed. Mining has occurred historically throughout the sub-watershed, particularly in the Castle Creek Valley. The old ghost town of Ashcroft was once a thriving silver mining town. Founded in 1879, it peaked a couple of years later with 2,500 residents, six hotels, 17 saloons, a jail, and a bowling alley. The focal point of Ashcroft's mining activities was the Montezuma Basin. In addition, the Little Annie/Richmond Ridge area was heavily prospected in the past. Iron ore was mined from Taylor Peak during the 1960s and 1970s. Castle Creek Road was paved to help accommodate the heavy truck traffic.

Table 4.5.1. Mine sites in the Maroon/Castle Creek Sub-watershed. Source: Colorado Division of Reclamation Mining and Safety. No date.

SITE NAME	STREAM	SIZE	COMMODITY	STATUS	PERMIT ISSUED
Conundrum Gulch Quarry	Conundrum Creek	5 acres	Marble	Terminated	5/17/1994
Gold Chance 1&2	Castle Creek	9.5 acres	Gold and silver	Application withdrawn	n/a
Pitkin Iron Mine	Castle Creek	37 acres	Iron	Terminated	12/15/1978

Recreation Activities

Four USFS developed campgrounds are in the sub-watershed, all located along Maroon Creek (Silver Bar, Silver Bell, Silver Queen, and Maroon Lake). Trails on USFS land follow Minnehaha Gulch, West Maroon, Maroon, Conundrum, and Pine creeks.

Most of the Aspen Highlands and part of the Buttermilk ski areas are located within this sub-watershed. Both Maroon and Castle creeks provide water for snowmaking for these two ski areas as well as for Aspen Mountain. Table 1.5 provides information pertaining to water use for these two ski areas.

The Southwest Paddler (www.southwestpaddler.com) and American Whitewater (http://www.americanwhitewater.org) websites recommend Castle Creek for kayakers. This Class IV to IV+ run begins at the Aspen Music School and ends at Slaughterhouse Bridge on the

Roaring Fork River. According to the Southwest Paddler website, diversions typically shorten the season to a few weeks in May through July.

According to "Flyfishing Guide for the Roaring Fork Valley" (Shook, 2005), "Maroon Creek offers anglers an opportunity to fish for rainbow trout in a small creek running down a beautiful valley." A similar description is given for fishing in Castle Creek.

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams and lakes in the sub-watershed have been stocked with the species listed (Table 4.5.2):

Table 4.5.2. Species stocked by the CDOW in streams and lakes of the Maroon/Castle Creek Sub-watershed.

STREAM/LAKE	SPECIES
Castle Creek	Rainbow trout
Maroon Creek	Rainbow trout
Cooper Creek	Pikes Peak cutthroat trout
American Lake	Colorado River cutthroat trout and rainbow trout
Cathedral Lake	Colorado River and Pikes Peak cutthroat trout
Maroon Lake	Colorado River cutthroat trout and rainbow trout
Willow Lake	Colorado River and Pikes Peak cutthroat trout

4.5.3 Resource Information

Several research studies and syntheses of information have been done in the Maroon/Castle Creek Sub-watershed, providing data on stream flows, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in this sub-section. For background information on the data sources, please refer to Chapter 3.

Water Quantity

Surface Water

There are no active stream gages in this sub-watershed. Four stream gages, two each on Maroon and Castle creeks, are no longer in operation. The two downstream gages in each drainage operated for less than 10 years in the early 1900s and the two gages further upstream operated from 1969-1994. Specific information about these historic gages can be found in Figure 4.5.5 and Appendix 3.1.1.

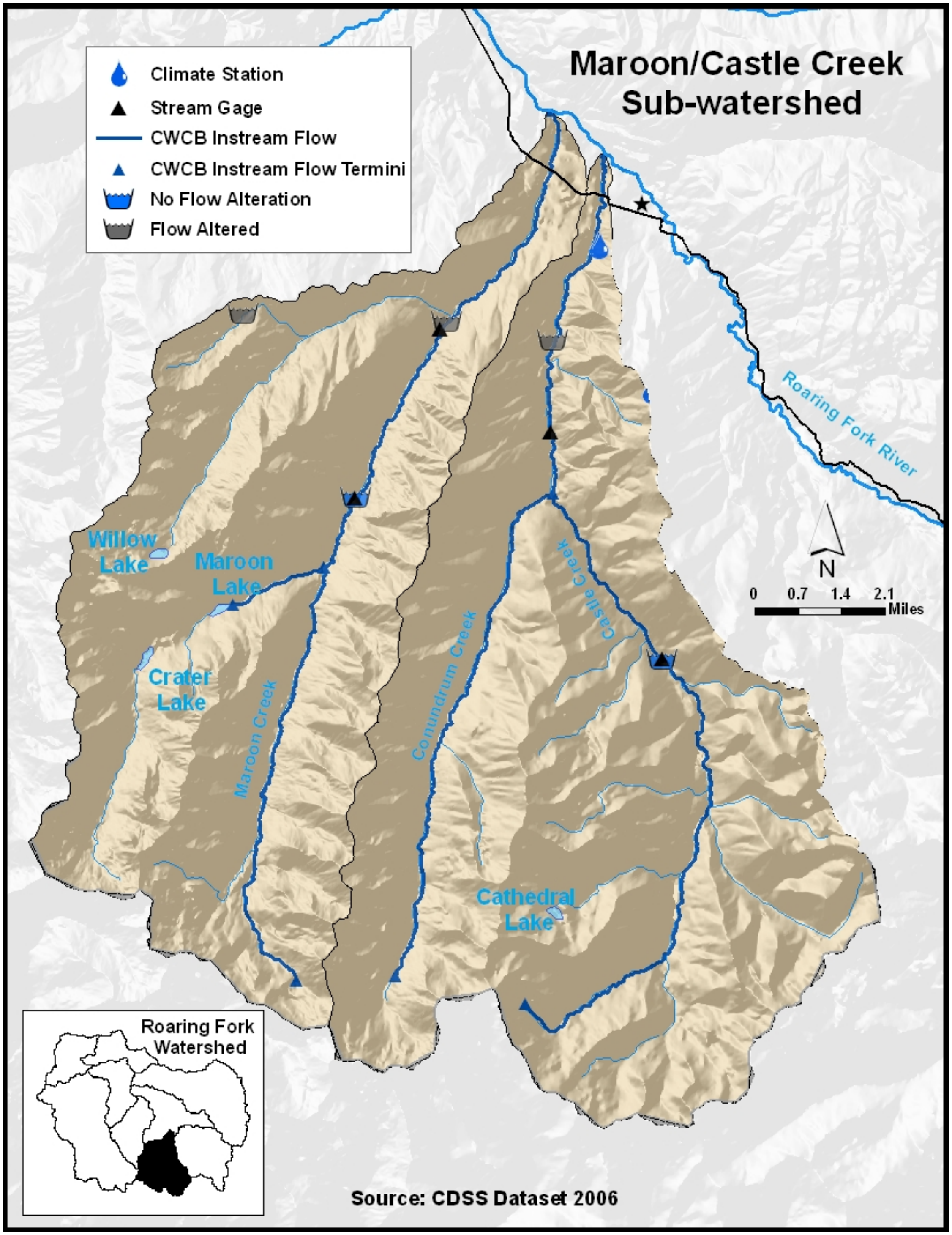


Figure 4.5.5. Water features in the Maroon/Castle Creek Sub-watershed.

Flow alteration was assessed using the Upper Colorado River Basin Water Resource Planning Model dataset (CWCB and CDWR, 2007a). The model accounts for diversions above 10 cfs. These data are available for four nodes in the sub-watershed: Castle Creek above Aspen, Castle Creek/Midland Flume Ditch, Maroon Creek/Maroon Ditch, and Willow Creek/Willow and Owl Ditch (Figure 4.5.5 shows the location of these nodes, depicted with the symbols for "no flow alteration" or "flow altered"). Appendix 3.1.2 and figures 3.1.4 - 3.1.6 show to what extent the flows on Castle, Maroon, and Willow creeks have been altered.

Figure 4.5.6 shows locations of all diversions in the sub-watershed, nine of which have a decreed capacity greater than 10 cfs (Table 4.5.3).

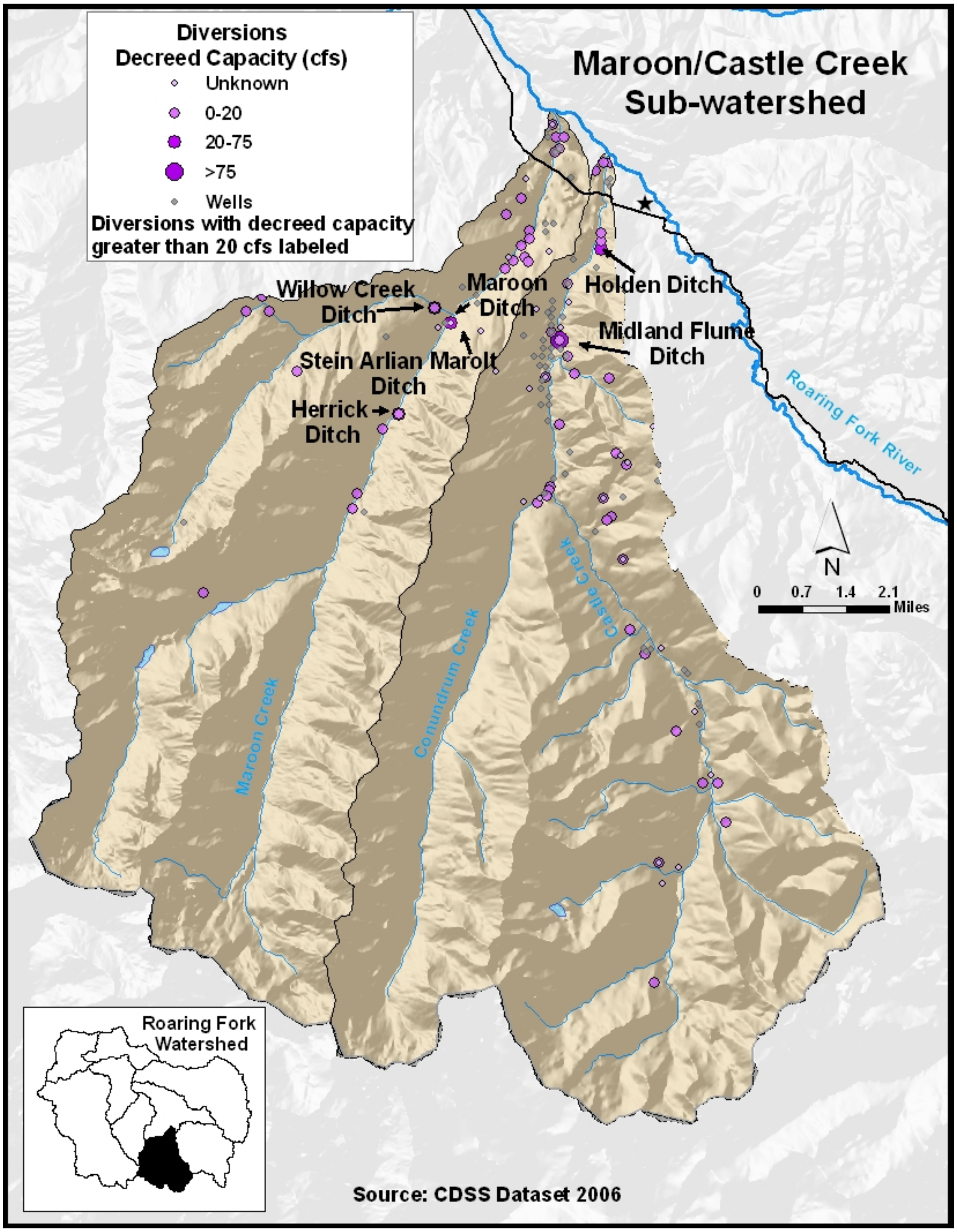


Figure 4.5.6. Diversions and wells in the Maroon/Castle Creek Sub-watershed.

Table 4.5.3. Diversions in the Maroon/Castle Creek Sub-watershed greater than 10 cfs. Source CDSS GIS Division 5 diversion data, 2006.

STREAM	DITCH	DECREED CAPACITY (cfs)
Castle Creek	Midland Flume Ditch*	160.00
Castle Creek	Holden Ditch*	30.00
Castle Creek	Marolt Ditch*	18.60
Willow Creek	Willow and Owl Ditch*	13.00
Willow Creek	Willow Creek Ditch*	40.00
Maroon Creek	Herrick Ditch*	64.86
Maroon Creek	Stein Arlian Marolt Ditch*	25.00
Maroon Creek	Maroon Ditch*	68.40
Maroon Creek	Stapleton Brothers Ditch*	16.01

* Used in CDSS modeling.

No flow alteration was detected at the Castle Creek above Aspen node because it is located above most of the major diversions. At the Castle Creek/Midland Flume Ditch node, located below this major diversion, flows were significantly reduced by 20-30 percent from November to March. Flows were reduced on Maroon Creek/Maroon Ditch by 15-20 percent from October to April. The Willow Creek/Willow and Owl Ditch node which is located on West Willow Creek above the Willow Creek Ditch showed significant flow alteration in September (decrease of 26 percent). In this sub-watershed peak flows were not significantly reduced.

Two studies were prepared for the City of Aspen by Enartech, Inc. (1994 and 1997) to address water availability. The 1994 study's results are relevant for Maroon and Castle creeks. The study concluded that:

- Water availability typically exceeds the combined demands of the city, instream flows, and other water users on Castle and Maroon creeks. During infrequent dry periods, however, stream flow may not be great enough to meet existing city demands and at the same time maintain desired instream flow conditions below the intake facilities.
- Simulation results indicate that with existing municipal demands, shortages in potable water supplies may be expected in the winter months of three out of 23 years studied (13 percent). As future development leads to larger municipal demands, the amount of dry-year potable shortages will increase, and the frequency of shortages may also increase. Potential snowmaking demands from Maroon Creek could also significantly increase the frequency and magnitude of water supply shortages.
- Shortages of untreated irrigation supplies may occur more frequently. On Castle Creek, it is estimated that shortages of irrigation water could occur in the late summer months in

nine out of the 23 years studied (39 percent). Availability of irrigation supplies could be further reduced as future development increases the amount of water diverted for potable supply.

According to a newspaper staff report (Aspen Daily News, 2007) just prior to the Enartech studies, city water use had peaked at 520 equivalent capacity units (ECU) per day. An ECU is a standardized measurement for the water demand of a two-bedroom, one-bath house. In 1993, the city began proactively to fix leaks, bury pipes deeper so they would not freeze, and require low flush toilets. In 2005 the city implemented tiered water rates that rewarded frugal customers. By 2007, customers were using 150 gallons per ESU, a 29 percent reduction. Even with increased growth, the amount of water used annually by the city has decreased from 1.9 billion gallons (5,830 acre-feet) in 1993 to 910 million (2,792 acre-feet) in 2007.

One direct-flow conditional water right greater than 10 cfs is located on Maroon Creek − the Maroon Creek Plant and Diversion dam (Table 2.4). The sub-watershed has two conditional storage rights greater than 1,000 acre-feet, which are for reservoirs located on Maroon and Castle creeks. The City of Aspen owns all of these rights (Table 2.5).

There are eight Colorado Water Conservation Board (CWCB) instream flow rights within the sub-watershed – five on Castle Creek, and one each on Maroon, East Maroon, and Conundrum creeks (Figure 4.5.5 and Appendix 2.2). Four of the five instream flow rights on Castle Creek are donated or acquired rights, with the result that their appropriation dates are prior to 1973 (1885, 1926, 1950, and 1902). Water rights owned by the City of Aspen are typically senior to ISF rights. Although the city could legally deplete the stream flow to an amount less than the ISF, it seeks to protect the environment below its diversion facilities, and has adopted a policy to bypass sufficient water to maintain these junior ISF rights downstream of all city facilities (City of Aspen, 1993). Enartech concluded that instream flow conditions associated with the CWCB instream flow rights may not provide a minimum flow necessary to protect or maintain aquatic habitat to a reasonable degree (1994). They recommended that the City pursue independent evaluations to determine flow conditions that meet desired environmental conditions.

Groundwater

No available groundwater data exist for the sub-watershed. A brief inventory of potential geology was compiled by Kolm and van der Heijde in 2007. It is suspected that the sub-watershed has combinations of shallow aquifers consisting of moraines, outwash plains, and alluvium, as well as a complex faulted bedrock system consisting possibly of Leadville limestone, the Dakota formation, and Tertiary intrusive rocks. For the inventory, Kolm and van der Heijde prioritized areas of the county to conduct future studies of geology and groundwater characteristics. The areas were prioritized based on geology and criteria such as threats, population densities, and growth. A determination was made that understanding the groundwater system in this sub-watershed is a moderate priority.

Water Quality

Author: U.S. Geological Survey

Within the Maroon/Castle Creek Sub-watershed, data have been collected at 27 water-quality sites dating back to 1966. Twenty-two of these sites were stream sites, two were mine/effluent sites, and the other three were groundwater sites. Streams that had at least some historical water quality data include Conundrum, Castle, West Maroon, and Maroon creeks. Castle Creek is the only stream with recent water-quality data. Data from the following 3 sites were used to summarize recent water-quality conditions in the sub-watershed and represent the time period of 1996 to 2007:

- Castle Creek near Aspen (Site 26)
- Castle Creek near Ashcroft (Site 27)
- Castle Creek (Site 28)

These sites are shown in Figure 4.5.7, along with locations and information about water and wastewater treatment facilities.For each site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

The Colorado River Watch Program is currently monitoring water quality at Castle Creek (Site 28). Previous summaries of available water quality data indicate that water-quality conditions in the sub-watershed are generally good (Roaring Fork Conservancy, 2006a).

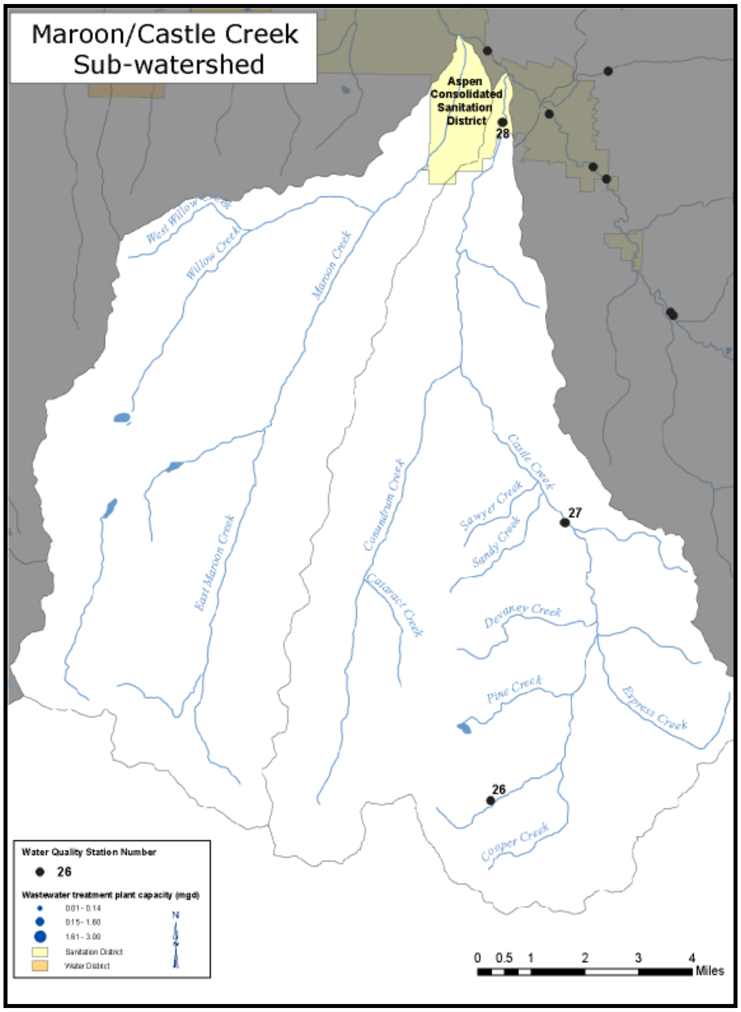


Figure 4.5.7. Water-quality sites and wastewater treatment providers in the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and CDOLA, No date b.

No water-quality exceedances occurred for pH or water temperature. Water temperatures indicate generally cold waters with maximum water temperatures below 14°C (57.2°F). Dissolved oxygen concentrations ranged from 7.6 mg/L to 11.5 mg/L indicating well-oxygenated conditions typical of high-gradient headwater streams.

Chloride concentration data were too limited for analysis. Sulfate concentrations ranged from 6 mg/L to 221 mg/L. Median total dissolved solid concentrations on Castle Creek were 320 mg/L, which indicates a source of dissolved material within the sub-watershed. The Maroon formation outcrops and underlies much of the drainage areas for both Maroon and Castle Creeks and is likely the source of the sulfate concentrations and total dissolved solids observed (Warner et al., 1985). Median hardness concentrations were 258 mg/L and indicate very hard water (Hem, 1985).

Limited nutrient data were collected for each site on Castle Creek. Of the 24 nutrient samples collected at all three sites, maximum nitrate concentrations were 0.105 mg/L, maximum total phosphorus concentrations were 0.0801 mg/L, and maximum un-ionized ammonia concentrations were 0.0052 mg/L. No nutrient constituent concentrations exceeded available water-quality standards or criteria.

Of the 40 to 45 cadmium, copper, manganese, selenium, and zinc concentrations, many values were censored and no Table Value Standard (TVS) exceedances were observed. Of the 40 total recoverable iron concentrations, values ranged from <10 to 1,387 µg/L, this upper value occurred at site 28 in November 2000 and exceeded the chronic TVS.

Riparian and Instream Areas

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed Maroon and Castle creeks in this sub-watershed. Figure 4.5.8 shows specific riparian and instream information, by habitat quality category, for each reach assessed. The habitat quality categories are shown in the riparian and instream assessment charts found in Section 3.3 and Section 3.4. Appendix 3.3.1 contains actual percentage values for each of these categories by sub-watershed and how they were determined. The sub-watershed has two stream segments:

- Maroon Creek Segment – Maroon Creek from the Silver Bar Campground to the Roaring Fork River (SHI MA1-1 through MA1-5); 5 miles.
- Castle Creek Segment – Castle Creek from Cooper Creek to the Roaring Fork River (SHI CS1-1 through CS2- 7); 15.16 miles.

A brief description of results follows. The SHI report contains detailed narrative description. “Right bank” and “left bank” refer to the orientation of the riparian zone when facing downstream.

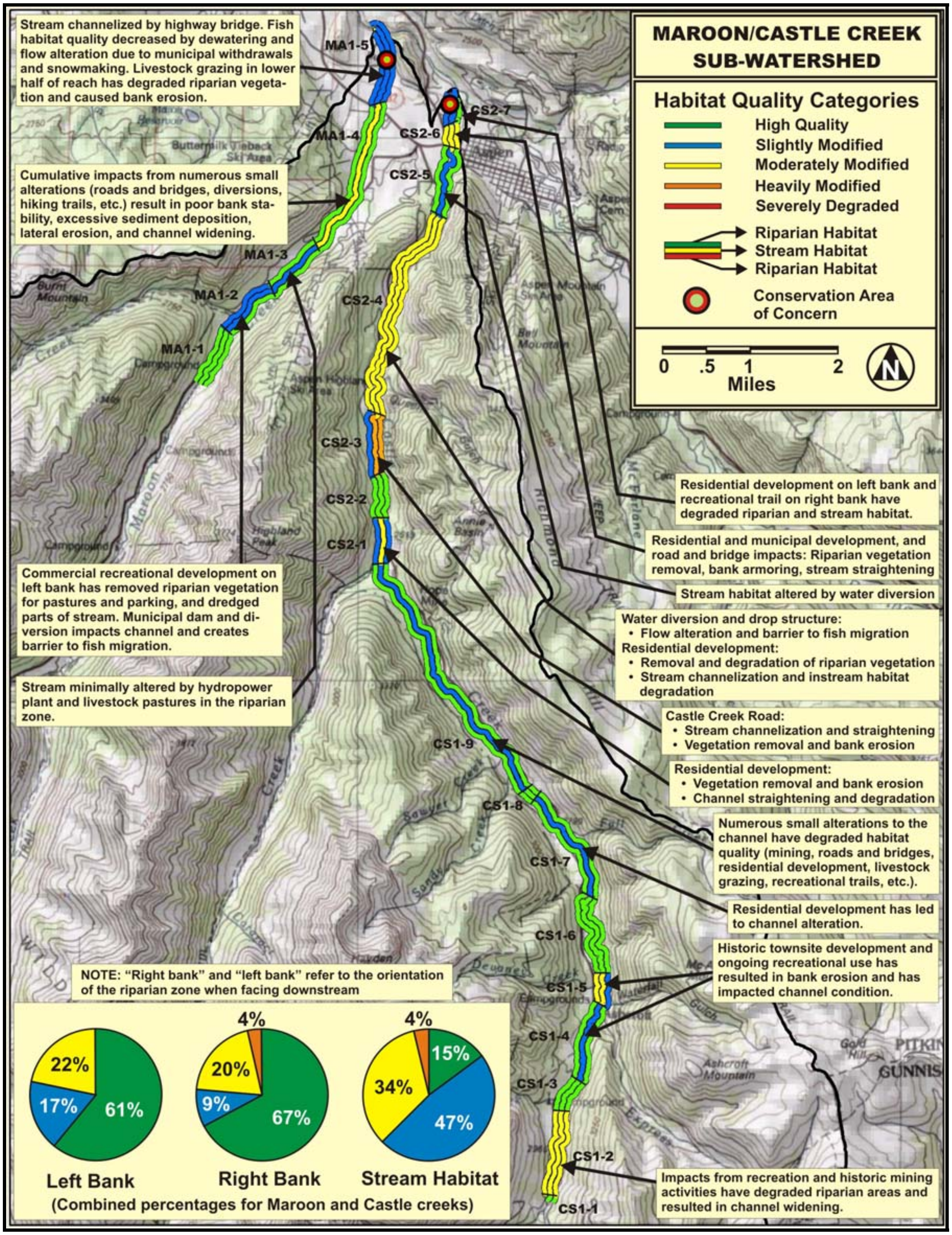


Figure 4.5.8. Riparian and instream habitat quality in the Maroon/Castle Creek Sub-watershed.

Uplands – Maroon Creek

Most of the uplands in the sub-watershed are designated wilderness, which explains why these habitats in the upper part of the Maroon Creek drainage are generally in good condition. Exceptions occur where recreational and pack trails have caused erosion and have acted as corridors for weed invasion. Upland development threatens stream health in the lower part of the drainage in reach MA1-2, and from MA1-4 to the confluence with the Roaring Fork River (Figure 4.5.9). In reach MA1-2, a commercial operation has introduced building and parking lots and converted upland habitat into summer pastures and winter snowmobile tracks. Downstream, the Buttermilk Ski Area to the west of Maroon Creek has continued the hillslope deforestation that initially occurred with mining-related logging. During the summer the ski area is grazed and residential/golf course development now dominates the base of the slopes. Further downstream, on the river terrace above Maroon Creek, sage meadows have been cleared for pasture and a golf course. On river terraces above and to the east of Maroon Creek, native sage meadows have been cleared and converted to recreational ball fields, a golf course, and residential developments with associated roads, parking lots, and bridges. Home development along the canyon edge has frequently resulted in vegetation removal with consequent slope erosion.

Figure 4.5.9. MA1- 4: Upland development has led to excessive hillslope erosion that moves sediment into the stream.

Riparian Habitat and Wildlife – Maroon Creek

While much of the sub-watershed's uplands are within wilderness, a corridor from the White River National Forest (WRNF) boundary in the lower part of the Maroon Creek drainage to Maroon Lake falls under a USFS Management Area Prescription for "Scenery" because of the road to Maroon Lake. The riparian area along the road is managed primarily by default for wilderness values. Only one bridge across Maroon Creek in this section accesses the East Maroon Creek Portal trailhead. Because the stream is deeply and naturally entrenched over much of its length there has been little opportunity for alteration in the riparian zone. Consequently, much of the riparian corridor is undeveloped and in good condition. High quality, unmodified riparian habitat is present on 66 percent of the left bank, 34 percent is slightly modified; and there is no moderately or heavily modified or severely degraded habitat. On the right bank, 81 percent of riparian habitat is high quality and 19 percent is slightly modified. Table 4.5.4 provides a summary of the type and extent of impacts to riparian and instream habitat in the Maroon Creek drainage. In some areas riparian zone width and vegetative bank protective cover and quality are reduced by human land uses. More specifically, these impacts result from vegetation disturbance related to campgrounds and trails in reach MA1-1; a commercial recreation operation and related parking lots, pastures, and corrals in reach MA1-2; and recreational trails, domestic livestock grazing and corrals, and some residential development in reaches MA1-4 and MA1-5 (Figure 4.5.10). Noxious weeds are not common throughout most of the drainage, but there presence could threaten ecosystem functions if they increase as they already have at a few sites. As examples, weeds have invaded wilderness in reach MA1-1, public open space in MA1-5, and land adjacent to recreational trails and where disturbance by development or grazing has not been adequately revegetated. The USFS has an active weed control program on federal lands in the Roaring Fork Watershed; in the Maroon Creek Sub-watershed most treatments are adjacent to the road to Maroon Lake and along designated hiking trails (USFS, 2007a).

Figure 4.5.10. MA1-2: Left photo: Development in the riparian zone has cleared native vegetation, encouraged the spread of noxious weeds, and has led to destabilized and eroded streambanks. Right photo: MA1-3: Construction of a corral and buildings in the riparian zone has eliminated vegetation, thus reducing habitat value.

Table 4.5.4. Summary of land development impacts and threats to riparian and instream habitat within the Maroon Creek drainage.

MAROON/CASTLE: MAROON CREEK SEGMENT	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	RIGHT BANK
Total Stream Miles: 5	34%	9%	28%	34%	30%	19%

In general, Maroon Creek riparian habitat provides high wildlife potential. Exceptions occur where residential, commercial, and recreational development fragments and disturbs riparian habitat. Important wildlife values derive from the occurrence of high quality vegetation and complex habitat, the presence of numerous beaver pond complexes, and minimal human disturbance. These characteristics result in high quality breeding and foraging habitat for Neotropical migrant songbirds as well as large and small mammals such as black bear, mountain lion, pine marten, spruce squirrels, and snowshoe hare. The Maroon Creek corridor also functions as an important migration corridor for numerous mammal species including mule deer, elk, and Canada lynx. Beaver are plentiful throughout the segment, are integral to stream stability, and provide high wildlife values.

Several studies have assessed biological diversity in Maroon Creek including the Colorado Natural Heritage Program (CNHP) (Spackman et al., 1999) and the Stream Health Initiative (SHI) (Malone and Emerick, 2007a). CNHP identified Maroon-Castle Creek (stream reaches MA1-3 through MA1-5) and East and West Maroon Creeks as Potential Conservation Areas

(PCAs) (figures 4.5.11 and 3.3.2 and Appendix 3.3.2), assigning the PCA a rank of "B3" (high biodiversity significance). For the Maroon-Castle Creek PCA, CNHP identified residential and recreational impacts as threats and recommended restricting or limiting recreational activities, removing weeds, and not expanding recreational trails. Breeding bird surveys were done by the SHI. High diversity scores and community assemblage indicated high quality riparian habitats with low levels of disturbance in several reaches including MA1-1 and the lower half of MA1-5. The SHI also identified the lower half of stream reach MA1-5 as a Conservation Area of Concern because of high wildlife values and potential impacts from surrounding upland housing, golf course development, and stream diversions. Although the upstream half of this reach is impacted by recreation and noxious weeds, right bank habitat on the lower half of the reach provides exceptionally high wildlife value. Habitat here is complex with high quality vegetation, minimal disturbance, and landowner management that favors wildlife habitat. Breeding bird surveys showed high species diversity, indicating high quality habitat, and also documented two species of concern – Northern goshawk and olive-sided flycatcher.

Figure 4.5.11. MA1-4 (part of a CNHP-designated Potential Conservation Area): Plant communities are sustainable and wildlife values are high in undeveloped areas.

Instream Habitat and Wildlife – Maroon Creek

The lower four to five miles of Maroon Creek were surveyed. For this section, stream morphology and type is characterized by Type E streams in flatter gradient reaches such as MA1-1, by Type B streams in steeper reaches such as MA1-3, and by Type C streams in moderate gradient reaches such as MA1-5 (Rosgen and Silvey, 1996). Refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of these types of streams

In the surveyed section, 14 percent of Maroon Creek is unmodified and has high quality instream habitat, 49 percent is slightly modified, 37 percent moderately modified; and no heavily modified or severely degraded instream habitat. Above and including stream reach MA1-1, instream habitat is high quality and in sustainable condition. From reach MA1-2 to the confluence with the Roaring Fork River, numerous small channelizing activities have had a moderate to large impact on the instream habitat and the channel. Channel-altering activities include paved roads, bridges, culverts, hiking trails adjacent to the stream bank, beaver dam removal, water diversions and a dam, constructed ponds in the flood plain, and bank erosion and riprapping where riparian vegetation has been removed.

Instream habitat upstream of the WRNF boundary is in very good condition due to the wilderness designation. No livestock grazing permits are active in either Castle Creek or Maroon Creek drainages. The biggest impacts to instream habitats are sediment delivery from trails and campsites adjacent to the stream. Although camping is not allowed within 100 feet of a stream (WRNF, 2002), recreation activities associated with nearby camping and trails have the potential to affect instream areas.

Reduced stream flows, excess sedimentation, and habitat simplification have reduced aquatic wildlife potential in the surveyed reach. Habitat conditions for aquatic wildlife are optimal on 48 percent of the stream and suboptimal on 52 percent. Wildlife-limiting factors include reduced flows, embeddedness, and channel alteration and simplification in reaches MA1-4 and 1-5, and degraded bank vegetation in reaches MA1-2 and 1-4. Walsh Aquatic Consultants (2001) observed "good populations" of both brown and rainbow trout. They also found 21 brown trout redds, suggesting that brown trout are using Maroon Creek for spawning and over-wintering habitat. Maintaining adequate winter flow is critical to trout survival but diversions could threaten sustainable flows and trout survivability. The CDOW stocks catchable rainbow trout in lower Maroon Creek and Maroon Lake to provide a "put and take" recreational fishery, but naturally reproducing non-native brown and brook trout make up the bulk of the fishery. Brook trout is the predominant species in the sub-watershed. Species distribution in Maroon Creek is similar to the rest of the Roaring Fork Watershed: brown trout in the lower reaches, a mixture of brook and brown trout in the middle reaches, and brook trout in the upper reaches. High lakes are generally stocked with Colorado River cutthroat trout (CRCT) for recreational fisheries. No stream populations of CRCT are found in the Maroon Creek drainage.

Uplands – Castle Creek

The headwaters of Castle Creek begin at the foot of Castle Peak in the Elk Mountains and flow northward toward Aspen. The Elk Mountains are unique in Colorado. Two factors, their east-west alignment and lithological composition, create conditions that support plant species of the Northern Rockies that do not occur in the Southern Rockies (Weber, 1993). Because these plant populations are often small, human disturbance to this environment could be detrimental to the survivability of these plant species and communities. Although much of the landscape surrounding Castle Creek's headwaters is in the White River National Forest (including wilderness), historic mining roads crisscross the landscape. These roads provide motorized access into relatively pristine habitat and promote the spread of noxious weeds. Damage to fragile tundra plants and soils from vehicles illegally driving off-road is common. Throughout the drainage, numerous historic mines continue to cause sediment erosion, leading to upland and riparian habitat degradation.

In the lower section of the drainage, from CS2-1 to the confluence with the Roaring Fork River, anthropogenic development of upland habitat fragments and diminishes upland ecosystem functions such as water storage, soil conservation, and wildlife habitat. Ski area development occurs on both sides of the valley and has resulted in deforestation. Residential and commercial development impacts are extensive and intense, converting native habitats into non-native grass lawns and house sites. Infrastructure like roads and parking lots increase the impact.

Riparian Habitat and Wildlife – Castle Creek

Riparian habitat width and quality on the left bank of Castle Creek is high on 59 percent of the stream, 12 percent of riparian habitat has been slightly modified, and 29 percent has been moderately modified. On the right bank, riparian zone width and habitat quality is high on 62 percent of the stream, slightly modified on 6 percent, moderately modified on 27 percent, and heavily modified on 5 percent. There were no severely degraded reaches on either the left or right bank. For the most part, riparian habitat quality in the upper reaches of Castle Creek, from CS1-1 through CS1-9, is high and enhances ecosystem functions. However, in a few areas, notably where roads, recreational trails, or home developments occur in the riparian zone, vegetation has been damaged, soils compacted, and ecosystem functions compromised (Figure 4.5.12). In the lower reaches of Castle Creek, from CS2-1 through CS2-7, the cumulative effect of development activities has been to reduce the width and quality of the riparian zone and degrade ecosystem functions over the majority of the riparian corridor. Table 4.5.5 provides a summary of the impacts and threats to riparian and instream habitat on Castle Creek.

Figure 4.5.12. In residential developments throughout CS2-4, replacement of native riparian vegetation with non-native grass lawns has resulted in eroding banks and has affected stream flows.

Recreational trails along streambanks and through riparian habitat have damaged and removed bank-stabilizing riparian vegetation in stream reaches CS1-2, 1-4, 1-5,1-9, and 2-7. Consequences include destabilized banks with erosion producing down- and lateral bank cutting. Castle Creek Road parallels the stream along most of the drainage. Wherever the road is within the riparian corridor, as in reaches CS1-2, 1-9, 2-3, and 2-6, bank-stabilizing vegetation has been removed or altered, riparian habitat has been reduced, and functions have been lost. Historic and current development in the riparian zone has reduced the functional width of the zone and diminished vegetation quality. In reach CS1-5, historic townsite development altered riparian vegetation and continues to impact the area's habitat today (Figure 4.5.13). Residential development in reaches CS1-7, 2-1, 2-4, 2-6, and 2-7 has typically included removal of native understory herbs, shrubs, seedlings, and saplings and replacement with non-native grass lawns and ornamentals. This type of landscaping activity has decreased the likelihood of forest regeneration and reduced ecosystem functions by decreasing the functional width and quality of riparian habitat. Noxious weeds are not common, and currently are not a threat to ecosystem functions.

Figure 4.5.13. Historic development at the townsite of Ashcroft, which included removal of riparian vegetation, continues to impact riparian and instream habitat.

Table 4.5.5. Summary of land development impacts and threats to riparian and instream habitat within the Castle Creek drainage.

MAROON/CASTLE: CASTLE CREEK SEGMENT	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%)	
					LEFT BANK	RIGHT BANK
Total Stream Miles: 5	16%	12%	18%	24%	0%	0%

The Castle Creek riparian corridor provides important routes for daily and seasonal wildlife migration; elk and mule deer use the corridor to move between summer and winter range, black bear use Castle Creek as a route to find new foraging habitat, and Canada lynx use the corridor as a travel route. Wildlife potential is high in the uppermost reaches of Castle Creek where a diverse mosaic of structurally complex and species-rich habitats in combination with a relative lack of human disturbance provides the potential for a complete and sustainable community of native wildlife. Neotropical migrant songbirds find high quality breeding habitat in these undeveloped reaches. In the downstream reaches of Castle Creek, from CS2-1 to the confluence with the Roaring Fork River, the stream enters lower elevation montane ecosystems where land ownership transitions from mostly public to mostly private lands. Residential encroachment and road building in the riparian zone has reduced the amount and quality of riparian habitat available to wildlife and has increased disturbance. High quality riparian habitat still remains where development has not occurred, including in reaches CS2-2, CS2-5, and CS2-7 (Figure 4.5.14).

Figure 4.5.14. In reach CS2-7, high quality riparian and instream habitat provide excellent wildlife potential.

Several studies have assessed biological diversity in Castle Creek including the Colorado Natural Heritage Program (CNHP) (Spackman et al., 1999), the Stream Health Initiative (SHI) (Malone and Emerick, 2007a), and the Elk Mountain Biological Survey (EMBS) (PanJabi,1995). CNHP identified stream reaches CS2-4 through CS2-7 (at the confluence with the Roaring Fork) as a Potential Conservation Area (PCA) and assigned the PCA a rank of B3 (high biodiversity significance). CNHP identified residential and recreational impacts as threats and recommended restricting or limiting recreational activities, removing weeds, and not expanding recreational trails. Breeding bird surveys conducted by EMBS in high-elevation reaches upstream of CS1-1 documented the presence of several disturbance-sensitive species and species of concern, including Swainson's hawk, rufous hummingbird, olive-sided flycatcher, golden-crowned kinglet, and brown-capped rosy finch. The presence of these birds during the breeding season indicates high quality habitat. However, the presence of brown-headed cowbirds was also documented. Cowbirds are nest parasites not native to the mountains of Colorado. Their presence is directly associated with livestock feedlots and corrals, and they are known to parasitize birds such as warblers, flycatchers, vireos, finches, and sparrows. Breeding bird point-count surveys were also conducted by the Stream Health Initiative. High diversity scores and community assemblage indicated high quality riparian habitats with low levels of disturbance in several reaches including CS1-1, 1-3, 1-7, 1-8 and 1-9. SHI also identified one Conservation Area of Concern on the left bank of the upper half of CS2-7. Riparian habitat on the upper part of this reach is a good example of a narrowleaf cottonwood/blue spruce/thinleaf alder forest that is ranked as vulnerable by CNHP. Wildlife values are very high, disturbance is minimal on the left bank, and the ecological connection between riparian habitat and the stream is intact and functional. Surrounding development and stream flow alteration threaten these values.

Instream Habitat and Wildlife – Castle Creek

Stream morphology and type is characterized by Type E streams in flatter gradient reaches such as CS1-6, Type B streams in steeper reaches such as CS1-1, and Type C streams in moderate gradient reaches such as CS2-2 (Rosgen and Silvey, 1996). Refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of these types of streams.

The majority of instream habitat in the upper reaches of Castle Creek, from CS1-1 through CS1-9, is in sustainable condition with only a few sites degraded by anthropogenic modification. From stream reach CS2-1 through CS2-7 stream habitat becomes progressively modified and degraded by the increased intensity and cumulative impacts of riparian and channel alteration. Overall, 15 percent of stream habitat is unmodified and has high quality, 47 percent has been slightly modified, 33 percent moderately modified, 5 percent heavily modified; and no severely degraded instream habitat in Castle Creek.

Along a majority of the creek, the stream channel has a natural shape with minimal channelizing modifications, lateral cutting, or downcutting. Areas where historic and current development activities have occurred along streambanks and in the riparian zone, like Castle Creek Road and several dispersed camping sites within the riparian zone in reach CS1-2, have resulted in lateral bank erosion and channel widening. Within reach CS1-5, the historic development of the townsite of Ashcroft involved riparian vegetation removal, leading to channel downcutting. Further downstream, from CS2-1 through CS2-7, channel altering impacts increase and include trails, roads, bridges, culverts, water diversions, drop structures, bank erosion, and riprapping. Residential development with associated vegetation alteration and bank riprapping has affected reaches CS2-1, 2-4, 2-6 and 2-7. This residential development and the effects of Castle Creek Road along reaches CS2-3 and 2-6 have contributed to channel straightening which has led to reduction in sinuosity, increased gradient, and habitat simplification with excessive riffle or run habitat and reduced pool habitat (Figure 4.5.15).

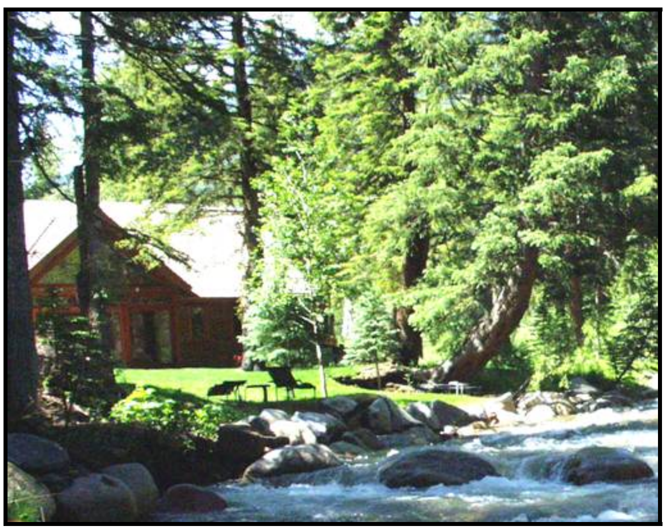


Figure 4.5.15. Clearing the riparian corridor's understory shrubs has reduced bank protection, contributes to channelization, eliminates wildlife habitat, and diminishes stream functions.

Hydrologic alteration occurs from diversions, reduced beaver activity, and riprapped banks. Beaver dam removal is the primary instream habitat threat in the Castle Creek drainage (Mark Lacy, USFS Fish Biologist, personal communication, March 23, 2008) . The cumulative effect has been to reduce base flow on the lower part of this segment, and on numerous reaches the width/depth ratio is inappropriately high.

Sedimentation is excessive in reaches CS1-2, 1-5, 2-4, 2-5, and 2-6. It results from bank erosion in CS1-2 and 1-5, can be attributed to altered flows and bank erosion in CS2-4 and 2-6, and stems from erosion in upstream reaches in CS2-5 (Figure 4.5.16). In reach CS1-9, there is natural sediment delivery into Castle Creek.

Figure 4.5.16. Along reach CS2-1 a roadcut has destabilized the hillslope causing erosion and excess sediment to move into the stream.

Aquatic wildlife potential is optimal on 63 percent of Castle Creek and suboptimal on 37 percent. Potential is typically high in upstream reaches from CS1-1 through CS1-9, but is generally reduced downstream from CS2-1 through CS2-7, where habitat conditions limit aquatic wildlife. Castle Creek was sampled in 2007 in reach CS1-9 and brook trout was the dominant salmonid species (75 percent), with rainbow trout making up the remaining 25 percent. Mottled sculpin was the most common fish species (78 percent of all fish sampled) (Appendix 3.4.1). Macroinvertebrate data indicated that 50 percent of the taxa was in the EPT taxa category (see Section 3.4 for explanation of this biological indicator), and 23 of 40 species were intolerant of pollution. These data indicate good water quality and species composition. The Management Indicator Species's survey will be repeated in 2012, and will generate valuable trend information on species composition and habitat change.

Historically, Express Creek was a Colorado River cutthroat trout stream, but brook trout is now the dominant species.

4.5.4 Important Issues

Below is a summary of key findings from available scientific information, data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the water resources of the sub-watershed.

Key Findings

The following bullet points refer specifically to the overall sub-watershed:

- Through proactive conservation measures, Aspen has reduced municipal water use by 48 percent since 1993 (affecting both Maroon and Castle creeks, sources for the city's water supply).
- The sub-watershed has one direct-flow conditional water right greater than 10 cfs and two conditional storage rights greater than 1,000 acre-feet.
- With respect to water quality, water-quality data is limited to three water quality sites. Based on available data at these sites, few water-quality standards are exceeded.
- Two breeding populations of boreal toad have been documented in the sub-watershed. The Colorado Natural Heritage Program (CNHP) identified one of these areas as a Potential Conservation Area (PCA)(Conundrum Creek).

The following bullet points refer specifically to Maroon Creek drainage:

- Compared to pre-developed flow patterns on lower Maroon Creek, a 15-20 percent flow reduction occurred from October to April.
- A significant flow reduction was seen on Willow Creek in September when compared with pre-developed flows.
- In the surveyed section of Maroon Creek, recreation activities (including trails) represent the greatest cause of impacts and threats to riparian and instream habitat, affecting 34 percent of the surveyed area. Development, flow alteration, and weeds also impact or threaten the stream corridor.
- Because much of the riparian corridor is not developed, it is generally characterized as high quality, with some areas that are slightly modified.
- No heavily modified or severely degraded instream habitat was found in the surveyed section of Maroon Creek; 14 percent is high quality, 49 percent slightly modified, and 37 percent moderately modified.
- CNHP identified Maroon-Castle Creek and East and West Maroon Creeks as Potential Conservation Areas with threats from residential and recreational activities and management recommendations for recreation restrictions (including no expansion of trails) and removal of weeds.
- The Stream Health Initiative (SHI) identified a Conservation Area of Concern (CAC) in the lowest reach on Maroon Creek due to high wildlife values and potential impacts from stream diversions and surrounding upland housing and golf course development.
- Breeding bird surveys showed high species diversity, indicating high quality habitat, and also documented several species of concern including Northern goshawk, olive-sided and cordilleran flycatcher, and MacGillivray's warbler.
- Aquatic wildlife habitat is optimal on 48 percent of the stream and suboptimal on 52 percent.

The following bullet points refer specifically to Castle Creek drainage:

- Compared with pre-developed flow patterns, flows in lower Castle Creek were significantly reduced by 20-30 percent from November to March.
- Within the surveyed section of Castle Creek, the greatest factor impacting or threatening riparian and instream habitat is flow alteration (affecting 24 percent of the surveyed stream corridor). Trails, roads, and development each impact or threaten from 12 to18 percent of the stream corridor's habitat.

- High quality riparian habitat is found on approximately 60 percent of both the left and right banks in the surveyed sections of the creek. Because of development activities along the lower creek, more than a quarter of the riparian habitat has been moderately modified on both the right and left banks.
- For the surveyed reaches, most of the instream habitat in the upper creek is in sustainable condition. It becomes progressively modified and degraded going downstream. Overall, 15 percent of instream habitat is high quality, 47 percent slightly modified, 33 percent moderately modified, and 5 percent heavily modified; Castle Creek has no severely degraded instream habitat.
- Wildlife potential is high in the uppermost reaches of Castle Creek. Neotropical migrant songbirds find high quality breeding habitat in these undeveloped reaches.
- CNHP has identified one PCA on Castle Creek. It identified residential and recreational impacts as threats to the PCA and recommended restricting or limiting recreational activities, removing weeds, and not expanding recreational trails.
- SHI also identified one CAC that is a good example of a narrowleaf cottonwood/blue spruce/thinleaf alder forest community (ranked as vulnerable by CNHP).
- Aquatic wildlife potential is optimal on 63 percent of Castle Creek and suboptimal on 37 percent.
- Brook trout is the dominant trout species (making up 75 percent of salmonid numbers) on Castle Creek, with rainbow trout making up the remaining 25 percent.

Data Gaps

A number of gaps in information for the sub-watershed limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Groundwater quantity data (none is available for the sub-watershed), including evaluation of sub-surface geology to determine availability, sustainability, and vulnerability of groundwater resources;
- Water-quality data collection in the upper part of the sub-watershed, and additional water-quality data for Conundrum, West Maroon, and Maroon creeks;
- Water-quality data for the following constituent groups:
  - Specific conductance – to help establish sources of dissolved material and describe other water-quality conditions
  - Suspended sediments – to evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals
  - Emerging contaminants – to establish a baseline to understand occurrence in the rest of the watershed;
- Water-quality data for groundwater sources;
- Data on upland habitat condition;
- Data on impacts of off-road vehicle use within upland and riparian habitats; and
- Information about upland and riparian mammal community diversity, amphibian and reptile populations, and population sustainability.

Relevant Local Initiatives, Plans, and Studies

- Two objectives from the Maroon/Castle Creek Master Plan are directly relevant to this report:
    - The "Water Use, Quantity, and Quality Objective" establishes a priority of protecting creeks, wetlands, and riparian areas. In addition, the objective highlights the importance of preservation of water quantity/stream flows, water quality, and aquatic habitat.
    - The "Natural Environment Objective" focuses on the importance of protection of open space, drainage ways, plant species, cover, and corridors for native wildlife species in the Castle and Maroon Creek valleys.

4.6 Snowmass/Capitol Creek Sub-watershed

4.6.1 Environmental Setting

Snowmass Creek and Capitol Creek together drain a portion of the Elk Mountains in the south-central part of the Roaring Fork Watershed. The 100-square mile Snowmass/Capitol Creek Sub-watershed contains public land, most of which is designated wilderness, along with rural residential and agricultural land uses. This sub-watershed contains an area known as "Old Snowmass," primarily a collection of residences that spreads out along the lower Snowmass Creek Valley from State Highway 82. The sub-watershed's ecoregions include Alpine Zone, Sedimentary Subalpine Forests, Sedimentary Mid-elevation Forests, and Foothill Shrublands. Since the 1970s there has been a debate about the diversions of water from East Snowmass Creek and Snowmass Creek for use in the Brush Creek drainage (where the Town of Snowmass Village is located), and the effects of such diversions on the creek's aquatic ecosystem. See Figure 4.1 for an overview map that shows the location of this sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions, and the sub-watershed's general physical characteristics are summarized in Table 4.1.

Topography and Geology

Snowmass Creek starts at Snowmass Lake (10,980 feet) and is joined by both West and East Snowmass creeks as it flows north to join the Roaring Fork River. The other major tributary in this sub-watershed, Capitol Creek, has it headwaters at Capitol Lake (11,560 feet). Capitol Creek flows into Snowmass Creek about a mile upstream of its confluence with the Roaring Fork River.

The Elk Mountains in the upper Snowmass and Capitol creek drainages are steep, with slopes greater than 30 and 45 percent (Figure 1.4). Several peaks in these mountains form the divides between the drainages of Snowmass and Capitol creeks and Avalanche Creek (which flows west, draining into the Crystal River), including Snowmass, Hagerman, and Capitol peaks and Snowmass Mountain. Capitol Peak and Snowmass Mountain are both more than 14,000 feet in elevation. All of these peaks are formed by Tertiary intrusive rocks. A strip of intrusive rock also separates Snowmass and East Snowmass creeks. On the eastern edge of the sub-watershed, the divide with Maroon Creek is made up of the Maroon Formation with names such as North Maroon and Maroon peaks (both more than 14,000 feet, known as the Maroon Bells) as well as Baldy, Buckskin, and Belleview mountains. The glacial history of this area can be seen in the glacial deposits found along a significant length of Snowmass Creek. Glacial lateral moraines are often deposited on oversteepened bedrock surfaces that were sculpted by the glaciers and are very prone to sliding and slumping (Figure 4.6.1). The predominant geologic formation in this sub-watershed is the less steep Mancos Shale, which is very susceptible to erosion, leading to mudflows, landslides, and other slope instability problems. The Maroon Formation has more porous soils than the Mancos Shale, which explains why these two geologic formations have different plant communities and different response levels to human disturbances (with Mancos Shale more prone to disturbance). Gravels and alluviums in the lowest part of the sub-watershed correspond to the more gently-sloped agricultural lands.

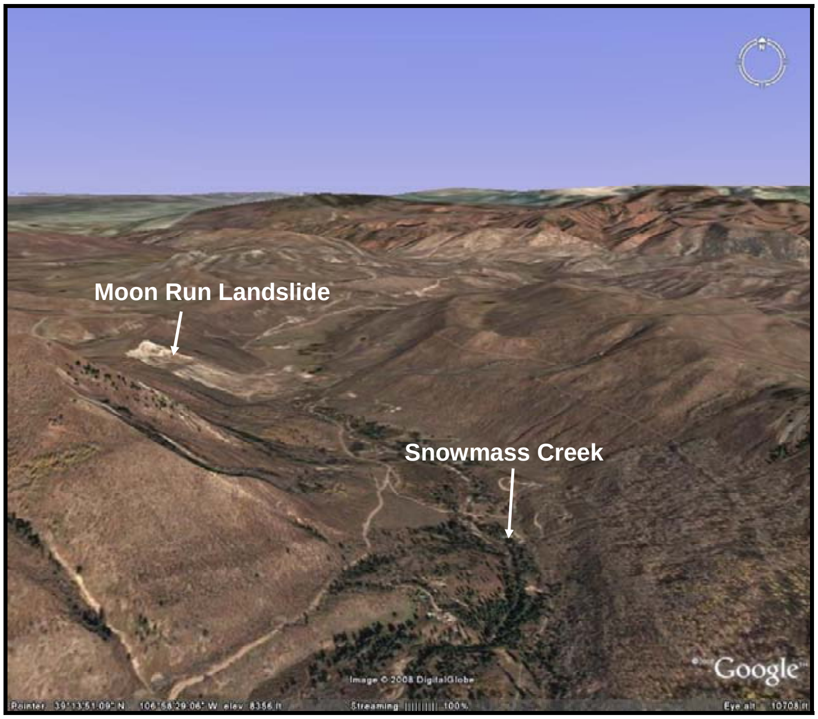


Figure 4.6.1. Moon Run landslide scar (lower left) in the Snowmass Creek drainage (Google Earth image downloaded March 15, 2008).

Weather/Climate

No Colorado Basin River Forecast Center SNOTEL sites, Western Regional climate stations, or Colorado Collaborative Rain, Hail, and Snow Network stations occur in this sub-watershed. General weather/climate information can be found in Chapter 1.

Biological Communities

Throughout the Snowmass Creek and Capitol Creek drainages, upland plant communities vary with elevation, aspect, and soil type (Figure 4.6.2). At Snowmass and Capitol lakes, uplands are characterized by alpine tundra ecosystems. Below the lakes, subalpine plant communities include dense stands of spruce-fir forests interspersed with aspen groves and herbaceous meadows. Montane plant communities begin at approximately 9,000 feet with aspen forests intermixing with spruce-fir forests, sage shrublands, and herbaceous meadows. As the geology becomes dominated by shales at around 7,500 feet, the upland plant community shifts to a mosaic of oak-serviceberry and sage shrublands intermixed with pinyon-juniper forest and, where soil moisture increases in drainages on north-facing slopes, by aspen groves and patches of Douglas fir forest.

The subalpine riparian habitat is mainly dense spruce-fir forest with an understory of willow and alder. In flatter canopy openings, it is made up of sedge meadows and willow carrs. Upper montane riparian ecosystems are characterized by riparian aspen-alder forests intermixed with conifer forests, wet meadows, and willow carrs. Further downstream, in the Montane Life Zone, plant communities transition to narrowleaf cottonwood-blue spruce forests interspersed with wide willow carr communities dominated by thinleaf alder, willow, red-osier dogwood, twinberry honeysuckle, gooseberry, currant, and Wood's rose.

Figure 4.6.2. The range of Life Zones from the Alpine to the Montane offers a diversity of ecosystems and plant communities within the Snowmass/Capitol Creek Sub-watershed (Snowmass Creek looking Southwest toward Mt. Daly).

Current land uses vary with sub-watershed elevation. Predominant land uses in higher elevation reaches include forest, grazing, and recreation (especially skiing and hiking). At lower elevations, land uses shift to agriculture including irrigated hay fields and pastures for grazing, and to a small extent, rural residential and commercial use.

A typical mix of native mammals is found in the undeveloped areas of the sub-watershed. The Stream Health Initiative (Malone and Emerick, 2007a) observed mammals or signs/tracks of species including marmot, pika, mountain lion, pine marten, elk, mule deer, black bear, and beaver. In the Hay Park area, through the use of track plates Malone (2001) documented the presence of bobcat, mountain lion, pine marten, long-tailed weasel, black bear, and fox, and with live-traps documented the presence of small mammals such as montane, long-tailed, and Southern red-backed vole.

Appendix 1.3 lists the riparian-related and instream species and communities of concern in the sub-watershed. Figure 3.3.5 provides a map showing bald eagle wintering range for the overall watershed, which includes the lower parts of Snowmass and Capitol creeks within the sub-watershed. The bald eagle is designated at the state level as threatened. A great blue heron nesting colony and foraging area is on Snowmass Creek (Figure 3.3.4). Within the sub-watershed, the Colorado Division of Wildlife (CDOW) has identified occurrence of the following fish species: Colorado River cutthroat (CRCT), brook, brown, and rainbow trout; and mottled sculpin (Harry Vermillion, CDOW, personal communication, March 3, 2008). Figure 3.4.6 shows the location of two conservation populations of CRCT in the sub-watershed.

4.6.2 Human Influences

Land Ownership and Use

Figure 4.6.3 shows ownership and protection status for the sub-watershed. Public lands that make up about half of this sub-watershed are federally managed. The upper portion is within the White River National Forest, managed by the U.S. Forest Service (USFS). Headwaters of all of the sub-watershed's major streams originate in the Maroon Bells-Snowmass Wilderness Area. The Eagle Mountain Wilderness Study Area, managed by the Bureau of Land Management (BLM), is adjacent to this USFS wilderness area. The lower half of the sub-watershed is predominantly in private ownership. Uplands of both sides of Snowmass Creek below the confluence with Capitol Creek are managed by the BLM. Several open space parcels lie along smaller tributaries (Appendix 4.1).

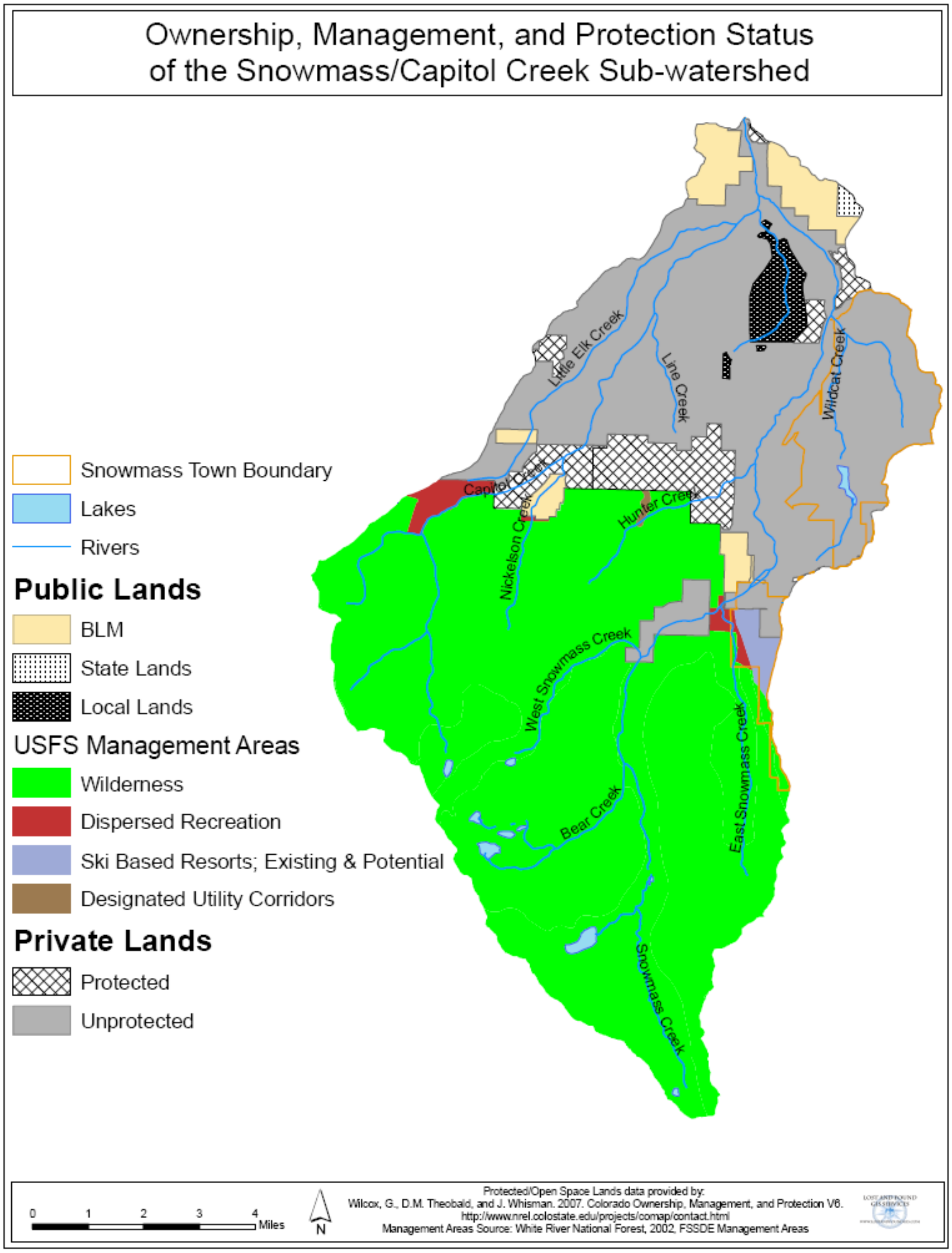


Figure 4.6.3. Ownership and protection status of the Snowmass/Capitol Creek Sub-watershed.

The sub-watershed is located entirely within Pitkin County. The Snowmass-Capitol Creek Caucus (SCCC), made up of landowners and residents of the sub-watershed, was formed and officially recognized in 1974. The caucus makes recommendations to Pitkin County regarding all matters directly affecting the caucus area (http://www.aspenpitkin.com/depts/77/snowmass_capitol_creek.cfm). The SCCC concerns itself with the privately-owned areas in the sub-watershed as well as with water use in nearby Snowmass

Village (http://www.aspenpitkin.com/pdfs/depts/7/snowcapmap.pdf). In September 2003, the SCCC Board approved its Master Plan, which was subsequently forwarded to the county. The plan includes goals, objectives, and implementation measures for seven areas: land use, environment, growth, infrastructure and essential community facilities, transportation, recreation and tourism, and mineral exploration/extraction. Several objectives relate directly to watershed issues and resources. As examples, the caucus stresses the importance of protection of the natural environment in the Snowmass and Capitol Creek valleys through land preservation, noxious weed control, and only allowing development that does not harm water availability and quality. Its master plan also contains detailed measures for protecting riparian and aquatic ecosystems and for monitoring and assuring adequate stream flows and water quality in Snowmass and Capitol creeks and their tributaries. These elements of the Master Plan are found in more detail in Appendix 1.5. Refer to the Master Plan for additional information, including implementation measures (http://www.aspenpitkin.com/depts/77/snowmass_capitol_creek.cfm).

Figure 4.6.4 shows roads in the sub-watershed and identifies roads within 150 feet of second order and higher streams (approximately 6 percent of the streams). No major roads parallel streams within the sub-watershed. County roads follow along the lower parts of both Snowmass Creek and Capitol Creek.

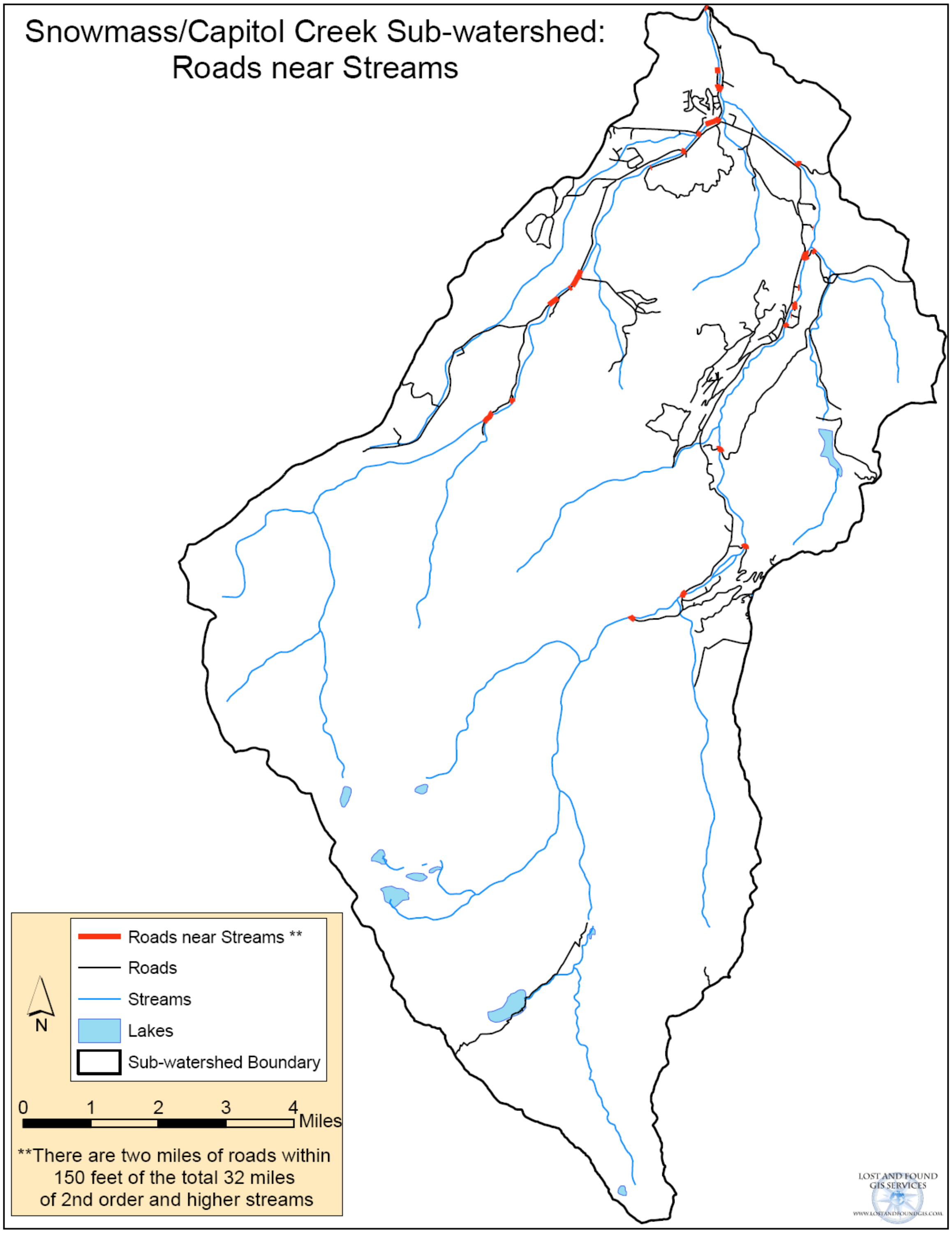


Figure 4.6.4. Roads near streams in the Snowmass/Capitol Creek Sub-watershed.

The Town of Snowmass Village is located partly in this sub-watershed, including most of the Wildcat Creek drainage. Water and wastewater treatment for the town are provided by the Snowmass Water and Sanitation District (SWSD) (Appendix 3.1.3). The SWSD uses a tiered water rate structure and a watering schedule to encourage water conservation. Its website provides water conservation tips (http://www.swsd.org/water-conservation). See Figure 4.6.5 for a map of the SWSD's service area and Figure 4.6.9 for locations of its water and wastewater treatment facilities. SWSD water supplies come primarily from East Snowmass Creek Spring and are supplemented by East Snowmass Creek when required by demand (http://www.swsd.org/about-us). SWSD uses water from the East Snowmass Creek drainage due to impaired water quality and limited physical supplies in the Brush Creek drainage (W.W. Wheeler and Associates, 2006). Additional sources include water rights from the mainstem of Snowmass Creek (CWCB and CDWR, 2007b). Water from Snowmass Creek is used when East Snowmass Creek is low or frozen (Lutz, 2008). Treated water is provided to the Brush Creek Metropolitan District (Figure 4.6.9) by SWSD. By contractual agreement, the amount delivered is not to exceed 150,000 gallons per day or 2 million gallons per month.

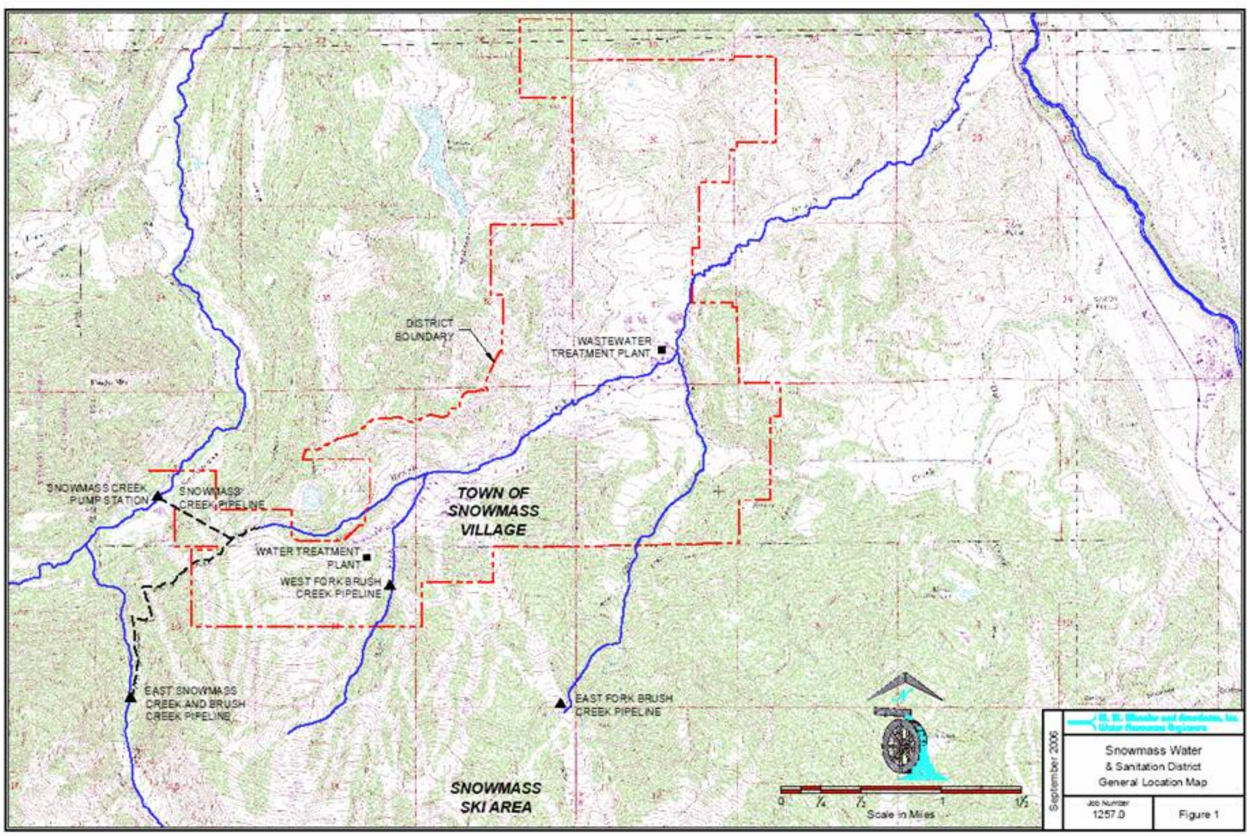


Figure 4.6.5. Snowmass Water and Sanitation District boundary and diversions from the Snowmass Creek basin to the Town of Snowmass Village. Source: Wheeler and Associates, 2006.

A 2006 study by W.W. Wheeler and Associates requested by SWSD evaluated the need for, and benefit of, securing raw water storage as a component of meeting future water demands and minimizing diversions from Snowmass Creek during periods of low flow. For two dry periods (1977 and 2002-2003), the study evaluated the amount of raw water storage that would be required to meet anticipated demand without additional mandatory water conservation measures, maintaining, to the extent possible, at least 7 cubic feet per second in Snowmass Creek and providing storage reserves for a catastrophic event.

The estimated amount needed to fulfill these goals ranged from 175 to 330 acre-feet annually, depending on the amount of development that would occur in Snowmass Village, and the level of severity of the drought event (1977 or 2002/2003). The estimated amount of storage needed to meet SWSD's demand for a three-week period, if supply were to be interrupted due to a catastrophic event, ranged from 105 to 120 acre-feet. The study did not evaluate potential raw water storage sites. Reservoir sites in both the Brush Creek and Snowmass Creek drainages have been contemplated. The SCCC pushed the SWSD to look at water sources within the Brush Creek drainage (Lutz, 2002).

In 2007, SWSD entered into an agreement with the Ziegler family for the purchase of Ziegler Reservoir (or Lake Deborah) located in the Brush Creek drainage (http://www.swsd.org/2007-newsletter). Approvals by the Pitkin County Commissioners in May 2008 allowed the reservoir to be expanded and used as water storage for Snowmass Village (Pitkin County, 2008). Enlarging the reservoir from the existing 18 million gallon capacity to 73 million gallons represents 14 times the amount of SWSD's current 5.2 million gallon potable water storage (http://www.swsd.org/2007-newsletter). Pitkin County approval was subject to 18 conditions, including:

- SWSD shall continue to abide by its contractual obligations with Pitkin County including the 1978 agreement, the 1995 Water Settlement Agreement, and the Trigger Point Methodology Agreement.
- SWSD will fill and refill Ziegler Reservoir only with water rights that are diverted in priority as administered by the Office of the State Engineer. When diverting from Snowmass Creek to fill or refill Ziegler Reservoir through the Snowmass Creek Pipeline, SWSD will obtain a new water right that will honor the senior administration of the CWCB minimum instream flow water right.
- SWSD will consent to the cancellation of any remaining portion of the Sam's Knob Reservoir conditional water right after the expanded Ziegler Reservoir is constructed and operational.
- SWSD intends to utilize Ziegler Reservoir to store water diverted from its direct-flow water sources for emergency purposes and system reliability. Direct-flow diversions from East Snowmass Creek will be the operationally preferred water source to fill and refill the reservoir. Additionally, SWSD intends to store water in the reservoir for use in the event that East Snowmass Creek, Brush Creek, or Snowmass Creek direct-flow water sources become untreatable or unavailable due to circumstances such as: 1) loss or diminished production due to a landslide, snow slide, pipeline blockage, or other interruption or failure of its diversion, treatment, or delivery facility; 2) contamination from forest fire, flood, chemical spill, contaminants, bacteria, turbidity, or similar occurrences; or 3) drought conditions or a loss of flow from direct-flow water sources.

  Under appropriate operational, hydrological, and atmospheric conditions, SWSD intends to utilize its direct-flow water sources from East Snowmass Creek and Brush Creek prior to commencing direct-flow diversion from its Snowmass Creek water sources through the Snowmass Creek Pipeline. Utilization of water stored in Ziegler Reservoir and direct flow diversions of water from its East Snowmass Creek and Brush Creek water sources will provide a buffering effect from direct flow diversions from its Snowmass Creek water source, especially at times of low stream flow in Snowmass Creek.

- Prior to submission of the earthmoving permit for reservoir maintenance or the reservoir expansion, SWSD, in consultation with CDOW, shall conduct a boreal toad survey. If a breeding population is found, SWSD shall create and implement a mitigation plan that is reviewed and approved by CDOW.

As part of the 2006 study, W.W. Wheeler and Associates estimated the current demand per Equivalent Residential Unit (EQR) for each month. Average daily use per EQR ranged from a low of 172 gallons in November to a high of 525 gallons in July, with an overall average of 323 gallons per day. Existing municipal development is at 4,600 EQRs, with a future estimate of 5,900 EQRs that includes Base Village and other redevelopment. Under the scenario of build-out within the district, the estimated number of EQRs is 6,200. A maximum development level resulting from additional future development and infill development within the district is 6,800 EQRs.

Although only part of the Snowmass Ski Area is in the Snowmass Creek basin, most of the water for snowmaking comes from this basin. Water for snowmaking is currently decreed for and provided by the junior East Snowmass Brush Creek Pipeline and Snowmass Creek Pipeline water rights, which are junior to instream flow rights (ISF) held by the Colorado Water Conservation Board on Snowmass Creek (see Section 4.6.3 for more information on the CWCB ISFs). These rights are decreed for snowmaking from October 15th to Dec 31st (W.W. Wheeler and Associates, 2006). In 1994, the Army Corps of Engineers (ACOE) worked with the U.S. Forest Service and Aspen Skiing Company on the Snowmass Ski Area Environmental Impact Statement (EIS), which included expansion of snowmaking activities using Snowmass Creek water provided by the SWSD. As a result of that work, the ACOE developed a minimum bypass flow for the diversion water used for snowmaking. It also modified the SWSD Section 404 permit to require that diversions for snowmaking cease when those diversions would cause the stream flow to drop below 8 cfs. This requirement does not affect municipal diversions (Claffee, No date). The ski area used about 206 acre-feet in 2004-2005, an increase of 46 acre-feet over 2003-2004 snowmaking water use (Table 1.5).

Mining

There are no permitted mines shown on the Colorado Division of Reclamation Mining and Safety GIS Mapping site for the sub-watershed.

Recreation Activities

Only a small portion of the White River National Forest land in this sub-watershed is outside of the Maroon Bells-Snowmass Wilderness Area, and there are no developed campgrounds in the sub-watershed. USFS trails follow Snowmass, East and West Snowmass, Hunter, and Capitol creeks. Popular hiking/backpacking destinations include Snowmass and Capitol lakes.

The Snowmass Ski Area is mostly located in the Brush Creek drainage, and is discussed in Section 4.2 (Upper Middle Roaring Fork Sub-watershed).

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams and lakes in the sub-watershed have been stocked with the species listed (Table 4.6.1).

Table 4.6.1. Species stocked by the CDOW in streams and lakes of the Snowmass/Capitol Creek Sub-watershed.

STREAM/LAKE	SPECIES
Snowmass Creek	Brook trout, Colorado River cutthroat trout, and rainbow trout
Capitol Lake	Colorado River and Pikes Peak cutthroat trout
Pierre Lake	Colorado River and Pikes Peak cutthroat trout
Snowmass Lake	Colorado River cutthroat trout and rainbow trout
Wildcat Reservoir	Colorado River cutthroat trout

4.6.3 Resource Information

Several research studies and syntheses of information have been done in the Snowmass/Capitol Creek sub-watershed, providing data on stream flows, groundwater sources, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in this sub-section. For background information on the data sources, refer to Chapter 3.

Water Quantity

Surface Water

There is one operational stream gage in the sub-watershed, the Snowmass Creek gage operated by the Colorado Division of Water Resources (CDWR) (Figure 4.6.6). Instantaneous data for this gage are available online, but, historical data are not online and need to be requested. Data for this gage are not useful for assessing flow alteration because they do not represent a pre-developed flow condition. Flow alteration was assessed using the Upper Colorado River Basin Water Resource Planning Model dataset (CWCB and CDWR, 2007a). The modeling accounts for diversions above 10 cubic feet per second (cfs). These data are available for three nodes in this sub-watershed: East Snowmass Creek/East Snowmass Brush Creek Pipeline, Snowmass Creek/Red Rock Bluff Ditch, and a Capitol Creek minimum flow node (Figure 4.6.6 shows the locations of the nodes, depicted by the symbols for “no flow alteration” and “potential flow alteration”). Appendix 3.1.2 and figures 3.1.4-3.1.6 show the extent to which flows in Snowmass and Capitol creeks have been altered. Figure 4.6.7 shows the locations of all the diversions in the sub-watershed, 14 of which have a decreed capacity greater than 10 cfs (Table 4.6.2).

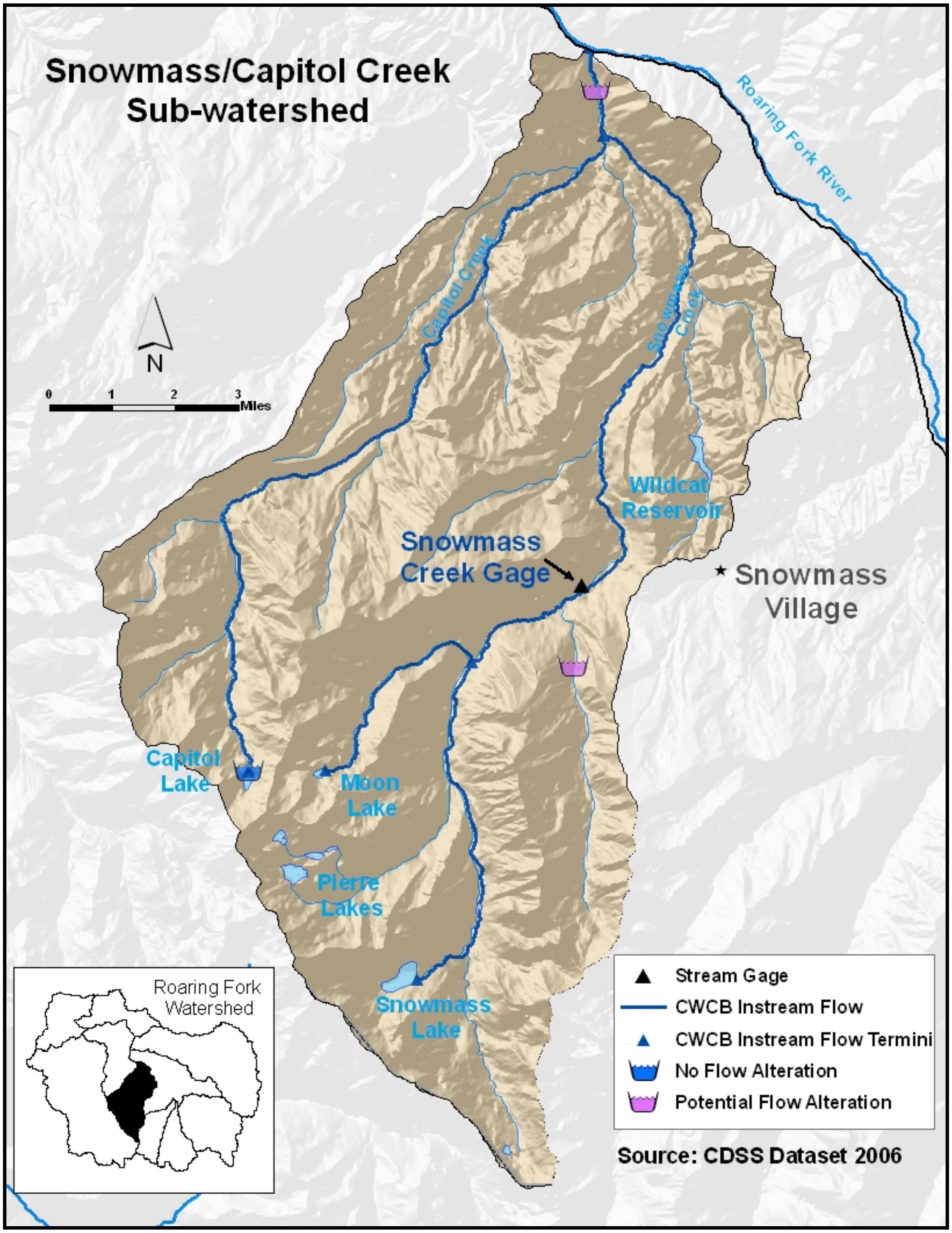


Figure 4.6.6. Water features in the Snowmass/Capitol Creek Sub-watershed.

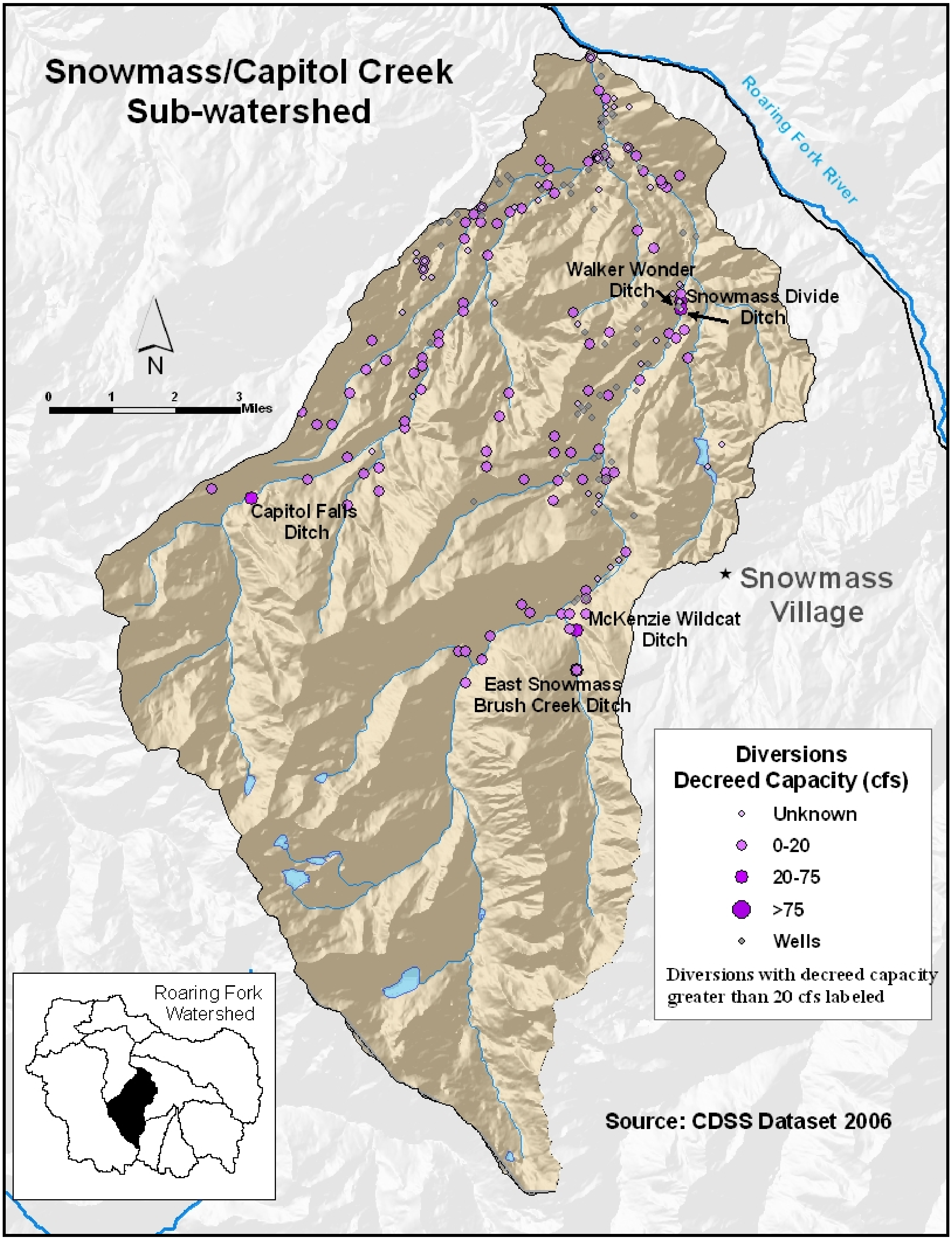


Figure 4.6.7. Diversions and wells in the Snowmass/Capitol Creek Sub-watershed

Table 4.6.2. Diversion in the Snowmass/Capitol Creek Sub-watershed greater than 10 cfs. Source CDSS GIS Division 5 diversion data, 2006.

STREAM	DITCH	DECREED CAPACITY (cfs)
East Snowmass Creek	East Snowmass Brush Creek Ditch*	34.00
East Snowmass Creek	East Snowmass Brush Creek Pipeline*	14.83
East Snowmass Creek	McKenzie Wildcat Ditch*	23.14
Snowmass Creek	Snowmass Creek Pipeline*	14.60
Snowmass Creek	Snowmass Divide Ditch*	33.40
Snowmass Creek	Walker Wonder Ditch*	71.92
Snowmass Creek	Red Rock Bluff Ditch*	13.40
Capitol Creek	Capitol Falls Ditch*	20.58
Capitol Creek	Green Meadow Ditch*	17.44
Capitol Creek	Desert Ditch*	16.87
Capitol Creek	Maurin Ditch*	12.70
Capitol Creek	Capitol Park Ditch*	11.00
Capitol Creek	Boram and White Ditch*	17.10
Capitol Creek	Williams No. 1 Ditch Capitol Creek*	15.00

* Used in CDSS modeling.

Analysis for the East Snowmass Creek/East Snowmass Brush Creek Pipeline node showed the greatest flow alteration, of around 7 percent, in February and March. The modeled data for this node may not represent actual conditions because there are no stream gages on this creek to accurately inform the modeled outputs. According to Division 5 Water Commissioner Bill Blakeslee, the greatest flow alteration for East Snowmass Creek occurs in August and September due to transbasin and inbasin diversions (personal communication, September 15, 2008). Tim McFlynn, a representative of the Snowmass-Capitol Creek Caucus (SCCC), reported times when the creek ran dry (Condon, 2003). This dewatering also has been documented by Sue Helm of the SCCC (See photo provided by Helm in Figure 4.6.8). No flow alteration was detected at the upper Capitol Creek minimum flow node. According to Bill Blakeslee (CDWR, Division 5 Water Commissioner, personal communication, March 20, 2008), lower Capitol Creek dried up in 2002, a severe drought year, but because of irrigation return flow, springs, and voluntary agreements between water-right holders, severe flow shortages are rare. At the node located below the confluence of Capitol and Snowmass creeks (the Snowmass Creek/Red Rock Bluff Ditch node), the greatest flow alteration occurred in May (10 percent) and September (19 percent). A slight increase in developed flows was seen in late fall/early winter, most likely due to agricultural return flows.

Figure 4.6.8. East Snowmass Creek, August 1992 (Photo credit: Sue Helm).

In the sub-watershed, two direct-flow conditional water rights are greater than 10 cfs, both on Snowmass Creek (Table 2.4), and there are no conditional storage rights greater than 1,000 acre-feet.

Figure 4.6.6 shows the location of the eight Colorado Water Conservation Board (CWCB) instream flow (ISF) rights in the sub-watershed (Appendix 2.2). Capitol and West Snowmass creeks each have one ISF right. Six ISF rights are on the mainstem of Snowmass Creek – one from Snowmass Lake to the confluence with West Snowmass Creek, two sets of coincident rights each with a seniority date in 1976 plus an enlargement in 1992, and one right from the Highlands Ditch headgate to the confluence of the Roaring Fork River. The first set of coincident rights starts at the West Snowmass Creek confluence and extends to the confluence with Capitol Creek where the second set starts and extends to the confluence with the Roaring Fork River.

In 1996, water rights decreed in Case No. W-2943 were decreased and an innovative multi-stage instream flow for the late fall and winter months was devised for the reach between West Snowmass Creek and Capitol Creek (see Appendix 2.2a). This multi-stage CWCB ISF accounts for natural year to year variability in stream flows. The multi-stage flows are set using four predicted recurrence intervals determined from the average daily flows from October 11th to October 15th (Figure 4.6.9). For example, if the average daily flows during this trigger time period are less than 19 cfs, the predicted recurrence interval is one in 10 years. For this scenario, the multi-stage ISF would be 9 cfs (10/16-10/21), 8 cfs (10/22-10/31), 7 cfs (11/1-12/31), and 8 cfs (01/1-3/31). In addition to the multi-stage ISF, the CWCB ISF provides additional protection following extremely dry periods, identified by the occurrence of three consecutive "less than 10th percentile years." Following such extremely dry periods, a "recovery year" is provided in which the stream is administered using the "50th percentile year or greater" multi-stage ISF regardless of the instream flow trigger in the recovery year.

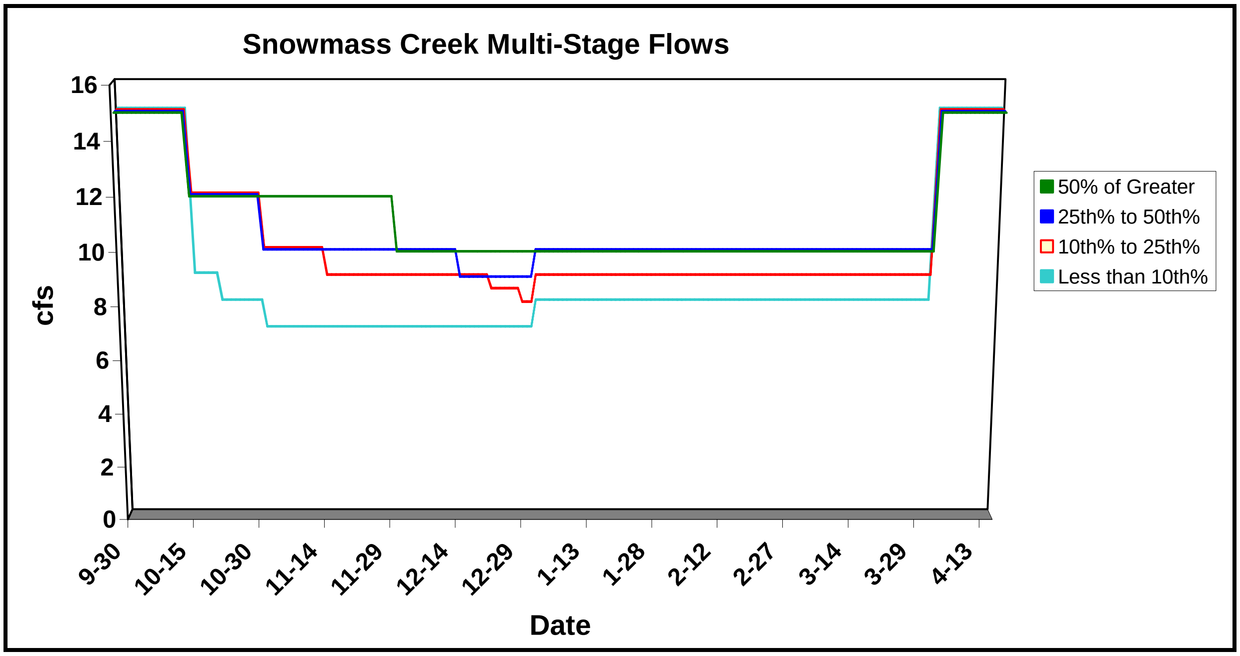


Figure 4.6.9. Snowmass Creek multi-stage CWCB instream flows for four predicted recurrence intervals. The recurrence interval is predicted from the flow from October 11th to 15th.

Two agreements, the 1978 (1978 Agreement between SWSD and Pitkin County) and "Trigger Point or Burnt Mountain" (1995 settlement agreement between SWSD and Pitkin County) agreements, require SWSD to implement conservation measures when the flow in Snowmass Creek drops below certain levels as a result of district diversions. Table 4.6.3 summarizes these agreements with regard to stream flow, diversion limitations, and required conservation measures.

Table 4.6.3. Snowmass Creek flow limitations per agreements (adapted from report by W.W. Wheeler and Associates, 2006).

SNOWMASS CREEK STREAM FLOW	DIVERSION LIMITATIONS AND CONSERVATION MEASURES	CONTRACT/AGREEMENT
12 cfs or greater	No limitations	
< 12 cfs	No limitations, but must use all sources to maximum*	1978 Agreement
< 9 cfs	No limitations, but must commence public awareness program	Trigger Point Agreement
< 7 cfs	No limitation, but must institute mandatory conservation	Trigger Point Agreement
< 6 cfs	No limitation, but must institute increased billing rates	Trigger Point Agreement
< 4 cfs	Only for emergency situations	1978 Agreement

*** Whenever diversions through Snowmass Creek Pipeline would cause the flow of Snowmass Creek to fall below this minimum stream flow, the SWSD agrees to use all sources of supply available to it through facilities owned or controlled by it prior to utilizing the Snowmass Creek Pipeline.**

In 2000 a petition was submitted to the Army Corps of Engineer (ACOE) to modify permit No. 190106516 (Snowmass-Capitol Creek Caucus et al., 2000). This Section 404 permit, issued in 1978, authorized construction of a diversion structure (Snowmass Creek Pipeline) for municipal purposes on Snowmass Creek. The petition stated that "The petitioners request that the permit be modified to add a protective condition making all withdrawals from October 16 - March 31 each year at the permitted structure subject to the stairstep minimum instream flow decreed to the CWCB, unless the ACOE determines that a more protective condition is needed in the public interest, as it has done in conditioning the District's permit in 1995." An ACOE staff report summed up the issues (Claffee, No date). "The CWCB's instream flow right is junior to the SWSD's water right, thus the stream can, and will be, depleted below the state's instream flow decreed to protect the environment to a reasonable degree. Basically, the state's instream flow only protects the stream for diversions of water for snowmaking purposes as the SWSD's water right that allows them to sell water to the ski area is junior to the state's instream flow right. The water diverted from Snowmass Creek for use in the Brush Creek valley does not return to Snowmass Creek as treated wastewater as the treatment plant discharges into Brush Creek." The ACOE worked with the CWCB to develop and implement an ongoing fishery and flow monitoring program on Snowmass Creek to determine if there is degradation occurring to the stream due to the permitted diversion structure or a clear trend that predicts degradation will occur in the future (October, 9, 2001 email from Art Champ, Chief Regulatory Branch, ACOE to Lori Potter, Attorney for Petitioners).The presence and condition of a self-sustaining trout fishery is often used as an indicator of the condition of the aquatic environment in mountain streams (Claffee, No date).

Groundwater

Groundwater in the upper Snowmass Creek area may be locally available in the Quaternary unconsolidated materials, and to a lesser extent, in the Ft. Hayes and Dakota/Burro Canyon bedrock units (Kolm et al., 2007). Groundwater in the lower Snowmass Creek and Capitol Creek areas may be locally available in the Quaternary and Recent unconsolidated materials. The groundwater in these materials is locally and variably sustainable depending on climate processes, slope steepness and aspect, connection to creeks, and anthropogenic land use (notably irrigation ditches). However, these shallow units are vulnerable as no natural protective cover exists to prevent contaminants from infiltrating into the water supply or from leaking into the aquifers from irrigation ditches or the creeks.

Water Quality

Author: U.S. Geological Survey

Within the Snowmass/Capitol Creeks Sub-watershed, data have been collected at six stream sites since 1966. Recent water quality data summarized for this sub-watershed are from 2000 to 2007. Current water quality sampling is occurring on Snowmass Creek (Site 29) and Capitol Creek (Site 30). These sites are shown in Figure 4.6.10, along with locations and information about water and wastewater treatment facilities. For each site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

Snowmass Creek and Capitol Creek were previously identified as sites where increased water quality monitoring should occur. The Colorado River Watch Program has been collecting samples for field parameters, nutrients, and trace elements at these two sites since 2000 (Roaring Fork Conservancy, 2006). Previous analysis of data at both sites noted the occurrence of water-quality exceedances and concluded that these sites cannot be classified as healthy streams given these exceedances (Roaring Fork Conservancy, 2006).

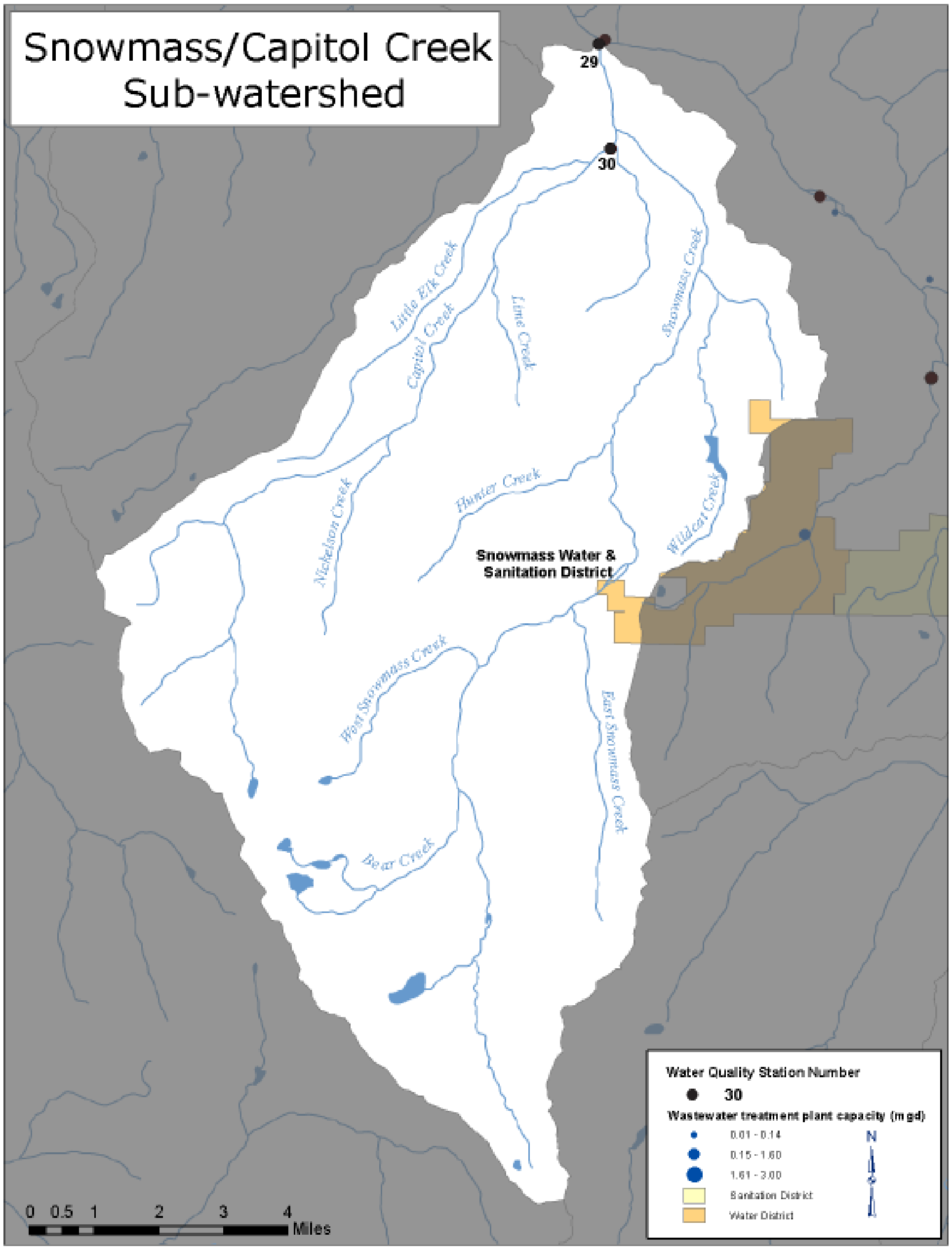


Figure 4.6.10. Water-quality sites and wastewater treatment providers in the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and CDOLA, No date b.

Field parameters were collected during all water quality sampling on Snowmass and Capitol creeks. pH results were found to be within the state standards, ranging from 7.02 to 8.68. Median pH values were 8.39 for Snowmass Creek and 8.44 on Capitol Creek. Water temperature rarely exceeded 20°C (68°F), with median values ranging from 6.5°C (43.7°F) to 7°C (44.6°F). Both sites exceeded the water temperature standard in July, 2002. Median dissolved oxygen concentrations at both sites were 9.8 mg/L, indicating generally well-oxygenated conditions.

Sulfate concentrations were found to exceed the sulfate water quality standard of 250 mg/L once on Snowmass Creek and three times on Capitol Creek. Exceedances occurred in February, May, and December of 2002-03, and 2005. During winter months, stream flow is likely dominated by groundwater inflows. Sulfate concentrations in groundwater are often higher due to longer residence time of the groundwater in contact with geologic units that contain sulfate salts. Median hardness was 296 mg/L on Snowmass Creek and 440 mg/L on Capitol Creek, indicating very hard water (Hem, 1985). This combination of high sulfate and hardness are indicative of the geology of the area, where Snowmass and Capitol creeks are underlain by Mancos Shale (Warner et al., 1985).

Nutrient data were too limited to provide a detailed characterization of seasonal or spatial trends. Un-ionized ammonia, nitrate/nitrite, and total phosphorous were collected biannually or annually on Snowmass and Capitol creeks from 2001 through 2007. Most of the nutrient samples were censored and available concentrations are generally low.

Total recoverable aluminum, total recoverable iron, and selenium were found either in higher concentrations or exceeded the water quality standard. Total recoverable aluminum concentrations were found to have concentrations greater than 750 µg/L in five of 19 samples from Capitol Creek, and two of 17 samples from Snowmass Creek. Of the 156 total recoverable iron concentrations, 12 exceedances of the chronic standard were observed where concentrations were three and four times the chronic standard of 1,000 µg/L. On several sampling occasions, the elevated aluminum and iron concentrations were found in the same sample, suggesting a relationship between these two trace elements. Selenium exceeded the chronic standard 16 times in 127 samples, with concentrations ranging from 1.2 µg/L to 10 µg/L. Exceedances of the chronic table value standard (TVS) for selenium in Capitol Creek occurred from March through October and are most likely related to irrigation of land underlain by Mancos Shale. Exceedances of the chronic TVS for selenium in Snowmass Creek occurred in November and December, during base flow conditions. This again would be related to the geology in the sub-watershed, where Mancos Shale is a known source of selenium and salt. Arsenic, cadmium, copper, manganese, lead, and zinc were sampled and concentrations did not exceed applicable TVS levels.

Suspended sediment concentrations at the two sites ranged from 6.4 mg/L to 89.8 mg/L with a median concentration of 6.7 mg/L for Snowmass Creek and 7.05 mg/L for Capitol Creek. Ten samples were collected at each site and four samples at each site had censored values (see section 3.2 for a description of censored data). Based on the limited available data, suspended sediment concentrations are generally low.

Riparian and Instream Areas

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed Snowmass Creek in this sub-watershed. Figure 4.6.11 shows specific riparian and instream information, by habitat quality category, for each reach assessed. The habitat quality categories are shown in the riparian and instream assessment charts in Section 3.3 and Section 3.4. Appendix 3.3.1 contains the actual percentage values for each of these categories by sub-watershed and how they were determined. In the sub-watershed one stream segment was surveyed:

- Snowmass Creek Segment – Snowmass Creek from reaches SN1-1 through SN1-7; 13.21 miles.

The following is a brief description of results. The SHI report contains detailed narrative description. "Right bank" and "left bank" refer to the orientation of the riparian zone when facing downstream.

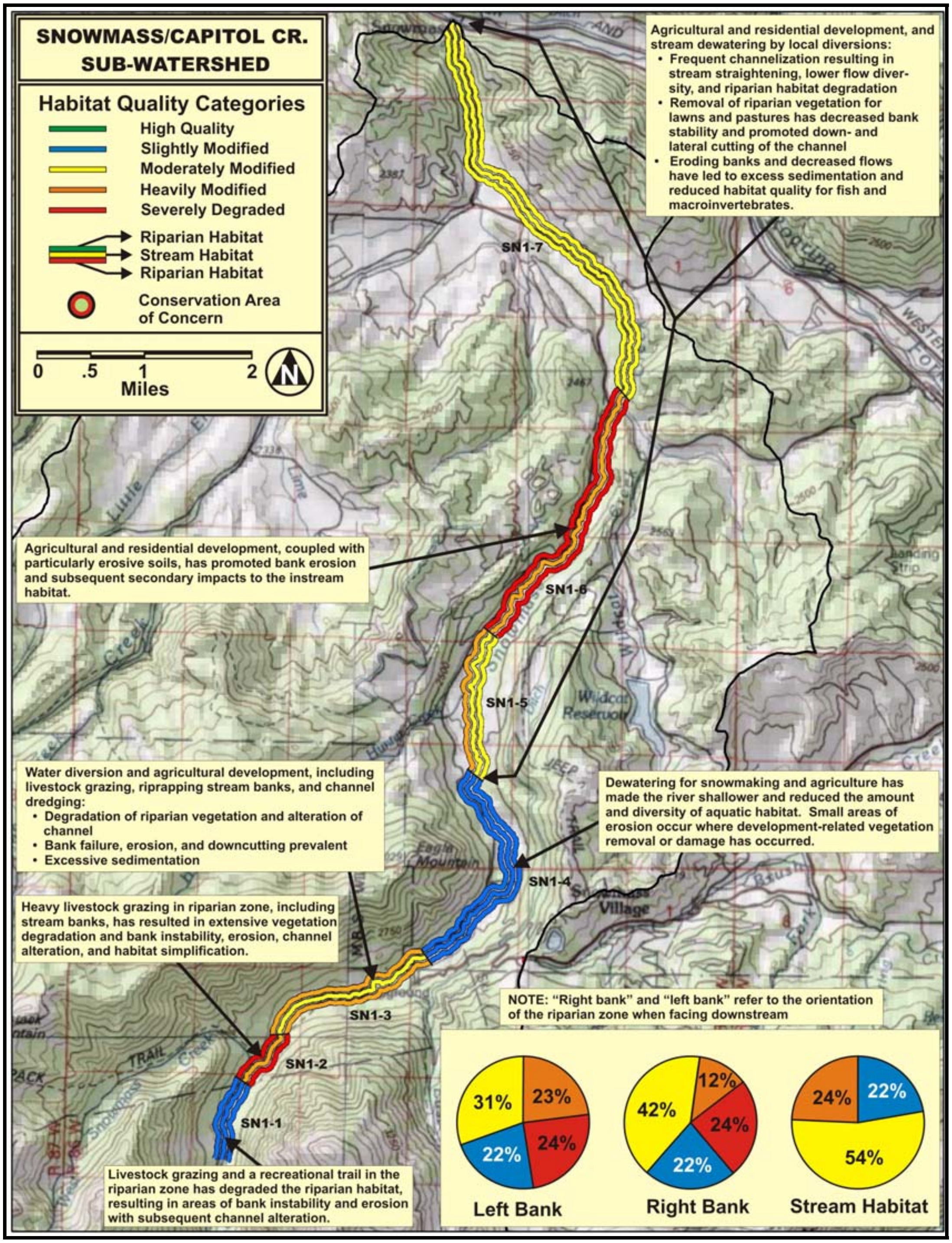


Figure 4.6.11. Riparian and instream habitat quality for the Snowmass/Capitol Creek Sub-watershed.

Uplands

In the higher reaches of the Snowmass/Capitol Creek sub-watershed, upland habitat is designated wilderness (within the Maroon Bells-Snowmass Wilderness Area) that is in fairly pristine condition. However, historic and present grazing activities in wilderness areas have altered native plant communities, enabled the spread of weeds, and changed soil characteristics in portions of the sub-watershed. Trees and shrubs are dominated by mature-aged growth and seedlings and saplings have been reduced by grazing. The herbaceous layer is dominated by low-to-the-ground or disturbance-tolerant species such as dandelion, wild strawberry, pussytoes, and clover. Recreational trails are heavily used by hikers and pack horses causing erosion and enabling the spread of weeds in some areas. A fairly recent study (Malone, 2001) compared wildlife diversity on recreational trails with diversity away from trails for the Hay Park Trail area in the upper Capitol Creek drainage. The results indicated that bird and mammal communities along trails differ from the communities more than 50 meters (165 feet) away from trails, with human tolerant species more prevalent near trails and sensitive species more prevalent away from trails. One notable observation from the study was that of nesting Northern goshawk (CNHP watch-list species).

On White River National Forest land north of the wilderness area, ski area development has resulted in the deforestation of large areas of steep, north-facing slopes. Deforestation and snow-grooming alter the overstory canopy, ground cover, and soils, affecting the snowmelt regime, infiltration rates, and stream flows (Wright Water Engineers, Inc. and Leaf, 1986). These activities also contribute to erosion. Agricultural activities, and, more recently, residential development, dominate land uses in the lower portion of the sub-watershed. Uplands often have been converted from native sage shrublands to hay meadows that require supplemental irrigation (Figure 4.6.12). Houses dot the hillslopes, some with more impact than others. Notable is the Wildcat Ranch development, which, because of county land use codes, has maintained the majority of its area as high quality wildlife habitat. Several thousand acres of privately owned upland habitat in the Snowmass and Capitol Creek drainages have also been conserved for agricultural, wildlife, and open space values by the Aspen Valley Land Trust and Pitkin County Open Space and Trails (Figure 4.6.3 and Appendix 4.1).

Figure 4.6.12. Conversion of native upland shrublands to pastures has affected stream flows by altering infiltration rates and by diverting water for irrigation.

Riparian Habitat and Wildlife – Snowmass Creek

Historic channel simplification, discussed more fully in the instream sub-section, has had a pervasive impact on some riparian areas in this sub-watershed. Healthy riparian habitat is interspersed with degraded habitat in both high and low elevation reaches. In some areas, such as reach SN1-7, native vegetation returned when grazing ended, and in other areas, such as reach SN1-4, landowners are managing riparian habitat for wildlife values.

Overall, riparian habitat has been modified and degraded by various types of development including grazing, conversion of native habitat into hay meadows, and residential developments with nonnative grasses (Figure 4.6.13). Consequently, no high quality stream reaches remain in the assessment area. On the left bank, 22 percent of riparian habitat has been slightly modified, 31 percent moderately modified, 23 percent heavily modified, and 24 percent severely degraded; on the right bank, 22 percent of the riparian habitat is slightly modified, 42 percent moderately modified, 12 percent heavily modified, and 24 percent severely degraded. Table 4.6.4 provides a summary of the type and extent of threats to riparian and stream habitat. Vegetation disturbance resulting from recreational trails has degraded 5 percent of streambank habitat in the assessment area. Trail impacts occur primarily on wilderness lands where trail-induced disturbance has damaged 10 percent of streambank vegetation in reach SN1-1, causing subsequent bank erosion in those areas. Snowmass Creek Road parallels the stream along most of the drainage but only occasionally traverses riparian habitat. The road fragments upland habitat, and where it has been built in the riparian zone or bridges cross the streambank, riparian vegetation has been eliminated and banks are destabilized and eroding.

Grazing is common in the riparian zone on stream reaches SN1-1, 1-2, and 1-3 and has resulted in damage to vegetation from trampling, and diminished plant vigor. In stream reaches SN1-5, 1-6, and 1-7, conversion of riparian habitat into hay meadows and pasture is common and has resulted in the clearing of willow carrs from much of the floodplain. Conversion of agricultural lands into housing developments is common and, in some cases, has included the removal of understory shrubs and herbs. Development has diminished plant species diversity, simplified habitat structure, and compacted soils.

Figure 4.6.13. Upper photo: Riparian willow carrs have been converted into hay meadows. Lower photo: At the bottom of this reach, a small natural area of willow carr habitat remains.

Table 4.6.4. Summary of land development impacts and threats to riparian and instream habitat in the Snowmass Creek drainage.

SNOWMASS/CAPITOL: SNOWMASS CREEK SEGMENT	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	RIGHT BANK
Total Stream Miles: 5	5%	10%	48%	83%	23%	34%

Riparian wildlife potential is optimal on 22 percent of the assessment area, suboptimal on 74 percent, and marginal on 4 percent. Snowmass Creek provides a migratory corridor for long distance as well as elevational migration, including travel corridors for Canada lynx, a connection between summer and winter habitat for elk, and a route for long distance migrations for Neotropical migrant songbirds. Wildlife potential is high in reaches upstream of SN1-1 and in areas throughout the drainage wherever native riparian habitat is intact, as in much of reach SN1-4 and adjacent upland habitat. Wildlife is limited where development has substantially impacted riparian wildlife habitat. Riparian willow carr/narrowleaf cottonwood habitat supports some of the most diverse wildlife communities in the Mountain West – conversion of these habitats to hayfields and houses results in habitat loss for birds, mammals, and amphibians.

Several studies have assessed riparian biological diversity in this sub-watershed including the Colorado Natural Heritage Program (CNHP) (Spackman et al., 1999), and the SHI (Malone and Emerick, 2007a). CNHP identified three Potential Conservation Areas (PCAs) in the sub-watershed (Figure 3.3.2 and Appendix 3.3.2). One PCA is at the base of Eagle Mountain in reach SN1-4, and was identified because of the presence of a great blue heron nesting colony (Figure 3.3.4). The other two are located on East Snowmass Creek and Snowmass Creek at Snowmass Peak. Both were assigned a rank of B3 ("high" biodiversity significance). CNHP justified the ranking of East Snowmass Creek because of a "good" occurrence of a globally-vulnerable lower montane willow carr. The ranking of Snowmass Creek at Snowmass Peak relates to an "excellent" occurrence of a globally-secure subalpine riparian plant community. CNHP assigned these areas a Protection Urgency Rank of P4 – meaning that they have no known threats for the foreseeable future. Breeding bird surveys were not conducted with the SHI habitat surveys in this sub-watershed due to the lateness of the season. However, the SHI surveys did include observations of birds and mammal species, signs, and tracks. In reach SN1-1, vulnerable or indicator bird species included Northern pygmy owl (CNHP watch-list species), golden-crowned kinglet, and MacGillivray's warbler. Observed mammals or signs/tracks included marmot, pika, mountain lion, pine marten, elk, mule deer, black bear, and beaver (Figure 4.6.14). The Snowmass/Capitol Creek Sub-watershed contains a breeding population of boreal toads (CDOW Boreal Toad Conservation, http://wildlife.state.co.us/WildlifeSpecies/SpeciesOfConcern/Amphibians/BorealToad.htm).

Figure 4.6.14. SN1-2: Beavers, through their dam-building, are integral to functioning instream and riparian ecosystems.

Instream Habitat and Wildlife – Snowmass Creek

Stream type and morphology in this sub-watershed varies between Type C streams in moderate gradient reaches such as SN1-1, to Type B streams in steeper gradient reaches such as SN1-3 (Rosgen and Silvey, 1996). Refer to Table 3.4.1 and Figure 3.4.4 for general characteristics of these stream types.

Historically, Type C streams (low gradient, meandering reaches) included multiple channels flowing across the floodplain interspersed with beaver dams. The location of these channels frequently changed from year to year, depending upon spring flows and beaver populations. When the valley was settled for agriculture the stream channel was commonly constrained to a single channel, often at the edge of the floodplain, and beaver dams and pools were removed to create pastures or tillable fields (Figure 4.6.15). This made the adjacent lands valuable for agriculture, but has impacted and continues to impact instream habitats and aquatic species. Confining the stream to a single channel has increased stream velocity, causing the stream to downcut and erode the adjacent banks. This bank erosion is caused by the stream's tendency to dissipate energy. If the erosion were allowed to continue, the stream would eventually reincorporate the natural meandering pattern that is normal for Type C channels. However, the issue is often addressed through use of rock or other material on the eroded sections to harden and protect the bank, thus preventing natural stream dynamics from bringing the channel back into balance. If the channel is permitted to flow in a more natural, meandering channel, riparian vegetation will generally protect the streambanks and improve instream habitats. Grazing and development cause additional alteration to these riparian areas, leading to more streambank instability (Figure 4.6.16). As examples, riparian vegetation degradation stemming from grazing in reach SN1-3, conversion to hay meadows in SN1-6, and home development in SN1-7, have led to bank erosion, and lateral and down cutting of the channel. Consequently, the stream in this area has widened and the channel has become straighter. Because of these modifications, no high quality stream reaches remain in the assessment area. Twenty-two percent of instream habitat is slightly modified, 54 percent moderately modified, and 24 percent heavily modified. No stream reaches are severely degraded.

Figure 4.6.15. In the photo's lower left is a constrained channel, resulting from agricultural land use, while the upper right of the photo contains a more natural, braided channel (Google Earth image downloaded March 15, 2008).

Figure 4.6.16. Riparian alteration has degraded the condition of the stream channel. Upper photo: grazing in SN1-1. Middle photo: habitat conversion in SN1-6. Lower photo: residential development in SN1-6.

High quality fish and wildlife habitat is found in the upper reaches of Snowmass Creek such as SN1-1 and 1-4. However, only 5 percent of the assessment area provided optimal wildlife potential, 74 percent was suboptimal, and 20 percent provided only marginal potential. Channel downcutting and beaver removal, in conjunction with water diversions, reduce or eliminate base and overbanking flows that maintain riparian and instream habitat and wildlife. One consequence of riparian vegetation reduction is the potential loss of large woody recruitment into the channel or adjacent floodplain, which diminishes instream habitat complexity.

How winter diversions from Snowmass Creek for snowmaking and municipal use in Snowmass Village affect fish populations and aquatic habitat is a matter of considerable debate. Section 3.4.4 provides a general discussion of how winter diversions can impact fish and their habitat. Specific to Snowmass Creek, several studies have been conducted for the parties involved in this debate (Chadwick and Associates, Inc. 1992 and 1993; Chadwick Ecological Consultants, 1996 and 1998; Chapman and Hillman, 1996; Leaf, 1998; Miller and Associates, 1992 and 1993; Walsh and Walsh, 1995). In response to a petition to the Army Corps of Engineers (ACOE) in 2000 (Snowmass-Capitol Creek Caucus et al., 2000), the ACOE evaluated these technical reports to determine if the permit for the Snowmass Creek Pipeline issued to the Snowmass Water and Sanitation District will create significant degradation to the aquatic environment in Snowmass Creek, and if that impact violates the legal standards the ACOE must abide by, primarily the Section 404 (b) (1) Guidelines, and whether the impact is contrary to the public interest (Claffee, No date). As discussed above, a fishery and flow monitoring program was initiated to determine if there is significant degradation to the aquatic environment. The ACOE report (Claffee, No date) states that “we have a wealth of scientific information on Snowmass Creek; in fact, we may have more technical information on the impacts of minimum flows for this stream than for most other streams of similar size in Colorado.” Some of the findings from these studies discussed in the ACOE report are listed below.

Two authors, Miller and Associates (1992 and 1993) and Chadwick Ecological Consultants (1992, 1993, and 1996), used models to simulate available trout habitat at different flows. Miller (1992) concluded that spawning habitat is the most limited habitat available and states that “there is a significant reduction in habitat for all life stages at a 4 cfs flow from existing conditions where flows range from 7 to 12 cfs. This reduction is as much as 63 percent for both brown and brook trout spawning (and egg incubation) habitat. The reduction for other life stages range from approximately 12 to 48 percent.” According to the Chadwick reports (1992 and 1996), trout populations are limited by a “bottleneck” that occurs during spring flows. Both Chapman (1996) and the ACOE refute this statement. The ACOE evaluation states that this logic appears to be flawed because high water does reduce trout habitat, temporarily, but fish seek refuge habitat such as flooded wetlands and side channels.

A later report by Chadwick Ecological Consultants (1998) asserts that there are minimal effects from 1 to 3 day low flows of 4 cfs. The ACOE concurs with this finding because occasionally ice dams occur that create instantaneous low flow events approaching 4 cfs that last only for a short time period. Chadwick Ecological Consultants (1998) and the ACOE differ in their opinion of the effect of longer duration low flow event on trout populations.

Chapman (1996) reports on the loss of habitat due to anchor ice and the increased likelihood of anchor ice with reduced flows. A conflicting study by Leaf (1998) demonstrates that the relatively minor increase in ice formation would not affect average velocities and the hydraulics of flow during the winter as compared to winter flows without ice formation.

Walsh and Walsh (1995) report on the effects of a decreasing winter flow regime on trout redds in Snowmass Creek. During the study period, SWSD only diverted small amounts of water from Snowmass Creek. The study looked at the change in percentage of fine sediments, redd depths, and velocity with decreasing discharge and found that all three changed significantly − percentage of fine sediments increased and depth and velocity decreased. The ACOE found this study to be very beneficial because it provides actual data for potential resource impacts of the proposed project to compare with published data on the same resources.

The long-standing issue concerning stream flows in Snowmass Creek continues given conflicting scientific analysis and conjecture, the potential for increasing water needs with the growth of Snowmass Village, and the desire to proactively prevent impacts to fish populations and aquatic habitat. The ongoing fishery and flow monitoring program will provide additional data to aid in the debate's resolution, and the proposal to expand Ziegler Reservoir would add protection for Snowmass Creek.

4.6.4 Important Issues

Below is a summary of key findings from available scientific information, a listing of data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the water resources of the sub-watershed.

Key Findings

- The greatest flow reduction on East Snowmass Creek occurs in August and September due to transbasin and inbasin diversions. A dewatered creek has been observed at times.
- On Capitol Creek, severe flow shortages in the late summer and early fall are rare because of irrigation return flow, springs, and voluntary agreements between water-right holders.
- Compared with pre-developed flow patterns, the greatest reduction in flows on lower Snowmass Creek occurred in May (10 percent) and September (19 percent).
- An innovative multi-stage CWCB ISF on Snowmass Creek takes into account natural year-to-year variability in stream flows.
- There are two direct-flow conditional water rights greater than 10 cubic feet per second in this sub-watershed.
- There is indication of the presence of local groundwater sources within the sub-watershed. These sources appear to be shallow and potentially vulnerable to contamination.
- The following trace elements sampled in both Snowmass and Capitol creeks were found either in higher concentrations of exceeded water-quality standards:
    - Total recoverable iron,
    - Selenium (most likely related to irrigation of land underlain by Mancos Shale),
    - Total recoverable aluminum, which often had high concentrations (> 750 µg/L), and
    - Sulfate and hardness concentrations, which were elevated compared to other sub-watersheds. These higher concentrations are generally consistent with conditions for streams that drain areas underlain by Mancos Shale.

- In the surveyed section of Snowmass Creek, the greatest factors impacting and threatening riparian and instream habitat sustainability are flow reduction (affecting 83 percent of habitat) and development (residential, agricultural, recreational, and commercial − affecting 48 percent). Weeds are also prevalent, affecting 23 percent of the left bank and 34 percent of the right bank.
- For reaches surveyed in Snowmass Creek, past and present land use activities have influenced riparian habitat quality. No high quality stream reaches were found. On the left bank, 22 percent of riparian habitat is slightly modified, 31 percent moderately modified, 23 percent heavily modified, and 24 percent severely degraded; on the right bank, 22 percent of riparian habitat is slightly modified, 42 percent moderately modified, 12 percent heavily modified, and 24 percent severely degraded.
- Colorado Natural Heritage Program (CNHP) identified three Potential Conservation Areas (PCAs) in the sub-watershed. One PCA is at the base of Eagle Mountain and was identified because of the presence of a great blue heron nesting colony. The other two are located on East Snowmass Creek and Snowmass Creek at Snowmass Peak. All were assigned a rank of B3 ("high" biodiversity significance).
- In lower Snowmass Creek, observed vulnerable or indicator bird species included Northern pygmy owl (CNHP watch-list species), American dipper, and MacGillivray's warbler.
- Overall, riparian and aquatic wildlife potential is suboptimal on a majority of the surveyed section of Snowmass Creek.
- No high quality or severely degraded stream reaches exist in the assessment area, with 22 percent of instream habitat slightly modified, 54 percent moderately modified, and 24 percent heavily modified. Causes of modification include historic and current agricultural activities, residential development, reduced beaver activity, and stream diversions.
- The question of whether existing and future winter diversions affect fish populations and aquatic habitat in Snowmass Creek has been studied and debated for more than 30 years and has yet to be resolved. However, flow and fishery monitoring is ongoing to inform this debate.
- The sub-watershed contains two conservation populations of Colorado River cutthroat trout and a breeding population of boreal toads.

Data Gaps

A number of gaps in information for the sub-watershed limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Publicly accessible (available online) historic stream gage data for Snowmass Creek;
- Additional stream gage data to administer Colorado Water Conservation Board instream flow rights;
- Information about how climate change may affect stream flow, water needs of the Snowmass Water and Sanitation District, and the Snowmass Ski Area;
- Analysis and interpretation of the ongoing fishery and flow monitoring study and continued monitoring, if warranted;
- An assessment of the potential implications of development of the two conditional water rights in the sub-watershed;

- Information about size and flow patterns of groundwater aquifers;
- Water-quality data for the upper portion of the sub-watershed;
- Water-quality data for the following constituent groups:
    - Continuous streamflow – to allow characterization of water-quality conditions
    - Specific conductance – to establish sources of dissolved material and help to describe other water-quality conditions
    - Suspended sediment – to evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals
    - Emerging contaminants – to help establish a baseline for understanding occurrence in the rest of the watershed;
- Water-quality information for groundwater sources;
- Riparian and instream habitat assessment of the Capitol Creek drainage;
- Breeding bird data in riparian and tundra habitats;
- Assessments of upland habitat condition and bird and mammal communities; and
- Information about upland and riparian mammal community diversity, amphibian and reptile populations, and population sustainability.

Relevant Local Initiatives, Plans, and Studies

- A 2000 Petition to the Army Corps of Engineers to modify Permit No. 190106516 recommended adding a protective condition making all withdrawals from October 16 to March 31 each year subject to the stairstep CWCB ISF, unless the ACOE determines that a more protective condition is needed in the public interest. Fishery and flow monitoring was initiated and is ongoing in response to this petition.
- Pitkin County Resolution No. 053-2008 granted approval of the Ziegler Reservoir Master Plan subject to 18 conditions, several of which relate to water diverted from the Snowmass Creek basin and one that addresses boreal toad populations.
- A 2006 study (W.W. Wheeler and Associates) evaluated the need for, and benefit of, securing raw water storage as a component of meeting future water demands and minimizing diversions from Snowmass Creek during periods of low flow.
- The Snowmass-Capitol Creek Caucus Master Plan outlines measures for protecting riparian and aquatic ecosystems as well as monitoring and assuring adequate stream flows and water quality in Snowmass and Capitol creeks and their tributaries.

4.7 Fryingpan River Sub-watershed

4.7.1 Environmental Setting

The headwaters of the Fryingpan Sub-watershed drain westward from the Continental Divide into the Fryingpan River, which meets the Roaring Fork River at Basalt. The Colorado Midland Railroad, which breached the Continental Divide through the Hagerman Tunnel, operated in the Fryingpan River Valley from 1887 until 1918. It linked Colorado Springs and Leadville with the Roaring Fork Valley. The Fryingpan-Arkansas (Fry-Ark) Project, constructed in the 1960s, is a large transmountain diversion project whose infrastructure is evident throughout the sub-watershed's headwaters in the form of diversion tunnels and Ruedi Reservoir, which was built to compensate the West Slope for the Fry-Ark Project's water depletions. The small communities of Meredith and Thomasville lie in the upper sub-watershed, and a number of homes ring the perimeter of Ruedi Reservoir. The Fryingpan River Valley serves as a popular destination for outdoor recreation including reservoir-based activities, camping, angling (including ice-fishing), hunting, snowmobiling, bicycling, and hiking. Ecoregions in the sub-watershed include Alpine Zone, Crystalline Subalpine Forests, Sedimentary Subalpine Forests, and Sedimentary Mid-elevation Forests in the lower elevations around and above Basalt. One of the largest issues in this sub-watershed has been how management of Ruedi Reservoir affects streamflows, the aquatic ecosystem, and angling activities in the lower Fryingpan River. See Figure 4.1 for an overview map showing the location of this sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions, and the sub-watershed's general physical characteristics are summarized in Table 4.1.

Topography and Geology

Draining the slopes of Mount Oklahoma (13,845 feet) and Deer Mountain (13,761 feet), the Main Fork of the Fryingpan River flows north and then northwest to join Ivanhoe Creek and the South Fork of the Fryingpan near Nast (Figure 4.7.1). About a mile further downstream, Chapman Creek joins the Fryingpan River in a large alluvial flat, where the small settlement of Norrie is located. The North Fork of the Fryingpan starts at Savage Lakes and is joined by several creeks (including Mormon, Carter, and Cunningham) before merging with the mainstem Fryingpan. Several lakes are found in the headwaters of Lime Creek, which joins the Fryingpan River near Thomasville several miles upstream of Ruedi Reservoir. The Fryingpan River feeds Ruedi Reservoir, a predominant feature of this sub-watershed. Rocky Fork Creek drains a majority of the area south of the reservoir and it is one of several tributaries that flow into the Fryingpan River downstream of the reservoir (others are Frenchman, Downey, Otto, Seven Castles, and Toner creeks).

Figure 4.7.1. Headwaters of the Fryingpan River.

The upper mainstem Fryingpan River and the Fryingpan's South Fork, along with Chapman Gulch, drain a large area of Precambrian granitic rocks and steep slopes. The North Fork of the Fryingpan River and Last Chance Creek are mostly located in an area of erodible Mancos Shale. Sections of glacial drift coalesce in a large area at the confluences of the North and South forks with the mainstem of the Fryingpan River, and at the confluence with Chapman Gulch. Lime Creek drains a large area of Mississippian/Cambrian rocks consisting primarily of Leadville Limestone. Two patches of Pennsylvanian evaporites are found north of Ruedi Reservoir. The instability and subsidence problems associated with these evaporitic deposits are highlighted by the two large landslide deposits in the area. The western part of this sub-watershed, which includes the lower Fryingpan River, Rocky Fork Creek, and several other drainages in the lower basin, is composed primarily of the Maroon and State Bridge formations. Slopes in this area often range greater than 30 percent. Debris flows are common in some of the drainages, as evidenced by the obvious scars in Figure 4.7.2. The most recent debris flow in the Seven Castles Creek drainage is discussed later in the Riparian and Instream Areas sub-section. See Figures 1.3 and 1.4 for maps of the geology and slope of the Roaring Fork Watershed, including the Fryingpan Sub-watershed.

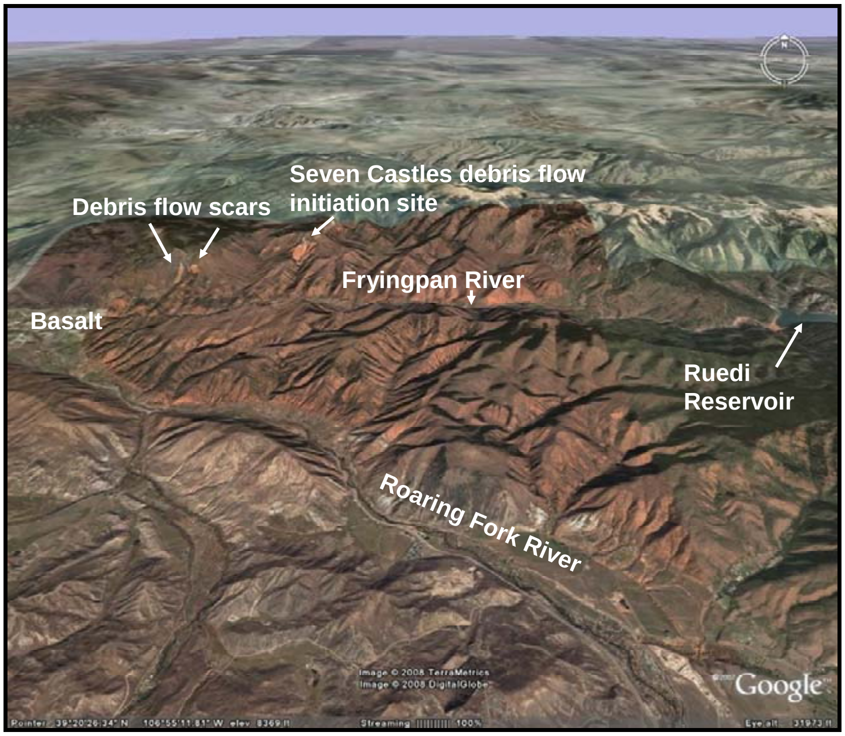


Figure 4.7.2. Originating area of Seven Castles Creek debris flows (Google Earth image, downloaded February 21, 2008).

Weather/Climate

Two Colorado Basin River Forecast Center SNOTEL sites are in the headwaters of the sub-watershed. Ivanhoe (IVHC2) is at 10,400 feet and Nast Lake (NSSC2) at 8,700 feet (http://www.cbrfc.noaa.gov/snow/snow.cgi) (Figure 4.7.10). During the 16-year period of record (1992-2007), snowpack varied considerably in both amount and timing. At the higher elevation Ivanhoe site, in an average year, peak snowpack was 15.4 snow water equivalent inches (SWE) and occurred between April 17th and April 27th (Figure 4.7.3). The two highest measurements recorded at this site were 24.2 inches (SWE) on May 13, 1995, and 21.9 inches (SWE) on May 4, 1997. Lowest peak snowpack was about 63 percent of average (9.7 inches SWE on April 12, 2002, and 11.5 inches SWE on April 26, 2002).

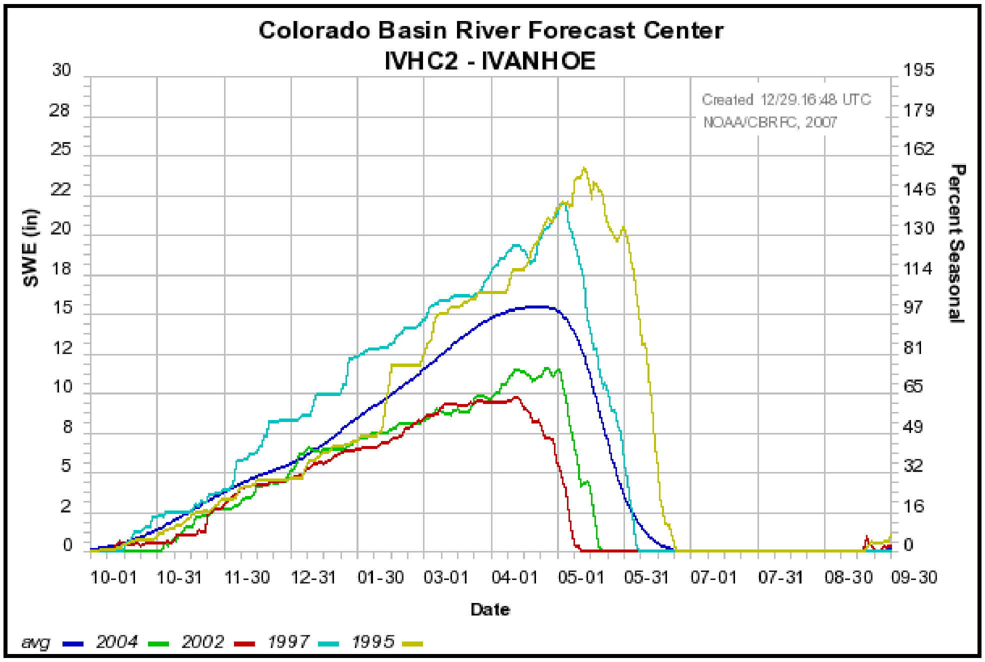


Figure 4.7.3. Highest and lowest recorded snowpack at the Ivanhoe SNOTEL site relative to average conditions (1986-2007).

The only climate station within the sub-watershed is at Meredith (055507). Located at an elevation of 7,830 feet, it was operated from August 1963 through June 2007 (http://www.wrcc.dri.edu/) (Figure 4.7.10). Based on data collected at this station, average total precipitation was about 16 inches and the three wettest months were June, July, and August (1.6, 1.7, and 1.6 inches, respectively). February was the driest month, averaging just over one inch of precipitation. Additional precipitation data can be found for the site on the Fryingpan River near Otto Creek associated with the Colorado Collaborative Rain, Hail, and Snow Network (Appendix 1.2) (http://www.cocorahs.org/).

Biological Communities

Because the Fryingpan River Valley trends east-west, upland plant communities vary with elevation as well as with aspect. In the Alpine Life Zone, high-elevation steep valley walls are characterized by avalanche chute wetlands and slope wetlands interspersed with krummholz islands. Further down in the Subalpine Life Zone, uplands are dominated by dense spruce-fir forests. As elevation decreases and the Life Zone transitions to the Montane, plant communities also transition to a habitat mosaic of spruce-fir, lodgepole pine, Douglas fir, and aspen forests interspersed with sage and serviceberry shrublands and herbaceous meadows.

At lower elevations, in the lower montane and Upper Sonoran Life Zones, north-facing slopes are made up primarily of Douglas fir-montane shrub communities, and south-facing slopes have pinyon-juniper woodlands mixed with sage shrublands. Near the confluence of the Fryingpan River with the Roaring Fork, both north- and south-facing slopes are dominated by pinyon-juniper woodlands.

The Fryingpan River begins as snowmelt from a steep, north-facing, talus slope in the Alpine Life Zone, flowing through boulders to the bottom of a glacially sculpted, U-shaped valley

(Figure 4.7.4). From the bottom of the glacial valley to Ruedi Reservoir the stream flows alternately through wide, flat valley openings and down steeper, boulder-lined slopes. In valley openings, where sinuosity is high and out-of-bank flows are common, wide willow carrs, wet meadows, and shallow ponds have developed with the meandering river. Riparian habitat in steeper stream reaches, where sinuosity is decreased and the riparian zone is narrow, is dominated by spruce-fir forest in the subalpine zone and by mixed conifer/aspen/cottonwood woodlands in the montane zone.

Figure 4.7.4. Looking north from the Continental Divide at the headwaters of the main stem of Fryingpan River to Fryingpan Lakes.

From the Ruedi Dam to the Roaring Fork River, riparian habitat alternates with the topography between narrow canyons with straighter, steeper streams and wider valley openings with lower gradient, meandering streams. In narrow canyons at higher elevations, riparian vegetation is characterized by a narrow band of spruce-fir forest that transitions with decreasing elevation to blue spruce-cottonwood forests and further downstream to narrowleaf cottonwood/red-osier dogwood communities. In wide, flatter valleys a mosaic of willow carrs, wet meadows, and cottonwood woodlands dominated the pre-development landscape.

Wildlife potential in the river corridor and in surrounding uplands varies with the level of human encroachment and disturbance of natural habitats. Common native species include elk, mule deer, bighorn sheep, mountain lion, bobcat, black bear, pine marten, osprey, bald eagle (in winter), peregrine falcon (in the Rocky Fork drainage), and a large diversity of songbirds. Brown trout are the dominant fish species downstream of Ruedi Dam and are the basis for the longest contiguous stream length of a Gold Medal Fishery in the state (which covers parts of the Fryingpan and Roaring Fork rivers).. Ruedi Reservoir provides anglers a mixed fishery containing brown, rainbow, lake, and brook trout. Upstream of Ruedi Reservoir brown and brook trout are the dominant salmonid species in the upper part of the sub-watershed. There are four isolated populations of Colorado River cutthroat trout (CRCT) in headwater streams (Figure 3.4.6). Many lakes are stocked with CRCT and several of the populations are self- sustaining. The remaining lakes contain self-sustaining populations of brook trout. One known boreal toad breeding population is in the sub-watershed (Figure 3.4.5) and additional surveys are needed to survey potential habitat for their presence. Mottled sculpin are common in the sub-watershed, as are tiger salamanders and chorus frogs. High-elevation undisturbed areas provide potential lynx habitat as indicated by the presence of lynx in the upper Fryingpan prior to their reintroduction (Halfpenny et al., 1989) Lynx have also been documented in the sub-watershed since their reintroduction (CDOW, No date b).

Appendix 1.3 lists the riparian-related and instream species and communities of concern in the sub-watershed. Figure 3.3.5 provides a map showing bald eagle wintering range for the Roaring Fork Watershed, including the lower Fryingpan River and the area north of Ruedi Reservoir within this sub-watershed. The bald eagle is designated at the state level as threatened. Two osprey nests and foraging areas are found near Ruedi Reservoir (Figure 3.3.3). The Colorado Division of Wildlife (CDOW) has identified occurrence of the following fish species: Colorado River cutthroat, brook, brown, and rainbow trout; mountain whitefish, white sucker, and mottled sculpin (Harry Vermillion, CDOW, personal communication, March 3, 2008).

4.7.2 Human Influences

Land Ownership and Use

Figure 4.7.5 shows ownership and protection status for the sub-watershed, the majority of which lies within the White River National Forest (WRNF) managed by the U.S. Forest Service (USFS). Headwaters of the Fryingpan River mainstem and South Fork along with Chapman Gulch originate in the Hunter Fryingpan Wilderness. The source of Last Chance Creek and the North Fork of the Fryingpan River is found in the Holy Cross Wilderness. The conservation organization Wilderness Workshop proposes that several other areas in the sub-watershed be reviewed for wilderness status, including Basalt Mountain, Red Table Mountain, Woods Lake, Mormon Creek, Wildcat Mountain, and Sloan Peak (http://www.whiteriverwild.org/aspen-region.php).The Bureau of Land Management (BLM) manages a few square miles of land located between the lower Fryingpan and Roaring Fork rivers. The lower Fryingpan River flows through sections of the Basalt State Wildlife Area, managed by the CDOW. Almost all of the private land in this sub-watershed can be found along water courses, and there are only a few locally-managed open space parcels (Appendix 4.1). Ruedi Reservoir is owned and operated by the U.S. Bureau of Reclamation (BOR).

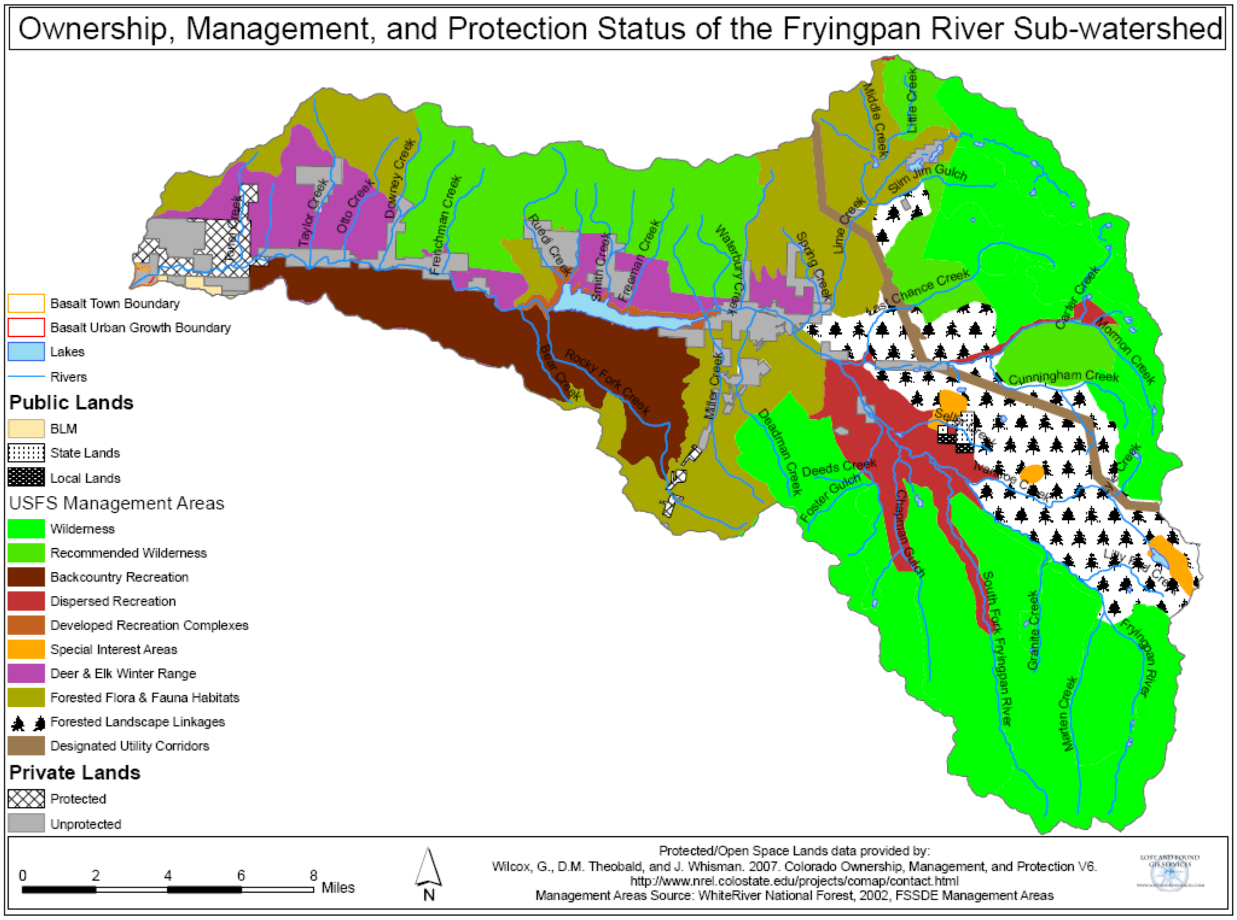


Figure 4.7.5. Ownership and protection status for the Fryingpan River Sub-watershed.

The sub-watershed is bisected by the boundary between Pitkin and Eagle counties. A small amount of irrigated agriculture (mainly pasture) is in Eagle County along the lower Fryingpan River near the confluences with Otto, Downey, and Frenchman creeks. Two other irrigated areas are on Taylor and Downey creeks (Figure 1.16). A decline in the amount of irrigated agriculture occurred from 1993 to 2000.

The town of Basalt and Ruedi Reservoir are divided by the county line. The Upper Fryingpan Valley Caucus submitted its master plan to both Pitkin and Eagle County boards of commissioners in 1999 (http://www.aspenpitkin.com/depts/77/fryingpan_valley.cfm). The water use and quality goal established by the caucus highlights protecting the water supply, acknowledged as a unique environmental resource for communities in both the upper and lower Fryingpan River Valley. Another goal is preserving wildlife areas and riparian and wetland areas. Specific actions recommended to achieve these goals can be found in the master plan (http://www.aspenpitkin.com/pdfs/depts/7/fryingpanmp.pdf).

Figure 4.7.6 shows roads within the sub-watershed and identifies roads within 150 feet of second order and higher streams (approximately 9 percent of these streams). Starting in Basalt, County Road 104 (the Fryingpan Road) follows the Fryingpan River, continuing around the reservoir and along the upper Fryingpan River where it eventually becomes USFS Road 105. Several streams are paralleled by USFS roads. These include Chapman Gulch; the Fryingpan, and North and South Fork Fryingpan rivers; Ivanhoe, Cunningham, and Middle Cunningham creeks; and parts of Lime Creek. Many of these roads were built in order to construct diversions and infrastructure for the Fryingpan-Arkansas Project and continue to be used for maintenance of these facilities.

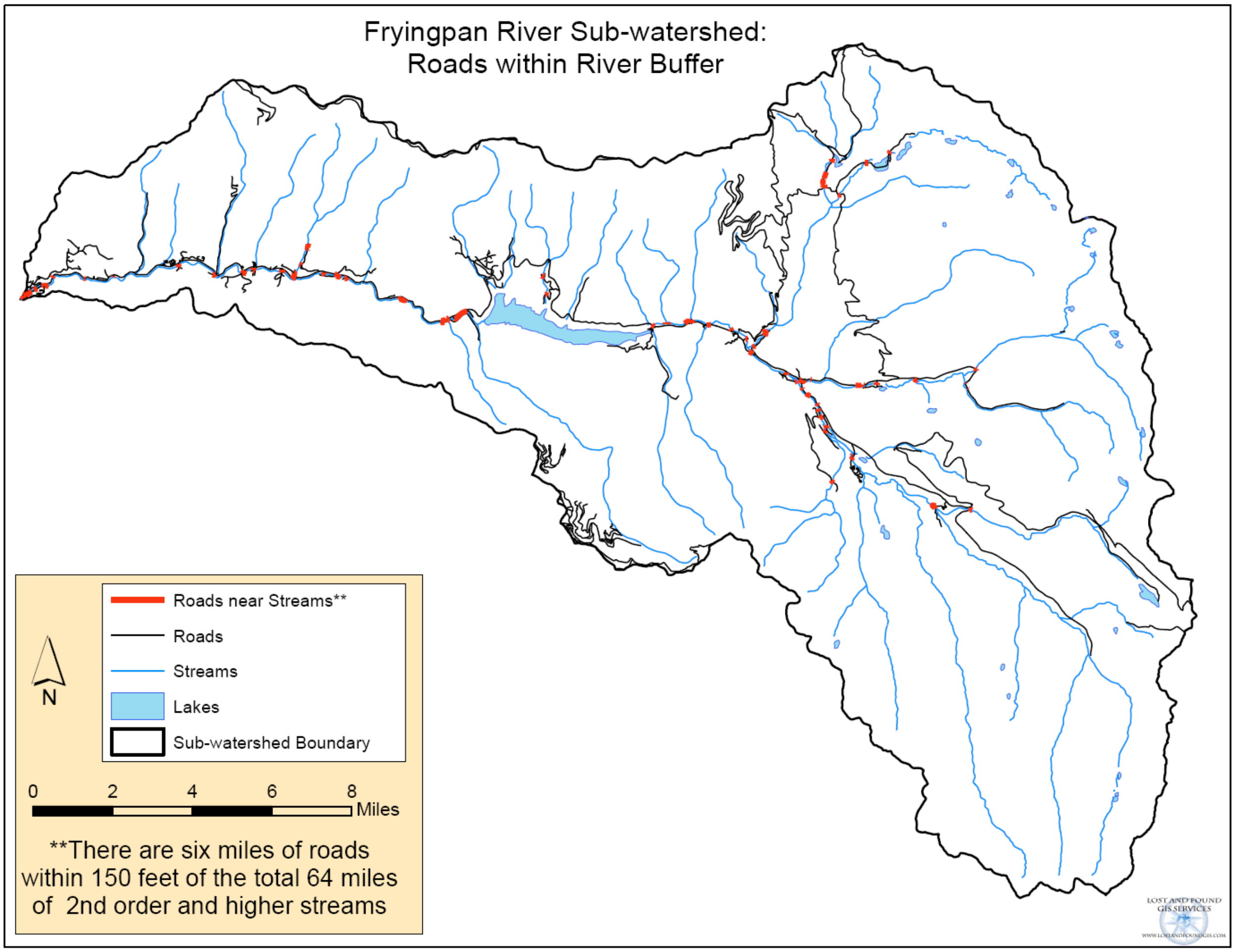


Figure 4.7.6. Roads near streams in the Fryingpan River Sub-watershed.

Part of Basalt and the unincorporated areas of Meredith and Thomasville are in the sub-watershed. Basalt's water sources are Basalt Springs on Basalt Mountain and two wells. Appendix 3.1.3 contains more information about this water supply. Planning initiatives that the town has explored in relation to its water resources and river corridors, including its river stewardship roundtable process and river master plan, are discussed in Section 4.3 (Lower Middle Roaring Fork Sub-watershed) and Appendix 3.1.7.

The geographic area covered by the Basalt Water Conservancy District (BWCD) includes part of the lower Fryingpan River Valley (Figure 2.1). More information about the BWCD can be found in Chapter 2.

Mining

No permitted mines are shown on the Colorado Division of Reclamation Mining and Safety GIS mapping site for this sub-watershed. Historically, there was a limestone extraction and production operation at Thomasville (called Calcium at that time). The kilns used to heat the limestone are still visible today along the Fryingpan Road. In addition, in the lower Fryingpan River Valley was a sandstone quarry at Peachblow. It produced much of the red sandstone used in early town buildings throughout the area.

Recreation Activities

As briefly discussed in Chapter 1, flyfishing on the Fryingpan River's Gold Medal-designated section below Ruedi Reservoir is a popular activity that generates local and regional economic benefits. The "Fryingpan Valley Economic Study" (Crandall, 2002) revealed a wide range of information about the lower Fryingpan River, including specific results of economic impacts related to recreation activities. Some of the study's findings follow:

♦ The 7.5 miles of publicly-accessible river on the lower Fryingpan River represent a significant tourist destination with related impacts on the local economy. Based on the study's data (collected from November 2000 through October 2001), the Fryingpan Valley's recreation activities contributed an estimated $1.8 million annually in total economic output to Basalt's economy.

♦ A majority of Fryingpan River visitors come from outside of the Roaring Fork Watershed specifically to fish on the Fryingpan River. The study discovered that these visitors tended to spend nights in commercial accommodations, resulting in total direct spending as high as $135 per visitor per day.

♦ Based on the study's data, commercial lodging represented an important component of lower Fryingpan River visitors' expenditure patterns, especially as a proportion of Basalt's total lodging sales.

♦ Based on visitor counts done as part of the study, the lower Fryingpan River supports an estimated 34,200 visitor days per year -- attributable mainly to flyfishing activities on the river. It was estimated that about 70 percent of these visitor days occur during the summer season and the other 30 percent during the off-season (October through May).

♦The study identified that lower Fryingpan River recreation supports sources of income and a number of jobs across several economic sectors both in the Basalt/El Jebel area and throughout the broader Roaring Fork Watershed.

♦ For the study period, although about half of the economic activity related to Fryingpan Valley recreation activities was felt in the Basalt area, spending by Fryingpan Valley visitors occurred throughout the Roaring Fork Watershed, as exemplified by the various towns in which visitors stayed overnight in commercial accommodations.

♦ Comments made by visitor survey respondents were wide-ranging, but a few common opinions emerged. A number of survey respondents stated their desire to return to the Fryingpan Valley.

Other comments noted lack of public access to the lower Fryingpan River, and the problem of overcrowding.

For additional results, please refer to the study's final report at: http://www.roaringfork.org/publications.

In the "Flyfishing Guide to the Roaring Fork Valley," Shook (2005) describes the Fryingpan River as one of the most famous trout fisheries in the West. It has a high concentration of trophy-sized trout, excellent aquatic habitat, and scenic beauty, adding to its popularity. The dam-controlled flows often allow fishing during peak runoff when other local rivers are high and waters are murky. Potential exists for the last four miles of the Fryingpan River to be influenced by high sediment runoff from Seven Castles Creek during heavy rains and snowmelt (Figure 4.7.7). The guide also mentions that the Fryingpan River above Ruedi Reservoir offers good fishing but access is limited and fish are smaller.

Figure 4.7.7. High sediment input in the Fryingpan River, originally coming from Seven Castles Creek, is seen here joining the Roaring Fork River (August 5, 2007) (Photo Credit: Chad Rudow).

Both upper and lower portions of the Fryingpan River are listed as boatable by the Southwest Paddler and American Whitewater organizations (Figure 1.11). According to the Southwest Paddler, most boaters only run the last 4.4 miles of the lower river starting at Seven Castles, although the river can be paddled all the way from the Ruedi Dam to the Roaring Fork River with adequate flow. The web site provides this general description about the lower Fryingpan: "This section is more widely known for its trophy, wild trout fishing than as a boating stream, but when the flow is good, LOOK OUT! This can be a very interesting and fun run in Class IV-whitewater" (http://southwestpaddler.com/docs/roaring8.html). Appendix 3.1.6 lists the maximum, minimum, and optimum suggested flows for three sections of the lower Fryingpan River.

In fact, the Fryingpan River is rarely navigated and economic activity associated with river boating is negligible. Unpredictable flows, large boulder gardens, and dead fallen trees are identified by Southwest Paddler as impediments to boating. Figure 4.7.8 shows a photo taken from the American Whitewater website, documenting the occurrence of wood in the stream.

Figure 4.7.8. Large wood accumulations in the Fryingpan River provided complex instream habitat (Photo credit: Kit Davidson) (http://www.americanwhitewater.org/content/Photo_detail_photoid_8521_size_big_).

Ruedi Reservoir provides a wide variety of recreational activities and is especially popular for watercraft/boating activities and camping (Crandall, 2002). The Aspen Yacht Club is located along the north shore of the reservoir. Two boat ramps use the reservoir – Dearhamer and the Ruedi Marina. Five developed USFS campgrounds are located close to the reservoir: Dearhamer, Little Mattie, Mollie B, Little Maude, and the Ruedi Marina, along with several day-use sites. Based on conservative statistics from the USFS White River National Forest, visitor day counts at Ruedi Reservoir for the 2001 summer season are shown in Table 4.7.1 (Crandall, 2002). Campground visits account for 62 percent of all visitor use, with day use representing the other 38 percent. These estimates do not include the Aspen Yacht Club, for which comprehensive use information is not available. The Yacht Club generally hosts one or two regattas every summer, with the two-day regatta in the summer of 2001 drawing 60 boats and 250-300 people, many of whom were non-local.

Table 4.7.1. Ruedi Reservoir 2001 summer season visitor use.

SITE	NUMBER OF VISITOR DAYS
DAY USE	
Ruedi Marina Day Use	4762
Freeman Mesa Day Use	346
Black Bess Day Use	651
TOTAL DAY USE	**5759**
CAMPGROUNDS	
Dearhamer Campground	1493
Little Maud Campground	1583
Mollie B Campground	4018
Little Mattie Campground	2003
Ruedi Marina Campground	450
TOTAL CAMPGROUND USE	**9547**
TOTAL VISITORY DAYS	**15,306**

The Fryingpan Valley Economic Study (Crandall, 2002) drew several conclusions specific to Ruedi Reservoir use, including the following:

♦ Ruedi Reservoir serves as a popular water-based recreation site for residents of the Roaring Fork Watershed. Based on the study's results, many of these local visitors make frequent trips during the summer season.

♦ For the study period (November 2000 through October 2001), 55 percent of Ruedi Reservoir visitors were local residents. The 45 percent from outside of the watershed had modest direct-spending patterns because they often were camping. Therefore, the resulting local and regional economic output related to Ruedi visitors was much lower than for visitors to the lower Fryingpan River.

♦ About half of Ruedi Reservoir respondents indicated they would take fewer trips if the reservoir followed a specific pattern of declining water levels throughout the season. In addition, some of the comments provided by survey respondents reflected opinions about Ruedi Reservoir water levels being too low.

Two additional campgrounds (Chapman and Elk Wallow) are located in the upper part of the sub-watershed. Recreational use is high in this sub-watershed and trails and roads provide access for hiking, horse packing, fishing, camping, and hunting. The following streams have trails adjacent to them: Rocky Fork, Last Chance, Lyle, and Granite creeks; and the South Fork and mainstem of the Fryingpan River.

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams and lakes in the sub-watershed have been stocked with the species listed (Table 4.7.2).

Table 4.7.2. Species stocked by the CDOW in streams and lakes of the Fryingpan River Sub-watershed.

STREAM/LAKE	SPECIES
Fryingpan River	Rainbow trout, Colorado River cutthroat trout
Lime Creek	Colorado River cutthroat trout, Kokanee (Sockeye salmon)
Cap K Ranch Pond	Hofer strain rainbow trout, splake brook x lake hybrid,
Chapman Reservoir	Colorado River cutthroat trout, rainbow trout, Snake River cutthroat trout
Chapman Lake	Brook trout, Colorado River cutthroat trout, rainbow trout
Deadman Lake	Colorado River and Pikes Peak cutthroat trout
Diemer Lake	Brook trout, Colorado River cutthroat trout, rainbow trout
Fryingpan Lake	Colorado River cutthroat trout
Fairview Lake	Pikes Peak cutthroat trout
Granite Lakes	Colorado River cutthroat trout
Halfmoon Lake	Colorado River cutthroat trout
Ivanhoe Lake	Colorado River and Pikes Peak cutthroat trout, rainbow trout
Lyle Lake	Kokanee and lake trout
Mormon Lake	Colorado River cutthroat trout
Nast Lake	Colorado River cutthroat trout, rainbow trout
Ruedi Reservoir	Bel-aire rainbow trout, brook trout, Kokanee, Colorado River cutthroat trout, Lake trout (Mackinaw), rainbow trout, Snake River cutthroat trout, Tasmanian rainbow trout
Savage Lake	Colorado River cutthroat trout
Sawyer Lake	Colorado River cutthroat trout
Sellar Lake	Colorado River cutthroat trout
Strawberry Lake	Colorado River and Pikes Peak cutthroat trout
Tellurium Lake	Colorado River cutthroat trout, brook trout

4.7.3 Resource Information

Several research studies and syntheses of information have been done in the Fryingpan River Sub-watershed, providing data on stream flows, groundwater sources, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in this sub-section. For background information on the data sources, please refer to Chapter 3.

Water Quantity

Surface Water

The largest influence on water quantity in this sub-watershed is the Fryingpan-Arkansas (Fry-Ark) Project. Background on this project can be found in Section 2.1.3. West Slope facilities for collection and conveyance of the Fry-Ark Project's water are divided into the North Side and South Side Collection systems (CWCB and CDWR, 2007b) (Figure 2.4). These two collection systems ultimately direct water through the Boustead and Busk-Ivanhoe tunnels to Turquoise Reservoir in the Arkansas River Basin. The rated capacity of the Boustead Tunnel, which is 5.4 miles long and 10.5 feet in diameter, is 945 cubic feet per second (cfs).

The North Side Collection System is designed to collect and transport approximately 18,400 acre-feet of water annually from the major tributaries of the North Fork of the Fryingpan River. Diversions are located on Mormon, Carter, Ivanhoe, Granite, Lily Pad, North Cunningham, Middle Cunningham, and South Cunningham creeks. The South Side Collection System consists of diversions from both the Fryingpan River Sub-watershed and Hunter Creek drainage (covered in Section 4.1, the Upper Roaring Fork Sub-watershed). South Side facilities in the Hunter Creek drainage include diversions from No Name, Midway, and Hunter creeks. In the Fryingpan River Sub-watershed, South Side diversions are located on Sawyer Creek, Chapman Gulch, and both the South Fork and the mainstem of the Fryingpan River. Figure 4.7.9 show photos of the Chapman Gulch diversion infrastructure. Collectively, the South Side Collection System is designed to collect and transport approximately 50,800 acre-feet of water annually. The Fry-Ark Project diverted an annual average of 52,167 acre-feet[1] (41 percent) of the Upper Fryingpan Sub-watershed from 1997-2005. From 1971 to 2005, the maximum amount diverted through the Boustead Tunnel was 107,612 acre-feet in 1984, and the minimum amount was 3,340 acre-feet in 1987. The maximum amount diverted through the Busk-Ivanhoe Tunnel was 9,754 acre-feet in 1984 and 2,453 acre-feet in 1996. More information about the Fry-Ark Project can be found within Section 2.1.3. Many of the future water quantity considerations discussed in Section 2.2 are directly relevant to the Fryingpan River Sub-watershed.

[1] Includes water from the Hunter Creek drainage in the Upper Roaring Fork Sub-watershed.

Figure 4.7.9. View of upper and lower ends of Fry-Ark Project diversion structure on Chapman Gulch (August 14, 2006).

Twenty-five stream flow gages in this sub-watershed are no longer operational. Many were used in the development of the Fry-Ark Project. Twelve stream gages are now operated by the U.S. Geological Survey, CDOW, and BOR (Figure 4.7.10 and Appendix 3.1.1). Much information from these gages is not useful for assessing flow alteration because it does not represent a significant period (at least 20 years) before the construction of the Fry-Ark Project's diversions and other features, including Ruedi Reservoir. A report on the peak Ruedi Reservoir release administered by the BOR in May 2006 (it peaked at 814 cfs for one day) (Clarke and Malone, 2006) used data from the gage below the reservoir to assess changes in peak flows. Analysis of the release found that overall monthly flows in May and June have decreased from before implementation of the Fry-Ark Project's diversions and Ruedi Reservoir to post-implementation, although it varies significantly from year to year. Median values dropped from 398 cfs to 305 cfs for May and from 831 cfs to 224 cfs for June.

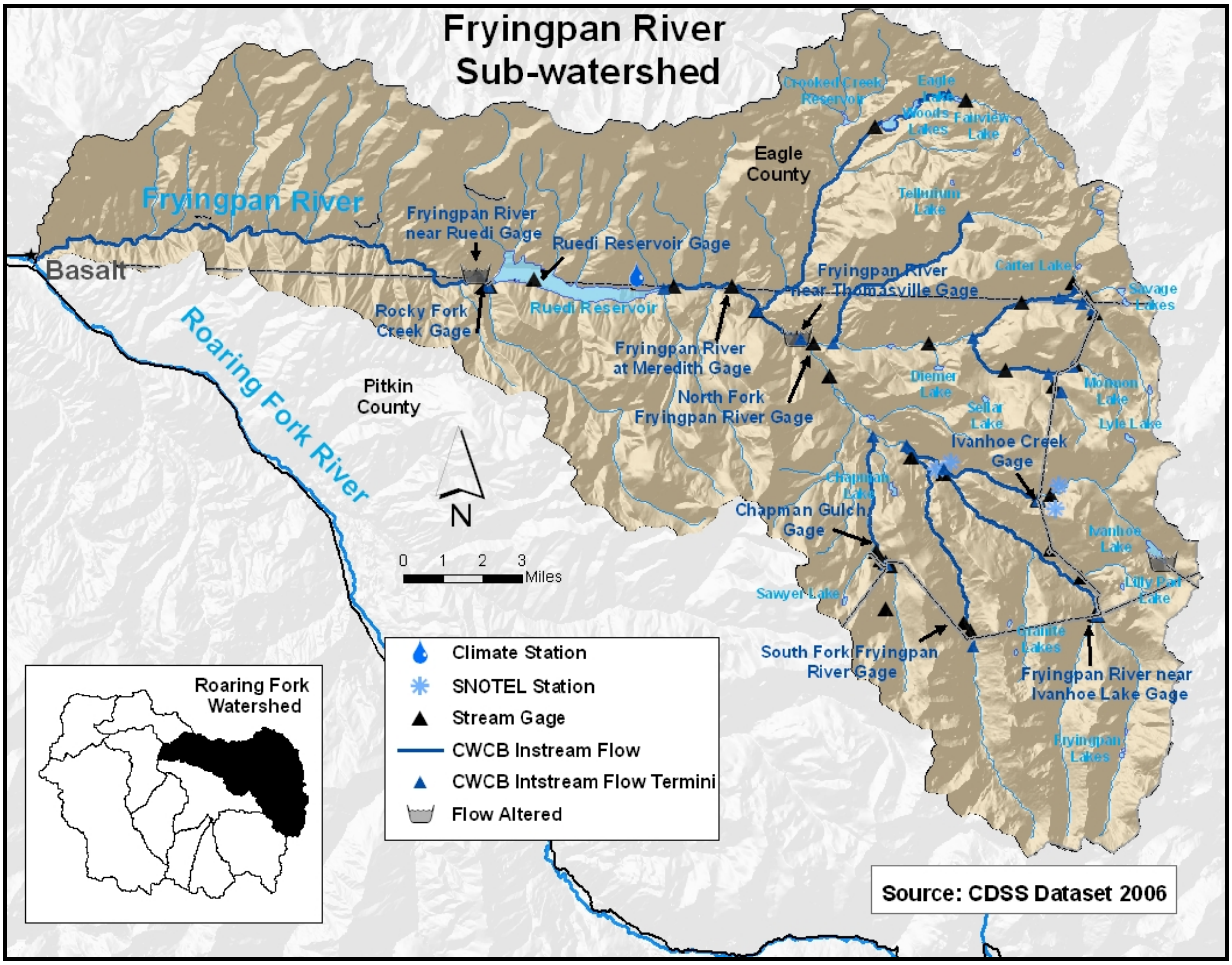


Figure 4.7.10 Water features in the Fryingpan River Sub-watershed.

Additionally, flow alteration was assessed using the Upper Colorado River Basin Water Resource Planning Model dataset (CWCB and CDWR, 2007a). Modeling accounts for diversions greater than 10 cfs. These modeled data are available for three nodes in this sub-watershed; Fryingpan River Ivanhoe Reservoir Tunnel; Fryingpan River near Thomasville; and Fryingpan River near Ruedi (Figure 4.7.10 show locations of the nodes, depicted by the symbol for “flow altered”). Appendix 3.1.2 and Figures 3.1.4 - 3.1.6 show to what extent flows at nodes in the sub-watershed have been altered. Flows at the Fryingpan near Thomasville node when compared with pre-developed flow patterns, are most greatly reduced during the peak runoff months of May, June, and July. This translates into a significant decline in the one-, three-, seven-, 30-, and 90-day maximum flows as well as reduction in the rise and fall rate and also a reduction in small and large floods (Figure 4.7.11). Under pre-developed flow conditions small floods would be expected to occur in four out of 10 years, and under developed flow conditions in less than one out of 10 years.

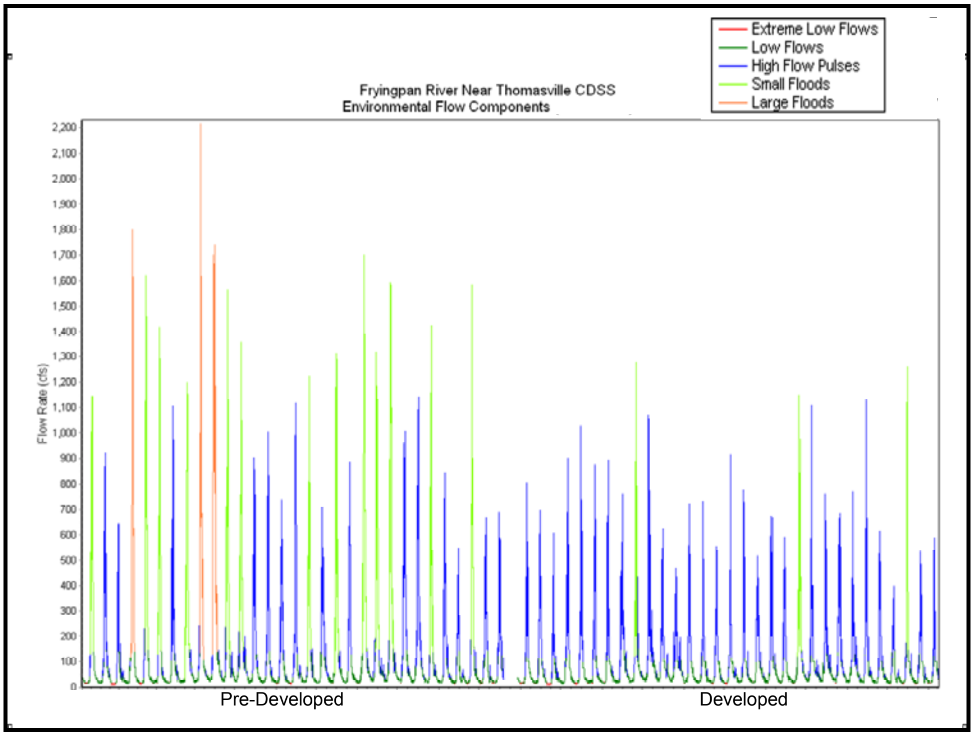


Figure 4.7.11. Reduction in the number of small and large floods on the Fryingpan River near Thomasville.

At the Fryingpan River Node below Ruedi Reservoir flows are significantly altered for every month with the exception of April. From August to April developed flows are higher than pre-developed flows due to reservoir releases. During the peak flow months of May through July, developed flows are significantly less than pre-developed flows because water is diverted by the Fry-Ark Project or is held in the reservoir for release later in the season. A reduction in small and large floods also occurs. Under pre-developed flow conditions, small floods would be expected in four out of 10 years, while under developed flow conditions, small floods would be expected to occur in less than one out of 10 years. All of the minimum flow parameters indicate higher developed minimums than under pre-developed conditions, and all of the maximum flow parameters indicate the opposite trend, that is, lower developed maximums than under pre-developed conditions.

Figure 4.7.12 shows locations of all diversions in the sub-watershed. Eleven of these, including the two transmountain diversions, have a decreed capacity greater than 10 cfs (Table 4.7.3). The second largest diversion listed for this sub-watershed, Ruedi Reservoir Power Plant, is essentially a non-consumptive use since it uses water released from the reservoir to generate power and returns it directly to the Fryingpan River. The capacity of the turbine and associated penstock is 300 cfs. When reservoir outflow is 300 cfs or less, the entire outflow is directed through the hydropower plant. When outflow is more than 300 cfs (i.e. during peak runoff and when major releases are in progress in late summer and early fall), 300 cfs goes through the plant and the remainder is directed through the original reservoir outlet works. Water diverted through the plant is released into the river about 50 yards downstream of the original outlet works and into the same stilling basin as the original works; thus, the impact on stream flow and riparian habitat from this diversion is negligible. Water that runs though the plant is propelled from a valve onto the blades of a large turbine inside the hydro plant to turn the turbine, but is not altered, consumed, or changed in any way by this process. During its 21 years of operation, no environmental impact from the power plant operation has been identified with the exception of an occasional small fish or invertebrate that passes through the filters and ends up in the turbine.

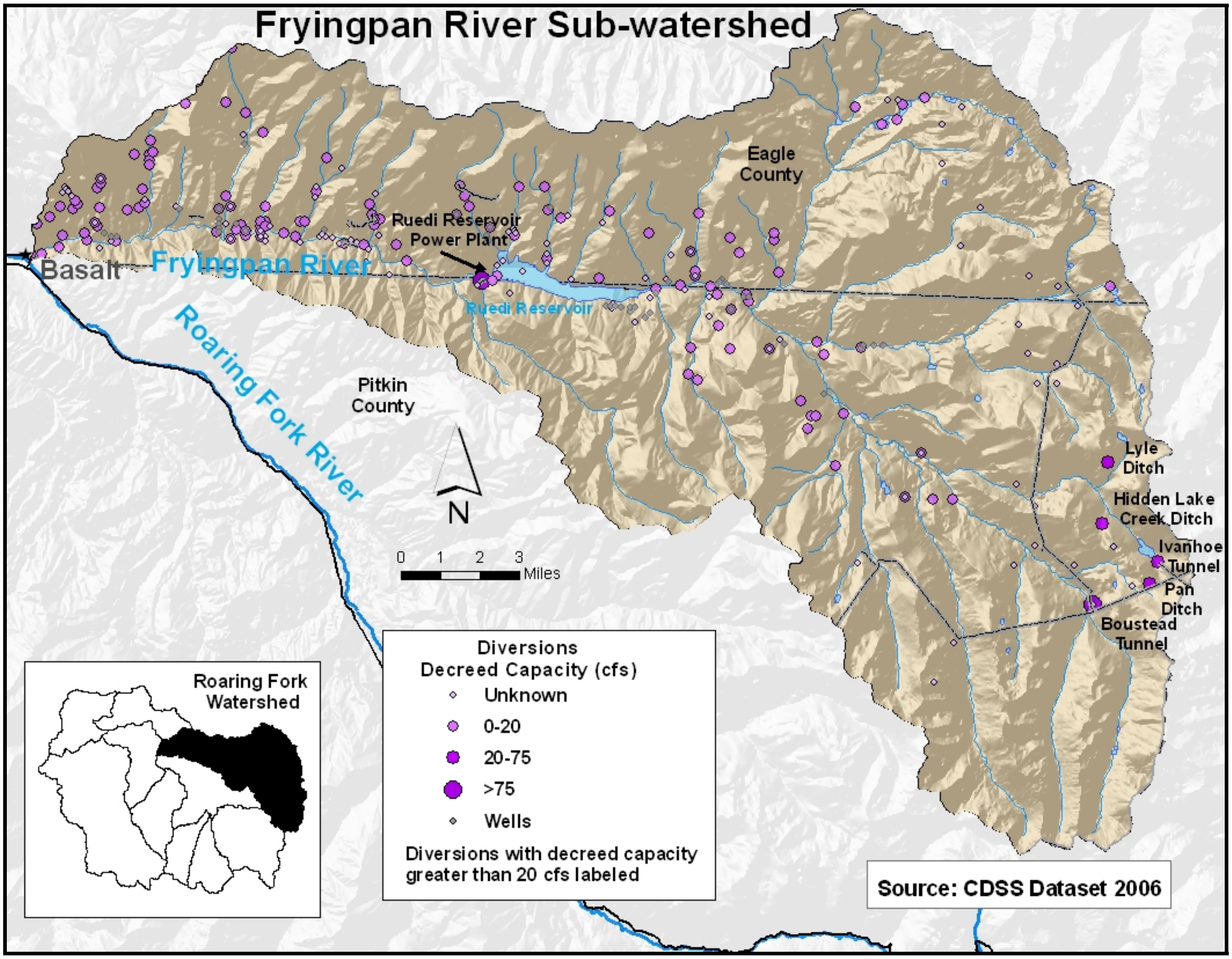


Figure 4.7.12. Diversions and wells in the Fryingpan River Sub-watershed.

Table 4.7.3. Diversions in the Fryingpan River Sub-watershed greater than 10 cfs. Source CDSS GIS Division 5 diversion data, 2006.

STREAM	DITCH	DECREED CAPACITY (cfs)
Fryingpan River	Fry-Ark Project Boustead Tunnel*	1,000.00
Fryingpan River	Pan Ditch*	25.00
Fryingpan River	Ivanhoe Reservoir Tunnel*	35.00
Ivanhoe Creek	Hidden Lake Creek*	70.00
Ivanhoe Creek	Lyle Ditch*	50.00
Fryingpan River	Koch Ditch*	20.00
Lime Creek	Wood Lake Reservoir Direct Flow*	15.00
Lime Creek	Alicia Lake Reservoir Direct Flow*	15.00
Fryingpan River	Troy Ditch 1st and 2nd Enlargement*	17.00
Fryingpan River	Ruedi Reservoir Power Plant*	300.00
Downey Creek	Jouflas Ditch Headgate No. 1*	12.16

*used in CDSS modeling

In addition to conditional water rights associated with the Fry-Ark Project (Appendix 2.6), two direct-flow conditional water rights greater than 10 cfs are on the Fryingpan River and one is on Carter Creek (Table 2.4). Three conditional storage rights greater than 1,000 acre-feet exist in the sub-watershed (Table 2.5). One storage right is associated with Ruedi Reservoir and the other two were originally sought by the Colorado Game, Fish, and Parks Commission for the Upper Chapman and Coke Oven reservoirs. The USFS manages Upper Chapman Reservoir and refurbished the dam in 2003 (Bill Blakeslee, CDWR, Division 5, Water Commissioner, personal communication, April 23, 2008). Coke Oven Reservoir was formerly Sellar Meadow and it no longer stores water (Bill Blakeslee, CDWR, Division 5, Water Commissioner, personal communication, April 23, 2008) and CDOW relinquished the conditional rights to this reservoir a few years ago (David Graf, CDOW, Regional Water Specialist, personal communication April 18, 2008).

Figure 4.7.10 shows locations of the 13 Colorado Water Conservation Board instream flow rights (ISFs) in this sub-watershed and the tabulation in Appendix 2.2 provides specific location information, length, amount, and appropriation date for each. For more information about these ISFs and Fry-Ark Project bypass flows refer so Section 2.1.3. According to the Stream Flow Survey Report (Clarke, 2006), the ISF on the Fryingpan River, from the confluence with the North Fork of the Fryingpan River to Ruedi Reservoir, was met less then 50 percent of the time in April at the Fryingpan at Meredith stream gage.

Groundwater

The Eagle Basin Bedrock Aquifer underlies most of the middle and lower Fryingpan Sub-watershed. No groundwater hydrology evaluations have been done specifically for the sub-watershed.

Water Quality

Author: U.S. Geological Survey

Water quality within the Fryingpan Sub-watershed has been monitored since 1957. Water diversions (Fry-Ark Project) and the construction of the Ruedi Reservoir within the sub-watershed have prompted several studies to look at how these management practices affect biology, water quality, water quantity, and stream health (Ptacek et al., 2003; Clarke, 2006; Roaring Fork Conservancy, 2006a; Clarke and Malone, 2007). In this sub-watershed, data have been collected at 28 water-quality sites, 26 of which are stream sites. Streams with at least some historical water quality data include Rocky Fork, Lime, Cunningham, and Ivanhoe creeks; Chapman Gulch; and the Fryingpan River; however, the majority of the recent water quality data have been collected on the Fryingpan River. Along the Fryingpan River, surface water quality sites exist above Ruedi Reservoir, directly below the reservoir, and at the mouth of the Fryingpan River. Data from the following sites were used to represent water-quality conditions in the sub-watershed, with data from 1995 to 2007:

Above Ruedi Reservoir:

- Fryingpan River at Meredith, Colorado (Site 31)

Below Ruedi Reservoir:

- Fryingpan River near Ruedi, Colorado (Site 32)
- Fryingpan River at Baetis Bridge (Site 33)

At the mouth:

- Fryingpan River near Basalt (Site 34)
- Fryingpan River at upper Basalt Bridge (Site 35)

These sites are shown in Figure 4.7.14. For each site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

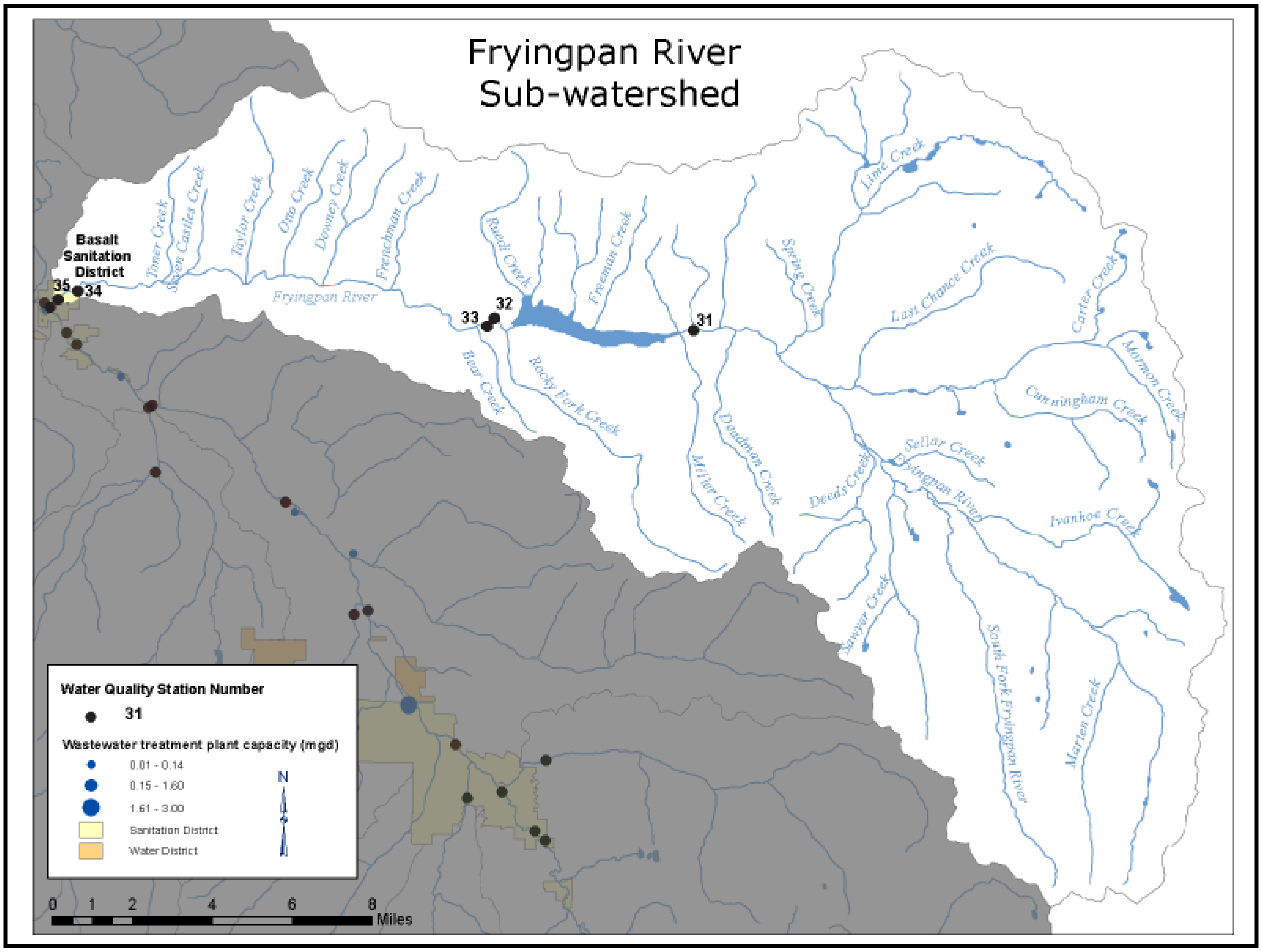


Figure 4.7.13. Water-quality sites in the sub-watershed wastewater treatment providers in the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and CDOLA, No date b.

The Colorado River Watch Program is monitoring water quality at three sites (sites 31, 33, and 35).

Water quality conditions on the Fryingpan River are fairly consistent for those constituents monitored from upstream of the Ruedi Reservoir to downstream at the mouth of the Fryingpan River.

Two hundred and forty-four pH values were collected in the sub-watershed that ranged from 7 to 9, with median pH values that ranged from 8.07 to 8.4. All 331 water temperature samples were below the applicable maximum standard, which has been set at 18.2°C (64.8°F) below the reservoir and 20°C (68°F) above the reservoir. Water temperature values ranged from 0°C (32°F) to 21°C (69.8°F), and median water temperatures ranged from 6°C (42.8°F) to 8°C (46.4°F). Specific conductance was available at Site 32, with values ranging from 125 µS/cm to 302 µS/cm, and a median value of 224 µS/cm. Dissolved oxygen concentrations indicate well-oxygenated conditions. Across 241 dissolved oxygen results, concentrations ranged from 6 mg/L to 17.8 mg/L, and median concentrations ranged from 9.35 mg/L to 10.15 mg/L.

Major ion data in the sub-watershed is limited, mostly consisting of calcium and magnesium concentrations (for hardness concentration calculations), and chloride and sulfate results. Thirty chloride concentrations ranged from 0.73 mg/L to 6 mg/L. Of the 55 sulfate concentrations, values ranged from 5 mg/L to 340 mg/L, and median sulfate concentrations ranged from 12.7 mg/L to 54 mg/L. The maximum sulfate concentration (340 mg/L) was observed at Site 35 in May 2002. Total dissolved solid concentrations were available only for Site 34, near the mouth of the Fryingpan River. They ranged from 61 mg/L to 190 mg/L, with a median of 160 mg/L. The median hardness concentration was 65 mg/L at Site 31, above the reservoir, and 128 mg/L at Site 35, near the mouth, signifying conditions ranging from moderately hard to very hard.

All sites except Site 32 had nutrient data; however, there were insufficient data to characterize seasonal trends. Of 38 nitrate results, the maximum observed concentration was 0.22 mg/L. Of the 36 un-ionized ammonia concentrations, 22 values were censored and the maximum observed concentration was 0.012 mg/L. One of 36 total phosphorus samples exceeded the total phosphorous criteria with a concentration of 0.172 mg/L at Site 33 in June 2005.

Arsenic, aluminum, cadmium, copper, iron, lead, manganese, selenium, and zinc have been sampled extensively with rare occurrences of water-quality standard exceedances. Of the 208 total recoverable aluminum samples collected (34 censored), one concentration was found to exceed 750 μg/L in August 2002 at Site 35. Four of the 169 selenium concentrations exceeded the chronic standard, with 129 values that were censored. All four selenium exceedances occurred below the reservoir at Site 33, Fryingpan River at Baetis Bridge.

Available suspended sediment concentration data indicate low suspended sediment concentrations (38 of the 55 total suspended solid concentrations were censored). Concentrations ranged from 4.3 mg/L to 128.3 mg/L and the maximum suspended solid concentration (128.3 mg/L) was observed at Site 33 in June 2005, which coincided with the total phosphorus concentration sample of 0.172 mg/L.

Riparian and Instream Areas

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed the lower Fryingpan River in this sub-watershed. Figure 4.7.14 shows specific riparian and instream information, by habitat quality category, for each reach assessed. Habitat quality categories are shown in the riparian and instream assessment charts in Section 3.3 and Section 3.4. Appendix 3.3.1 contains actual percentage values for each of these categories by sub-watershed and how they were determined. The sub-watershed has one stream segment:

- Fryingpan River Segment – Fryingpan River from the base of Ruedi Reservoir to the confluence with the Roaring Fork River (SHI reaches FP1-1 through FP1-10); 13.72 miles.

Following is a brief description of results. The SHI report contains detailed narrative description. "Right bank" and "left bank" refer to the orientation of the riparian zone when facing downstream.

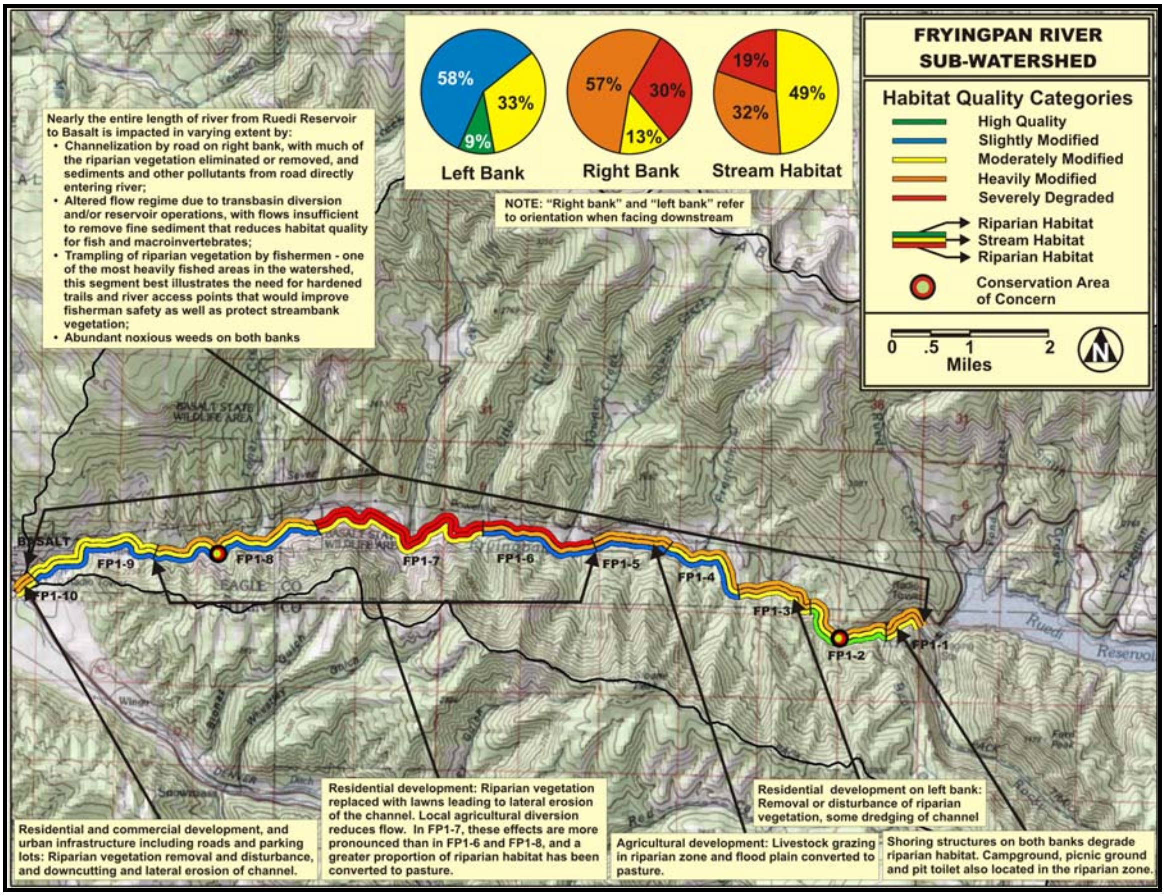


Figure 4.7.14. Riparian and instream habitat quality for the Fryingpan River Sub-watershed.

Uplands

Above Ruedi Reservoir upland habitat is generally in good condition and supports sustainable populations of native wildlife. Headwater reaches are in designated wilderness and are managed for sustainability and wildlife values. Outside of the wilderness boundary the majority of upland habitat is publicly owned and managed by the USFS. Although these lands are also generally in good condition, dispersed recreational use is high for hiking, horse packing, fishing, camping, and hunting. The USFS maintains roads and trails, controls weeds, and has closed and reclaimed roads to reduce sediment delivery into adjacent streams (Figure 4.7.15). This work is ongoing throughout the sub-watershed.

Figure 4.7.15. Decommissioning a non-system road at Sellar Lake, September 2007, (Photo Credit: Mark Lacy).

Further downstream, upland habitat is a mix of public and private ownership with uses including grazing, recreation, and residential development. Roads and trails scattered throughout the area are sources of erosion and corridors for weed invasion. Illegal motorized use on trails is common throughout the drainage and seriously threatens the resource. The north side of the sub-watershed above Ruedi Reservoir is bordered by Red Table Mountain (managed for wilderness values in the WRNF 2002 Forest Plan) and, below the reservoir, by Basalt Mountain. Both areas have a diversity of high quality habitats, are ecologically intact, and are large enough to support complete communities of native wildlife.

Riparian Habitat and Wildlife

Habitat modification from agricultural, rural, and recreational development degrades riparian functions throughout the segment, but development-related impacts have been focused on the wider valley openings. Impacts occur primarily from four sources: conversion of native habitat into pasture and lawns; hydrologic alteration affecting river processes such as out-of-bank flows; recreational use that has damaged and eliminated riparian vegetation (Figure 4.7.16); and the Fryingpan Road which channelizes the river and disconnects it from its historic floodplain (Figure 4.7.17). Riparian habitat quality has been modified over the majority of the assessment area. On the left bank, 9 percent of the habitat is high quality, 58 percent is slightly modified, 33 percent is moderately modified; and none heavily modified or severely degraded. On the right bank, no high quality or slightly modified habitat remains, 13 percent is moderately modified, 57 percent is heavily modified, and 30 percent is severely degraded.

A variety of anthropogenic impacts have altered riparian habitat and reduced ecosystem functions. Table 4.7.4 summarizes the type and extent of those modifications. The cumulative effect of development has been to alter native ecosystems. Undesignated social and angler trails are common throughout the drainage, especially on the right bank. These trails have damaged or eliminated riparian vegetation and promoted weed invasion. The Fryingpan Road is adjacent to the stream on the majority of the right bank. Road impacts are prominent on reaches FP1-1 through 1-4, 1-7, and 1-8. In areas where the road disconnects the river from its floodplain consequences include reduced cottonwood recruitment and dying trees (Figure 4.7.18).

Agricultural and residential development has focused on the wider, flatter valley openings such as FP1-3, 5, and 7 and resulted in the conversion of native willow carrs and cottonwood forests to hay meadows and non-native grass lawns. Resulting effects include loss of native habitat and wildlife, and altered runoff-infiltration regimes (Figure 4.7.19).

Figure 4.7.16. Recreational disturbance has damaged and eliminated riparian vegetation.

Figure 4.7.17. Fryingpan Road and riprap on the right bank channelizes the stream and inhibits stream processes and functions.

Figure 4.7.18. FP1-7: This cottonwood stand is comprised mainly of old individuals with few recruits to replace them when they die. Lack of flooding flows and drying soils inhibit recruitment of seedlings and saplings.

Figure 4.7.19. FP1-5: Agricultural conversion of native riparian habitat into hay meadows and pastures on the right bank of the river has diminished riparian values.

Table 4.7.4. Summary of land development impacts and threats to riparian and instream habitat within the lower Fryingpan River drainage.

FRYINGPAN RIVER SUB-WATERSHED	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	RIGHT BANK
Total Stream Miles: 13.72	25%	37%	12%	76%	58%	89%

Native wildlife is limited by habitat and resource loss, and by habitat fragmentation due to roads, power line corridors, and residential development in the lower Fryingpan River Valley. Development impacts occur on both sides of the river, but are especially pervasive on the right bank throughout the segment. However high quality habitats are scattered throughout the assessment area. These sites are always found away from the road on the left bank of the stream, in undeveloped areas fairly inaccessible to recreationists. These higher quality areas have a naturally diverse and structurally complex habitat with good wildlife potential. They include the left bank of FP1-2, a small area on the left bank of FP1-3 that is managed by the USFS (Figure

4.7.20), and most of the left bank of reaches FP1-4 through 1-6, 1-8, and 1-9, which are a mix of public and private lands that are typically steep-walled and difficult to access. Additionally, the steep canyon walls and cliffs that characterize much of the stream corridor provide nesting habitat for songbirds such as Northern rough-winged swallows, Cordilleran flycatchers, and American dippers, and mammals like bushy-tailed woodrats.

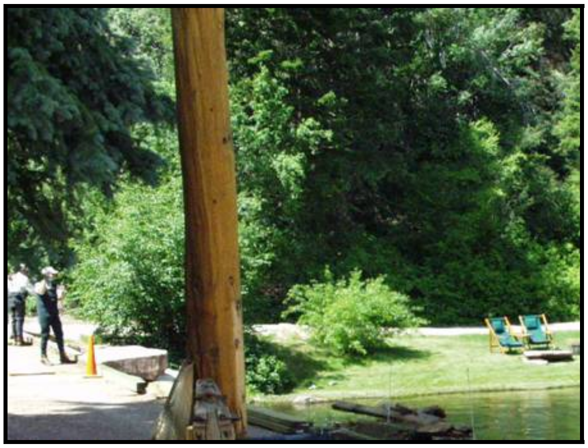


Figure 4.7.20. Upper photo: Conversion of riparian habitat to lawns on reach FP1-3 reduces wildlife potential. Lower Photo: A small area on the left bank of FP1-3 that is managed by the USFS provides good quality wildlife habitat.

Several studies have assessed biological diversity in this sub-watershed including the Colorado Natural Heritage Program (CNHP) and the SHI. CNHP designated three riparian habitats in the sub-watershed as Potential Conservation Areas (PCAs) (Figure 3.3.2 and Appendix 3.3.2) due to their high biodiversity significance: Toner Creek riparian habitat from the headwaters to the confluence with the Fryingpan due to the occurrence of two examples of a globally vulnerable plant community (cottonwood riparian forest-*Populus angustifolia/Cornus serecia*) (Figure 4.7.21); and the headwaters of the Fryingpan and the North Fork of the Fryingpan River due to a globally-vulnerable plant community (lower montane willow carr-*Salix drummondiana/Calamagrostis canadensis*).

Figure 4.7.21. FP1-8: A globally-vulnerable plant community occurs on the left bank of the river; the right bank has been severely degraded by the roadcut and recreational disturbance.

The SHI identified two Conservation Areas of Concern (Table 4.7.5): reaches FP1-2 and 1-8 (which corresponds with one of CNHP's PCAs). Habitat and wildlife potential on the left bank of both reaches is high but threatened with recreational disturbance. SHI breeding bird surveys indicate a greater diversity of human-sensitive and vulnerable bird species in higher quality habitats compared to disturbed or developed reaches. Vulnerable species (CNHP or Audubon watchlist) observed include willow flycatcher, olive-sided flycatcher, and Northern goshawk; human-sensitive species include Western tanager, Swainson's thrush, and MacGillivray's warbler.

Table 4.7.5. SHI Conservation Areas of Concern in the Fryingpan River Sub-watershed.

LOCATION	JUSTIFICATION
FP1-2	Left bank provides high quality wildlife habitat. Threats are from a dirt road that enables easy access and has resulted in disturbance with subsequent bank destabilization.
FP1-8	A globally-vulnerable plant community, narrowleaf cottonwood/ red-osier dogwood, characterizes the riparian habitat. The left bank is in good condition but the right bank is degraded from disturbance related directly to unmanaged recreation.

Instream Habitat and Wildlife

Stream type and morphology in the sub-watershed varies between Type E streams that meander through wide, unconfined flat valleys, Type C streams in slightly confined and steeper reaches, and Type B streams in fairly steep, narrow, confined areas of the valley (Rosgen and Silvey, 1996). Refer to Table 3.4.1 and Figure 3.4.2 for general characteristics of these different types of streams.

Since completion of the Ruedi Dam in 1968, the river channel below Ruedi Reservoir has downcut slightly and become constrained with armored banks and island formations. Rocky Fork and other tributaries below the dam still provide sediment, gravel, and large wood to the lower Fryingpan River, but overall, the dam and its modifications to flow have reduced these nourishing materials to below historic levels. The instream habitat below Ruedi has become more simplified, but provides habitat for a Gold Medal brown trout fishery. The instream habitat has been changed by modifications to stream flow and riparian habitat. The Fryingpan Road is adjacent to the river in many locations, constraining the channel (Figure 4.7.22), and numerous areas alongside the road have been riprapped to protect the roadway from the natural lateral migration of the channel (BRW, Inc. et al., 1999). Other development in the lower reach, such as agricultural and residential, has converted portions of the historic floodplain into pastures and lawns, and has simplified what historically was a braided meandering channel with beaver dams into a single channel that no longer meanders across the floodplain, thus reducing instream habitat. The impact on instream habitat is decreased quality throughout the assessment area, with no high quality or slightly modified instream habitat present. Forty-nine percent of the instream habitat has been moderately modified, 32 percent heavily modified, and 19 percent severely degraded. However, the river still provides an excellent recreational fishery due in large part to a new food source resulting from the dam (mysis shrimp) and enhanced macroinvertebrate populations caused by higher base flows that increase habitat availability.

Figure 4.7.22. FP1-7: Fryingpan Road is adjacent to the lower Fryingpan River in many locations.

Hydrologic alteration in the lower Fryingpan River has resulted from a combination of factors including dam-controlled stream flows, irrigation diversions, and land development that decreases infiltration and increases runoff. Consequently, river processes and functions have been impaired. Out-of-bank flooding flows occur infrequently and minimally due to dam-controlled hydrology. Dam-controlled flows have resulted in decreased duration and extent of flooding, leading to stream habitat simplification and degradation because of the increased presence of periphyton and embeddedness of the sediments and cobbles within the stream channel.

To further explore the importance of natural peak flow events in the lower Fryingpan River, a 2007 study by Clarke and Malone compared surveys for five instream habitat indicators before and after the BOR's May 2006 Ruedi Reservoir peak release to determine if habitat conditions improved. No improvements in aquatic vegetation, embeddedness, sediment deposition, or bank-full depth were found, and the study concluded that the release of 814 cfs during one day was not long enough, or perhaps not high enough, to improve aquatic habitat by removing entrained sediments. In addition, it is possible that a greater frequency of flows of this magnitude would be required to effectively mobilize entrained sediments. Existing infrastructure from residential development limits how much water can be released from Ruedi without causing property damage; therefore, a longer duration release at an average pre-Fry-Ark Project diversion level might be needed to mobilize entrained sediments (e.g. 1,000 cfs for 10 days).

In response to a debris flow in the summer of 2007 (Figure 4.7.23), a study initiated by the Roaring Fork Conservancy determined the immediate and potential long-term effects of the debris flow (Miller, 2008). As a result of sampling in October 2007, Miller concluded that the Fryingpan River and its biota were recovering from the sediment flow. Based upon results of the study, the funding partners have decided to allow natural stabilization to occur in the channel, to monitor and control noxious weeds, and to look at the possibility of undertaking a riparian planting project sometime in 2009. Although short-term impacts resulted from the debris flow, it was a natural event and provided the Fryingpan and Roaring Fork rivers with gravel and other channel building materials. In the Fryingpan River just upstream of the alluvial fan from Seven Castles Creek, a new gravel bar provided spawning habitat for brown trout in the fall of 2007. More than 50 redds were observed in October 2007 (Mark Lacy, USFS Fish Biologist, personal communication, March 30, 2008).

Figure 4.7.23. The Fryingpan River below the Seven Castles Creek debris flow that occurred on August 7, 2007 (Photo Credit: Chad Rudow, September 17, 2008).

Instream habitat in the Fryingpan above Ruedi is generally in good to excellent condition and provides habitat for brown and brook trout. The channel is relatively unaltered and beaver dams are common in wider reaches in the floodplain. The floodplain widens out upstream of Chapman Campground, and the channel is braided, stable, and intermixed with beaver dams, creating complex instream habitat for fish and other aquatic species (chorus frogs and tiger salamanders). The North Fork Fryingpan River increases in gradient, and the North Fork and its tributary streams have lakes above them in the headwaters. One population of Colorado River cutthroat trout (CRCT) lives in this drainage (Figure 3.4.4), and CDOW stocks CRCT in many of the lakes for a recreational fishery (Table 4.7.2). Most of the streams are dominated by brook and brown trout and many of the lakes have brook trout. The mainstem of the Fryingpan River continues upstream to the South Fork, which is similar to the North Fork in species distributions and habitat quality, but has fewer lakes. In both the South Fork and mainstem Fryingpan River brook and brown trout are the dominant species, and several populations of CRCT are in these drainages.

Evidence of whirling disease was first detected near the confluence with Taylor Creek in the middle 1990s and corresponded to a dramatic decline of rainbow trout in the Fryingpan River between 1994 and 1998 (Nehring and Thompson, 2001). The presence of whirling disease has significantly changed the species composition below Ruedi Reservoir. Wild rainbow trout, which are very susceptible to whirling disease, have almost been eliminated and replaced by a predominately brown trout fishery. CDOW has conducted extensive research in local fish ponds determined to be the initial source of whirling disease infection. Studies have involved implemented "best management practices" to reduce ambient levels of TAM (whirling disease parasitic life stage) production by manipulating fish population dynamics in the ponds, constructing a wetland biofilter below the ponds, and stocking Hofer rainbow trout that are resistant to whirling disease infection (Nehring, 2008). To restore the rainbow trout fishery, the CDOW will begin stocking Hofer rainbow trout in the mainstem Fryingpan River in 2008.

Given the lower Fryingpan River's dam-influenced flow regime, several studies have looked specifically at the effects of Ruedi Reservoir operations on the aquatic ecosystem. A study by Miller Ecological Consultants, Inc. (Ptacek et al., 2003) characterized the instream habitat and flow, macroinvertebrate community, spawning, trout populations, thermal regime, and hydrology for the lower Fryingpan and Roaring Fork rivers. Main conclusions from the study specific to the lower Fryingpan River include the following:

- The amount of suitable trout habitat has increased with post-dam conditions as compared to habitat available before the construction of the Ruedi Dam.
- Hypolimnetic releases and regulated flows in the Fryingpan River are responsible for maintaining extraordinarily high densities and biomass of macroinvertebrates. Densities were highest immediately below Ruedi Dam.
- Rainbow trout spawning success is temperature-limited and may be further reduced by whirling disease.
- Relative abundance of brown trout has significantly increased over the past 20 years and maximum size and overall biomass of brown trout have increased dramatically since installation of the dam.
- The annual maximum temperature of the thermal regime has shifted from late summer (pre-dam) to late fall/early winter (post-dam). Water released is warmer than normal in the fall and winter and cooler than normal in the late spring and summer.
- Since dam construction, base flows are augmented by reservoir releases and spring peak flows are reduced. Since 1989, reservoir releases have been significantly increased during the late

summer/fall (August through October). As an example of this phenomenon, in four out of the last nine years, maximum yearly flow occurred during September.
• Extreme fluctuations in reservoir releases on hourly and daily levels occur fairly frequently.

One of the key outcomes of this main study was a hypothesis that erratic changes in discharge have a negative impact on benthic macroinvertebrates. Therefore, a supplemental study undertaken collected enough information to suggest that the flow regime may have an important physical influence on benthic macroinvertebrate communities (Rees et al., 2003). An additional follow-up study evaluated potential impacts associated specifically with low winter flows (Miller Ecological Consultants, Inc., 2006). This study concluded that the impact to the macroinvertebrate community at the Basalt site from anchor ice appears to be influenced more by ambient air conditions than Ruedi-influenced base flow releases. The study's results also indicated that macroinvertebrate diversity and evenness appear to recover in one to two years after severe anchor ice formation if winter flows remain greater than 70 cfs, and that flows greater than 70 cfs seem to result in less anchor ice in the upper half of the river than do flows around 40 cfs. For more detail, the full study report can be accessed at:
http://www.roaringfork.org/images/publications/RFFP_Summary_Report_Sep_10_2006.pdf.

The Colorado Natural Heritage Program (CNHP) identified five PCAs in this sub-watershed based on the biodiversity found within the aquatic community (three were designated in part because of presence of Colorado River cutthroat trout). These areas are located in Rocky Fork Creek headwaters of the mainstem Fryingpan, and in the North Fork of the Fryingpan (Spackman et al., 1999) (Figure 3.3.2 and Appendix 3.3.2).

The CDOW and USFS have done extensive fish and habitat surveys throughout this sub-watershed. In addition, the USFS has established several long-term study reaches to observe changes for fish, macroinvertebrates, and habitat (Mark Lacy, USFS Fish Biologist, personal communication, March 30, 2008).

4.7.4 Important Issues

Below is a summary of key findings from available scientific information, a listing of data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the Fryingpan River Sub-watershed's water resources.

Key Findings

- Most of the sub-watershed's major headwater streams are strongly influenced by the transmountain diversions related to the Fryingpan-Arkansas (Fry-Ark) Project. The upper Fryingpan River's hydrologic regime – including flow magnitude, duration, and inter-annual variation – has been dramatically changed, with an average of 41 percent of the sub-watershed's yield diverted to the East Slope annually.
- Flows are significantly altered below Ruedi Reservoir for every month with the exception of April. From August to April developed flows are higher than pre-developed flows due to reservoir releases. During the peak flow months of May through July, developed flows are significantly less than pre-developed flows as water is diverted by the Fry-Ark Project or held in the reservoir for release later in the season. There is also a reduction in small and large floods.

- Ruedi Reservoir releases increase late summer, fall, and winter flows, moderate water temperatures, and enhance fishing opportunities in the lower Fryingpan River.
- In addition to the conditional water rights associated with the Fry-Ark Project, there are two direct-flow conditional water rights greater than 10 cfs and three conditional storage rights greater than 1,000 acre-feet in this sub-watershed.
- In the sub-watershed, compared with current state and national water-quality standards and previous studies, the Fryingpan River has good water quality suitable for all specified uses.
- Impacts and threats to riparian and instream habitat sustainability below Ruedi Reservoir include trails and related disturbance (25 percent); roadcuts, bridges, and culverts (37 percent); development (12 percent); weeds (48 percent on the left bank and 89 percent on the right bank); and flow alteration (76 percent).
- Riparian habitat quality has been modified over a majority of the Fryingpan River below Ruedi Reservoir. On the left bank, 9 percent of riparian habitat is high quality, 58 percent slightly modified, 33 percent moderately modified, and no heavily modified or severely degraded habitat was found. The right bank has no high quality or slightly modified riparian habitat, with 13 percent moderately modified, 57 percent heavily modified, and 30 percent severely degraded.
- SHI breeding bird surveys indicated the presence of a greater diversity of human-sensitive and vulnerable bird species in higher quality habitats compared to disturbed or developed reaches. Vulnerable species (CNHP or Audubon watch-list) observed included willow flycatcher, olive-sided flycatcher, and Northern goshawk; human-sensitive species included Western tanager, Swainson's thrush, and MacGillivray's warbler.
- Instream habitat in the lower Fryingpan River has been altered by the cumulative impacts of modifications to stream flow and riparian habitat, with no high quality instream habitat found in the assessment area. Forty-nine percent is moderately modified, 32 percent heavily modified, and 19 percent severely degraded.
- Upstream of Ruedi Reservoir brown and brook trout are the dominant trout species. Four isolated populations of Colorado River cutthroat trout have been observed in headwater streams.
- The longest Gold Medal Fishery in the state occurs from Ruedi Dam to Glenwood Springs, including the lower Fryingpan River. It is mainly comprised of brown trout.
- There is one known boreal toad breeding population in the sub-watershed.
- CNHP identified three Potential Conservation Areas (PCAs) for riparian biodiversity attributes, and five PCAs that contain important instream biodiversity values. The SHI identified two Conservation Areas of Concern in the sub-watershed.
- The Seven Castles Creek area in the lower Fryingpan River Valley has been identified by the Roaring Fork and Fryingpan Rivers Multi-Objective Study (BRW, Inc. et al., 1999) as a major debris flow site that delivers high sediment loads to the river. It experienced a significant debris flow event in the summer of 2007.

Data Gaps

A number of gaps in information for the sub-watershed limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Detailed information about groundwater hydrology;

- No recent water-quality data for the following constituents and constituent groups:
    - Specific conductance – could aid in establishing sources of dissolved material and describing other water-quality conditions
    - Suspended sediment – to evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals
    - Microorganisms – to establish potential for water-born disease
- Water-quality monitoring of groundwater and lakes/reservoirs;
- Instream and riparian habitat survey data for the mainstem Fryingpan River above Ruedi Reservoir and the North Fork of the Fryingpan River; and
- Information about upland and riparian mammal community diversity, amphibian and reptile populations, and population sustainability.

Relevant Local Initiatives, Plans, and Studies

- Prompted by significant flooding within the sub-watershed (as well as upstream of it) in 1995, the Roaring Fork and Fryingpan Rivers Multi-Objective Study (BRW, Inc. et al., 1999) was undertaken to locate areas of high flood hazards, areas and causes of instability, and infrastructure at risk, including on the Fryingpan River below Ruedi Reservoir.
- A study by Miller Ecological Consultants, Inc. (Ptacek et al., 2003) conducted on the lower Fryingpan and Roaring Fork rivers characterized the physical habitat and aquatic biota relative to the operation of Ruedi Reservoir. The conclusions of the study related to instream habitat and flow, the macroinvertebrate community, spawning, trout populations, thermal regime, and hydrology.
- Another study evaluated potential impacts associated with low winter flows (Miller Ecological Consultants, Inc., 2006) and made several conclusions about the formation of anchor ice and impact of anchor ice on macroinvertebrates.
- The water use and quality goal established by the Upper Fryingpan Valley Caucus highlights protecting the water supply and preserving wildlife areas and riparian and wetland areas.
- To address instream habitat impact below the 2007 Seven Castles Creek debris flow, a study was conducted by Miller Ecological Consultants, Inc. Based on its recommendations, it has been determined to allow the channel to undergo natural stabilization with continued monitoring, weed controlling activities, and consideration of a riparian planting project in 2009.

4.8 Crystal River Sub-watershed

4.8.1 Environmental Setting

The Crystal River Sub-watershed is in the southwestern part of the Roaring Fork Watershed. It is the largest sub-watershed and extends from peaks in the Elk Mountain Range to Carbondale, where the Crystal River joins the Roaring Fork River. Ecoregions in this sub-watershed are the Alpine Zone in the headwaters, a large extent of Sedimentary Subalpine Forests, a short band of Sedimentary Mid-elevation Forests, and Foothill Shrublands in the lower reaches. Extensive areas of sedimentary rock formations significantly influence the sub-watershed's landscape, vegetation patterns, and streams and rivers. The sub-watershed is known for its mining history. The Mid-Continent Resources Coal Mine operated in Coal Creek basin, and historic coke ovens can still be seen at Redstone, along with Redstone Castle, all originally developed by Charles Osgood. Marble mining continues at the Yule quarry near Marble, and a historic water-driven ore-processing mill is at the old townsite of Crystal. The main valley is accessed by State Highway 133, a designated Scenic Byway, from Carbondale over McClure Pass (9,500 feet in elevation) to the North Fork of the Gunnison Basin and its communities of Paonia and Hotchkiss. The Crystal River is one of the few rivers on Colorado's West Slope not affected by dams or transbasin diversions. See Figure 4.1 for an overview map showing the location of the sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions. The sub-watershed's general physical characteristics are summarized in Table 4.1.

Topography and Geology

The Crystal River Sub-watershed includes several major drainages in addition to the Crystal River. The North and South Fork of the Crystal River are the headwaters that drain the Elk Mountain Range. Yule Creek joins the mainstem near the town of Marble, Coal Creek enters at Redstone, and Avalanche Creek joins the Crystal River about five miles further downstream. The largest drainage area, Thompson Creek, is located in the western portion of the lower sub-watershed. Prince Creek drains the northern flanks of Mount Sopris.

A significant portion of the upper sub-watershed has slopes greater than 30 percent (Figure 1.4). Slopes greater than 45 percent are commonly found along the Crystal River below the confluence of the North and South forks of the Crystal River, and within the drainages of Rapid and Avalanche creeks.

As shown in Figure 1.3 (the surface geology of the Roaring Fork Watershed), the upper sub-watershed is a glacial valley carved mostly in Cretaceous shales. During heavy rains, mudflows are common on the steep, glaciated valley slopes. In 1941, a mudslide destroyed most of the town of Marble, which was relocated just west of the original location. According to a report on the critical landslides of Colorado (Rogers, 2005), the Marble townsite and vicinity are listed as a tier one (most severe) debris flow and rockslide priority area. Marble is affected by debris flows from both Slate and Carbonate creeks. Another hazard in this area, the Mount Daly rockslide, could potentially impact Marble's water supply and contribute to flash floods or debris flows on the Carbonate Creek fan. The town of Marble is named for the recrystallized Leadville

Limestone that formed with the intrusion of Treasure Mountain's igneous core (Chronic and Williams, 2002).

Assignation Ridge parallels much of the western side of the Crystal River and is comprised of parallel bands of the Maroon Formation and Triassic, Jurassic, and Cretaceous shales and sandstones. These formations are mostly stable with rockfalls being the most common problem. The town of Redstone is appropriately named for the Maroon Formation located on both the west and east sides of the river valley in that area. Cretaceous shales are very susceptible to erosion, leading to mudflows, landslides, and other slope instability problems. A large area of Cretaceous shale is found in Coal Creek drainage. Rogers (2005) lists the area comprising Dutch Creek, Coal Creek, and Redstone as a tier three (meaning the least severe or occurring only in a localized area) priority area because of the risk of debris flows, debris avalanches, and associated flooding. It is noted that coal mining activities in the steep, upper part of the Dutch Creek drainage were frequently disrupted by debris flows and the area continues to experience frequent debris flows that feed coarse rock and wood into Coal Creek. This rock and wood collects at the confluence of Coal Creek and the Crystal River causing pooling of water and erosion by both streams, exacerbating the spring flood threat to Redstone and Highway 133. Coal was mined from deposits within the Mesaverde Group (Cretaceous sandstones). Younger sedimentary rocks and ancient alluviums are found in the headwaters of Thompson Creek. These sedimentary rocks are soft and susceptible to erosion (a photograph of Thompson Creek is shown in Figure 4.8.1). The Thompson Creek drainage is geologically unstable due to the combination of these soft sedimentary rocks and the highly erodible Cretaceous shales. A large landslide deposit is located in the North Thompson Creek drainage.

Figure 4.8.1. Thompson Creek, September 9, 2006.

The distinctive peaks in the sub-watershed are formed by tertiary intrusive rocks: Chair Mountain and Rapid Peak that form the headwaters for Rapid Creek; Meadow Mountain, Mount

Daly, Mount Richey, and Capitol Peak that surround the headwaters of Avalanche Creek; and Mount Sopris.

The more gently sloping lower sub-watershed is a mixture of ancient alluviums, gravels, and alluviums. This includes the confluence of the Crystal River with the Roaring Fork River and the confluences of several tributaries with the Crystal River.

Weather/Climate

Two Colorado Basin River Forecast Center SNOTEL sites are in the headwaters of this sub-watershed – Schofield Pass (SOSC2) at 10,700 feet, and McClure Pass (MCPC2) at 9,500 feet (http://www.cbrfc.noaa.gov/snow/snow.cgi) (Figure 4.8.7). Based on the 20-year period of record (1986-2007), snowpack varied considerably in both amount and timing. At the Schofield Pass site, average peak snowpack was 38.5 snow water equivalent (SWE) inches, occurring on April 27 (Figure 4.8.2). The two highest measurements recorded at this site were 61.8 inches (SWE) on May 15, 1995 and 52.6 inches (SWE) on April 30, 1986. The lowest peak snowpack was about 70 percent of average and occurred almost a month earlier than average (25.3 inches SWE on April 1, 1992 and 27.9 inches SWE on March 31, 2002).

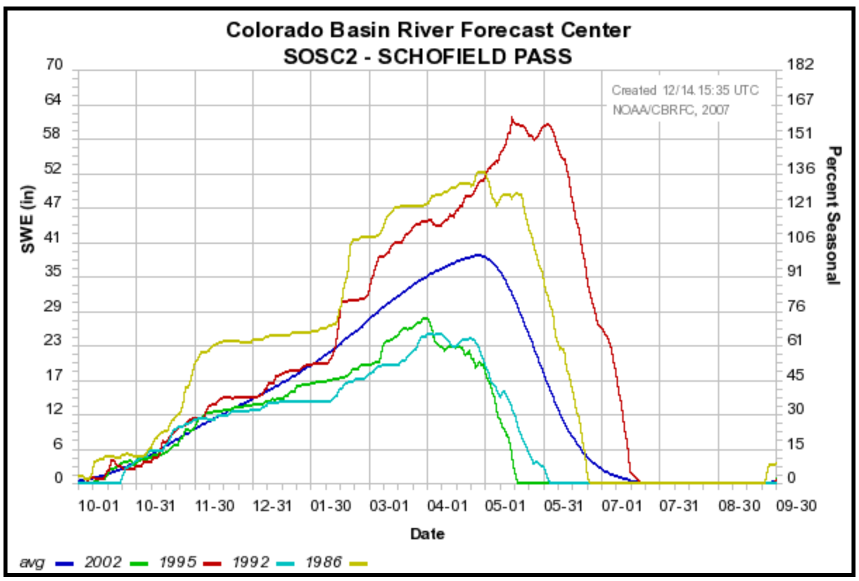


Figure 4.8.2. Highest and lowest recorded snowpack relative to average conditions (1986-2007).

Within the sub-watershed a climate station located at 8,070 feet operated from 1979 to 1994 at Redstone (056970) (Appendix 1.2 and http://www.wrcc.dri.edu/) (Figure 4.8.7). According to the data from this climate station, average total annual precipitation during the period of record was about 28 inches. On average, March and October received more than three inches of precipitation, and less than one inch during January, June, and August. The probability of one inch of rain a day was greatest in September and October. These intense rain events coupled with steep slopes and erodible rocks cause high sediments loads in the streams. Additional precipitation data exists for the four active sites in the sub-watershed associated with the Colorado Collaborative Rain, Hail, and Snow Network (Appendix 1.2) (http://www.cocorahs.org/). These data, collected by a volunteer network, are best used for assessing daily conditions.

Because of the number of data gaps, they are of limited use for summarizing historical conditions.

Biological Communities

The Crystal River begins at the confluence of the North Fork and South Fork just downstream of the historic townsite of Crystal. Riparian habitat here is in the Upper Montane Life Zone and is characterized by mixed spruce and aspen forests, quickly transitioning to mixed blue spruce-cottonwood forests interspersed with stands of willow and open wet meadows. Beaver activity has increased stream meandering and width of the riparian zone by creating small wetlands along the margin of the river (Figure 4.8.3). Upland habitat is comprised of a mosaic of spruce-fir forests, aspen woodlands, open meadows, and, on rocky outcrops, stands of limber pine. Surrounding peaks reach up into the Alpine Life Zone where broad expanses of alpine turf meadow are interspersed with rocky outcrops and slope wetlands. From the townsite of Crystal the stream flows west through a steep, rock-walled canyon for about four miles before entering a wide, flat, expansive willow carr wetland just above the town of Marble. Historically, the river meandered widely through willow carrs where abundant beaver activity created dozens of open water ponds. Now, a large portion of the willow carr has been dredged and dammed and turned into a fishing lake. Beaver activity is still high in the remainder of the wetlands, which are in sustainable condition and provide high quality habitat for a diversity of songbirds, waterfowl, mammals, and fish species.

Figure 4.8.3. CR1-1: Near the town of Marble abundant beaver activity has helped to restore this willow carr wetland and stabilize the stream.

From Marble to Carbondale the Crystal River traverses two Life Zones and numerous ecosystems, alternating between narrow canyons and wide valley openings. Montane ecosystems characterize vegetation communities from Marble to the historic townsite of Janeway where the Life Zone transitions to the Upper Sonoran, continuing to the confluence with the Roaring Fork River. Downstream from Marble, the stream travels through wide, low gradient valleys interspersed with narrow, steep gorges. Valley floor riparian habitat is characterized by mosaics of willow carrs, mixed blue spruce-cottonwood forests, alder thickets, wet herbaceous meadows, and open ponds. Riparian habitat in the steeper gorges is composed of mixed conifer-narrowleaf cottonwood forests with an understory of red-osier dogwood and mountain maple. Upland habitat on north-facing slopes consists mainly of spruce-fir forests and on south-facing slopes of a mix of Douglas fir and aspen forests, sage and oak shrublands, and interspersed stands of Ponderosa pine and Rocky Mountain juniper. At the townsite of Janeway, riparian habitat is dominated by narrowleaf cottonwood, with only a few blue spruce, and box elder is fairly common. Birch, alder, willow, and dogwood continue to be common shrub species and silverberry, hawthorn, and three-leaf sumac have become co-dominants. Adjacent upland habitat has transitioned to domination by pinyon-juniper woodland and sage shrubland.

From the Crystal River headwaters to Avalanche Creek, upland landscapes are steep, expansive and remote – ideal conditions for a diversity of native wildlife. Upland landscapes are large and relatively unfragmented with high habitat diversity and elevational variation that provides year-round wildlife resources. Elk and mule deer are abundant; bighorn sheep, mountain lion, black bear, pine marten, coyote, and red fox are common; moose are occasionally observed; and Canada lynx travel the corridor.

Appendix 1.3 lists the riparian-related and instream species and communities of concern in the sub-watershed. Winter range and roost sites for the bald eagle, a state-threatened species, occur in this sub-watershed (Figure 3.3.5). The overall range for otter extends into the lower Crystal River and foraging areas for osprey are located in this sub-watershed (Figure 3.3.3). According to Colorado Division of Wildlife (CDOW) records, Colorado River cutthroat, brook, brown, and rainbow trout; bluehead, flannelmouth, and white suckers; mountain whitefish; mottled sculpin; and common carp have been recorded in this sub-watershed (Harry Vermillion, CDOW, personal communication, March 3, 2008).

4.8.2 Human Influences

Land Ownership and Use

Figure 4.8.4 shows the ownership and protection status for the sub-watershed. Much of the middle and upper sub-watershed is in the White River National Forest, managed by the U.S. Forest Service (USFS), including parts of two wilderness areas: Maroon Bells-Snowmass and Raggeds. The conservation organization Wilderness Workshop is proposing that several other areas in the sub-watershed be reviewed for wilderness status: Treasure Mountain, Hayes Creek, Thompson Creek, Crystal River, Assignation Ridge, and Hay Park (http://www.whiteriverwild.org/carbondale-region.php). Although the upper and middle sub-watershed is predominantly public land, much of the land adjacent to the Crystal River and Yule Creek is private. In addition, within the Coal Creek drainage the headwaters, confluence with the Crystal River, and several in-holdings are private, as is most of the land along the Crystal River in the lower sub-watershed. Parts of Thompson and Prince creeks and a small section of Thomas Creek are on lands managed by the Bureau of Land Management (BLM). The BLM identified a 4.76-mile segment of Thompson Creek within the Thompson Creek Area of Critical Environmental Concern as eligible for Wild and Scenic Status (Tetra Tech, 2007). During its Resource Management Plan revision process, the BLM will determine if this segment is suitable for Wild and Scenic status. Several open space parcels lie along the Crystal River (Appendix 4.1). Pitkin County Open Space and Trails has management plans for three of these properties -

Red Wind Point, Thompson Creek (interim), and Filoha Meadows Nature Preserve (draft) (Pitkin County, 2005, 2007, and 2008).

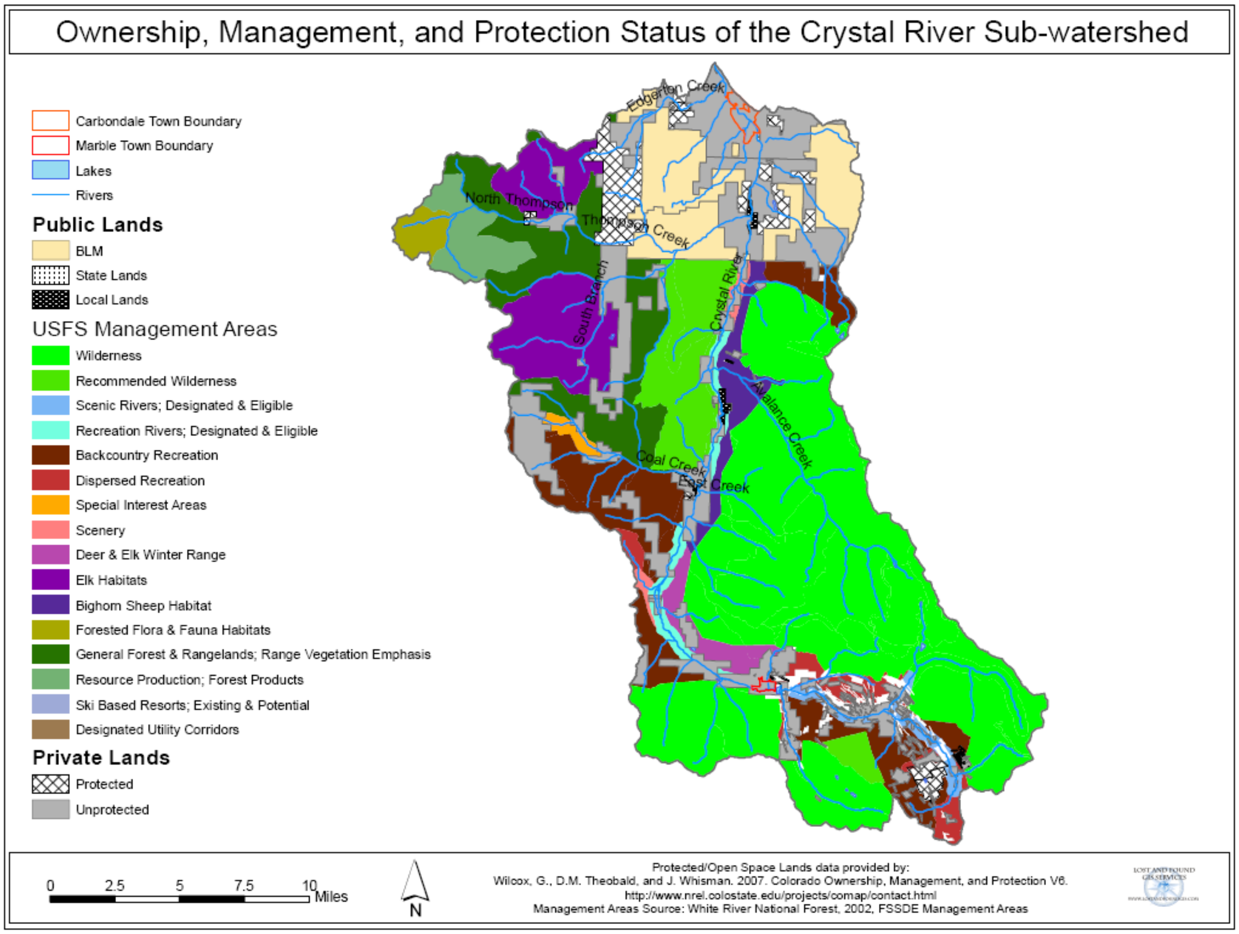


Figure 4.8.4. Ownership and protection status for the Crystal River Sub-watershed.

The sub-watershed is split between three counties: Gunnison in the headwaters, Pitkin for the mid-section, and Garfield in the lower section. Most of the irrigated agriculture in this sub-watershed is found in Garfield County along the lower Crystal River; parts of Barbers, Bowles, and Smith gulches; and Edgerton, Prince, and Thomas creeks (Figure 1.16). The amount of irrigated agriculture has declined from 1993 to 2000. A map of zone districts in Garfield County is found on the county's web site (http://www.garfield-county.com/Index.aspx?page=991). Zoning and parcel information for unincorporated areas in Pitkin County can be found on the county GIS website (http://www.aspenpitkin.com/depts/46/GISMOdisclaimer_parcels.cfm and http://www.aspenpitkin.com/depts/46/GISMOdisclaimer_zoning.cfm).

Two active caucus groups (the Upper Crystal River and Crystal River) and the non-profit Crystal Valley Environmental Protection Association (CVEPA) focus on issues within the sub-watershed. The Upper Crystal River Caucus works with Gunnison County and is encouraging the Gunnison County Commissioners to designate the upper Crystal River Valley as a "Special Geographic Area for Natural Beauty."

The Crystal River Caucus (http://www.aspenpitkin.com/depts/77/crystal_river.cfm) was formed to make recommendations to Pitkin County regarding all matters directly affecting the caucus area. The Crystal River Valley Master Plan adopted in 2003 includes goals, objectives, and implementation measures for seven topic areas: growth; housing; agriculture; commercial and retail use; environment and open space; recreation; and transportation. Some of the water-related objectives established by the caucus include:

- Limitations on development to protect water quality, wildlife habitat, and view corridors;
- Protection of lands from the impacts of extractive development activities;
- Protection and enhancement of instream flows (including prevention of dam/reservoir construction);
- Voluntary provision of stream access for recreation activities as well as the granting/purchase of conservation, fishing, and trail easements.

More detailed master plan objectives are provided in Appendix 1.5, and the implementation measures can be found in the master plan itself (http://www.aspenpitkin.com/pdfs/depts/7/finalcrystalplan.pdf).

Figure 4.8.5 shows roads within the sub-watershed and identifies roads within 150 feet of second order and higher streams (approximately 11 percent of the streams). Colorado Highway 133 parallels the west bank of the Crystal River for most of the river's length between Carbondale and the base of McClure Pass. Constraining the river on the east side is a historic railroad bed. A county road follows the river west from the Highway 133 corridor through Marble. Prince Creek is also flanked by a county road. The lower sections of Coal and Avalanche creeks have USFS roads adjacent to them.

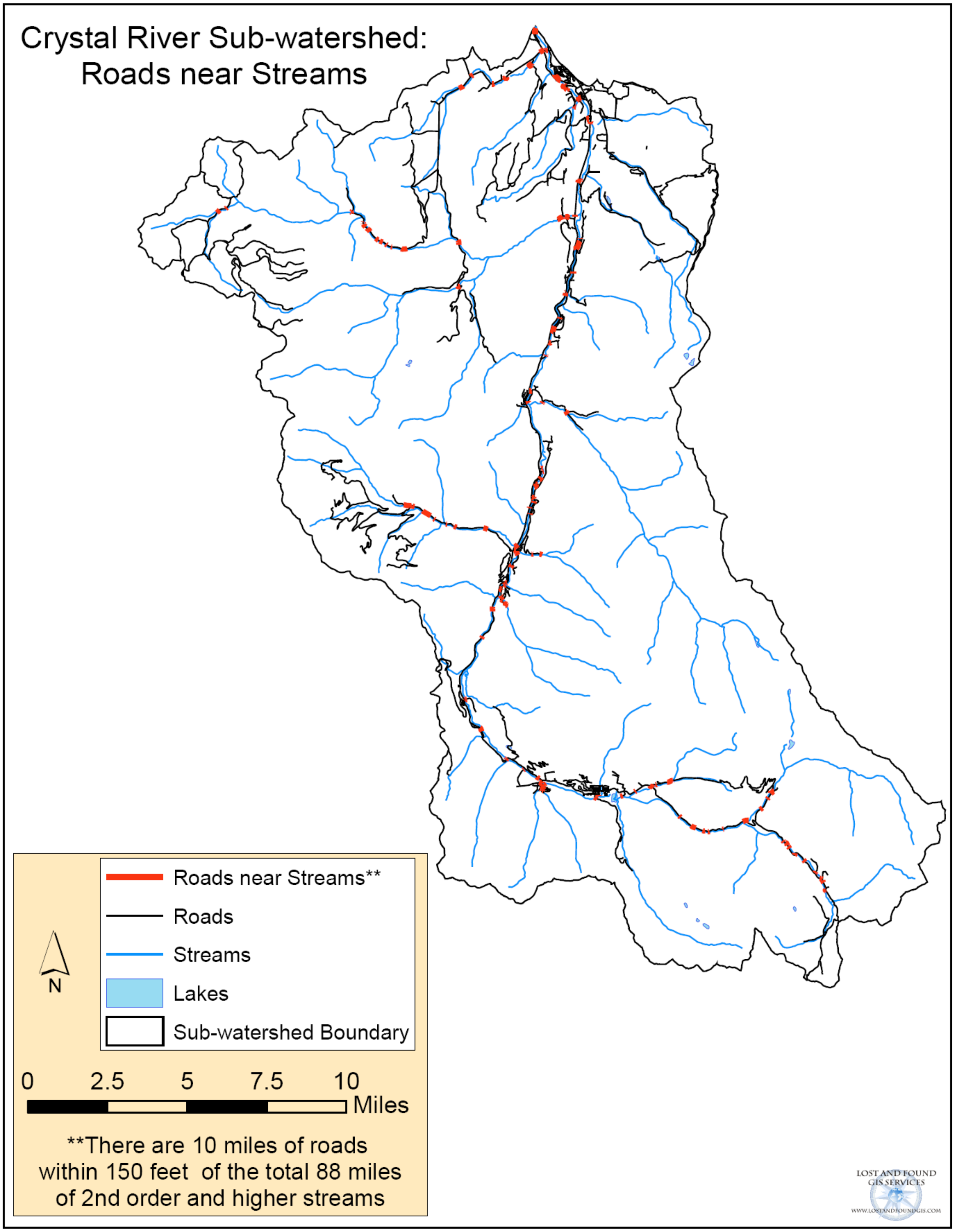


Figure 4.8.5. Roads near streams in the Crystal River Sub-watershed.

The town of Carbondale occupies an area of just over 20 square miles situated between the Crystal and Roaring Fork rivers. The town municipal codes have several provisions relevant to watershed resources. These fall under Title 13 Public Utilities, which includes the following chapters: 13.28 Water Conservation and Waste, 13.32 Pollution of Water and Wastewater Systems, 13.44 Town Ditch System, and 13.50 Town Water Rights Dedication. Title 15 Buildings and Construction, includes Chapter 15.20 Flood Damage Prevention. Title 18 Zoning, has Chapter 18.45 Overlay Districts. The complete code can be found at: http://municipalcodes.lexisnexis.com/codes/carbondale/, and relevant excerpts are provided in Appendix 4.8.1.

The town currently diverts the majority of its municipal water supply from Nettle Creek, a tributary of the Crystal River. The town's water rights are in the Carbondale Water System and Pipeline, decreed for 8.75 cubic feet per second. For future supplies, the town is developing wells in the alluvium of the Roaring Fork River. See Table 4.8.1 for a summary of Carbondale's municipal water sources and Appendix 3.1.3 for information about the town's water usage.

According to the Colorado Department of Water Resources water commissioner for the area and a consultant for the town, some questions exist about the reliability of the historical diversion records for the Carbondale Water System and Pipeline in the state database (available for the period November 1974 through September 1980) (CWCB and CDWR, 2007b).

Table 4.8.1. Carbondale municipal water sources. Source: Town of Carbondale 2007 drinking water consumer confidence report for calendar year 2006 (http://www.carbondalegov.org/).

SOURCE	WATER TYPE
South Nettle Creek Diversion	Surface water
North Nettle Creek Diversion	Surface water
Well RFWF No 1, 2, and 3	Groundwater under the influence of surface water
Well Crystal River No 2	Groundwater

The town owns water rights, including the main and lateral ditches of Weaver Ditch, Leonhardy Ditch, Carbondale Town Ditch, Rockford Ditch, and Vetter Ditch (this is referred to as the "Town Ditch System"). Carbondale's wastewater treatment plant is located on the Roaring Fork River just downstream of the Carbondale boat ramp in the Lower Middle Roaring Fork Sub-watershed. More information about this treatment plant can be found in the 2002 Roaring Fork Watershed Plan done by Northwest Colorado Council of Governments (http://www.nwc.cog.co.us/Programs/Water/PDF/RFR02REV.final.pdf). The town has plans to upgrade this plant.

The Town of Marble and the unincorporated area of Redstone are located in the upper portion of the sub-watershed. Marble gets its water from two wells located along Carbonate Creek (Charley Parker, The Marble Water Company, personal communication, July 7, 2008) and Redstone's municipal source is East Creek. Figure 4.8.9 shows the location of the Marble Metropolitan District and the Redstone Water and Sanitation District. The West Divide Water Conservancy District serves unincorporated areas in this sub-watershed north of Marble and west of the Crystal River (Figure 2.1), and it is discussed in more detail in Chapter 2.

Mining

Table 4.8.2 lists the permitted active and inactive mines in the sub-watershed. Both of the large coals mines are inactive. Reclamation activities occurred on the Coal Basin Mines from 1994-2000. CVEPA recently submitted a proposal to the USFS and the owner of a private in-holding to sponsor a reclamation project in this area. Reclamation is ongoing at the North Thompson Creek Mine (Figure 4.8.6). The Colorado Yule Marble Company began operation in 1905 and operated until 1941. It is most famous for producing the blocks of marble used for the Lincoln Memorial and Tomb of the Unknown Soldier. The quarry re-opened in 2004, and is operated by Polycor, a Canadian-based dimension stone company. Dimension stone is natural stone that has been cut to specific sizes and shapes.

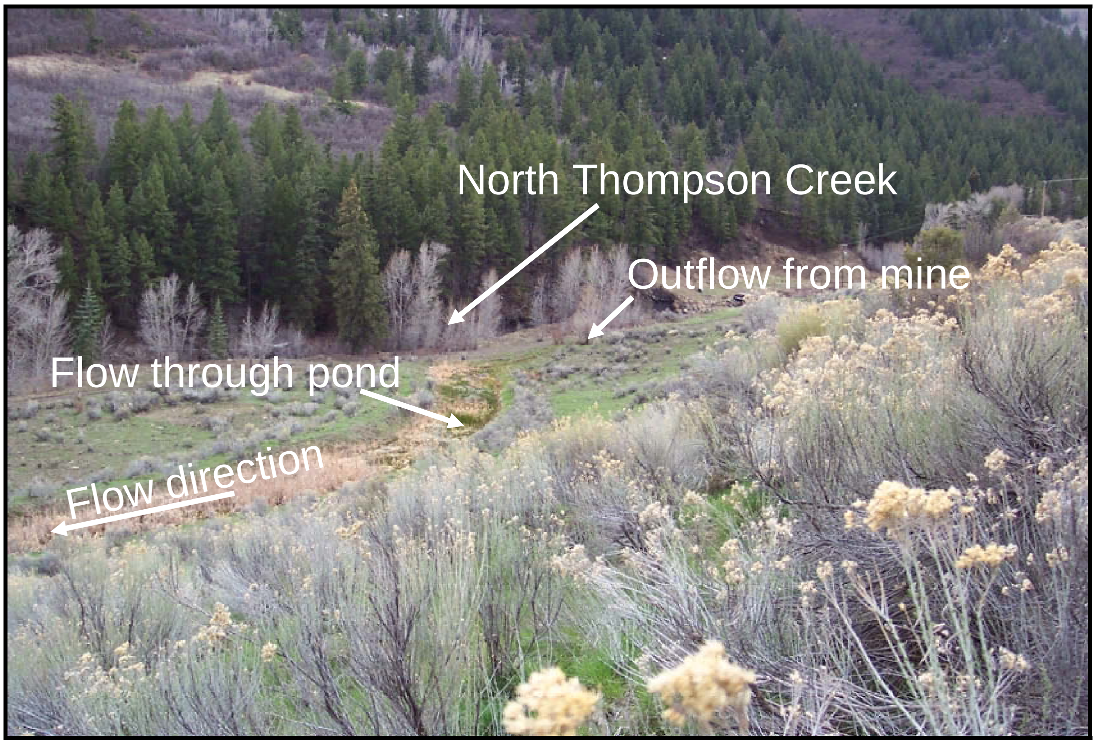


Figure 4.8.6. Part of the North Thompson Creek Mine outflow treatment system, April 17, 2007 (Photo credit: Chad Rudow).

Table 4.8.2. Mine sites in the Crystal River Sub-watershed. Source: Colorado Division of Reclamation Mining and Safety, GIS mapping, No date.

SITE NAME	STREAM	SIZE	COMMODITY	STATUS	PERMIT ISSUED
Yule Quarry	Crystal River	9.8 acres	Marble	Revoked	4/23/1990
Yule Marble Quarry	Crystal River	6.7 acres	Dimension stone	Active	8/20/1999
Conger Harvesting Area	Crystal River	7.6 acres	Stone	Active	6/5/1998
Aspen Granite Pit	Crystal River	n/a	Stone	Illegal	n/a
Coal Basin Mines	Coal Creek	11,386 acres	Coal	Revoked	5/31/1983
Mid-Continent LST	Crystal River	23 acres	Limestone	Active	4/25/1983
White Bank Avalanche Creek	Avalanche Creek	1.9 acres	Dimension stone	Terminated	2/7/1992
White Banks Mine	Avalanche Creek	3.5 acres	Anhydrite, gypsum	Active	1/4/2000
North Thompson Creek Mine	Thompson Creek	3,336 acres	Coal	Inactive	8/15/1983
Crown Meadows	Thomas Creek	4.5 acres	Sand and gravel	Terminated	8/1/1980
Redstone Pit Confluence	Crystal and Roaring Fork Rivers	16.2 acres	Sand and gravel	Terminated	7/21/1977

Recreation Activities

Three USFS campgrounds are in the sub-watershed – two located near the Crystal River (Bogan Flats and Redstone) and one on Avalanche Creek (Avalanche). On August 16, 1992 a rain event triggered a mud flow that ran toward the historic Janeway Campground. It appeared likely that the next big rain event would put the campground at risk, so, as a safety measure, the White River National Forest closed and decommissioned it. USFS trails follow water courses, including East, Avalanche, Braderich, Yule, and Carbonate creeks. In numerous places where trails traverse riparian areas or are adjacent to streambanks, vegetation trampling and erosion impacts are severe. The upper part of the sub-watershed is popular for four-wheeling (in areas such as Lead King Basin, Crystal, and Schofield Pass), hiking, mountain biking, horse packing, and backpacking.

The organization American Whitewater lists seven reaches in the sub-watershed used for rafting (see Figure 1.11 for a map of commercial rafting and kayaking reaches in the Roaring Fork Watershed). Appendix 3.1.6 lists the reaches, and provides the class, minimum, maximum, and optimum flow levels for each. The lower Crystal River is not used for commercial trips. According to the Southwest Paddler website (http://www.southwestpaddler.com/), the Crystal River is considered appropriate only for expert kayakers and rafters and has reaches where not even rafts can or should go. The report also notes that the Crystal River Valley is remote and parts of it have very high canyon walls, steep drops, big waterfalls, and narrow river channels clogged by house-size boulders. The only official kayak event in the Roaring Fork Watershed occurs on the Crystal River in Carbondale. These races are hosted by the Colorado Rocky Mountain School on the school's kayak course (Urquhart, 2008).

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams and lakes in the sub-watershed have been stocked with the species listed (Table 4.8.3).

Table 4.8.3. Species stocked by the CDOW in streams and lakes of the Crystal River Sub-watershed.

STREAM/LAKE	SPECIES
Avalanche Creek	Rainbow and Colorado River cutthroat trout
North Fork Crystal River	Rainbow trout brook trout, Colorado River and Pikes Peak cutthroat trout
Crystal River	Snake River cutthroat trout and rainbow trout
Middle Thompson Creek	Colorado River and Pikes Peak cutthroat trout, rainbow trout, brook trout
North Thompson Creek	Colorado River and Pikes Peak cutthroat trout, rainbow trout
Yank Creek	Brook trout
Prince Creek	Brook trout
Avalanche Lake	Colorado River and Pikes Peak cutthroat trout
Beaver Lake	Rainbow trout
Galena Lake	Pikes Peak cutthroat trout
Geneva Lake	Pikes Peak cutthroat trout
Island Lake	Rainbow trout
Lizard Lake	Brook trout and rainbow trout
Little Gem Lake	Colorado River and Pikes Peak cutthroat trout
McClure Pond	Rainbow trout
Pierre Lakes	Colorado River and Pikes Peak cutthroat trout
Siberia Lake	Colorado River and Pikes Peak cutthroat trout
Thomas Lake	Colorado River and Pikes Peak cutthroat trout
Williams Lake	Brook trout and Colorado River cutthroat trout
Yule Lake	Colorado River and Pikes Peak cutthroat trout

For this sub-watershed, the "Flyfishing Guide for the Roaring Fork Valley" (Shook, 2005) contains angling information for the Crystal River and Avalanche Creek. The angling guide notes that mining has had a negative effect on fishing, but that the river is recovering. July and August are recommended as the best months for fishing, after which time the river runs low and mountain whitefish tend to dominate the good holes. Although the river offers excellent pocket water and riffles, and deep runs and holes, high sediment loads after rain storms negatively influence the fishing.

4.8.3 Resource Information

Several research studies and syntheses of information have been done in the Crystal River Sub-watershed, providing data on stream flows, groundwater sources, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in the following sub-section. For background information on data sources, refer to Chapter 3.

Water Quantity

Surface Water

Three stream gages operate in this sub-watershed (Figure 4.8.7). The Crystal River above Avalanche Creek near Redstone gage has recorded stream flows since 1955. The other two operating gages are relatively new. The furthest downstream gage on the river, the Crystal River below Carbondale gage, began operation in 2000. Flows upstream of this gage are often lower than at the gage because of irrigation return flows. The third gage, Crystal River at DOW Fish Hatchery above Carbondale, was installed in 2006 by the Colorado Division of Water Resources (CDWR) and Colorado Water Conservation Board (CWCB). This newest gage will allow the CDWR to administer better the lower Crystal River, including placing calls to meet CWCB instream flows. In 2004, the CDWR determined that, had this gage been in place, it would have supported administration for an estimated additional 24 cubic feet per second (cfs) in the river during the low-flow late summer months. The other seven stream gages in the sub-watershed are no longer in operation and operated for various periods. Specific information about these gages can be found in Figure 4.8.7 and Appendix 3.1.1. None of the active or historical gage data were useful for assessing flow alteration because they are either located above the major diversions or do not represent a pre-developed flow condition.

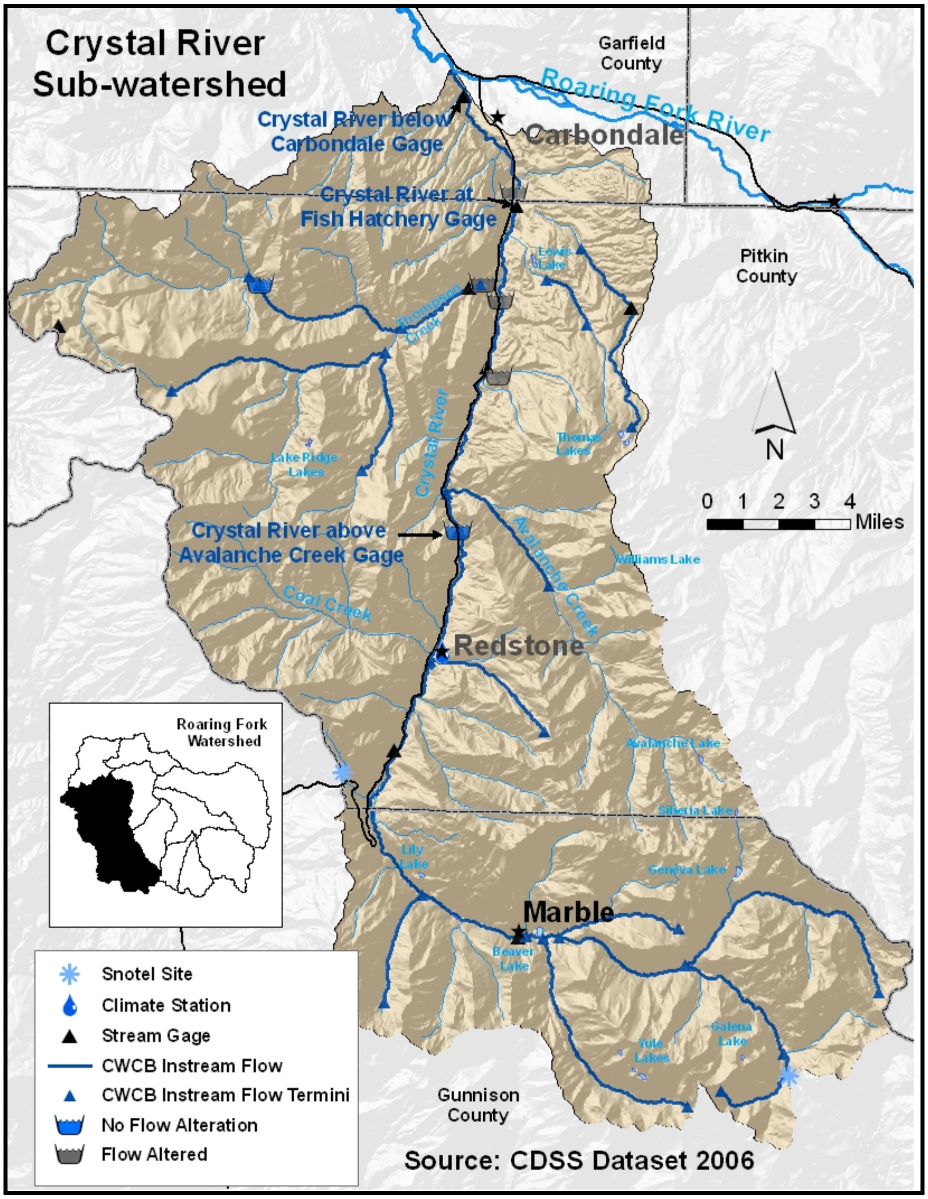


Figure 4.8.7. Water features in the Crystal River Sub-watershed.

Flow alteration was assessed using the Upper Colorado River Basin Water Resource Planning Model dataset (CWCB and CDWR, 2007a). The model accounts for diversions above 10 cfs. These data are available for six nodes in the sub-watershed: Crystal River above Avalanche Creek near Redstone, Crystal River/Lowline Ditch, Crystal River/Rockford Ditch Diversion, Nettle Creek, North Thompson Creek, and Thompson Creek/Pioneer Ditch (Figure 4.8.7 shows the location of the nodes, depicted by the symbols for “no flow alteration” or “flow altered”). Appendix 3.1.2 and figures 3.1.4 - 3.1.6 show the extent to which flows on the Crystal River, Nettle Creek, and Thompson Creek have been altered.

Figure 4.8.8 shows the locations of the diversions in the sub-watershed. The largest diversions are located along the lower portion of the river and used to irrigate land south of Carbondale

(Grand River Consulting Corp., 2003). Fifteen of the diversions have a decreed capacity greater than 10 cfs (Table 4.8.4). With the exception of the Thompson Creek Feeder Ditch Diversion, all diversions are in the lower part of the sub-watershed. The Thompson Creek Feeder Ditch diverts water to Divide Creek.

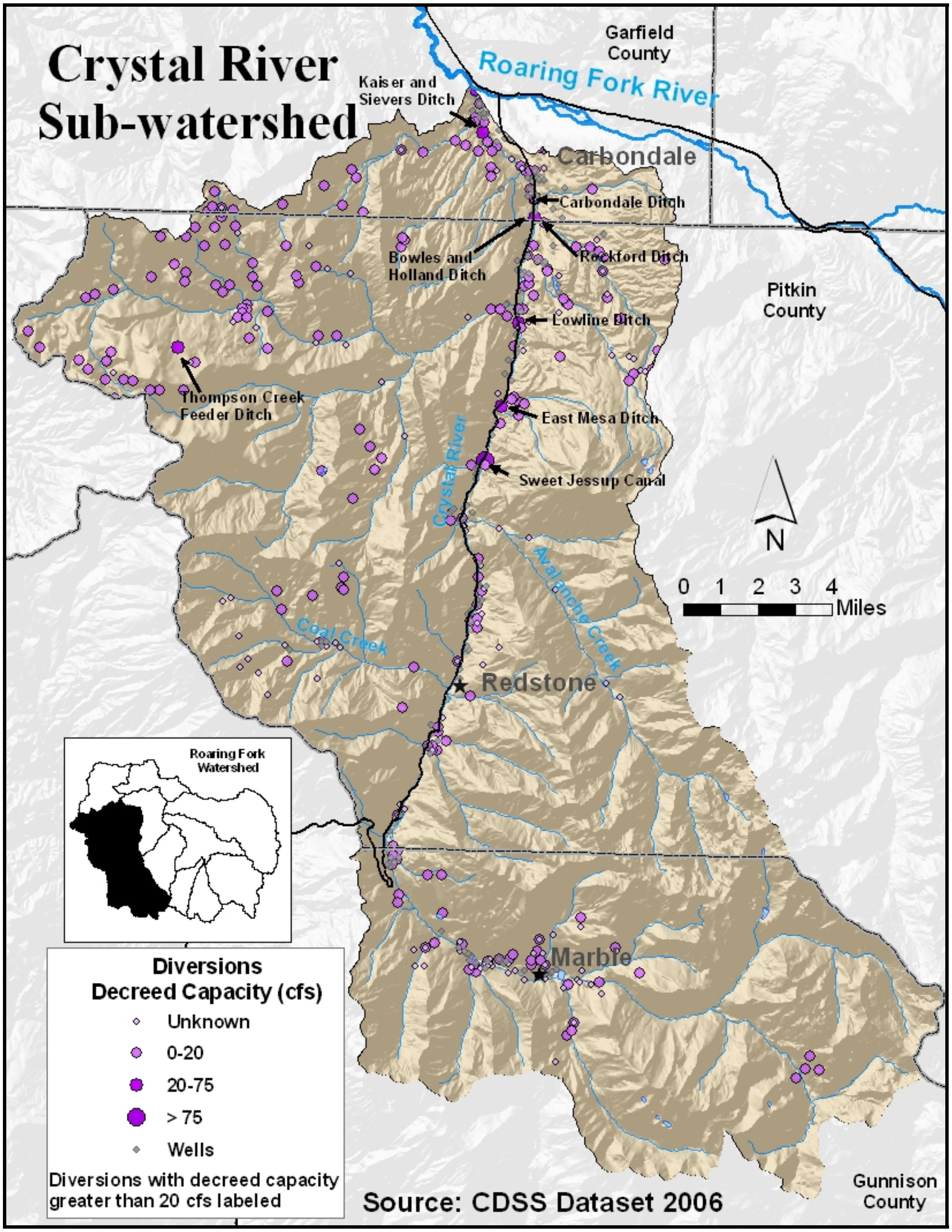


Figure 4.8.8. Diversions and wells in the Crystal River Sub-watershed.

Table 4.8.4. Diversions in the Crystal River Sub-watershed greater than10 cfs. Source CDSS GIS Division 5 diversion data 2006.

STREAM	DITCH	DECREED CAPACITY (cfs)
Crystal River	Sweet Jessup Canal*	75.00
Crystal River	East Mesa Ditch*	41.80
Crystal River	Lowline Ditch*	40.50
Crystal River	Ella Ditch*	15.10
Crystal River	Bowles and Holland Ditch*	23.80
Crystal River	Rockford Ditch*	35.20
Crystal River	Carbondale Ditch*	41.24
Crystal River	Colo St G F Prop Col Sys (for Crystal River Hatchery)*	18.00
Crystal River	Weaver and Leonhardy Ditch*	12.36
Crystal River	Kaiser and Sievers Ditch *	21.44
Crystal River	Southard and Cavanaugh Ditch*	12.40
Thompson Creek	Thompson Creek Feeder Ditch*	24.00
Thompson Creek	Pioneer Ditch*	12.51
Prince Creek	Prince Ditch* [1]	13.40
Edgerton Creek	Walkers Gulch Spring Ditch*	11.96

* Used in CDSS modelling

[1] Transferred to Mount Sopris Prince Creek Ditch

No flow alteration was detected at the Crystal River above Avalanche Creek near Redstone node. Flow alteration on the lower Crystal River was assessed using two nodes – one above and one below the confluence with Thompson Creek. Agricultural diversions caused significant flow alterations for both of these nodes in August, September, and October. Base and peak flows were minimally altered. For the lower node, base flow increased slightly because of return flows. No flow alteration was detected at the North Thompson Creek node. Similar to the lower Crystal River, flows in lower Thompson Creek were significantly altered in August and September. Nettle Creek, the municipal water supply for Carbondale, showed significant flow alteration for most of the year. Peak flows in May and June were not significantly altered. However, because the pre-developed flows for the other 10 months were low, any reduction in flow translates to a large percent and significant change. A 2003 study by Grand River Consulting that combined historic real and simulated data estimated that 27 percent of the years between 1955 and 2000 would have had an irrigation shortage in the month of August at the confluence of the Crystal and Roaring Fork rivers. The study estimated that an irrigation shortage would have occurred in 22 percent of the years in September and 18 percent of the years in October.

Eight direct-flow conditional water rights greater than 10 cfs are in this sub-watershed (Table 2.4). Five are on the Crystal River and three on Thompson Creek. The Thompson Creek basin has four conditional storage rights greater than 1,000 acre-feet and two such storage rights are on the Crystal River (Table 2.5). These conditional water rights can have priority dates senior to existing absolute water rights. If these large water rights were to be developed, they could significantly impact flows in the sub-watershed. The largest of these water rights is associated with the West Divide Project. Appendix 2.7 contains maps of the River District's conditional water rights for the Osgood, Placita Reservoirs, and Avalanche Canal Projects; Yank Reservoir and Fourmile Canal Projects; and West Divide Project. In 2003, Grand River Consulting completed an evaluation of potential water needs within the sub-watershed to help assess the demand for development of the West Divide Project's facilities (Grand River Consulting Corp., 2003). The study concluded that the project could provide water supplies for existing irrigation demands, instream flow uses, and future domestic demands. The study did not address any environmental impacts associated with potential development of the project.

Within the sub-watershed are 18 CWCB instream flow rights (ISFs) with four on the Crystal River mainstem and the others on various tributaries and headwater stream reaches. See Figure 4.8.7 and Appendix 2.2 for more detail on these ISF rights. With the exception of the mainstem of the Crystal River ISF, no stream gage data are available to administer these rights and to determine how often they are met. The ISFs for Thompson, Prince, and Thomas creeks do not extend to the mouths of the streams, leaving these lowest reaches without any ISF protection. The CWCB ISF on the lower Crystal River is 100 cfs from May 1st to September 30th and 60 cfs from October 1st to April 30th. According to the Stream Flow Survey Report (Clarke, 2006) this ISF was met less than 50 percent of the time in August and September, but the 60 cfs ISF amount in October was met more often. Another study done by Grand River Consulting (2003) came to a similar conclusion. Based on combined historic real and simulated data, it was estimated that 66 percent of the years between 1955 and 2000 would have had stream flows lower than the presently-established ISF right in the month of August at the confluence of the Crystal and Roaring Fork rivers. The study estimated that an ISF shortage would have occurred in 75 percent of the years in September and 44 percent of the years in October.

Groundwater

The edge of the Piceance Basin Bedrock Aquifer is located in the upper Thompson Creek and Crystal River drainages. The Eagle Basin Bedrock Aquifer extends into the middle and lower sections of the Crystal River. The Crystal River Alluvial Aquifer is found adjacent to the lower Crystal River starting from Potato Bill Creek.

In a 2006 groundwater study for Pitkin County, Kolm and van der Heijde noted that the Crystal River area contains diverse groundwater hydrology with shallow aquifers of various types (moraines, outwash plains, alluvium), and a complex, faulted bedrock system (possibly including the Leadville limestone, the Dakota formation, and Tertiary intrusive bedrock). In order to better understand the system, work is currently underway to analyze the basin's hydrologic parameters, and is expected to be completed by mid-2008.

Water Quality

Author: U.S. Geological Survey

Within the Crystal River Sub-watershed, data have been collected at 88 water quality sites dating from 1960 to the present. Recent water-quality data summarized for this sub-watershed are from 1996 to 2007, the majority of which are from stream monitoring sites (58 sites). In the mid-1970s, groundwater data were collected at 25 sites in the sub-watershed, and water-quality data were collected at four point-source sites associated with mines. Streams with at least some historical water quality data include Thompson, Prince, Coal, Lost Trail, Yule, and Dutch creeks, and the Crystal River. Data from two sites on Coal Creek and nine sites along the mainstem of the Crystal River were used to summarize recent water-quality conditions for this subwatershed:

- Crystal River near Marble, Colorado (Site 36)
- Crystal River at Center Mine Bridge (Site 37)
- Crystal River above confluence with Coal Creek (Site 38)
- Coal Creek Rec. at Redstone Park at confluence (Site 39)
- Coal Creek at mouth in Redstone (Site 40)
- Crystal River at Redstone (Site 41)
- Crystal River above Avalanche Creek, near Redstone, Colorado (Site 42)
- Crystal River at Penny Hot Springs (Site 43)
- Crystal River at Hatchery (Site 44)
- Crystal River at Sweet Hill Bridge (Site 45)
- Crystal River below Carbondale, Colorado (Site 46)

These sites are shown in Figure 4.8.9, along with locations and information about water and wastewater treatment facilities. For each site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

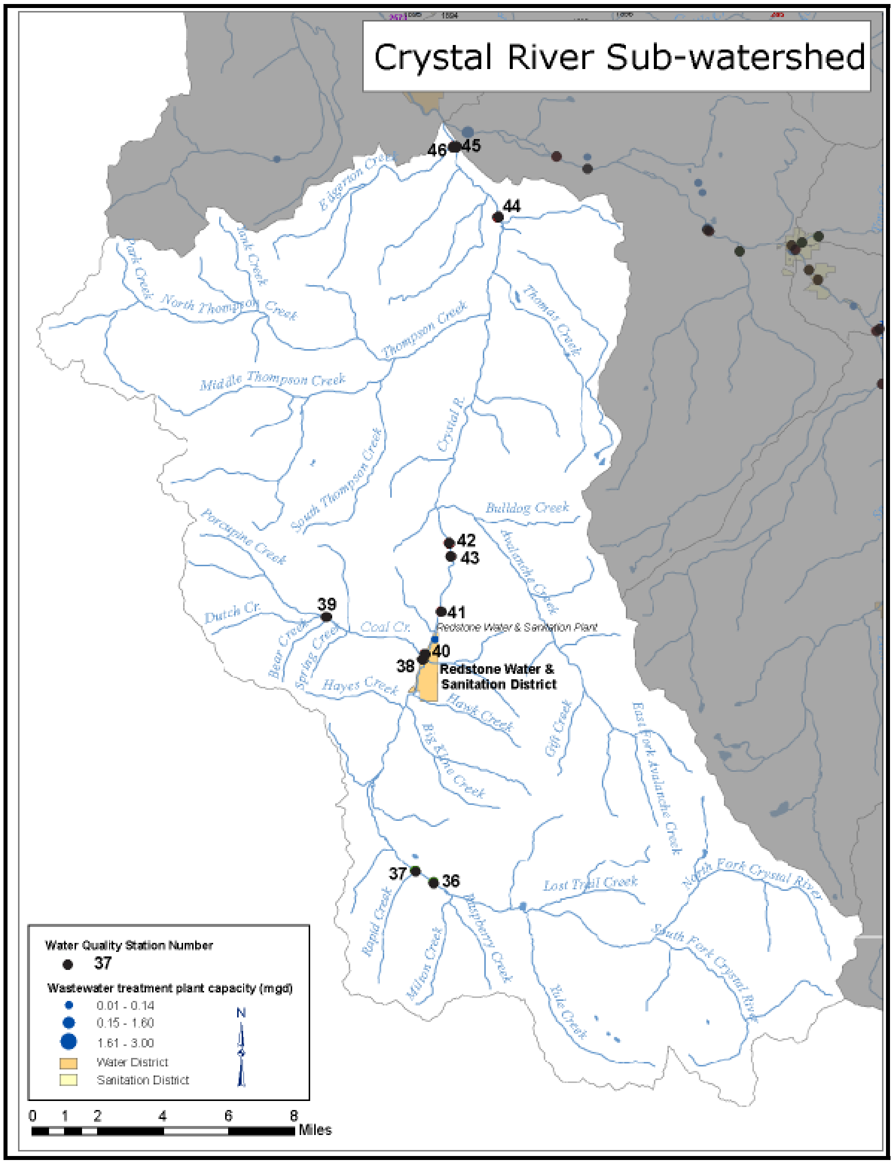


Figure 4.8.9. Water-quality sites and wastewater treatment providers in the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and DOLA, No date b.

Site 46 is currently being monitored by the USGS for stream flow and water quality. The Colorado River Watch Program currently is monitoring water-quality data on the Crystal River (sites 37, 41, 44, and 45), Site 39 on Coal Creek, and, as of 2006, a site on Thompson Creek (data currently unavailable). The sub-watershed has a history of water quality issues including trace element concentrations that exceed aquatic life criteria, elevated levels of naturally occurring calcium and sulfate, total phosphorus, dissolved solids, and turbidity. Coal Creek is a known source of iron and is on the state's 303(d) list as impaired with respect to total recoverable iron. The source of iron on Coal Creek is attributed to the Mid-Continent Resources Coal Mine (11,386 acres). Coal Creek is also on the monitoring and evaluation list for sediment (CDPHE, 2007). A coal mine of approximately 3,000 acres on Thompson Creek is currently undergoing reclamation, thus water-quality monitoring will help track the effects of reclamation on the creek. The Redstone wastewater treatment plant, which has a capacity of 0.05 million gallons per day, is upstream of Site 41 and downstream of Site 40 (Figure 4.8.9). High concentrations of calcium and sulfate observed in the sub-watershed likely originate from the Eagle Valley evaporite (Kirkham et al., 1999; Warner et al., 1985), especially downstream from Redstone.

Of the 432 pH results, values ranged from 6.6 to 9.1 and the median pH ranged from 7.7 to 8.54. Only one pH result exceeded the water-quality standard, occurring at Site 40 in November 2002. Of the 558 water temperatures, the maximum observed water temperature was 21°C at Site 45. Otherwise, water temperatures ranged from -2°C (28.4°F) to 20°C (68°F), and median water temperatures ranged from 3.3°C (37.9°F) to 11°C (51.8°F). Within the sub-watershed, dissolved material can be expected to be high due to geothermal mineral springs that act to dissolve and transport dissolved material to streams. In addition, the dissolution of halite and gypsum from geologic units like the Eagle Valley evaporite increases salt loads in the sub-watershed (Chafin and Butler, 2002). Specific conductance results reflect this with concentrations that range from 152 µS/cm to 1,410 µS/cm, and median results ranging from 431 µS/cm to 778 µS/cm. Specific conductance generally increases from upstream to downstream.

Dissolved oxygen concentration data at all but one site were above 6 mg/L. Most concentrations were high and generally indicated well-oxygenated conditions. Site 43 had dissolved oxygen concentrations consistently equal to or less than the minimum standard of 6 mg/L (ranging from 4 mg/L to 6 mg/L). These 19 dissolved oxygen concentrations were collected from 1996-97, and more recent measurements would be needed to determine the current dissolved oxygen concentrations.

Major ion data indicate a predominately calcium bicarbonate/sulfate water type (Appendix 3.2.2, figures 4 and 5), which is consistent with the geologic formations like the Eagle Valley evaporite and the Mancos shale that underlie and outcrop throughout the sub-watershed. Seasonal variability between bicarbonate and sulfate is especially evident at Site 42 (Appendix 3.2.2, Figure 4). Major ion data indicate that from April to June, stream flow is derived from snowmelt-dominated source water and that from August to March, during base flow, stream flow is derived from groundwater. Chloride was not found to exceed water quality standards; however, sulfate occasionally exceeded 250 µg/L at two sites, which is consistent with the geology of the area. One-hundred-seven chloride concentrations ranged from 0.67 mg/L to 20 mg/L. Of the 160 sulfate concentrations, values ranged from 5 mg/L to 530 mg/L, and median sulfate concentrations ranged from 41 mg/L to 72 mg/L. Site 41 had a sulfate concentration of 270 mg/L in February 2002, at which time streamflow was likely to be dominated by base flow. Site 44 had a sulfate concentration of 530 mg/L in May 2002 and a concentration of 260 mg/L in February 2003. These elevated concentrations are consistent with the sulfate-bearing formations in the sub-watershed. Total dissolved solid concentrations ranged from 87 mg/L to 690 mg/L, and median concentrations ranged from 140 mg/L at Site 46 to 480 mg/L at Site 40. Hardness concentrations ranged from 47 mg/L to 340 mg/L and median concentrations from 158 mg/L to 223 mg/L, indicating very hard water. Both total dissolved solids and hardness concentrations reflect the geology within the sub-watershed, which consists of evaporates, shales, limestones, and other sedimentary rocks of the Cretaceous and Permian/Pennsylvanian ages.

Total phosphorus is the only nutrient that was found to exceed water quality standards in the sub-watershed. Ten of the 11 sites had some nutrient data, with only Site 43 lacking any nutrient data. Elevated total phosphorus concentrations typically occur in the spring and could be related to naturally occurring phosphorus that adheres to suspended sediments flushed from streams during early snowmelt runoff (Wynn et al., 2001). Total phosphorus concentrations greater than 0.1 mg/L occur at five sites in the sub-watershed. Four total phosphorus concentrations exceeded the 0.1 mg/L standard at sites 39 and 40 on Coal Creek in April and May, 1998, 2000-01, and 2003. Further downstream, on the Crystal River at Site 41, two total phosphorus concentrations exceeded the 0.1 mg/L recommended criteria in February and May, 2003. Sites 42 and 44 each had a single total phosphorus exceedance in May of 2003 and 2005, respectively. No water-quality exceedances occurred for un-ionized ammonia, nitrate, or nitrite.

Total recoverable iron is often found at high concentrations and exceeding the water-quality standard in the sub-watershed. All 11 sites were sampled for total recoverable iron concentrations and all but two sites had samples with concentrations that did not exceed the chronic standard of 1,000 µg/L. The major source of iron is Coal Creek, where the Mid-Continent Resource Coal Mine is a point source of iron and sediment. The two most upstream sites (sites 36 and 37), which are upstream of Coal Creek, did not exceed the chronic standard. A single exceedance was observed upstream of the confluence of the Crystal River and Coal Creek, at Site 38 (in May 1998). Exceedances occurred at both sites on Coal Creek, and maximum concentrations at Site 40 are greater than those observed at Site 39. Most of the samples that exceeded the standard occurred in the spring (April and May), and the maximum total recoverable iron concentration was observed at Site 40 (Coal Creek at the mouth) in April 2001. Further downstream on the Crystal River, total recoverable iron concentrations exceeded the chronic standard at all remaining sites, mainly in the spring. The number of exceedances ranged from 3 to 10 values at each site. Aside from Coal Creek, some of the highest total recoverable iron concentrations were observed at Site 41, just downstream from Coal Creek, and at Site 44, Crystal River at Hatchery (10,336 and 15,192 µg/L, respectively).

Selenium concentration data was collected at 10 of the 11 sites, and 4 of these sites had samples that exceeded the chronic standard. In general, the source of selenium in the Roaring Fork Watershed is the Mancos shale, which occurs in the Crystal River Sub-watershed. Four selenium concentrations exceeded the chronic standard at Site 41, which also had the two highest selenium concentrations, 17.3 µg/L and 16.5 µg/L in August and June, 2000, respectively. Downstream at Site 44, exceedance concentrations ranged from 5.8 µg/L to 6.4 µg/L. They occurred in July, August, September, and November of 2003-04 and may be related to irrigation activities on lands underlain by Mancos Shale. Based on when the exceedances occurred at Site 41 versus Site 44, it would appear there is no correlation between the exceedances at these two sites. Total recoverable aluminum was collected at 7 of the 11 sites and found in relatively high concentrations (greater than 750 µg/L). From upstream to downstream, the maximum observed concentration at each site generally increased, going from 582 µg/L to 11,272 µg/L (sites 37 and 44, respectively). Many of the observed high concentrations occurred during April and May. Site 44 (Crystal River at Hatchery) had 10 concentrations that were greater than 750 µg/L and also had the highest total recoverable aluminum concentration in the sub-watershed (11,272 µg/L in May 2001). Of the 246 arsenic concentrations, all but 10 were censored values and no Table

Value Standards (TVS) were exceeded. Within the over 300 cadmium, copper, lead, manganese, and zinc samples, many of the values were censored and only two exceeded TVS. One copper concentration at Site 41 exceeded the chronic copper TVS in August 2002, while one lead concentration at this same site exceeded the chronic lead TVS in June 2000.

Total suspended solids concentrations ranged from <10 mg/L to 1260 mg/L at Site 40, Coal Creek at the mouth. Above Coal Creek, concentrations ranged from <10 mg/L to 44 mg/L, while below Coal Creek, concentrations ranged from 1.1 mg/L to 215 mg/L. Coal Creek partially contributes to the higher suspended solid concentrations observed downstream of its confluence with the Crystal River.

Riparian and Instream Areas

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed the Crystal River in this sub-watershed. Figures 4.8.10 and 4.8.11 show specific riparian and instream information, by habitat quality category, for each reach assessed. The habitat quality categories are shown in the riparian and instream assessment charts found in sections 3.3 and 3.4. Appendix 3.3.1 contains the actual percentage values for each of these categories by sub-watershed and how they were determined. The sub-watershed has one stream segment:

- Crystal River Segment – the Crystal River from Marble to the Roaring Fork River SHI reaches CR1-1 through CR2-10; 31.10 miles.

What follows is a brief description of results. The SHI report contains detailed narrative description. “Right bank” and “left bank” refer to the orientation of the riparian zone when facing downstream.

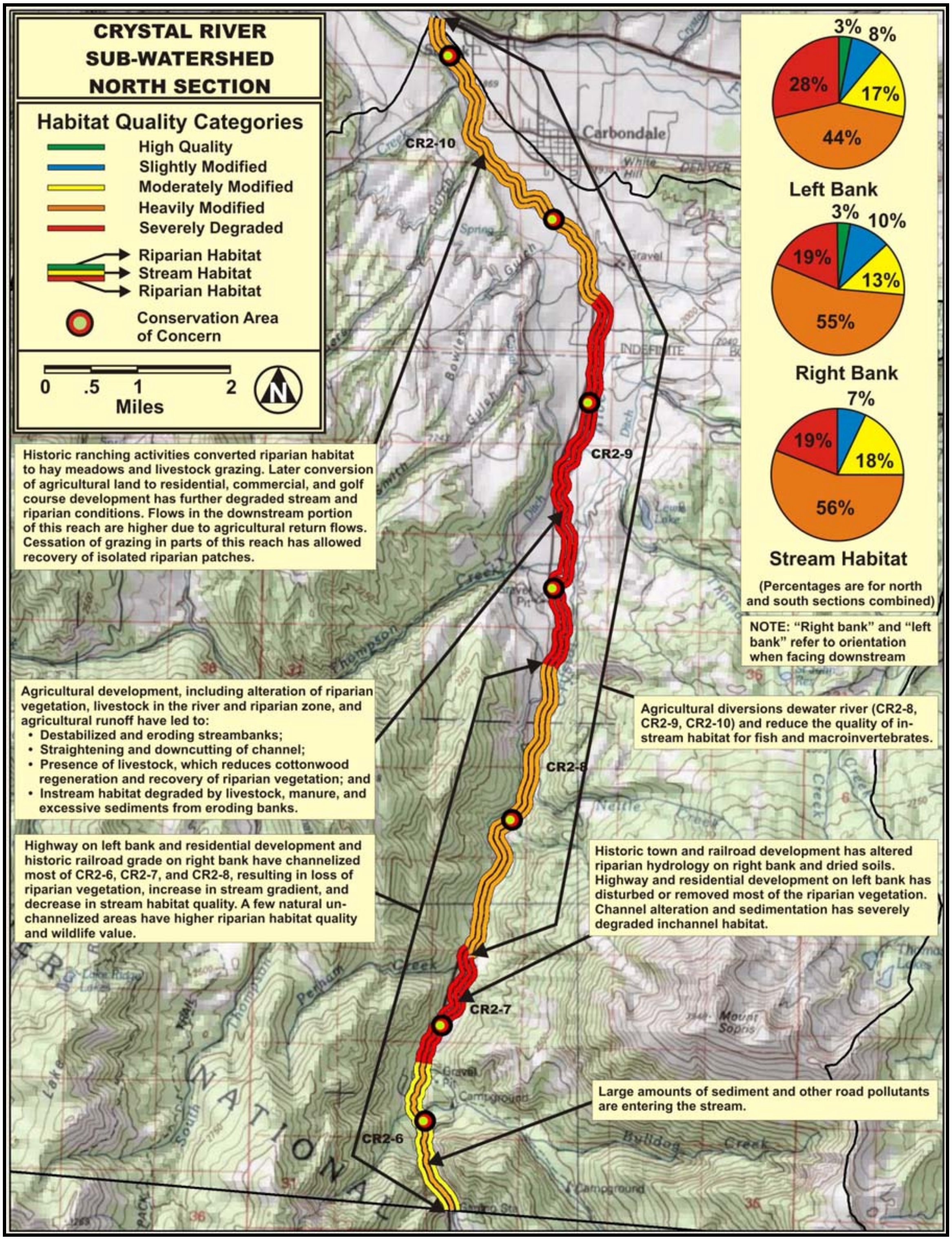


Figure 4.8.10. Riparian and instream habitat quality for the Crystal River Sub-watershed (north section).

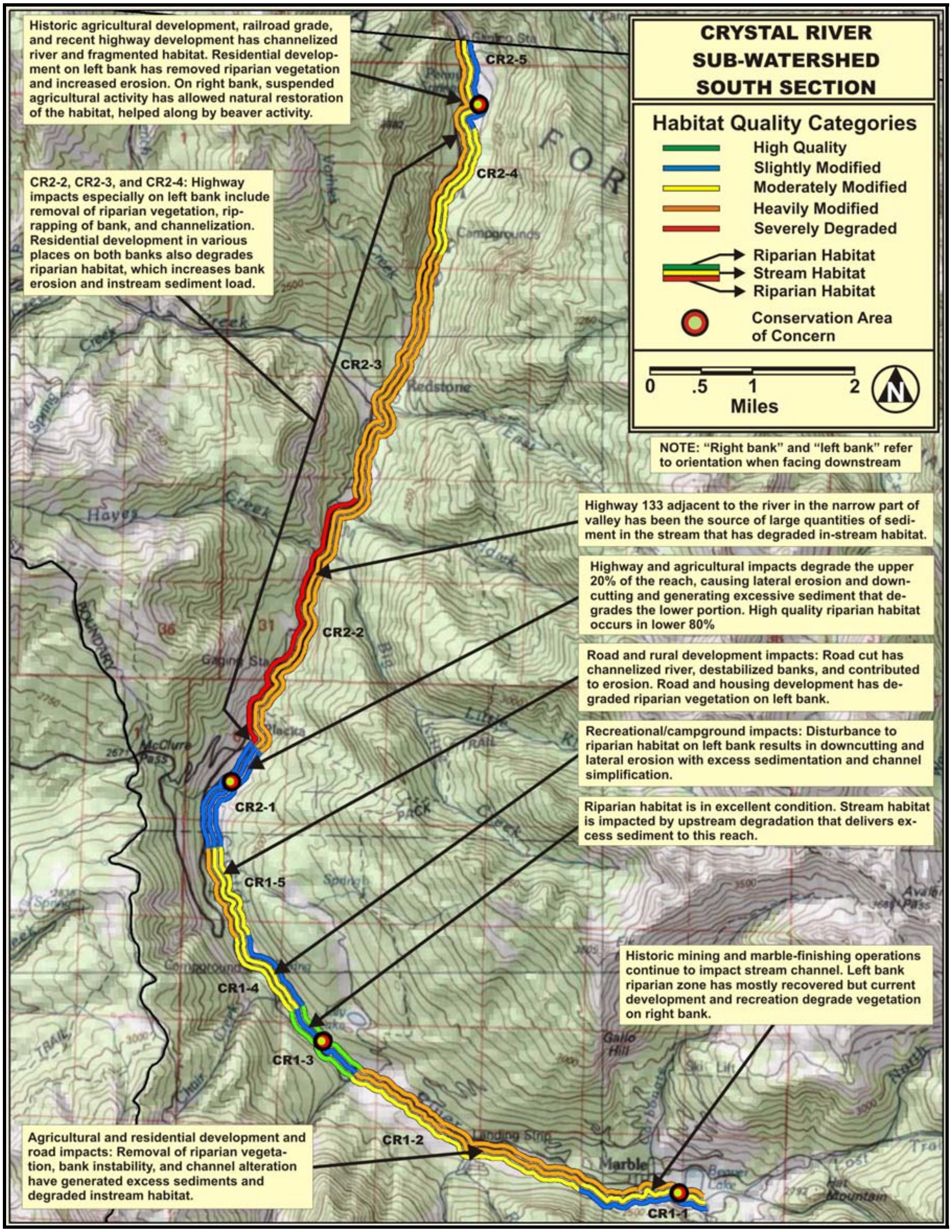


Figure 4.8.11. Riparian and instream habitat quality for the Crystal River Sub-watershed (south section).

Uplands

Historically much of this area was altered by mining-related activities. In higher stream reaches, mountainsides were mined for silver, coal and marble and surrounding spruce-fir forests were logged. In Marble and on Coal Creek near Redstone, mining activities resulted in upland deforestation and destabilized hillslopes. Construction of a railroad (built to support the mining industry) contributed to deforestation. Concurrent agricultural and ranching development converted native sage meadows into pastures, hay meadows, and potato fields. Current land use varies with elevation. Predominant land uses in higher elevation reaches include grazing and motorized and non-motorized recreation. As elevation decreases in the downstream direction land use also changes, becoming dominated by livestock grazing, hay meadows, and residential/golf course development.

Riparian Habitat and Wildlife

Both historic and recent land uses have altered the condition of riparian habitat, and, consequently, the river channel. Riparian habitat continues to be impacted by historic land uses such as railroad grades built on streambanks, mill sites and town sites built in the floodplain, and by domestic livestock grazing. Recent impacts have resulted from agricultural, highway, residential, and recreational activities (Figure 4.8.12). Over time, much of the upland and riparian areas that were historically degraded have been restored by natural processes, although channel degradation has not been completely remediated and stream function continues to be impaired. Additionally, new and ongoing development activities continue to encroach into riparian habitat, alter streambank vegetation, and degrade riparian habitat. The majority of the segment's riparian habitat has been modified and ecosystem functions degraded. On the left bank, riparian habitat is high quality on 3 percent of the segment, slightly modified on 8 percent, moderately modified on 17 percent, heavily modified on 44 percent, and severely degraded on 28 percent. On the right bank, 3 percent of riparian habitat is high quality, 10 percent slightly modified, 13 percent moderately modified, 55 percent heavily modified, and 19 percent severely degraded. The extent and type of activities that have modified riparian and instream habitat in the Crystal River segment are summarized in Table 4.8.5.

Figure 4.8.12. CR2-10: Replacement of riparian vegetation with a golf course has eliminated riparian functions such as pollution filtration, and has increased impermeable surfaces and runoff.

Table 4.8.5. Summary of land development impacts and threats to riparian and instream habitat in the surveyed part of the Crystal River drainage.

CRYSTAL RIVER SUB-WATERSHED	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	WEEDS COMMON-ABUNDANT (5-10%) RIGHT BANK
Total Stream Miles: 31.0	7%	26%	38%	64%	63%	56%

The Crystal River, throughout much of its length, has been channelized. Several historic railroad grades continue to affect riparian habitat and the river channel, but more recent road and agricultural development have had the greatest effect on riparian and instream habitat, followed closely by golf course/residential development. The Highway 133 roadcut has resulted in the removal and degradation of streambank vegetation and habitat loss on 27 percent of the segment. Where Highway 133 parallels the river, the river is channelized, riparian habitat and the floodplain are fragmented, streambanks are eroding, and road-based pollutants drain into the river. The road inhibits the natural movement of large wood and other organic material from the uplands to the stream channel. Stream reaches especially impacted by the highway roadcut include CR1-2 and 1-5, and CR2-1, 2-2, 2-3, 2-4, 2-6, 2-7, and 2-8 (Figure 4.8.13).

Figure 4.8.13. CR1-2: The roadcut has eliminated streambank stabilizing vegetation, resulting in bank instability, erosion, and stream sedimentation.

Agricultural and residential development in the riparian zone has impacted 39 percent of native riparian habitat. Consequences include bank erosion and severe channel downcutting; and loss of riparian functions such as bank stabilization, provision of large woody material, pollution filtration, energy dissipation, and wildlife habitat (Figure 4.8.14). Stream reaches especially impacted by agricultural development include CR1-2, 2-9, and 2-10. Newer residential development, including the conversion of agricultural lands into residential areas, is a trend that has exacerbated agricultural impacts and created additional impacts such as increased impervious surfaces and degraded wildlife habitat. Reaches impacted by residential development include CR1-1, 1-2, and 1-3, and CR2-3, 2-4, 2-7, 2-9, and 2-10. Along much of the segment, the native cottonwood woodlands that historically lined the river banks are dying and not being replaced.

Figure 4.8.14. Upper photo: Agricultural development has resulted in severe downcutting and the loss of native cottonwood forests. Lower photo: Pasture grasses have not adequately stabilized the streambank, resulting in bank failure.

Although some ecological recovery has occurred following the end of historic mining activities, many riparian areas continue to be impaired. In reach CR1-1, marble mining impacts still inhibit revegetation and restoration of some streambanks. In reach CR1-2, a combination of historic and recent riparian and channel alteration has resulted in channel downcutting, widening, and braiding. In reach CR2-7, the development of the historic town of Janeway fundamentally altered the ecosystem, resulting in a change from a riparian cottonwood forest to domination by an upland, drought-tolerant plant community. Additionally, throughout the segment numerous areas occur where banks are riprapped.

Numerous small areas of high quality habitat remain along the river corridor and provide wildlife with critical resources (figures 4.8.15 and 4.8.16). Often these areas retain high wildlife value because they remain connected to adjacent high quality upland habitat. In those reaches where beaver activity is high, such as CR1-1 and 2-1, habitat diversity and wildlife value is enhanced. Other high value reaches occur in unroaded or somewhat remote and inaccessible areas where steep-walled canyons make development difficult.

Figure 4.8.15. CR1-3: High quality native vegetation stabilizes streambanks even during flooding flows and provides wildlife with essential foraging and breeding habitat.

Figure 4.8.16. CR2-1: A wide floodplain at Placita is "connected" with high quality upland habitat especially valuable for wildlife.

Several studies have assessed biological diversity in this sub-watershed including the Colorado Natural Heritage Program (CNHP) (Spackman et al., 1999) and the SHI (Malone and Emerick, 2007a). CNHP has identified nine Potential Conservation Areas (PCAs) in the sub-watershed (Figure 3.3.2 and Appendix 3.3.2). Seven are located, at least partially, on the Crystal River or a tributary: Lost Trail Creek, Big Kline Creek, East Creek, Avalanche Creek, Middle Thompson Creek, Crystal River at Potato Bill, and Sutank. These sites were identified as PCAs because of several globally- and state-imperiled or vulnerable plant communities and species of plants and animals such as Boreal owl, large-flowered globe-mallow and narrowleaf cottonwood-blue spruce- thinleaf alder riparian forest. The other two PCAs are upland areas; Whitehouse Mountain and McClure Pass. These areas were identified as PCAs due to the "good or fair occurrence" of globally- and state-imperiled or vulnerable plant species at each site, and, on McClure Pass, a vulnerable bird species that is imperiled during the breeding season. Identified threats and management recommendations at the McClure site include weed control, recreation restrictions, and restoration. Although the Whitehouse Mountain site includes lands owned and managed by the USFS and The Nature Conservancy, the area could be threatened by mining activities. Several Conservation Areas of Concern (CAC) were identified by the SHI. Table 4.8.6

lists some of those CACs and the reason for their designation. As indicated by sites where bird communities were composed of a diversity of sensitive species, numerous other opportunities for conservation, protection, and restoration exist throughout the sub-watershed. Breeding bird surveys identified several areas supporting a high richness and abundance of bird species that depend on good quality habitat, including reaches CR1-1, CR1-3, the upper half of CR1-4, CR2-1, and CR2-8.

Table 4.8.6. SHI Conservation Areas of Concern in the Crystal River Sub-watershed.

LOCATION	JUSTIFICATION
CR1-1	Willow carr wetland and beaver pond complex provides high quality breeding bird habitat. Willow flycatchers (Audubon watch list) were breeding in the willow carr. The area is threatened by unmanaged recreation and habitat alteration from dredging.
CR1-3	High quality riparian conifer forest characterizes this reach. Threats come from a developed campground which occurs at the bottom of this reach at CR1-4, and is a source of poorly managed recreation.
CR2-1 (Placita)	High quality willow carrs and beaver pond complex. Threats come from recreation.
CR2-5 (Filoha)	This area provides critical winter range for bighorn sheep and elk and several rare plant species occur here. This area is owned and managed by Pitkin County as open space.
CR2-7 (Janeway)	One of the few wide, flat areas along the river corridor. Currently the area is severely degraded but with hydrologic and riparian restoration could provide good quality wildlife habitat. Lewis's woodpeckers (Audubon watch list) were breeding in remnant cottonwood stands.
CR2-8 (Red Wind Point)	Riparian shrubland on the right bank of the river provides good quality breeding bird habitat and is connected to critical upland habitat. Threats come from a recreational trail and corresponding disturbance.
CR2-10	A small area within a golf course/residential development has been conserved as wildlife habitat and provides good resources for raptors, wading birds and songbirds. Lewis's woodpeckers (Audubon watch list) were observed here nesting in remnant cottonwood stands. Threats come from surrounding development and related disturbance.

Instream Habitat and Wildlife

In the Crystal River, stream morphology and type varies with the landscape, ranging from Type A streams in steep-walled canyons to Type B where the valley has a less steep gradient, and Type C streams where the valley is wider and flatter (Rosgen and Silvey, 1996). Refer to Table 3.4.1 and Figure 3.4.2 for general characteristics of these different types of streams. In many reaches within this sub-watershed, development-induced channelization in combination with hydrologic modification has altered the natural, pre-development characteristics that determine stream type.

The Crystal River runs predominately south to north before joining the Roaring Fork River (Figure 4.8.17). Carbondale is situated at the confluence of these two rivers. From the confluence upstream to Thompson Creek the river is in a broad alluvial valley that remains in agricultural use. Parts of the historic river channel were braided and complex, and interacted with the floodplain annually. This interaction created new channels with large cottonwood galleries, large pools, water-dependent shrub and grass species, and extensive wetland complexes from beaver dam construction. This reach was simplified by urbanization and agriculture, leaving the river as a single, wide, shallow, and incised channel that rarely flowed over its banks. Additionally, large wood and beaver dams were removed to improve agricultural lands and create more suitable building sites, thus further simplifying the channel.

Figure 4.8.17. Confluence of the Crystal and Roaring Fork rivers (Source: Google Earth image, downloaded March 23, 2008).

Upstream of Thompson Creek the river enters a canyon reach upstream to Placita. The natural orientation and topography reduce solar input, resulting in decreased primary plant production. The instream habitat is altered from historic railroad construction and, currently, from Highway 133. Many of the streambanks along the railroad grade have restored naturally and are well-vegetated with stable banks. Although naturally constrained by the canyon, the channel is further constrained from these transportation features, which disconnect many areas where the channel historically meandered. Several of these locations are easily observed today, including just upstream of Red Wind Point, where the old railroad grade cut off the adjacent floodplain to the east (Figure 4.8.18). Two large tributaries (Avalanche and Coal creeks) flow into the Crystal

River, depositing alluvial fans that form wider valleys within this canyon reach (including the Janeway and Redstone townsite areas) (Figure 4.8.19) and creating “hot spots” for aquatic life. These important aquatic zones are discussed further in Section 3.4. At the historic townsite of Janeway in reach CR2-7, the channel’s current condition is caused by the cumulative impacts of historic townsite development and recent highway development, which have channelized and straightened the stream and contributed to bank erosion that inhibits overbanking flows. The resultant drier soils foster the invasion of upland plant species such as oak, juniper, and sage into riparian habitat. These drought-tolerant upland species do not stabilize bank soils effectively, leading to erosion and channel alteration (Figure 4.8.20). Conversely, the Placita meadow is a classic hot spot of animal diversity, where stable braided channels, beaver dams, and sediment and wood deposition create complex habitat for both aquatic and terrestrial wildlife (Figure 4.8.21).

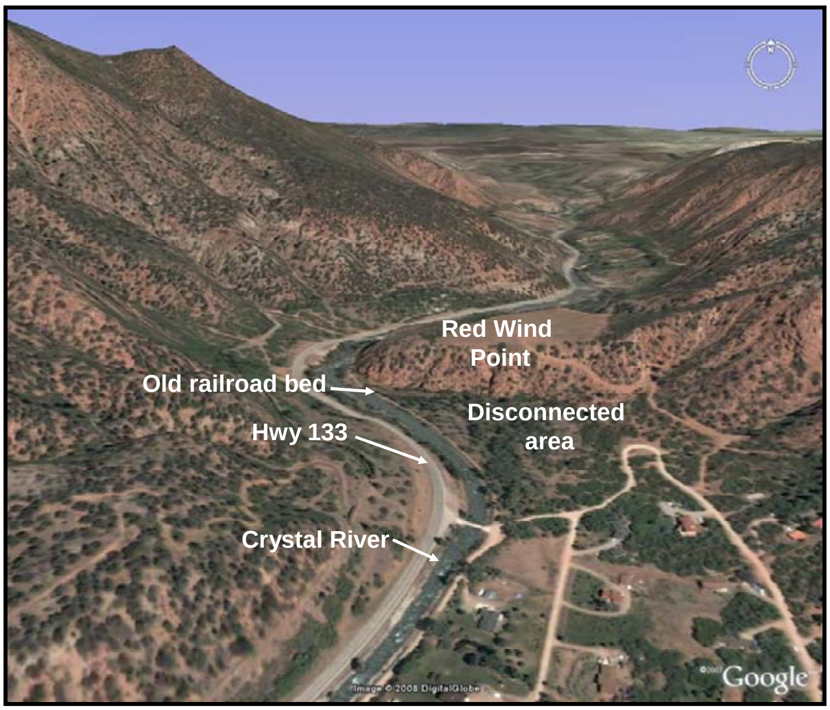


Figure 4.8.18. Upstream of Red Wind Point, the meander channel was cut off by the old railroad line (Source: Google Earth image, downloaded March 24, 2008).

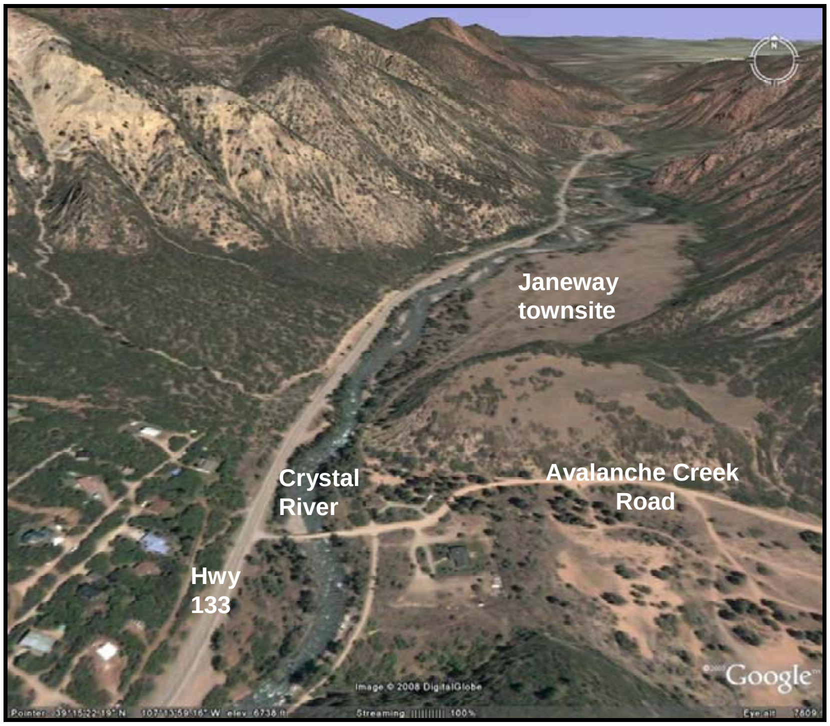


Figure 4.8.19. Historic Janeway townsite on alluvial fan (Source: Google Earth image, downloaded March 24, 2008).

Figure 4.8.20. CR2-7: A combination of historic and recent development impacts have resulted in drier soils that have changed riparian vegetation to upland vegetation.

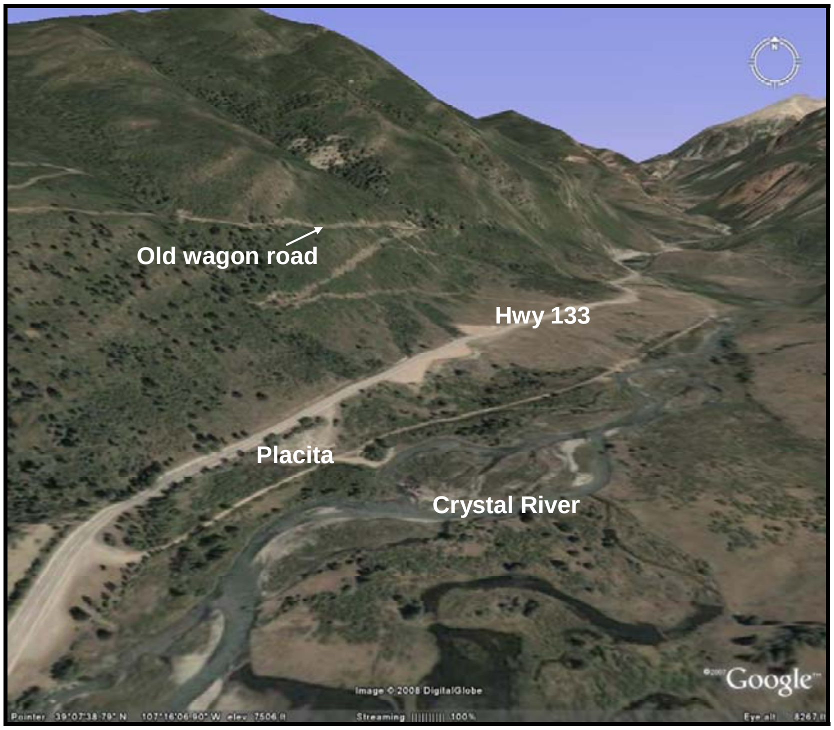


Figure 4.8.21. Historic townsite of Placita (Source: Google Earth image, downloaded March 23, 2008).

From upstream of the Placita meadow to the Crystal townsite and continuing into the North and South forks, the Crystal River has high gradient canyon reaches interspersed with wider valleys and tributary junctions.

No high quality instream habitat is present within the SHI surveyed section – with 7 percent slightly modified, 18 percent moderately modified, 56 percent heavily modified, and 19 percent of the instream habitat severely degraded due to anthropogenic impacts and inherent landscape characteristics. The Crystal River Sub-watershed is naturally high in sediment because of the surrounding geology. This naturally high sediment load has been exacerbated by roads, railroads, mining, development, and agriculture. Development impacts have altered channel condition, diminished stream functions, and impaired stream processes by three general means: riparian vegetation degradation, channelization (discussed above), and flow reduction. Riparian vegetation degradation results in bank instability followed by erosion and channel downcutting and/or lateral cutting with channel straightening and/or widening (Figure 4.8.22). Channel downcutting is prevalent in reaches CR2-1, 2-9, and 2-10; reaches CR1-2, CR2-3, and 2-7 are wider and shallower as a result of both lateral- and down-cutting (Figure 4.8.23). In this sub-watershed, flow reduction results from a variety of causes including diversions on the Crystal River and tributary streams, alteration of upland infiltration-runoff regimes, and reduction of beaver populations and activity. Reduction in late summer and early fall flows impacts instream habitat from below reach CR2-7 to the confluence with the Roaring Fork River. In the surveyed section, a few high quality areas remain where aquatic wildlife potential is high, including CR1-1, 1-3 (Figure 4.8.24), the upper half of CR1-4, 2-1, and the lower half of 2-6 near the confluence with Avalanche Creek.

Figure 4.8.22. CR2-10: Conversion of native habitat into pasture has enabled weed invasion. Neither pasture grasses nor weeds adequately stabilize streambanks and severe bank instability and changes to channel morphology result from this conversion.

Figure 4.8.23. CR1-2: Channel widening and braiding have occurred from vegetation removal and channel dredging.

Figure 4.8.24. Above CR1-3: In those stream reaches where native vegetation and natural, stable channel characteristics remain, aquatic wildlife potential is high.

Non-native, naturally reproducing brown trout are the dominant trout species in the lower Crystal River. The CDOW stocks the Crystal River with catchable rainbow trout reared at the Crystal River hatchery just outside of Carbondale. Whirling disease is present in the Crystal so natural reproduction for these non-native rainbow trout is limited. To provide a recreational fishery, CDOW stocks larger fish (8 inches and longer) that are less susceptible to whirling disease. Although suitable habitat exists in the lower Crystal for native Colorado River cutthroat trout (CRCT), whirling disease and past introductions of non-native trout (brook, brown, and rainbow) have eliminated them. However, six tributary streams within the sub-watershed have populations of CRCT and some of these fish migrate into the main river, although the numbers are low and do not contribute to the fishery. In the upper sub-watershed (North and South forks and tributaries), streams are predominately occupied by brook trout. In general, brown trout are found in the lower reaches, mixed stocks of brook trout and brown trout in middle reaches, and brook trout in the upper reaches. The CRCT populations are generally isolated from these non-native trout populations by natural barriers. One population in the Thompson Creek drainage is an anomaly in that non-native trout species exist upstream and downstream of the CRCT with no apparent barriers. This population is at high risk and may not survive without management intervention. Boreal toads have not been observed in the sub-watershed, but survey information is limited.

4.8.4 Important Issues

Below is a summary of key findings from available scientific information, a listing of data gaps, and a listing of local initiatives, studies, and plans that provide relevant recommendations for managing the sub-watershed's water resources.

Key Findings

- Reductions in late summer/fall stream flows in the lower Crystal River and Thompson Creek are due to agricultural and municipal diversions.
- A 2003 study by Grand River Consulting that combined historic real and simulated data estimated that 27 percent of the years between 1955 and 2000 would have had an irrigation shortage in the month of August at the confluence of the Crystal and Roaring Fork rivers. It was estimated that an irrigation shortage would have occurred in 22 percent of the years in September and 18 percent of the years in October.
- Nettle Creek, the municipal water supply for Carbondale, shows significant flow alteration for most of the year. Peak flows in May and June were not significantly altered.
- Based on combined historic real and simulated data, Grand River Consulting (2003) estimated that 66 percent of the years between 1955 and 2000 would have had stream flows below the presently-established Colorado Water Conservation Board’s instream flow right (ISF) in the month of August at the confluence of the Crystal and Roaring Fork rivers. It was estimated that an ISF shortage would have occurred in 75 percent of the years in September and 44 percent of the years in October.
- Eight direct-flow conditional water rights greater than 10 cfs and six conditional storage rights greater than 1,000 acre-feet are in this sub-watershed. These conditional water rights can have priority dates senior to existing absolute water rights. If these large water rights were to be developed, they could significantly impact flows in the sub-watershed.

- The following constituents exceeded water-quality standards on more than one occasion at the sub-watershed's monitoring sites on the Crystal River and Coal Creek:
  - Total phosphorus (exceedances on Coal Creek and the lower Crystal River)
  - Dissolved oxygen at Crystal River at Penny Hot Springs site
  - Total recoverable iron (the major source is in the Coal Creek drainage where a historic coal mine is a point source of iron and sediment)
  - Selenium (a major source is Mancos Shale)
- Coal Creek contributes to the higher suspended solid concentrations observed downstream of its confluence with the Crystal River. Coal Creek is on the state's (CDPHE) monitoring and evaluation list for sediment.
- Total recoverable aluminum often had high concentrations in the lower Crystal River, exceeding 750 µg/L.
- Throughout much of its length, the Crystal River has been channelized. Roadcuts have resulted in the removal and degradation of streambank vegetation and habitat loss on 27 percent of the segment. Agricultural and residential development in the riparian zone has impacted 39 percent of native riparian habitat. Weeds impact more than 50 percent of the surveyed reaches.
- Both historic and recent land uses have altered the condition of riparian habitat, leading to degradation of ecosystem functions and alteration of the river channel. Riparian habitat on both banks is heavily modified or severely degraded on more than 70 percent of the surveyed reaches.
- Along much of the surveyed segment, native cottonwood woodlands that historically lined the river banks are dying and not being replaced. Nesting by Lewis's woodpecker, a species of concern, has been documented in a few of those sites where cottonwood stands remain.
- CNHP has identified nine Potential Conservation Areas in the sub-watershed including Lost Trail Creek, Big Kline Creek, East Creek, Avalanche Creek, Middle Thompson Creek, Crystal River at Potato Bill, and Sutank. The SHI identified seven Conservation Areas of Concern.
- Vegetation degradation, channelization, and flow reduction have impacted instream habitat quality. No high quality instream habitat is present in the assessment area – with 7 percent slightly modified, 18 percent moderately modified, 56 percent heavily modified, and 19 percent severely degraded.
- In general, brown trout are found in the lower reaches of the sub-watershed, mixed stocks of brook trout and brown trout in middle reaches, and brook trout in the upper reaches. Whirling disease is present in the Crystal River, causing limited natural reproduction of rainbow trout.
- Six tributary streams within the sub-watershed have populations of Colorado River cutthroat trout (CRCT) and some of these fish migrate into the main river. These CRCT populations are generally isolated from non-native trout populations by natural barriers.

Data Gaps

A number of gaps in information for the sub-watershed limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Long-term stream flow gage data in the lower Crystal River drainage;

- Information about ditch efficiencies and how return flows influence stream flows;
- Stream flow gage data for lower Thompson Creek;
- An assessment of groundwater quantity;
- Water-quality data for the following constituent groups:
  - Specific conductance – could aid in establishing sources of dissolved material as well as helping to describe other water-quality conditions
  - Suspended sediment – to evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals. Further monitoring on Coal Creek will determine if stream is impaired with respect to sediment
  - Emerging contaminants – to establish a baseline for understanding occurrence at sites
  - Microorganisms – collected to establish potential for water-born disease;
- Water-quality data for Thompson Creek;
- Groundwater-quality monitoring data;
- Upland habitat conditions and bird and mammal populations; and
- Riparian and instream habitat conditions on Avalanche, Thompson, Coal, and Prince creeks.

Relevant Local Initiatives, Plans, and Studies

- Water-related objectives established by the Crystal River Caucus include limitations on development to protect water quality, wildlife habitat, and view corridors; protection and enhancement of instream flows (including prevention of dam/reservoir construction); and voluntary provision of stream access for recreation activities as well as the granting/purchase of conservation, fishing, and trail easements.

4.9 Cattle Creek Sub-watershed

4.9.1 Environmental Setting

The Cattle Creek Sub-watershed is located in the northwest part of the overall watershed, where Cattle Creek's headwaters are fed by Basalt Mountain. The area, including much of what is known as Missouri Heights, has been dominated by agricultural ranching for generations, a practice steadily being replaced by residential development, including large-lot "ranchettes." Pronounced commercial/industrial activities lie along Cattle Creek before its confluence with the Roaring Fork River. The sub-watershed is dominated by the Foothill Shrublands Ecoregion, with some Sedimentary Mid-elevation Forests and Sedimentary Subalpine Forests Ecoregions at higher elevations. The effect of land use activities directly adjacent to Cattle Creek, including grazing and development, represent an important issue for water quality and riparian and instream habitat health. See Figure 4.1 for an overview map showing the location of this sub-watershed within the overall Roaring Fork Watershed. Figure 4.2 is a map of the ecoregions, and the sub-watershed's general physical characteristics are summarized in Table 4.1.

Topography and Geology

The headwaters of Cattle Creek begin on Red Table Mountain and flow 23 miles to its confluence with the Roaring Fork River. Cattle Creek's main tributary, Coulter Creek, enters downstream of the Eagle/Garfield County line. The majority of the sub-watershed has been formed by Quaternary and Tertiary extrusive igneous rocks. These rocks are stable, although rock falls can occur in areas underlain by easily erodible evaporites. The steepest slopes (30 to 45 percent) occur among the bands of sedimentary rocks in the upper part of the sub-watershed. A significant area of highly erodible Cretaceous shale is located in near the confluence of the Cattle Creek mainstem with the North Fork of Cattle Creek. Ancient alluvium deposits occur downstream of these shales and there are evaporite deposits in the lower part of the sub-watershed and along the north side of the lower creek. Alluvium has been deposited where Cattle Creek enters the Roaring Fork River.

Weather/Climate

There are no NOAA climate stations in the sub-watershed. Data can be found for one site in the sub-watershed associated with the Colorado Collaborative Rain, Hail, and Snow Network (Appendix 1.2).

Biological Communities

The headwaters of Cattle Creek start at 11,200 feet on southwest-facing slopes of Red Table Mountain in the Subalpine Life Zone and flow down steep slopes into the Montane Life Zone. From here the stream traverses unstable shales into the Upper Sonoran Life Zone, eventually joining with the Roaring Fork River at an elevation of about 5,930 feet. Headwater habitat is characterized by a mixture of dense spruce-fir forest, aspen woodland, shrublands, herbaceous meadows, and slope wetlands. Habitat diversity is high in part because the valley trends east-west so that north and south facing slopes have different soil moisture characteristics with correspondingly different plant communities. North-facing slopes are dominated by conifer forests, and south-facing slopes are dominated by shrublands with aspen stands occurring in drainages. Subalpine riparian habitat is characterized by Engelmann spruce, subalpine fir, and aspen riparian forests interspersed with patches of thinleaf alder, willows, and wet meadows. From the lower subalpine down into the montane the drainage is somewhat narrow and the gradient is steep. However, abundant beaver activity has filled the valley with a complex of dams and ponds creating a wide riparian zone with willow carr wetlands, alder and birch thickets, and wet meadows bordered by mixed conifer and aspen woodlands. Beaver ponds stair-step the stream down into the Montane Life Zone, where upland plant communities change to sage and oak shrublands on south-facing slopes and to mixed conifer forests on north-facing slopes. Montane riparian habitat is characterized by a mosaic of willow carrs, wet meadows, and alder-birch thickets with blue spruce bordering the north side of the riparian zone. Further downstream, where the valley widens and gradient decreases, the stream enters the Upper Sonoran Life Zone. Uplands are characterized by stands of pinyon-juniper woodlands intermixed with sage shrublands and herbaceous meadows on south-facing slopes, and by oak shrublands on north-facing slopes. Pre-development riparian habitat was characterized by narrowleaf cottonwood woodlands, willow carrs, hawthorn and alder thickets, and wet meadows.

Native wildlife along headwater reaches is species-rich and abundant (Figure 4.9.1). The common occurrence of predatory species such as mountain lions, pine martens, owls, eagles, and hawks indicates the presence of an abundant food base and large, disturbance-free landscapes. On lower-elevation privately-owned land, habitat condition is typically degraded with a commensurate reduction in wildlife species diversity. Aquatic habitat in headwater reaches is in good condition and supports two known populations of Colorado River cutthroat trout (Figure 3.4.4). Brown trout dominate the lower reaches of Cattle Creek and are co-dominant with brook trout throughout the rest of the sub-watershed. Mottled sculpin are abundant in the upper reaches. No known populations of boreal toads exist in the sub-watershed, but chorus frogs and tiger salamanders are fairly common.

Figure 4.9.1. The headwaters of Cattle Creek provide essential and high quality year-round wildlife habitat.

Appendix 1.3 lists the riparian and instream species and communities of concern in the sub-watershed. Winter range for the bald eagle, a state-threatened species, occurs in this sub-watershed (Figure 3.3.5). The Colorado Division of Wildlife (CDOW) has identified occurrence of the following fish species in the sub-watershed: Colorado River cutthroat, brook, and rainbow trout (Harry Vermillion, CDOW, personal communication, March 3, 2008).

4.9.2 Human Influences

Land Ownership and Use

Figure 4.9.2 is a map of the sub-watershed showing ownership and protection status. With the exception of a private inholding adjacent to Cattle Creek near Yeoman Creek, upper Cattle Creek is mostly in the White River National Forest, managed by the U.S. Forest Service (USFS). The conservation organization Wilderness Workshop is proposing that Basalt Mountain and Red Table Mountain in the sub-watershed be reviewed for wilderness status (http://www.whiteriverwild.org/aspen-region.php). About a mile downstream of the North Fork of Cattle Creek, ownership changes to a mixture of private land and public land managed by the Bureau of Land Management (BLM). Aspen Valley Land Trust holds several sizeable conservation easements on upland parcels in the sub-watershed. West Coulter and Fisher creeks flow through contiguous sections of BLM land. Downstream of Coulter Creek, Cattle Creek flows through about 1.5 miles of BLM land, and further downstream, BLM land is in close proximity but not contiguous to Cattle Creek.

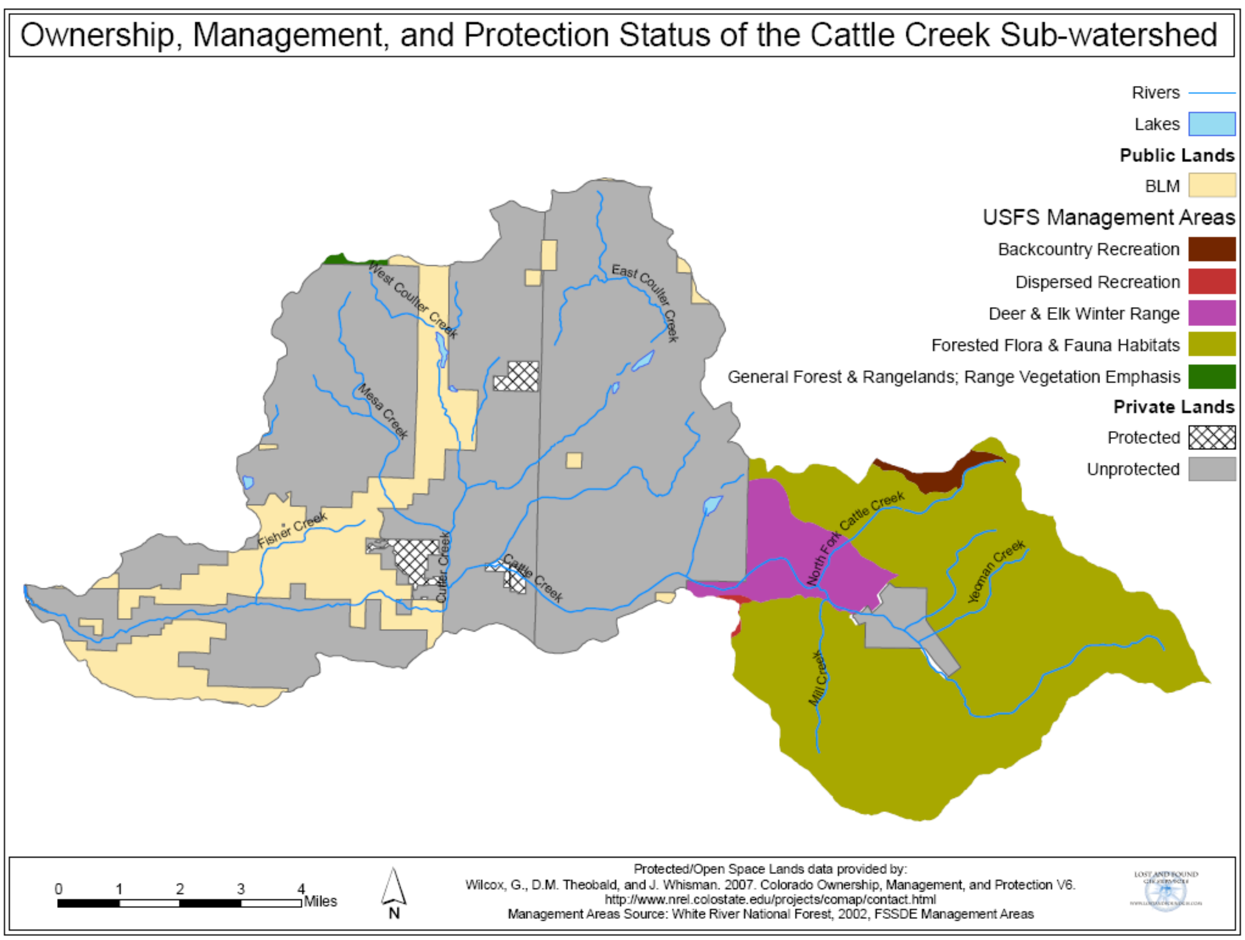


Figure 4.9.2. Ownership and protection status for the Cattle Creek Sub-watershed.

As mentioned earlier, the sub-watershed is bisected by the Garfield-Eagle county line. The upper portion of the sub-watershed is in Eagle County and the lower portion lies in Garfield County. Most of upper Cattle Creek is forested. Most of the sub-watershed's private land in Garfield County is zoned agriculture residential rural density http://www.garfield-county.com/Index.aspx?page=991, and in Eagle County it is zoned rural. The middle and lower portion of the sub-watershed, including Coulter Creek, is used primarily for grazing and irrigated agriculture (Figure 1.16). Most of the irrigated agriculture is found on Cattle Creek above Coulter Creek, near the confluence of West Coulter and Mesa creeks, and along lower Cattle and Fisher creeks.

Figure 4.9.3 shows roads within the sub-watershed and identifies roads within 150 feet of second order and higher streams (approximately 13 percent of the streams). County roads follow Cattle and Coulter creeks and Shippees Draw.

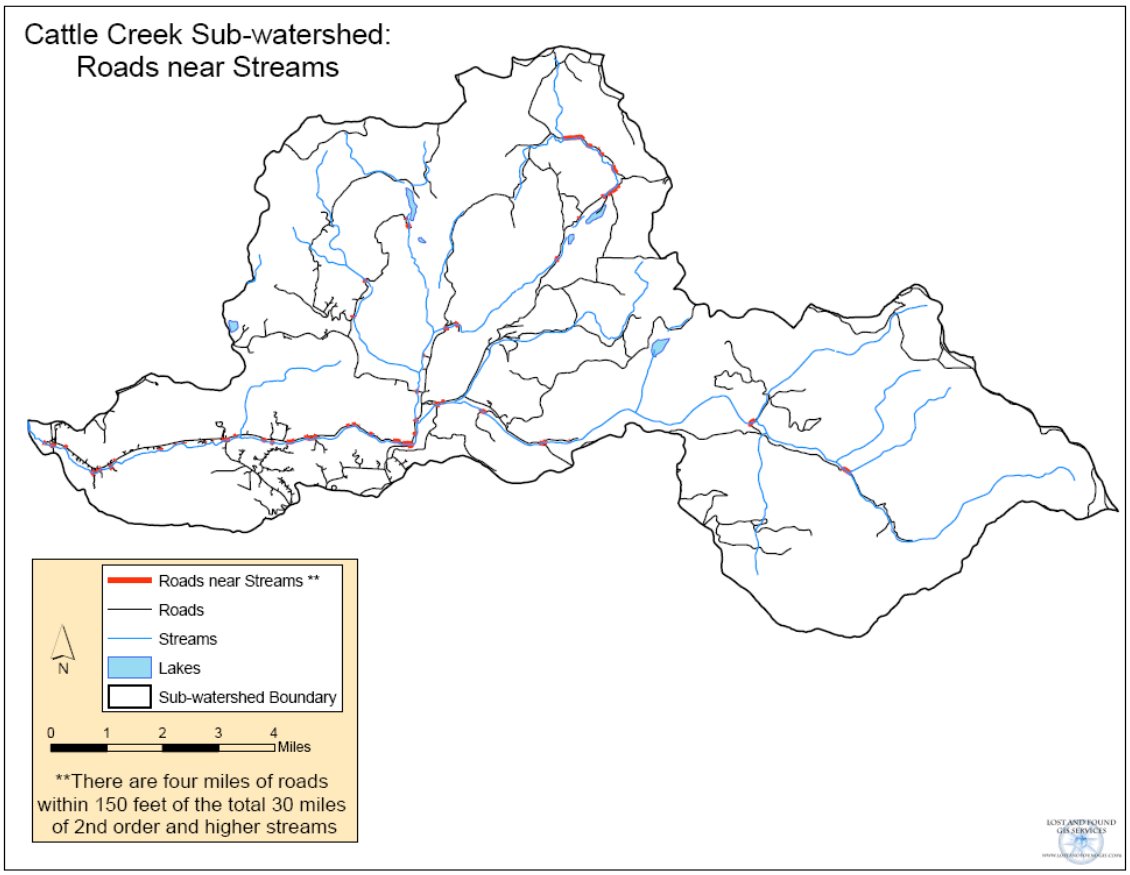


Figure 4.9.3. Roads near streams in the Cattle Creek Sub-watershed.

The Basalt Water Conservancy District (BWCD) serves all of the unincorporated areas in this sub-watershed outside of the White River National Forest (Figure 2.1), and is discussed in more detail in Chapter 2. The Aspen Glen Water and Sanitation District boundary extends into the lower part of the sub-watershed. (Figure 4.9.7). More information about this district can be found in the 2002 Roaring Fork Watershed Plan done by the Northwest Colorado Council of Governments (http://www.nwc.cog.co.us/Programs/Water/PDF/RFR02REV.final.pdf).

Mining

Table 4.9.1 lists permitted active and inactive mines in the sub-watershed. The first three are located next to Cattle Creek in the vicinity of the Eagle/Garfield county line. The terminated Cattle Creek Pits are just upstream of the creek's confluence with the Roaring Fork River.

Table 4.9.1. Mine sites in the Cattle Creek Sub-watershed. Source: Colorado Division of Reclamation Mining and Safety, No date.

SITE NAME	STREAM	SIZE	COMMODITY	STATUS	PERMIT ISSUED
Grant's Pumice	Cattle Creek	9 acres	Pumice	Terminated	7/27/1978
McNulty Cinder Pit	Cattle Creek	9.3 acres	Sand and gravel	Active	1/23/1980
McNulty Sandstone	Cattle Creek	3 acres	Sand and gravel	Terminated	11/13/1984
Cattle Creek Pit	Cattle Creek	n/a	Borrow material	Illegal, terminated	n/a
Cattle Creek Pit	Cattle Creek	5 acres	Sand and gravel	Terminated	11/22/1978

Recreation Activities

Looking at recreation activities, the sub-watershed is used by mountain bikers throughout the snow-free months, by early summer season hikers and anglers, and by hunters in the fall.

CDOW fish stocking records from 1973 to 2007 were provided by Jenn Logan, CDOW Wildlife Conservation Biologist (personal communication, April 19, 2007). The following streams in the sub-watershed have been stocked with the species listed (Table 4.9.2).

Table 4.9.2. Species stocked by the CDOW in streams of the Cattle Creek Sub-watershed.

STREAM/LAKE	SPECIES
Cattle Creek	Brook trout and rainbow trout
North Fork Cattle Creek	Rainbow trout

4.9.3 Resource Information

Several research studies and syntheses of information have been done in the Cattle Creek Sub-watershed, providing data on stream flows, surface water-quality conditions, and riparian and instream habitat and wildlife status. This body of existing scientific information is presented in this sub-section. For background information on the data sources, refer to Chapter 3.

Water Quantity

Surface Water

Only one stream gage has operated in this sub-watershed, Cattle Creek near Carbondale (Figure 4.9.4). It was run by the U.S. Geological Survey (USFS) from 1950-1972 upstream of the Mountain Meadow Ditch. These gage data are not useful for assessing flows in Cattle Creek because they represent only historic conditions in upper Cattle Creek. Flow alteration was assessed using Upper Colorado River Basin Water Resource Planning Model dataset (CWCB and CDWR, 2007a) modeled stream flow data. The model accounts for diversions more than 10 cubic feet per second (cfs). These data are available for two nodes in this sub-watershed: Needham Ditch on Cattle Creek and Park Ditch on Cattle Creek (Figure 4.9.4 shows the location of the nodes, depicted by the symbols for “no flow alteration” or “flow altered”). Both nodes indicate significant hydrologic alteration. Although primarily used for agriculture, year-round diversions from Cattle Creek to Spring Park Reservoir contribute to its year-round flow alteration. Appendix 3.1.2 and figures 3.1.4 - 3.1.6 show to what degree Cattle Creek’s stream flows are affected by the diversions. Flows are most greatly affected from March through October. Overall, Cattle Creek has more extreme low flow conditions and fewer occurrences of high flows and associated floods when compared with its natural undiverted flow regime (Figure 4.9.5). Under pre-developed flow conditions, small floods would be expected to occur in four out of 10 years, and would be expected in one out of 10 years with developed flow conditions.

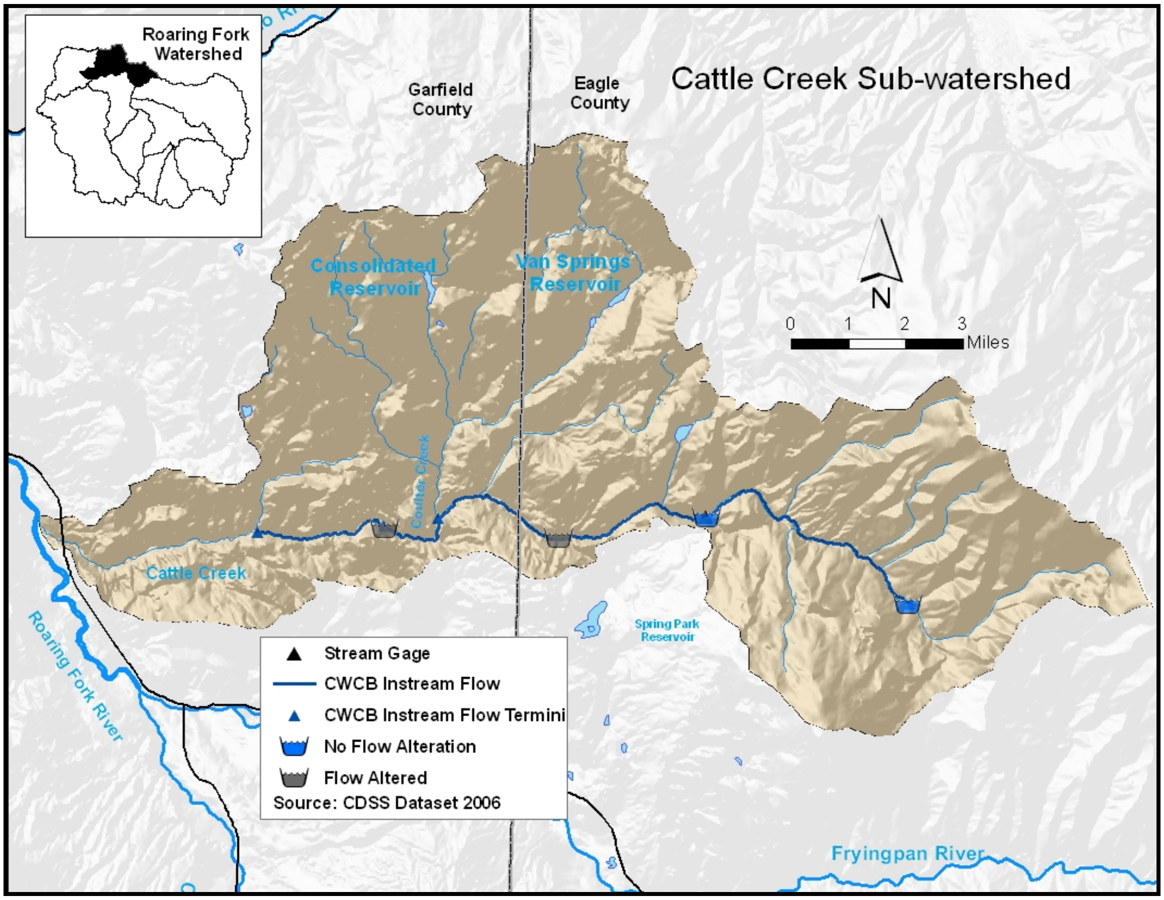


Figure 4.9.4. Water features in the Cattle Creek Sub-watershed.

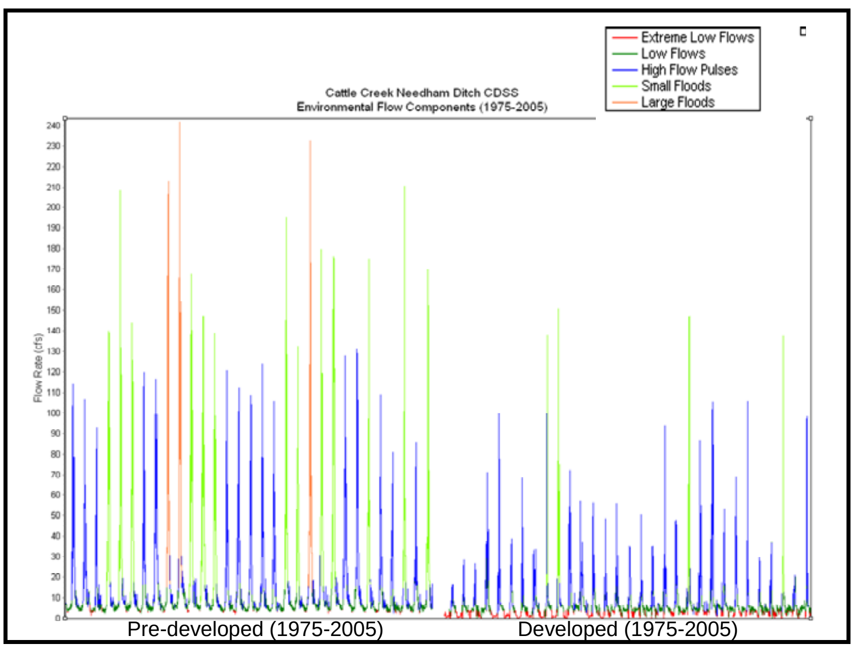


Figure 4.9.5. Comparison of modeled pre-developed flows to developed flows on Cattle Creek. There are more extreme low flows and fewer small and large floods under current developed conditions.

Figure 4.9.6 shows the location of all diversions in the sub-watershed. Five diversions have decreed capacities greater than 10 cfs (Table 4.9.3). With the exception of the Van-Cleve-Fisher FDR Ditch, all divert from the mainstem of Cattle Creek. Mountain Meadow Ditch, the largest diversion on Cattle Creek, diverts water out of the sub-watershed to Spring Park Reservoir, in the Lower Middle Roaring Fork Sub-watershed. It should be noted that a number of wells exist in the lower part of the sub-watershed.

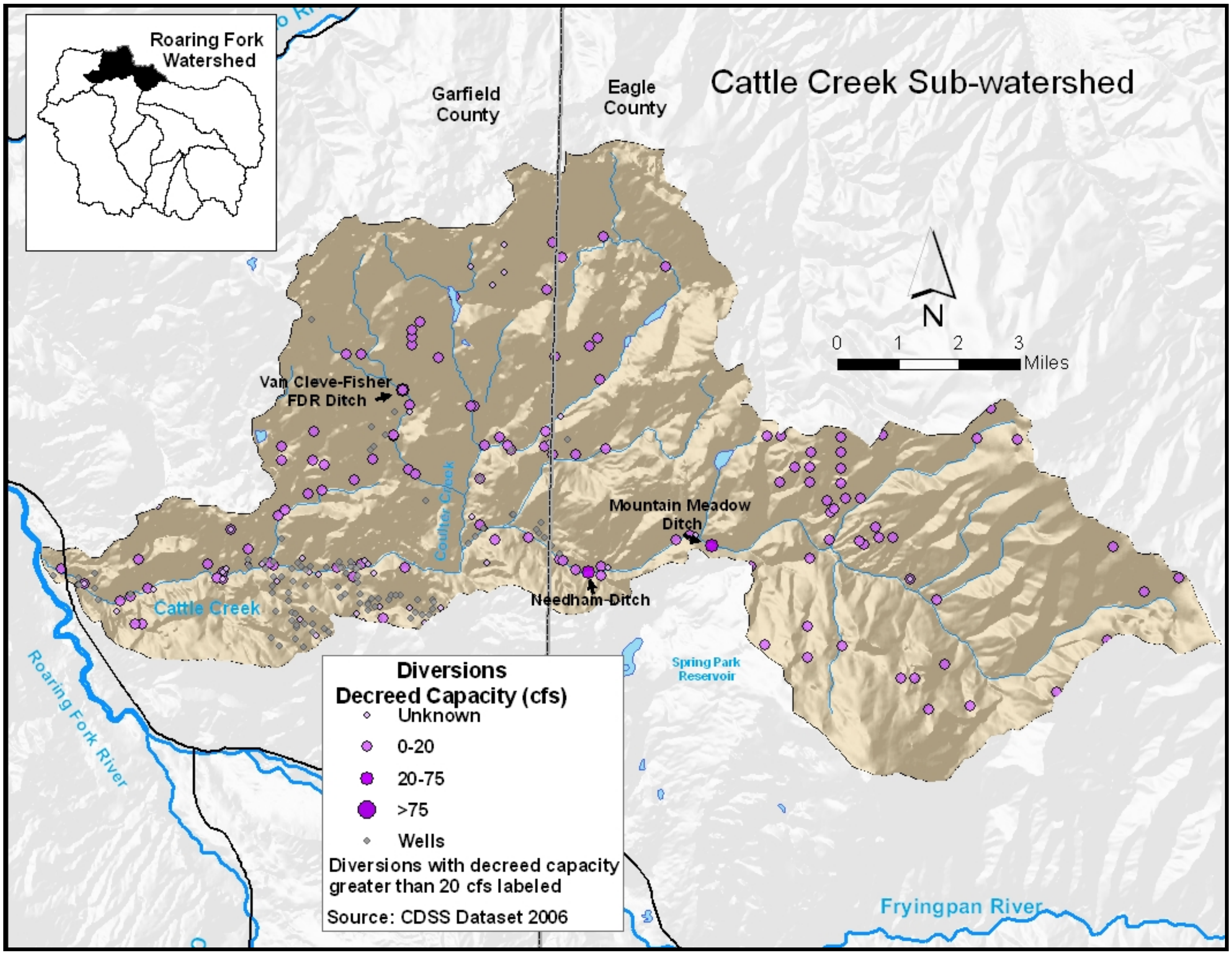


Figure 4.9.6. Diversions and wells in the Cattle Creek Sub-watershed.

Table 4.9.3. Diversions in the Cattle Creek Sub-watershed greater than 10 cfs. Source: CDSS GIS Division 5 diversion data.

STREAM	DITCH	DECREED CAPACITY (cfs)
Cattle Creek	Mountain Meadow Ditch*	53.00
Cattle Creek	Needham Ditch*	27.20
Cattle Creek	C&M Ditch*	14.00
Cattle Creek	Park Ditch*	16.90
Mesa Creek	Van Cleve-Fisher FDR D*	26.40

*Used in CDSS modeling

There are two Colorado Water Conservation Board (CWCB) instream flow (ISF) rights in this sub-watershed, both on Cattle Creek (Figure 4.9.4 and Appendix 2.2). The first right for 4 cfs year-round was appropriated in 1985 and extends for 13.8 miles from the confluence of Iola Creek to the confluence of Fisher Creek. An enlargement was made in 1997 for 2 cfs from May 1st to October 31st along a 3.5-mile stretch from the confluence of Coulter Creek to the Park Ditch head gate. No ISF rights are on lower Cattle Creek downstream of Fisher Creek. No stream gage data are available to determine how often these rights are met.

Groundwater

The Eagle Basin Bedrock Aquifer underlies all of the Cattle Creek Sub-watershed. No groundwater hydrology evaluations have been done specifically for the sub-watershed.

Water Quality

Author: U.S. Geological Survey

Within the Cattle Creek Sub-watershed, data have been collected at 21 water quality sites, dating as far back as 1962. Eight of these sites were stream sites and 13 were groundwater sites. Groundwater data were collected during 1975 from groundwater wells and springs within the sub-watershed. Streams with at least some historical water quality data include Cattle and Cutler creeks; however, only Cattle Creek at the mouth (site 47) has recent water-quality data, which are summarized for this sub-watershed for the time period 2002 to 2004. The site is shown in Figure 4.9.7 along with locations and information about water and wastewater treatment facilities in the sub-watershed. For this site, Appendix 3.2.1 has the period of record; number of samples; and minimum, maximum, and median value for each water quality parameter in the six parameter groups (field parameters, major ions, nutrients, trace elements, microorganisms, and total suspended solids/suspended sediment).

The Roaring Fork Conservancy listed Cattle Creek as a sub-watershed targeted for increased water-quality sampling (Roaring Fork Conservancy, 2006a). The Colorado River Watch Program is currently monitoring water quality at Site 47. Previous studies summarizing water-quality findings for this sub-watershed indicate that conditions are impacted with respect to selenium, manganese, and suspended solids (Roaring Fork Conservancy, 2006).

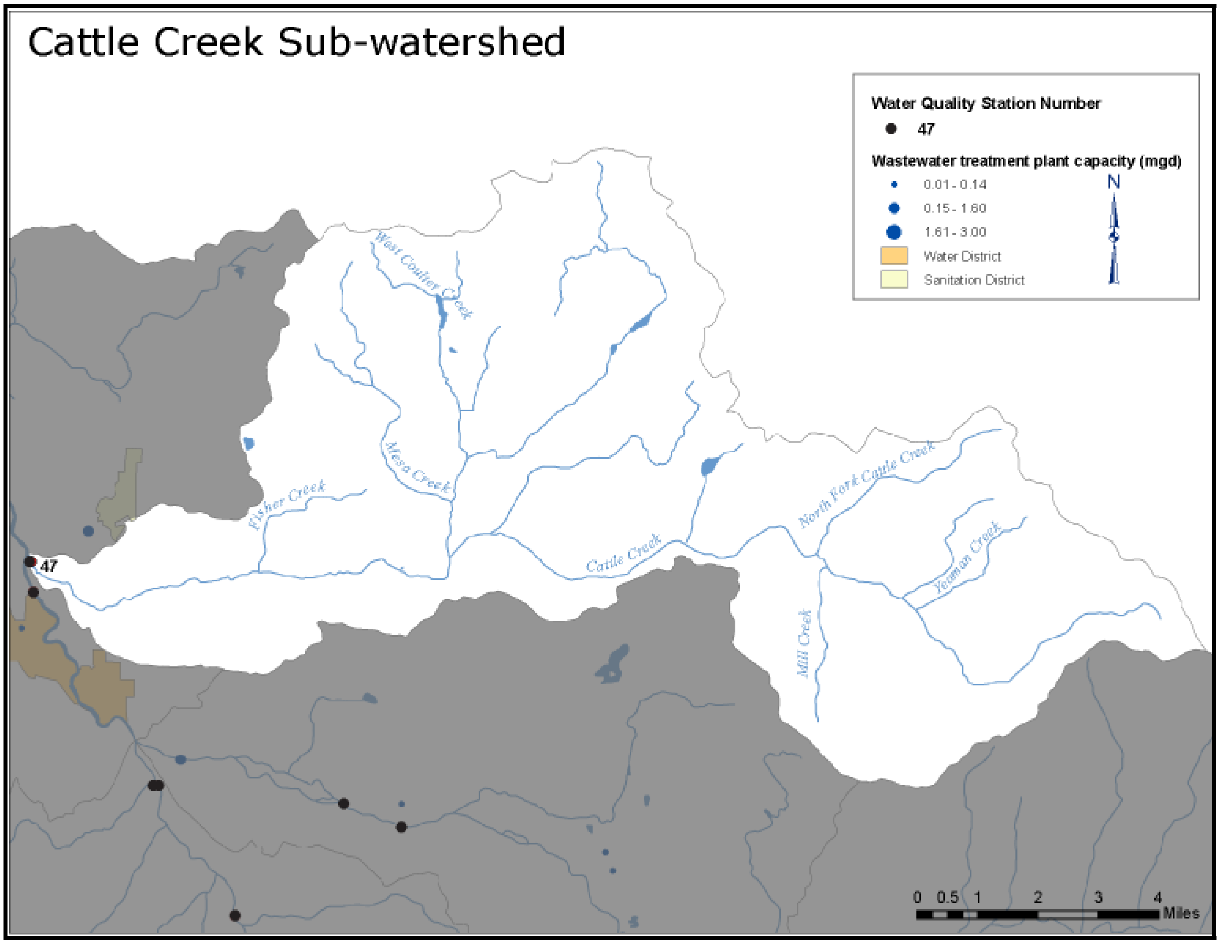


Figure 4.9.7. Water-quality sites and wastewater treatment providers in the sub-watershed. Wastewater information sources: O'Keefe and Hoffman, 2005 and CDOLA, No date b.

pH values ranged from 8.07 to 9.21, and the median was 8.31 (one pH value exceeded 9). High pH values reflect the geology in the sub-watershed, which consists of tertiary intrusive rocks underlain by the Mancos shale and Eagle Valley evaporite. Water temperatures ranged from 1.5 C° (34.7°F) to 18°C (64.4°F), with a median water temperature of 10°C (50°F). Twenty-six dissolved oxygen concentrations ranged from 7.2 mg/L to 12.7 mg/L, indicating well-oxygenated conditions.

Chloride and sulfate concentration were too limited for meaningful analysis. Hardness concentrations ranged from 110 mg/L to 350 mg/L, with a median of 242 mg/L, and indicate very hard water.

Nutrient data were not available for the sub-watershed.

Six selenium concentrations exceeded the chronic water-quality standard. The exceedances occurred from January through April of the years 2002–04, which corresponds mainly to the base flow period. One exceedance occurred in July of 2003. Selenium is leached from Mancos shale that outcrops and underlies Cattle Creek. One of 26 total recoverable iron concentrations exceeded the chronic standard, with concentrations ranging from <10 µg/L to 1291 µg/L. Of the 26 manganese concentrations, 17 were censored and values ranged from <10 to 994 µg/L. The extrusive igneous rocks that outcrop in the sub-watershed act as a source of both iron and manganese. No water quality exceedances were observed for cadmium, copper, lead, or zinc.

Riparian and Instream

The Stream Health Initiative (SHI) (Malone and Emerick, 2007a) surveyed Cattle Creek in this sub-watershed. Figure 4.9.8 shows specific riparian and instream information, by habitat quality category, for each reach assessed. Habitat quality categories are shown in riparian and instream assessment charts found in Section 3.3 and Section 3.4. Appendix 3.3.1 contains the actual percentage values for each of these categories by sub-watershed and how they were determined. The sub-watershed has one stream segment:
Cattle Creek Segment – Cattle Creek from above the confluence with the North Fork of Cattle Creek to its confluence with the Roaring Fork River, reaches CT1-1 through CT1-4; 19.46 miles.

A brief description of results follows. The SHI report contains detailed narrative description. “Right bank” and “left bank” refer to the orientation of the riparian zone when facing downstream.

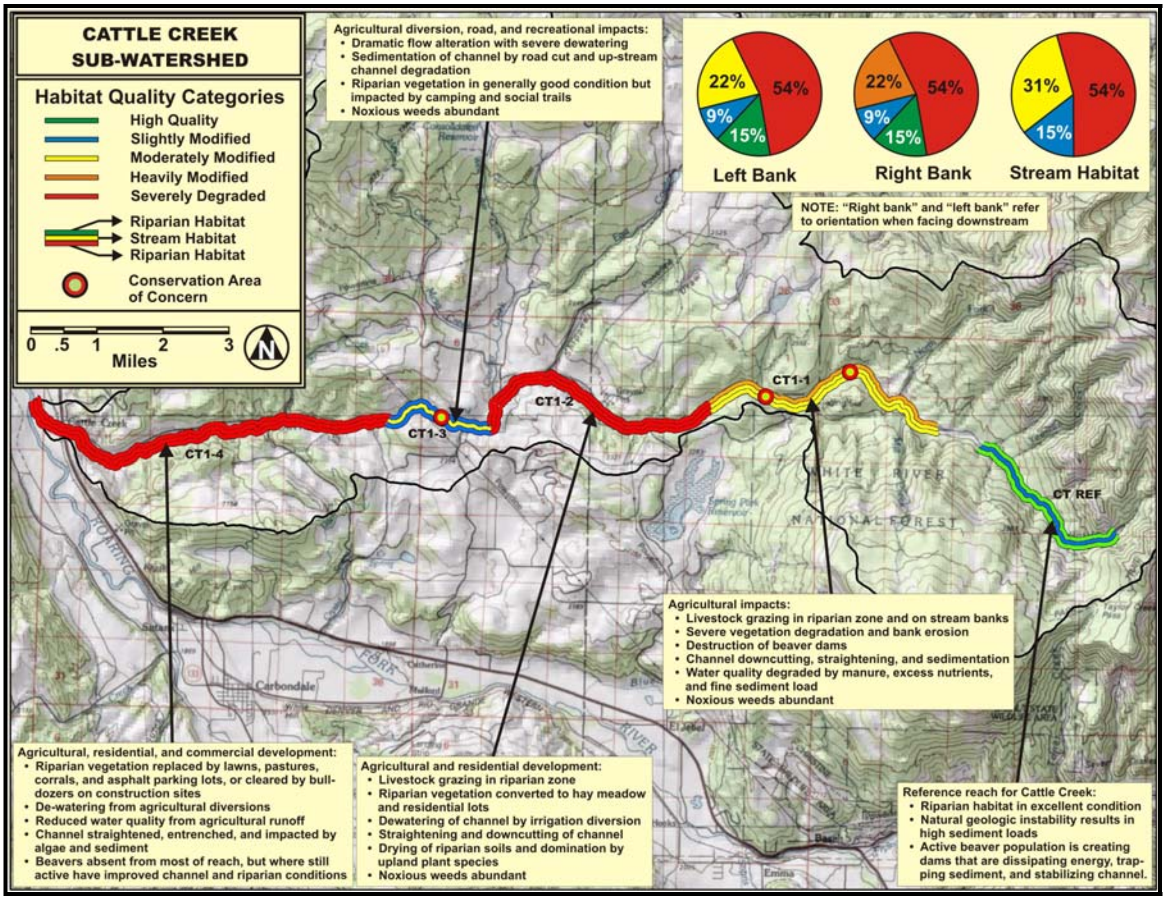


Figure 4.9.8. Riparian and instream habitat quality for the Cattle Creek Sub-watershed.

Uplands

Uplands surrounding headwater stream reaches are mostly public lands managed by the USFS, and are generally in sustainable condition. Red Table Mountain, located in the upper sub-watershed is managed as wilderness. Exceptions occur where inholdings, recreational trails, and grazing have altered plant communities and disturbed soil. Several inholdings occur in headwater reaches and have contributed to vegetation alteration and weed invasion. Frequent and illegal motorized use of a recreational hiking trail has caused severe erosion in some areas, especially where the trail traverses slope wetlands, streams, and meadows. Grazing by domestic livestock has had the largest impact on ecosystem sustainability, altering plant community composition, degrading soils, and encouraging the spread of noxious weeds (Figure 4.9.9).

In the lower sub-watershed, upland habitats are dominated by agricultural development and, more recently, by conversion of agricultural land into rural residential developments, causing further impact to remaining natural habitats.

Figure 4.9.9. CT1-2: Upland and riparian habitats have been converted to hay meadows and ranch land. Cattle Creek has been channelized.

Encroachment by residential development and its related activities (such as installation of non-native lawns and roads) into native habitat has severely degraded wildlife values and led directly to conflicts between wildlife and humans. These mid- to low-elevation habitats provide critical winter range for a variety of native wildlife including elk, deer, and their predators. One relatively undisturbed area is the BLM-managed upland habitat adjacent to reach CT1-3. Both north- and south-facing upland slopes (as well as the riparian area) have been identified as a Potential Conservation Area (PCA) by the Colorado Natural Heritage Program (CNHP) due to their moderate biodiversity significance (Figure 3.3.2 and Appendix 3.3.2). Pinyon-juniper/sagebrush communities characterize south-facing slopes, and Gambel oak-mountain mahogany shrublands, classified as a globally-vulnerable plant community, typify north-facing slopes. Identified threats to the north-facing slope of the PCA include roads and a power line that are causing erosion impacts in the riparian zone and acting as conduits for invasive weeds.

Riparian Habitat and Wildlife

Riparian habitat quality varies from high quality in headwater reaches to severely degraded in low elevation reaches (Figure 4.9.10). In the headwaters of Cattle Creek, wide willow carrs fill the narrow valley. Further downstream, habitat alteration has reduced native plant species diversity and age-class distribution, diminishing riparian functions such as stream stabilization, water filtration, and wildlife habitat. Native habitat has been altered by ranching and agricultural uses, rural residential development, and, presently, by urbanization that is slowly extending up the valley. Where the valley narrows, remnants of native riparian plant communities remain. However, riparian habitat quality has been reduced in the majority of the assessment area. On the right bank, 15 percent of riparian habitat is high quality, 9 percent slightly modified, 21 percent heavily modified, and 55 percent severely degraded. On the left bank, 15 percent of riparian habitat is high quality, 9 percent slightly modified, 22 percent moderately modified, and 54 percent severely degraded.

Figure 4.9.10. Upper photo: In an ungrazed section of reach CT1-1, a dense cover of native vegetation stabilizes streambanks. Lower photo: In areas with cattle grazing, banks are destabilized and downcutting.

Riparian quality and functions depend on both the width of the riparian zone and the quality of riparian vegetation. Each has been altered by agricultural and development activities, and by damage to beaver dams and reduction in beaver activity. Table 4.9.4 provides a summary of the types and extent of habitat-altering development in the Cattle Creek drainage.

Table 4.9.4. Summary of land development impacts and threats to riparian and instream habitat in the Cattle Creek drainage.

CATTLE CREEK SUB-WATERSHED	TRAILS & RELATED DISTURBANCES	ROADCUT, BRIDGES, AND CULVERTS	DEVELOPMENT (Residential, commercial agricultural, recreational)	SUBOPTIMAL FLOW	WEEDS COMMON-ABUNDANT (5-10%) LEFT BANK	RIGHT BANK
Total Stream Miles: 19.46	2%	17%	56%	67%	100%	100%

In Cattle Creek, beaver activity is integral to riparian and instream habitat. In undisturbed headwater reaches where beaver dams are abundant, riparian zone varies in width on each bank from 65 feet to 330 feet, the native plant community is species rich and structurally complex, and herbaceous vegetation covers more than 35 percent of the streambanks. In stream reach CT1-1, where cattle have grazed or beaver dams have been damaged or removed, the vegetated width of the riparian zone has been reduced to less than 65 feet and herbaceous vegetative cover reduced to less than 5 percent. Livestock grazing has also reduced the quality of riparian vegetation by changing plant community species composition. Consequences include severe erosion and channel instability, downcutting, dried-out soils, and spread of weeds (Figure 4.9.11). In ungrazed portions of the reach, riparian zone width is typically greater than 200 feet and native herbaceous plant cover averages between 35 and 50 percent.

Figure 4.9.11. CT1-2: Grazing has reduced riparian vegetation and resulted in increased erosion.

Further downstream on privately-owned land, grazing activities and conversion of flood plains to hay fields and corrals for domestic livestock have eliminated most riparian habitat and beaver activity. In reach CT1-2 the vast majority of the floodplain has been converted to hay meadows. Where the riparian zone once was dominated by willow carrs and sedge meadows hundreds of feet wide, the width of the riparian zone now averages 20 feet and is frequently less than 3 feet wide. Floodplain soils have dried to the point where irrigation is required to sustain hay crops. Similar to reach CT1-1, livestock grazing along streambanks has degraded the quality and reduced the cover of remaining riparian vegetation.

Wildlife potential and limitations correspond to habitat condition and degree of disturbance. A rich and abundant community of Neotropical migrant songbirds breeds in the headwaters region, indicating high quality habitat. However, where development has resulted in the removal or alteration of native plant communities, wildlife potential is reduced, as indicated by shifts in the breeding bird community to domination by disturbance-tolerant species. An exception occurs wherever beaver-created wetlands are intact – here birds find refuge and essential resources for breeding and raising young.

Several studies have assessed biological diversity in this sub-watershed including CNHP and the SHI. As noted in the uplands description, reach CT1-3 has been designated by CNHP as a PCA due to the “moderate” biodiversity significance of two globally-vulnerable plant communities. The riparian community here is characterized by a dense canopy of blue spruce with an understory of red-osier dogwood. Riparian habitat is in fairly good condition but threatened by noxious weeds, development pressure, and recreation-related disturbance. The SHI documented plant communities, species, and habitat structure throughout the segment and consequently identified three Conservation Areas of Concern in two stream reaches (Table 4.9.5). The time of year precluded breeding bird surveys, but observations of bird and mammal species, signs, and tracks were conducted. In the Cattle Creek reference reach (an undisturbed, representative reach against which other reaches are compared) and in CT1-1, recent mountain lion sign was noted as were signs of elk, deer, mink, black bear, and long-tailed weasel. Beaver were commonly observed and the CDOW has identified these areas as potential Canada lynx habitat. Notable birds seen in CT1-1 included Northern goshawk (CNHP watch-list species), golden-crowned kinglet, Swainson's hawk, golden eagle, and great blue heron (CNHP watch-list species).

Table 4.9.5. SHI Conservation Areas of Concern in the Cattle Creek Sub-watershed.

LOCATION	JUSTIFICATION
CT1-1	Riparian habitat is characterized by a mosaic of blue spruce forests, beaver ponds, alder thickets, wet meadows and wide willow carrs that provide high wildlife potential. Threats to sustainability come from cattle grazing in the riparian zone.
CT1-3	Riparian habitat is characterized by a blue spruce-narrowleaf cottonwood forest with an understory dominated by red-osier dogwood, a globally-vulnerable plant community. Threats come from stream depletions, noxious weeds, recreation activities, roadcuts, and stream sedimentation.

Instream Habitat and Wildlife

Stream morphology and type varies with the landscape and land use. Anthropogenic alteration of the channel has often been severe enough to alter stream type. Stream type in headwater reaches varies between Type E in lower gradient valleys such as CT1-1, to Type B in steeper gradient reaches such as CT1-3. Stream type in CT1-2 and 1-4 has been altered from a pre-development Type E to a Type G stream (Rosgen and Silvey, 1996). Refer to Table 3.4.1 and Figure 3.4.2 for general characteristics of these various types of streams.

Stream stability in the Cattle Creek drainage is dependent on sufficient cover of high quality vegetation, high quality upstream habitat, and beaver dams. Due to the unstable geology that characterizes the majority of this sub-watershed, the stream is highly sensitive to disturbance. Instream habitat is affected by the sub-watershed's activities of grazing, agricultural conversion of native vegetation to hay meadows, disruption of beaver activity, and rural, residential, and commercial development. Results include altered vegetation, stream sedimentation, and channel downcutting (Figure 4.9.12). Instream habitat quality is reduced over the entire assessment area. No high quality habitat remains, 15 percent of stream habitat has been slightly modified, 31 percent moderately modified, and 54 percent severely degraded. Upstream of the SHI surveyed reaches; the instream habitat is in good condition (USFS MIS data; Appendix 3.4.1).

Figure 4.9.12. Removal of a beaver dam has resulted in severe channel downcutting and excessive stream sedimentation.

In areas within reach CT1-1 and much of the length of the creek from CT1-2 to the confluence with the Roaring Fork River, grazing activities and removal of beaver dams have degraded riparian areas, leading to streambank destabilization, severe channel downcutting, stream straightening with loss of sinuosity, and loss of habitat and flow diversity (Figure 4.9.13). Where beaver dams and riparian vegetation remain intact, the channel has a sinuous pattern and diverse instream habitat with numerous deep pools, a diverse flow regime, and stable banks. Consequently, some areas of reach CT1-1 contain enough good quality vegetation to enable restoration. Rural development, including houses with lawns, horse corrals, and pastures along the edge of the stream, dominates the majority of the landscape in reach CT1-4. Native riparian habitat has generally been converted to non-native grasses and, in combination with flow reduction, has resulted in further channel straightening, simplification, erosion and downcutting, and degradation of stream function and sustainability (Figure 4.9.14). Below the Highway 82 overpass, agricultural land is being converted to an urban landscape. Currently, upland habitat scraped by bulldozers has led to the spread of noxious weeds; the riparian zone now is a narrow strip dominated by weeds; and the channel continues to resemble an irrigation ditch (figures 4.9.15 and 4.9.16).

Figure 4.9.13. Cattle Creek has been straightened over much of the drainage, with loss of habitat and flow diversity.

Figure 4.9.14. Rural development has reduced native riparian vegetation, promoted the establishment of non-native plants, and degraded stream function.

Figure 4.9.15. Conversion of agricultural lands into an urban development has severely altered both upland and riparian habitat. Cattle Creek is inside the sediment barrier.

Figure 4.9.16. Confluence of Cattle Creek and the Roaring Fork River. (Source: Google Earth image, downloaded March 23, 2008).

In those few areas where beaver are active or development has not occurred, instream habitat is in good condition. In other locations where agriculture has ceased, riparian zones have begun to re-establish themselves within the downcut channel. In many of these sustainable areas, beaver activity has maintained a functional and structurally diverse stream channel. In reach CT1-3, the stream enters a steep narrow canyon made up of a dense cover of native riparian vegetation that contributes to channel stability and wildlife habitat. However, instream habitat quality is threatened by diversion-induced flow reduction and fluctuations, and by excess sedimentation from upstream reaches and surrounding upland areas.

Aquatic wildlife habitat in headwater reaches is in good condition and provides the resources necessary to sustain two populations of Colorado River cutthroat trout (Figure 3.4.4). A natural barrier (waterfall) protects these populations from a non-native fish invasion (Hirsch et al., 2005). Below this barrier, non-native fish (especially brook trout) are common. Further downstream, habitat simplification, reduced quality and quantity of substrate important for colonization and spawning, and stream depletions have reduced the abundance and quality of essential instream foraging and cover resources for fish. However, Cattle Creek is an important tributary for brown trout spawning. Brown trout move into lower tributaries from the lower Roaring Fork and Colorado rivers for spawning (CDOW fish surveys). Maintaining adequate fall flows is important to maintain spawning habitat for brown trout in Cattle Creek

4.9.4 Important Issues

Below is a summary of key findings from available scientific information and a listing of data gaps.

Key Findings

- Although primarily used for agriculture year-round diversions from Cattle Creek to Spring Park Reservoir contribute to year-round flow alteration. Flows are most greatly affected from March through October. Overall, Cattle Creek has more extreme low flow conditions and fewer occurrences of high flows and associated floods when compared with its natural, undiverted flow regime.
- For the one water-quality monitoring site at the mouth of Cattle Creek, selenium had frequent exceedances of the chronic standard (the likely source is Mancos Shale within the sub-watershed).
- Native riparian habitat in the surveyed section of Cattle Creek has been altered by ranching and irrigated agriculture, rural development, and the more recent trend of urban development. Riparian habitat quality has been reduced in a majority of the assessment area. On the right bank, 15 percent of riparian habitat is high quality, 9 percent slightly modified, 21 percent heavily modified, and 55 percent severely degraded. On the left bank, 15 percent of riparian habitat is high quality, 9 percent slightly modified, 22 percent moderately modified, and 54 percent severely degraded.
- All riparian and instream habitat on the surveyed segment is threatened or impacted by weeds, and most of it is affected by reduced flows and development activities.
- A rich and abundant community of Neotropical migrant songbirds breeds in the headwaters region, indicating high quality habitat. Notable birds observed in the upper surveyed reach include Northern goshawk (CNHP watch-list species), Swainson's hawk, golden eagle, great blue heron (CNHP watch-list species), willow flycatcher, and golden-crowned kinglet.
- There is one Colorado Natural Heritage Area (CNHP) Potential Conservation Area, CT1-3, which supports globally vulnerable plant communities in its riparian area and surrounding upland.
- Two Conservation Areas of Concern were identified by the Stream Health Initiative in the sub-watershed (CT1-1 and 1-3 – both with important plant communities).
- Instream habitat quality is reduced over the entire surveyed segment, with no high quality habitat, 15 percent slightly modified, 31 percent moderately modified, and 54 percent severely degraded.
- In Cattle Creek, beavers are an integral part of healthy riparian and instream habitat. In those few areas where beaver remain active, riparian and instream functions, including support of diverse wildlife communities, are preserved.
- Brown trout dominate the lower reaches and are co-dominant with brook trout throughout the rest of the sub-watershed.
- Headwater reaches of the sub-watershed, above the SHI surveyed segment, are in good condition and suitable for Colorado River cutthroat trout.

Data Gaps

A number of gaps in information for the sub-watershed limit the ability of this report to draw certain in-depth and/or site-specific conclusions about watershed resources. These gaps include:

- Stream gage on Cattle Creek to evaluate flows and administer the Colorado Water Conservation Board instream flow right on lower Cattle Creek;
- Evaluation of groundwater hydrology in the sub-watershed;
- Information on the effects of pumping on groundwater and surface water supplies;
- Recent water-quality data for the mid- and upper parts of the sub-watershed (water-quality data collection occurs only at one site at the mouth);
- Recent water-quality data for the following constituent groups:
- Continuous stream flow – to help characterize water-quality conditions
- Specific conductance – to establish sources of dissolved material and help describe other water-quality conditions
- Suspended sediment – to help evaluate the potential for ecosystem impairment from habitat disruption, temperature changes, or increased runoff of sediment-bound chemicals;
- Recent data on groundwater-quality;
- Upland and riparian bird communities surveys;
- Data on upland habitat conditions; and
- Herpetofauna and fish distribution data.

5. Next Steps

The State of the Watershed Report is the result of many months of labor by a host of people including experts in the field of water resources and regular citizens. It is the first step in creating a comprehensive, practical, broadly-accepted Watershed Plan for the Roaring Fork Watershed. The report is based on the premise that we need to know about existing conditions before planning how best to use, conserve, restore, and develop those resources. The goal was to create a valuable stand-alone document representing the accumulated knowledge about the Roaring Fork Watershed, which can act as a common reference for resource managers and private citizens in the future. This report puts us, as a community, in position to translate the mass of its data and findings into action in the form of a Watershed Plan that will be the product of Phase II of the watershed planning process.

In addition to the above goals, the State of the Watershed Report is intended to catalog and analyze the water resources and needs within the watershed, using existing data sources. This body of information will provide the basic data needed to develop strategies and priorities for future study and management of the watershed in Phase II of the Roaring Fork Watershed Plan. Phase II will include a set of goals and objectives developed through citizen input and in consultation with governments and water managers who have an interest in the water resources of the Roaring Fork Watershed. Phase II of the Plan will produce recommendations on critical issues identified in the report. Although the exact nature of those recommendations cannot be predicted at this time, they might address such issues as:

- The potential impact of increased transmountain diversions on local water quantity and quality,
- The projected impacts of residential and commercial growth and changing land uses on local water resources and riparian areas,
- Local wildlife habitat, wildlife populations, and ecosystem components that might be threatened due to changing water uses,
- Trends in domestic, agriculture, recreation, instream, and industrial water uses and conservation,
- Trends in water quality,
- Current amounts of consumptive and non-consumptive uses in comparison to supply, and
- The impact of climate change on local water resources and implications for water managers.

In addition, Phase II of the Plan will include recommendations to local water planners, managers, and governments regarding future water management policies and activities. Those recommendations will contribute to the accomplishment of the Plan's goals and objectives. Recommendations might address the following:

- Water conservation measures to be adopted by major water users and suppliers,
- Cooperative management activities or policies that could be adopted by water users or agencies,
- Drought management policies,
- Stream and lake setback standards,
- Standards to protect water resources from related impacts of construction activities

- Recommendations for construction, re-operation, rehabilitation, or enlargement of existing water storage and management infrastructure,
- Stormwater treatment standards,
- Water rights acquisition programs,
- Specific water development projects aimed at meeting the Plan's goals and objectives,
- Further studies or follow-up projects,
- Education and outreach opportunities,
- Riparian and instream restoration projects, and
- Implementation and monitoring strategies.

It is important to note that recommendations contained in the Watershed Plan will be reviewed to assure their consistency and compatibility with existing state water laws and water rights. The recommendations will not seek to overturn, subvert, or challenge those laws and rights, but will instead suggest ways in which water management can be improved within the context of those laws and rights. Recommendations will be developed in a cooperative, collaborative process that will emphasize consensus and compatibility with existing policies and regulations.

The process for creating the Watershed Plan will include the following elements:

- A series of public meetings to present the State of the Watershed Report to the public and local government officials and to solicit discussion and debate on the report's findings;
- The convening of a Technical Committee, made up of water resource experts and professionals, that will help to assess the practical, technical, legal, and scientific validity of the Plan's goals, objectives and recommendations;
- Meetings with local elected officials; local, regional, state, and federal water and land managers; and private water managers to review, discuss, and reach consensus on Plan recommendations that are mutually supportive and practical; and
- Composition of a narrative report including goals and objectives, recommended actions, implementation strategies, monitoring programs, and future studies.

Phase II of the Roaring Fork Watershed Plan will begin immediately following the release of the State of the Watershed Report. It will be less data-driven than Phase I and will require an ongoing effort by involved individuals, agencies, governments, and organizations if it is to succeed. The process will be overseen by the Ruedi Water and Power Authority, as was Phase I. Primary project management will be undertaken by the Roaring Fork Conservancy and its subcontractors. We invite readers of this State of the Watershed Report to check local media and relevant websites (including the site of Roaring Fork Conservancy, http://www.roaringfork.org and the Ruedi Water and Power Authority http://www.rwapa.org) for further information and for opportunities to participate in Phase II.

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7.0 Acronyms, abbreviations, and glossary

ACEC	Area of Critical Environmental Concern
ACOE	Army Corps of Engineers
AF	acre-feet
AF/Ac/Yr	acre-feet per acre per year
AFY	acre-feet per year
AGCI	Aspen Global Change Institute
ATV	all-terrain vehicle
AVLT	Aspen Valley Land Trust
AWUDS	USGS Aggregate Water-Use Data System
BLM	Bureau of Land Management
BOR	U.S. Bureau of Reclamation
BWCD	Basalt Water Conservancy District
CAC	Conservation Area of Concern
CAP	Conservation Action Plan
C-BT	Colorado Big Thompson Project
CDNR	Colorado Department of Natural Resources
CDOW	Colorado Division of Wildlife
CDPHE	Colorado Department of Public Health and Environment
CDPOR	Colorado Department of Parks and Outdoor Recreation
CDSS	Colorado Decision Support System
CDWR	Colorado Division of Water Resources
cfs	cubic feet per second
CGS	Colorado Geological Survey
CNHP	Colorado Natural Heritage Program
Collaborative	Roaring Fork Watershed Collaborative Water Group
Conservancy	Roaring Fork Conservancy
CPR	Conserve, Protect, Restore
CRCT	Colorado River cutthroat trout
CRWCD	Colorado River Water Conservation District
CU	consumptive use
CWA	Clean Water Act
CWCB	Colorado Water Conservation Board
CWT	Colorado Water Trust
DOLA	Colorado Department of Local Affairs
DRMS	Division of Reclamation, Mining, and Safety
EA	Environmental Assessment
EIS	Environmental Impact Statement
ELOHA	Ecological Limits of Hydrologic Alteration
EPA	U.S. Environmental Protection Agency
EQR	Equivalent Residential Unit
ESA	Endangered Species Act
ESRI	Environmental Systems Research Institute, Inc.
ESWM	Ecologically Sustainable Water Management
FEMA	Federal Emergency Management Agency

FERC	Federal Energy Regulatory Commission
FLPMA	Federal Land Policy and Management Act
Forest Plan	2002 White River Land and Resource Management Plan
Fry-Ark	Fryingpan-Arkansas Project
GHG	greenhouse gas
GIS	Geographic Information System
gpcd	gallons per capita per day
gpd	gallons per day
GSFO	Glenwood Springs Field Office (BLM)
HB-1177	Colorado for the 21st Century Act
HUP	Historic Users Pool
IBCC	Intrabasin Compact Committee
IHA	Indicators of Hydrologic Alteration
IPCC	Intergovernmental Panel on Climate Change
IPTDS	Independence Pass Trans-mountain Diversion System
ISF	Colorado Water Conservation Board (CWCB) Instream Flow Program appropriations
IWR	irrigation water requirement
maf	million acre-feet
mgd	million gallons per day
Multi-Objective Study	Roaring Fork and Fryingpan Rivers Multi-Objective Planning Project
M&I	municipal and industrial
NDIS	Natural Diversity Information Source
NEPA	National Environmental Policy Act
NHD	National Hydrography Data
NRCS	National Resource Conservation Service
NWCCOG	Northwest Colorado Council of Governments
NOAA	National Oceanic and Atmospheric Administration
PBO	Programmatic Biological Opinion
PCA	Potential Conservation Area
PSOP	Preferred Storage Options Plan
River District	Colorado River Water Conservation District
RICD	Recreational In-channel Diversion
RWAPA	Ruedi Water and Power Authority
RMP	Resource Management Plan
SCCC	Snowmass/Capitol Creek Caucus
SEO	State Engineer's Office
SHI	Stream Health Initiative
SNOWTEL	Snowpack Telemmetry
SRES	Special Report on Emissions Scenarios
SSI	self-supplied industrial
StatMod	Stream Simulation Model
Southeastern	Southeastern Colorado Water Conservancy District
SWE	snow water equivalent
SWSI	Statewide Water Supply Initiative

TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TRT	Technical Roundtable
TVS	Table Value Standards
Twin Lakes	Twin Lakes Reservoir and Canal Company
UCRB	Upper Colorado River Basin
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
West Divide	West Divide Water Conservancy District
WQCC	Water Quality Control Commission
WQCD	Water Quality Control Division
WRCC	Western Regional Climate Center
WSA	Wilderness Study Area
WSL	water supply limited
WSR	Wild and Scenic River
WWTP	wastewater treatment plant

Glossary

Aggradation – The process by which material is deposited within a channel as a result of sediment overloading
Allochthonous – Organic matter which arises by photosynthesis from outside the stream ecosystem, but becomes an input to the stream.
Anion – A negatively charged ion, which has more electrons than it has protons.
Autochthonous – Organic matter input which arises by photosynthesis from within a stream ecosystem.
Backwater pools – Pools which are found along the stream edge and are caused by eddies behind large obstructions such as roots, boulders and root wads.
Bedload – That portion of the total sediment load whose immersed weight is carried by the solid stream bed.
Bedrock-controlled channels – Channels that are fixed in bedrock conferring long-term channel stability.
Benthic – Of, relating to, or occurring at the bottom of a body of water.
Biome – A major biotic community characterized by the dominant forms of plant life and the prevailing climate
Braided stream channel – Channel which is characterized by multiple channels that divide and rejoin and is indicative of an unstable stream ecosystem.
Call – Demand for administration of water rights, In times of water shortages, the owner of a decreed water right will make a "call" for water. The call results in shut down orders against decreed water uses and decreed junior water rights as necessary to fill the beneficial use needs of the decreed senior calling rights.
Carr – Shrubland community composed of species such as willow, alder and birch growing in wet soil.
Cation – A positively charged ion, which has fewer electrons than protons.

Censored Value – When a water quality constituent is reported as less than the method reporting limit, this constituent value is called a “censored value.”
Channel alteration – A measure of anthropogenic changes to the shape of the stream channel; includes channelization, clearing and snagging, selective snagging, riprapping, bank stabilization, realignment, lining, and dredge and fill activities. Channel alteration is present when artificial embankments, riprap, and other forms of artificial bank stabilization or structures are present; when the stream is very straight for significant distances; when dams and bridges are present; and when other such changes have occurred.
Channelization – Artificial straightening, stabilizing, or diverting of channels, resulting in a straighter and deeper channel.
Chitrid Fungus – A fungus (*Batrachochytrium dendrobatidis*) that causes chytridiomycosis a highly infectious disease of amphibians.
Colluvium – Deposits that collect at the foot of a steep slope or cliff.
Confined channel – A channel which is in continuous or repeated contact with the outside of major meander bends.
Conservation population – Reference to Colorado River Cutthroat Trout. If a population is greater than 90% genetically pure, it is considered a “Conservation Population” according to the Colorado River Cutthroat Trout Conservation Team.
Consumptive use – The part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.
Critical habitat – According to U.S. Federal law, the ecosystem upon which endangered and threatened species depend.
Cut bank – The concave (outer) bank located on the outside of meander bends.
Drought – A period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance
Duration – The length of time that a specific flow condition lasts such as the duration of extremely low flow conditions
Ecosystem – The biotic community and its abiotic environment functioning as a system.
Effluent – An outward movement of water, as a stream from a lake or waste water from a treatment plant.
Embeddedness – Refers to the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become embedded, the surface area available to macroinvertebrates and fish (shelter, spawning, and egg incubation) is decreased.
Entrenched channel – A channel in which the stream bank is in continuous contact with the valley walls or terraces.
Epifauna – Animals that live upon the surface of sediments.
Eutrophic – Having waters rich in mineral and organic nutrients that promote a proliferation of plant life, especially algae, which deplete oxygen content and often causes the extinction of other organisms
Floodplain – Lowlands bordering a stream which are subject to recurrent flooding. Flood plains are composed of sediments carried by rivers and deposited on land during flooding.
Flow status – The degree to which the channel is filled with water.
Frequency – How often a particular condition, such as high pulse or flood, has occurred
Frost Heave – Upthrust of ground or pavement caused by the freezing of moist soil

Gradient – The degree of inclination, ascent or descent.
Groundwater – That portion of the water below the ground surface that is under greater pressure than atmospheric pressure; that part of the subsurface that is in the zone of saturation.
Groundwater recharge – The movement, usually downward, of surface water or precipitation into the groundwater system.
Grus – An accumulation of angular, coarse-grained fragments resulting from the granular disintegration of crystalline rocks.
Guzzling – As used here refers to the effect that downstream channelization has on the previous upstream reach. Downstream reach channelization impacts the previous upstream reach by increasing stream velocity which results in changes to the upstream channel such as excessive bank erosion, downcutting and channel widening.
Histogram – A graphical display of tabulated frequencies showing what proportion of cases fall into each of several categories.
Hydric soil – Soil that is saturated or flooded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation.
Hydrology – The properties, distribution, and circulation of water.
Hydrologic alteration of flow alteration – Change in stream flow
Hydrologic modification or Hydromodification – Direct modifications to stream channels that alter stream gradient, sinuosity, shape, and/or channel structure.
Hypolimnetic – The layer of water in a thermally stratified lake that lies below the thermocline, is non-circulating, and remains perpetually cold.
Hypoxia – A deficiency of oxygen reaching bodily tissues resulting in an impairment of cellular respiration
Interstitial space – Area between the rocks in the bottom of a stream channel
Krummholz – At the tree line, tree growth is often very stunted, with the last trees forming low, densely matted bushes. If it is caused by wind, it is known as krummholz formation, from the German for 'twisted wood'.
Left Bank – Facing downstream (SHI DATA)
Lithological – Referring to the physical character of rock or rock formations
Macroinvertebrates - An animal lacking a backbone and generally visible to the unaided eye or generally larger than 0.5 mm at its greatest dimension.
Magnitude – The amount of water passing a fixed point in the river at a specific point in time (e.g. how big is the high flow pulse or flood?)
Meander – A stream reach that includes one complete bend, curve, or loop.
Mesic – Adapted or pertaining to an environment with a balanced supply of moisture
Municipal and Industrial – SWSI definition-all publicly-supplied and self-supplied residential, commercial, institutional, and industrial water uses
Neotropical migrant – Bird species that nest and reproduce in North America and then migrate to Mexico, Central or South America to overwinter.
Node – A physical location where developed and pre-devloped flows were simulated. The Upper Colorado River Basin Water Resource Planning Model dataset (2007), was developed by the CWCB and CDWR under the Colorado Decision Support System (CDSS).
Non-Conservation population – Reference to Colorado River Cutthroat Trout
Nonpoint source pollution (NPS) – Pollution that is not discharged through pipes or a point source but rather originates from a multitude of sources over a large area. Common sources of

non-point pollution include failing septic systems, improper animal-keeping practices, forest practices and urban and rural runoff.

Overbanking – Refers to streamflow that moves out of the channel and onto the floodplain or into the riparian habitat.

Periphyton – A large assortment of unicellular and filamentous algae that are sessile and attach to cobble, gravel, submerged logs, large plants and other substrates.

Phreatophytes – A deep-rooted plant that obtains its water from the water table or the layer of soil just above it.

Pocket water – Pockets of calmer water created where fast current rushes around boulders and other obstructions.

Point bar – Sediment deposited along the inside margin of bends or meanders in streams and rivers caused by the reduced velocity along the inner radius.

Point source – A pipe, channel, conduit or other discrete conveyance from which pollutants are discharged.

Potential – As used here, the term refers to the highest ecologically stable state possible for a stream reach, without significant human interference. Potential is influenced by the natural interactions of hydrology, soils, and climate affecting the reach.

R2Cross – A method to determine streamflow requirements for habitat protection. R2Cross is used by the CWCB in the development of instream flow recommendations for Colorado's Instream Flow Program.

Rate of change – How quickly the flow changes, as flows rise or fall from day-to day

Redd – A trout redd is the nest that trout use to both reproduce and incubate the young.

Return flow – Water that reaches a ground-water or surfacewater source after release from the point of use and thus becomes available for further use.

Right Bank – Facing downstream (SHI DATA)

Riffle – Shallow water area with rapid current and with flow broken by a substrate of gravel or rubble.

Riparian Areas – Ecosystems that occur along watercourses and water bodies. These areas have high water table and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.

Riparian Vegetation – Any extra-aquatic vegetation that directly or indirectly influences the stream environment.

Riprapping – The placement of irregular permanent material such as rock or boulders in critical areas along the stream to protect streambanks against excessive erosive forces.

Run – A relatively deep stretch of water which is fast flowing with an unbroken surface.

Salmonid – Belonging to the family Salmonidae, which includes salmon, trout, and whitefish

Stability rating – As used here refers to vegetation with deep, binding root masses that are capable of stabilizing streambank soils to prevent excessive erosion. 1=least stability rating, 10= greatest stability rating

Sediment – Fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits and is transported by, suspended in, or deposited by water. Certain contaminants, including bacteria, tend to collect on and adhere to sediment particles.

Sediment deposition - Measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms.

Self-supplied Industrial Use – SWSI definition includes snowmaking facilities and identified facilities with significant water use.
Self-supplied water use – Water withdrawn from a groundwater or surface-water source by a user rather than being obtained from a public supply.
Sinuosity – The ratio of the length of the channel in a given curve to the wavelength at the curve.
Snow Water Equivalent (SWE) – Depth of liquid water that would result from melting snow. SWE is the product of snow depth and density.
Stenothermal – Capable of living or growing only within a limited range of temperature
Stormwater runoff – Rainfall or snowmelt that runs off over the land surface, potentailly carrying pollutants to streams, lakes, or reservoirs.
Stream – All sizes of flowing water channels, longitudinally linked drainage systems extending from the most meager headwater beginnings to an arbitrarily identified end, mouth or estuary.
Stream order – A system of stream classification where a first-order stream has no tributaries, a second-order stream is formed by the confluence of two first-order streams and so on.
Substrate – The physical properties components and particles of materials with in the channel.
Superfund – Superfund is the common name for the United States environmental policy officially known as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 U.S.C. § 9601–9675), enacted by the United States Congress on December 11, 1980. The Superfund law was created to protect people, families, communities and others from heavily contaminated toxic waste sites that have been abandoned. Superfund provides broad federal authority to clean up releases or threatened releases of hazardous substances that may endanger public health or the environment.
Timing –The time of year at which particular flow events occur, such as the timing of annual floods or low flow conditions
Thermocline – A layer in a large body of water, such as a lake, that sharply separates regions differing in temperature, so that the temperature gradient across the layer is abrupt.
Table Value Standards – Numerical water quality standards based on general scientific research, rather than on site-specific conditions.
Tuff – Volcanic ash
Turbidity – A measure of the amount of material suspended in the water. High levels of turbidity over extended periods are harmful to aquatic life.
Water quality – The biological, chemical and physical conditions of a water body; a measure of a water body's ability to support life.
Water year – The water year deals with the surface-water supply for a 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 2006, is called the "2006 water year." The water year is used as a basis for processing streamflow and other hydrologic data and selected to begin and end during a relatively dry season.
Watershed – The geographic region within which water drains into a particular river, stream or body of water. A watershed includes hills, lowlands, and the body of water into which the land drains.

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