State of the Watershed: Water Quality of Boulder Creek, Colorado

By Sheila F. Murphy

Prepared in cooperation with the City of Boulder, Colorado

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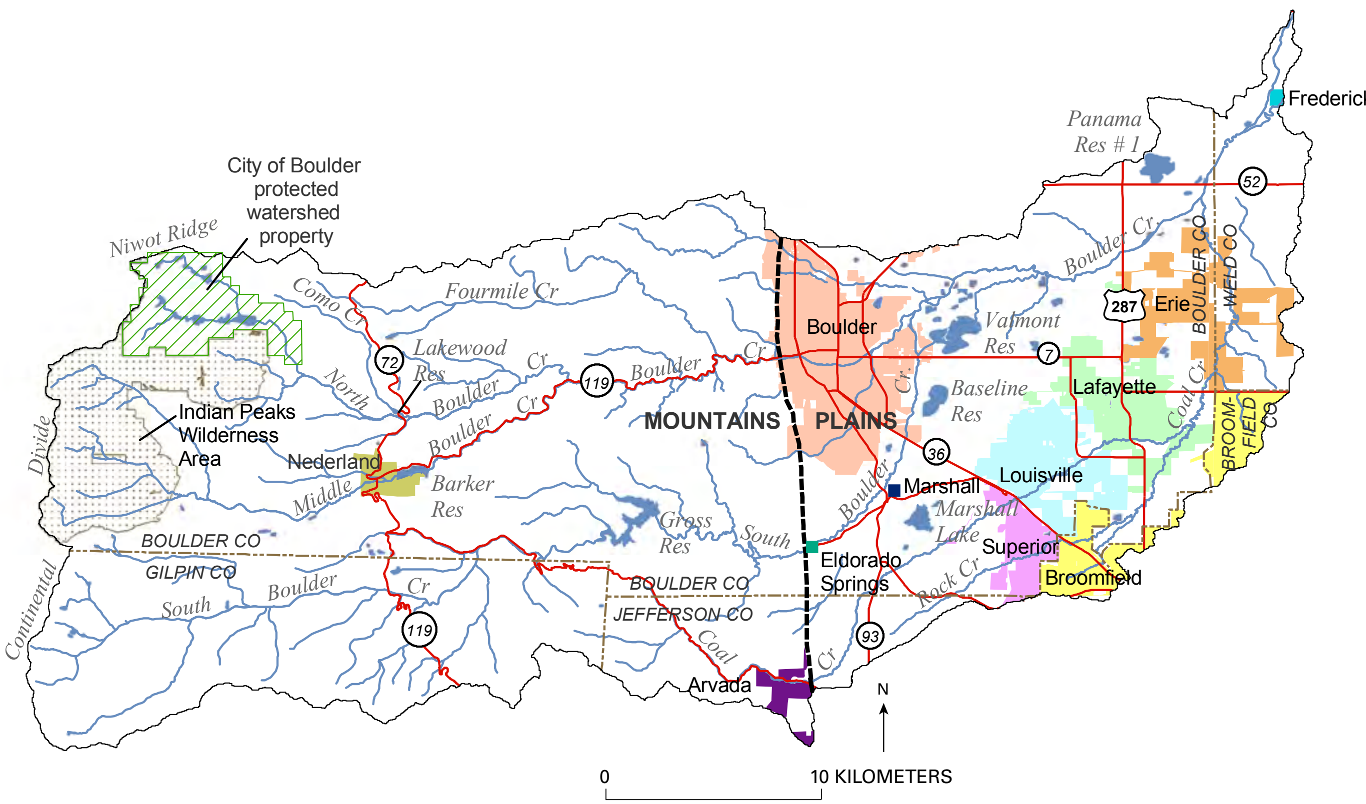
Contents

Welcome to the Boulder Creek Watershed

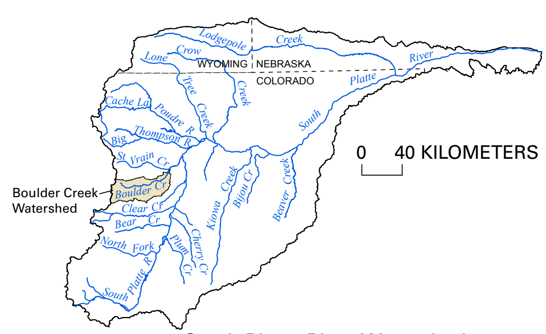
The Boulder Creek Watershed is approximately 1,160 square kilometers (447 square miles) in area and is located in the Front Range of the Colorado Rocky Mountains, east of the Continental Divide. The watershed includes all the land area that drains water into Boulder Creek. The watershed has great variation in geology, climate, and land cover. Tributaries of Boulder Creek include North, Middle, and South Boulder Creeks, Fourmile Creek, Coal Creek, and Rock Creek, along with several smaller streams. These streams generally flow from west to east. Boulder Creek empties into Saint Vrain Creek, which empties into the South Platte River. The water in Boulder Creek eventually reaches the Mississippi River and the Gulf of Mexico. The communities of Boulder, Louisville, Lafayette, Erie, Superior, and Nederland are in the watershed, along with parts of Arvada, Broomfield, and Frederick. In 2000, about 185,000 people lived in the Boulder Creek Watershed (U.S. Census Bureau, 2001).

A reliable source of high-quality water is important for drinking-water supply, recreation, aquatic life, and agriculture. In the semiarid environment of the Colorado Front Range, water resources are limited, and waterways are subject to stress by competing uses. The population of the five largest communities in the watershed (Boulder, Lafayette, Louisville, Superior, and Erie) grew by 36 percent from 1990 to 2000, increasing demands on water resources. This report, prepared by the U.S. Geological Survey in cooperation with the City of Boulder, presents the state of water quality in the Boulder Creek Watershed in 2005 and how it has changed over the past 160 years, and identifies potential future water-quality concerns.



Boulder Creek Watershed (from Murphy and others, 2003)

Mississippi River Watershed



South Platte River Watershed

Environmental Setting

The Boulder Creek Watershed lies within two physiographic provinces. The mountainous upper watershed is part of the Southern Rocky Mountains Province and is characterized by deep, steeply sloping valleys. The flatter, lower watershed is part of the Colorado Piedmont Section of the Great Plains Province and slopes gently to the northeast. The two regions differ substantially in geology, climate, and land cover.

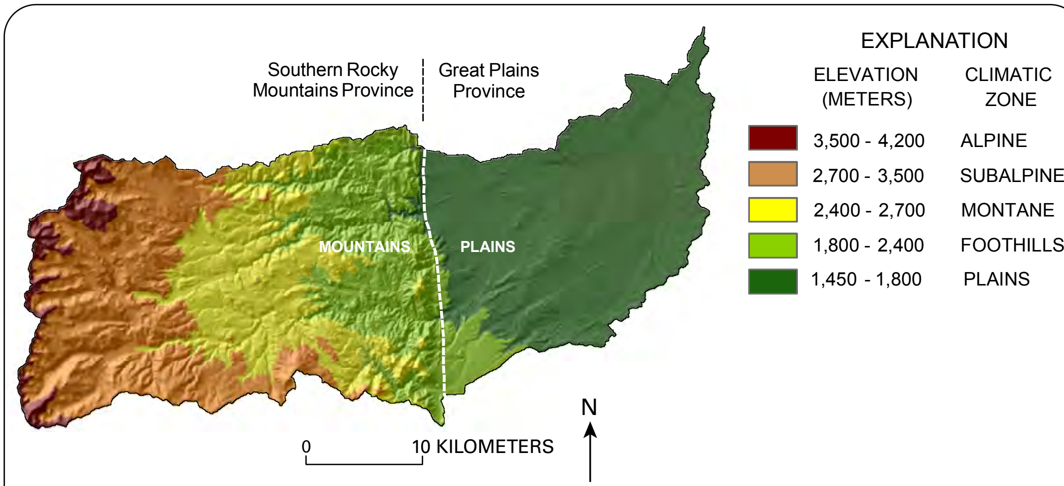
Near the Continental Divide

Urban corridor

Agricultural reach of Boulder Creek

Physiography

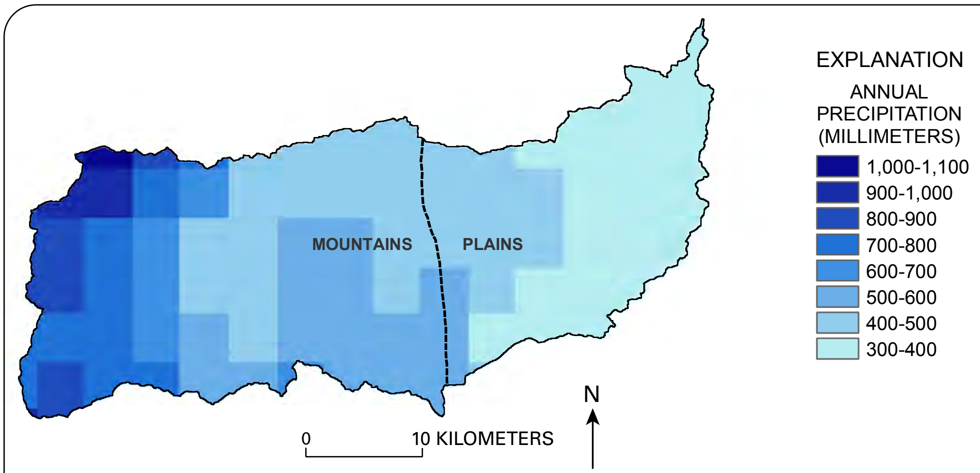
Elevations in the watershed range from 4,120 meters (13,520 feet) at the Continental Divide to 1,480 meters (4,860 feet) at the confluence of Boulder Creek and Saint Vrain Creek. The great variation in topography produces five distinct climatic/ecological zones: alpine, subalpine, montane, foothills, and plains.



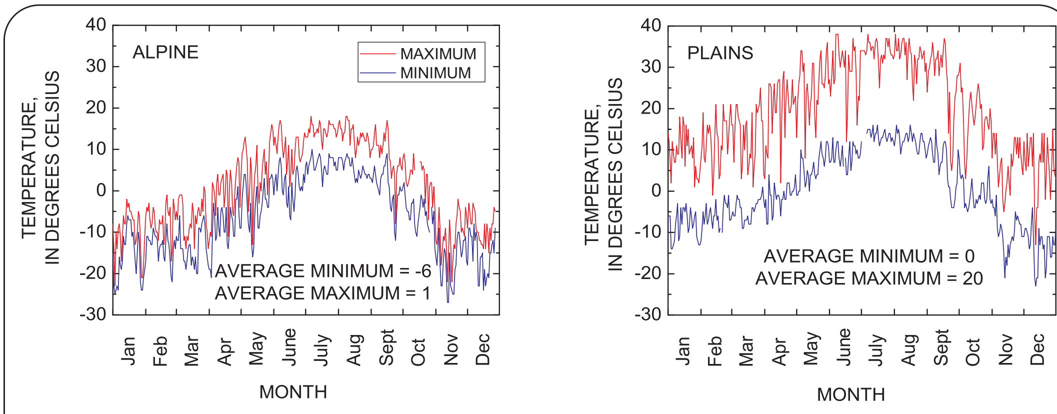
Elevation and climatic/ecological zones (data from U.S. Geological Survey, 2005a; a few mesas are included in the plains climatic/ecological zones despite higher elevations).

Climate

Temperatures vary widely across the climatic/ecological zones of the watershed; generally, temperature increases and the difference between minimum and maximum temperatures increases with decreasing elevation. Most precipitation falls as snow in the mountains during winter and spring. Melting of snow produces high flows in Boulder Creek and its tributaries in spring and summer.



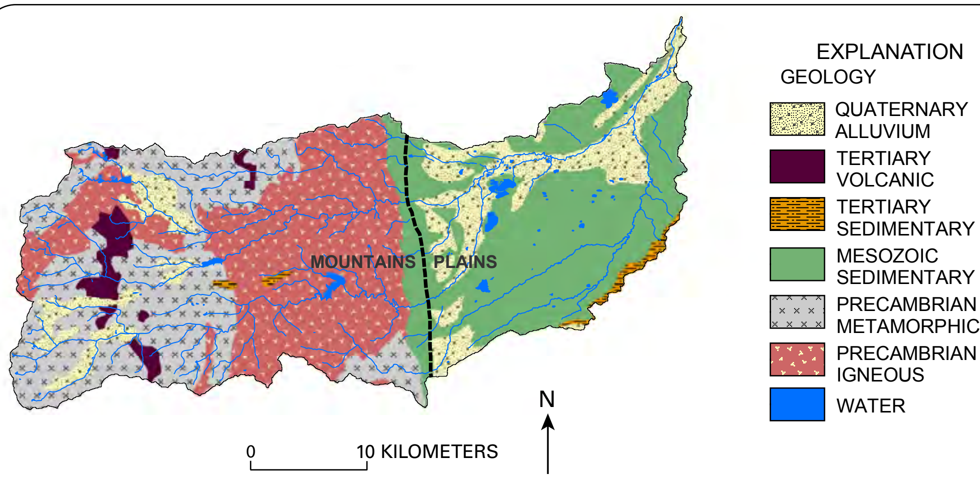
Estimated average annual precipitation (based on a model from Daly and others, 1994 for 16-square-kilometer grid cells).



Air temperatures in the alpine and plains in 2000 (data from Niwot Ridge Long-Term Ecological Research Program, 2002, and National Oceanic and Atmospheric Administration, 2002).

Geology

The upper watershed is underlain by 1.4–1.8 billion-year-old metamorphic and granitic bedrock, with deposits of gold, silver, tungsten, and other metals that were emplaced 30–60 million years ago. The lower watershed is underlain by 65–300 million-year-old sedimentary rocks, including shale, sandstone, limestone, and coal-bearing deposits (Murphy and others, 2003). Mountain-building events that occurred about 70 million years ago caused steeply dipping rock layers at the edge of the mountain front. Ridges and valleys reflect subsequent erosional processes. Metal and coal mining fueled settlement of the watershed in the 1860s. Today, sand and gravel is mined along Boulder Creek, and oil and natural gas are extracted in the eastern part of the watershed.



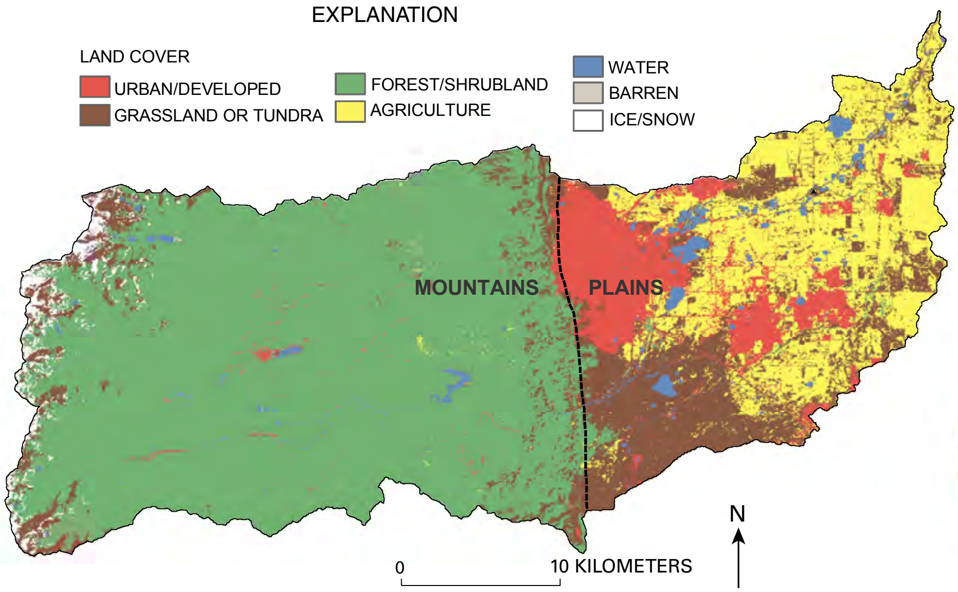
Geology (from Tweto, 1979, and Green, 1992).

Land Cover

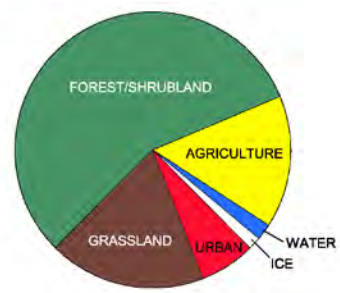
The upper watershed consists primarily of forest, shrubs, and alpine tundra. The lower watershed consists of grassland, agricultural land, and urban/developed land. Agricultural lands primarily consist of pasture and fields of alfalfa, wheat, corn, and barley. Urbanized land of the plains and foothills has increased substantially in the past 30 years in areas that were previously forest, grassland, or agricultural land. Reservoirs have increased in number and size, and sand and gravel quarries along Boulder Creek have filled with water and formed ponds.

Upper watershed

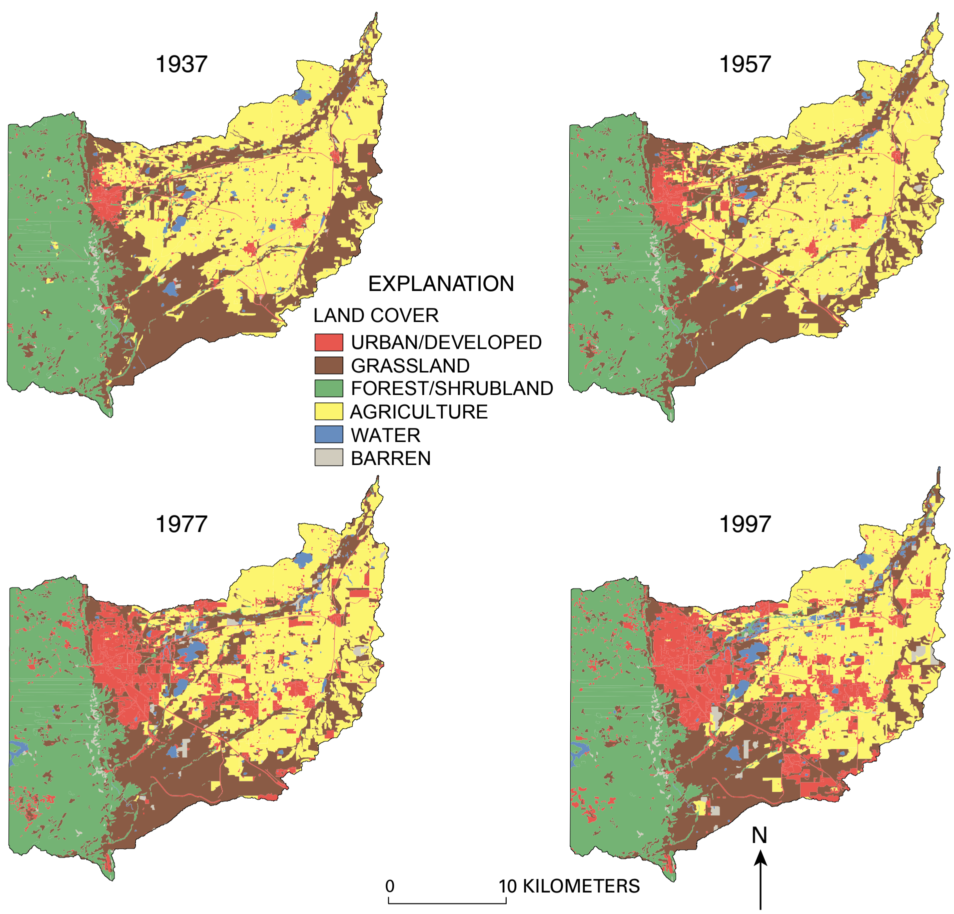
Lower watershed



Land cover in 1992 (data from USGS, 2003).



Relative percentages of land cover in 1992 (data from USGS, 2003).

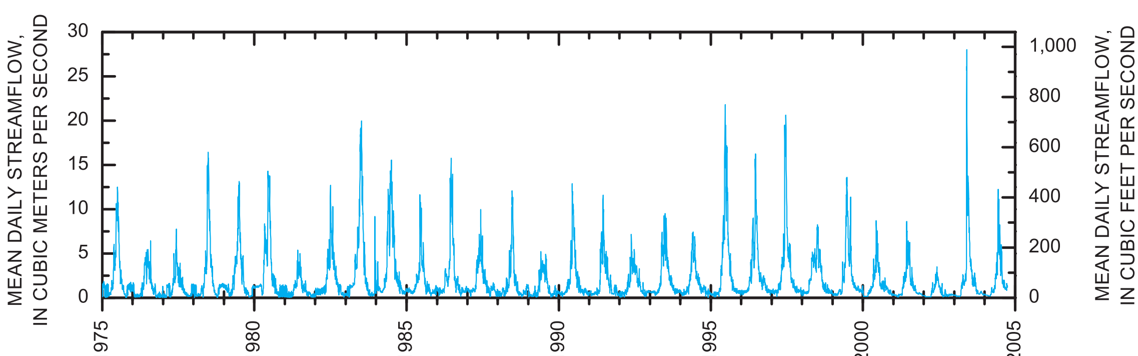


Land cover of the plains and foothills over time (data from USGS, 1998).

Hydrology

Streamflow in Boulder Creek originates primarily as snowmelt near the Continental Divide, so discharge varies seasonally and annually depending on snowpack depth and air temperature. Low-flow conditions occur from October to March; high-flow conditions occur from May to July and usually peak in June. Discharge (flow rate) of Boulder Creek and its tributaries is recorded by several streamflow-gaging stations. Stream discharge data are important in allocating water rights, estimating flood potential, and evaluating long-term changes in hydrology and water quality. The Orodell streamflow-gaging station, located on Boulder Creek in Boulder Canyon, has been recording discharge since 1906.

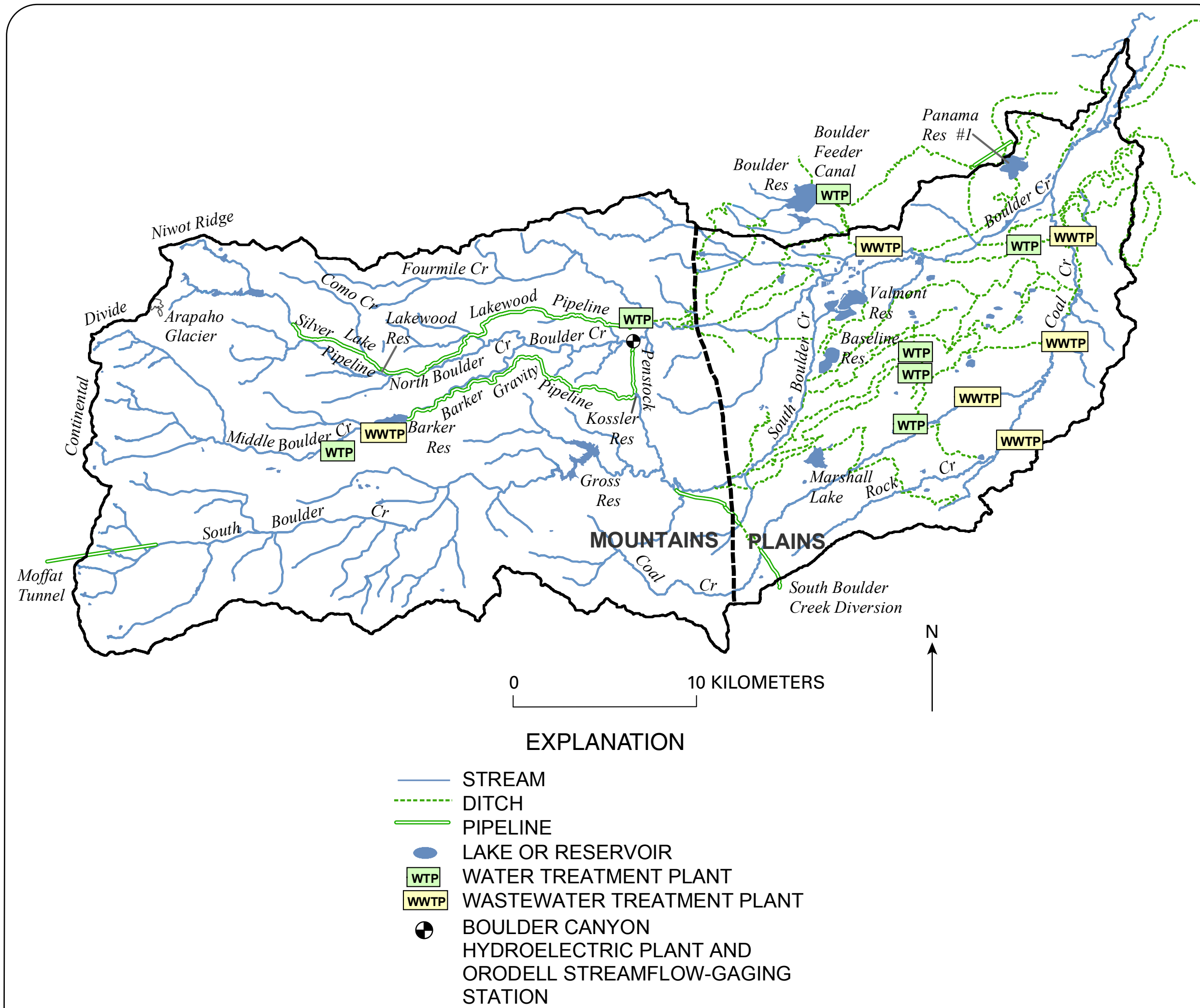
Orodell streamflow-gaging station on Boulder Creek



Discharge of Boulder Creek at the Orodell streamflow-gaging station, 1975–2004 (data from USGS, 2004, and Colorado Division of Water Resources, 2005).

Boulder Creek and its tributaries are part of a complex water-management system. Diversions remove water from streams for municipal, industrial, and agricultural use. Reservoirs store water for a reliable year-round supply. Water is brought into and out of the watershed by transbasin diversions. Wastewater treatment plants contribute treated effluent that can account for a substantial portion of flow in streams in the lower watershed during low-flow conditions.

Boulder Creek at Idaho Creek Ditch



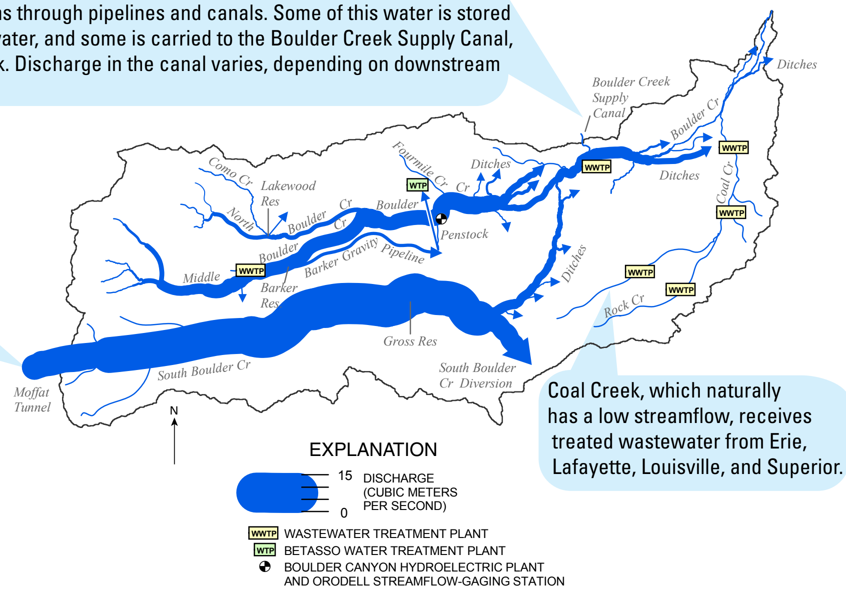
Hydrologic features (data from USGS, 2002).

How does water management affect the flow of Boulder Creek?

The many water diversions and returns in the watershed lead to complex temporal and spatial variations in discharge, affecting both the quantity and quality of water in Boulder Creek and its tributaries.

The Colorado-Big Thompson Project conveys water from the Colorado River Basin to many Front Range communities and farms through pipelines and canals. Some of this water is stored in Boulder Reservoir for drinking water, and some is carried to the Boulder Creek Supply Canal, which discharges to Boulder Creek. Discharge in the canal varies, depending on downstream delivery requests.

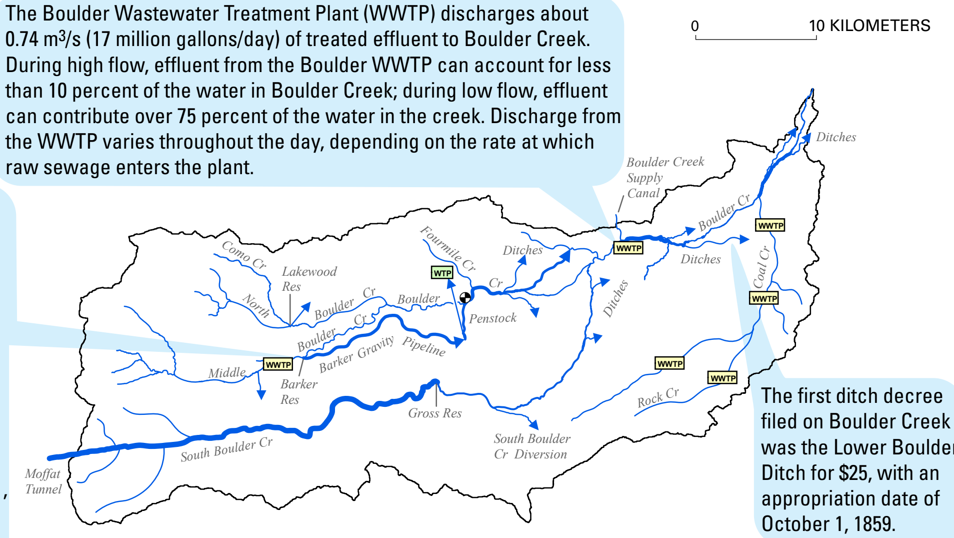
The City of Denver diverts water from the Williams Fork and Fraser River Basins to South Boulder Creek through the Moffat Tunnel. The diverted water, along with some native water, is stored in Gross Reservoir and then conveyed by South Boulder Creek and the South Boulder Creek Diversion Canal out of the watershed to Denver's Moffat Water Treatment Plant.



Coal Creek, which naturally has a low streamflow, receives treated wastewater from Erie, Lafayette, Louisville, and Superior.

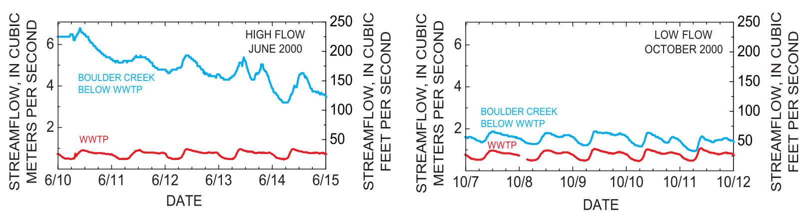
The Boulder Wastewater Treatment Plant (WWTP) discharges about 0.74 m^3/s (17 million gallons/day) of treated effluent to Boulder Creek. During high flow, effluent from the Boulder WWTP can account for less than 10 percent of the water in Boulder Creek; during low flow, effluent can contribute over 75 percent of the water in the creek. Discharge from the WWTP varies throughout the day, depending on the rate at which raw sewage enters the plant.

Water stored in Barker Reservoir is diverted to the City of Boulder's Betasso Water Treatment Plant or the Boulder Canyon Hydroelectric Plant. Prior to 2001, Middle Boulder Creek was often dry for some distance downstream from the reservoir; hydroelectric plant discharge would make up most of the water in Boulder Creek downstream from the plant during low flow. Since being purchased by the City of Boulder in 2001, less water is being used by the hydroelectric plant, which has been in operation since 1910. Boulder now releases some water from Barker Reservoir to maintain a minimum flow in Boulder and Middle Boulder Creeks.



The first ditch decree filed on Boulder Creek was the Lower Boulder Ditch for $25, with an appropriation date of October 1, 1859.

Estimated discharge in the watershed during high flow (June 2000, top) and low flow (October 2000, bottom) (width of blue line represents discharge; data from Murphy and others, 2003, and Colorado Division of Water Resources, 2005).



Measured discharge of Boulder Creek and WWTP during high flow (June 2000) and low flow (October 2000) (data from Murphy and others, 2003).

How clean is the water in Boulder Creek?

The answer to this question depends on what one means by "clean." Water that is considered good quality for aquatic life may not be considered suitable for human consumption, and vice versa. Water that is esthetically appealing may contain invisible water contaminants. One way to assess water quality is to compare it to established standards.

Water-quality standards

The Federal Clean Water Act requires States to establish water-quality standards, which are approved by the U.S. Environmental Protection Agency (USEPA). Standards have three main components: designated use classifications, water-quality criteria, and policies to protect against degradation of water quality.

Designated uses are human and ecological uses that are officially recognized and protected. Colorado's designated use categories are:

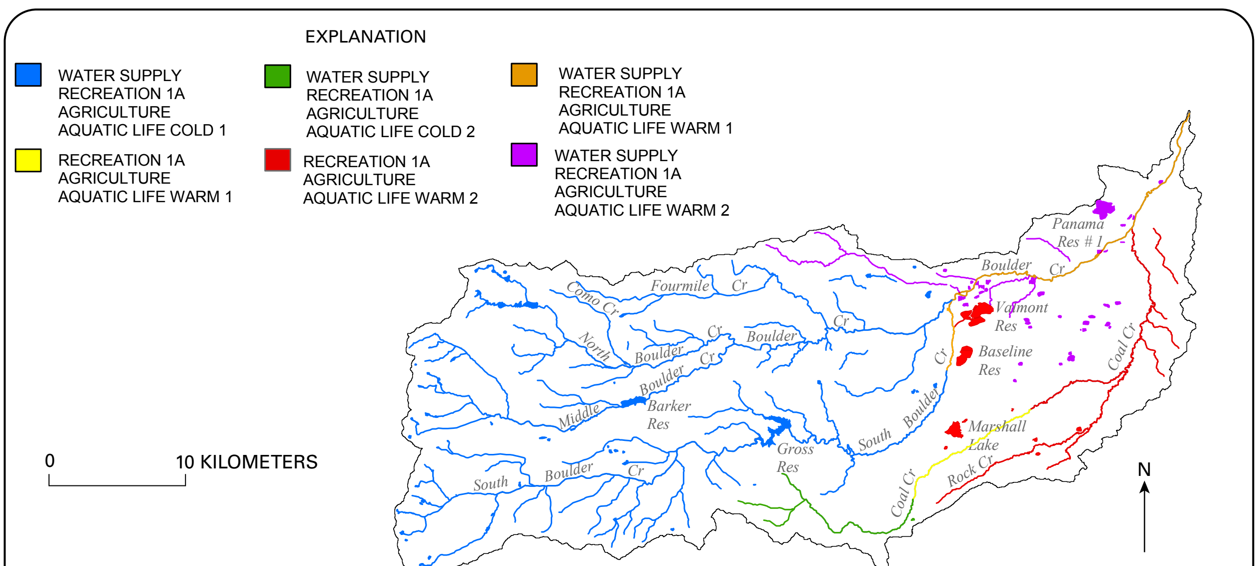
Recreation:
Class 1 - Primary Contact: Waters suitable for recreational activities when ingestion of water is likely, such as swimming, kayaking, and tubing. There are two subcategories: Class 1A (existing use) and Class 1B (potential use). ***Class 2 - Secondary Contact:*** Waters not suitable for primary contact, but suitable for recreational uses such as wading and fishing.
Agriculture:
Waters suitable for crop irrigation and for livestock drinking water.
Aquatic Life:
Class 1: Waters capable of sustaining a wide variety of aquatic life, including sensitive species. There are two subcategories: cold water and warm water. ***Class 2:*** Waters not capable of sustaining a wide variety of cold-water or warm-water aquatic life, including sensitive species, due to physical habitat, water flows, or uncorrectable water-quality conditions.
Domestic Water Supply:
Surface waters suitable for drinking-water supplies. After standard treatment, these waters will meet Colorado drinking-water regulations.

(Complete versions of Colorado standards are available from the Colorado Department of Public Health and Environment (CDPHE; 2005a)

Surface waters within a watershed are divided into segments, which are then assigned designated uses based on how the waters are currently used and what uses are desired for the future. Several designated uses have been applied to waters in the Boulder Creek Watershed. All of the waters have been classified for recreation 1A and agricultural use, and all except for parts of Coal Creek have been classified for domestic water supply (CDPHE, 2005b). Aquatic-life classifications vary, depending on water temperature and discharge.

Water-quality criteria are descriptions of the chemical, physical, and biological conditions necessary to achieve and protect a water body's designated uses. For waters with multiple designations, the criteria must support the most sensitive use (CDPHE, 2005a). There are both narrative and numerical criteria. Narrative criteria describe water-quality goals and provide protection against contaminants that do not have specific numerical standards. Numerical standards set the acceptable concentrations of specific contaminants in streams, lakes, and reservoirs. Water-quality variables for which criteria exist include physical and biological constituents (such as dissolved oxygen and fecal coliform), inorganic constituents (such as ammonia and chloride), and metals (such as arsenic and lead).

Anti-degradation policies are used to protect water quality. Colorado provides three levels of provisions: outstanding waters, for which no degradation is allowed; use-protected waters, for which degradation is allowed so long as water-quality standards are still met; and reviewable waters, for which degradation is allowed so long as no reasonable alteratives are available and water-quality standards are still met (Colorado Foundation for Water Education, 2003). In the Boulder Creek Watershed, all of the tributaries within the Indian Peaks Wilderness Area are designated as outstanding waters. In general, Boulder Creek and other tributaries in the mountains are reviewable waters, while surface waters on the plains are mostly use-protected waters (CDPHE, 2005b).



Water-quality classifications in the Boulder Creek Watershed (data from CDPHE, 2005b).

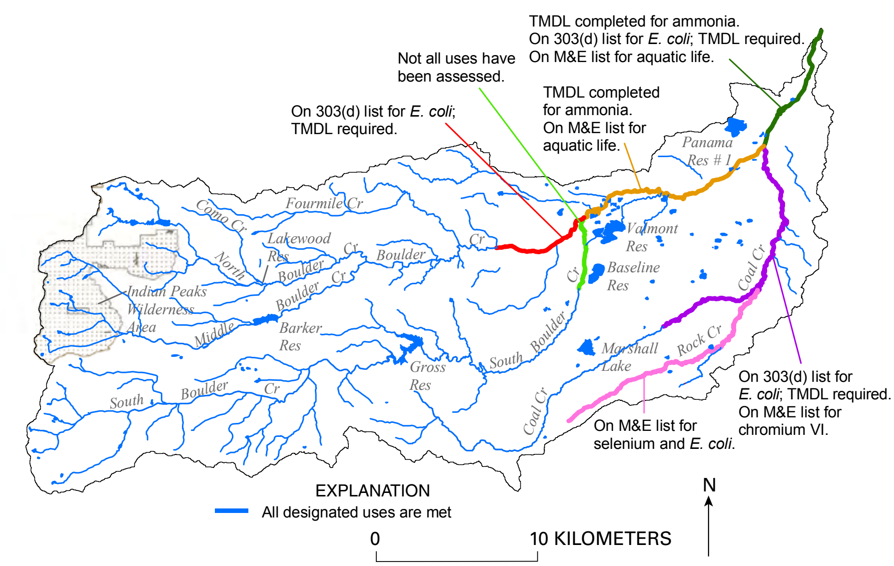
Water-quality assessment

States are required by section 305(b) of the Federal Clean Water Act to assess and report on the quality of the State's waters to Congress through the USEPA. Section 305(b) reports describe the ways a State measures water quality, the quality of water bodies in the State, and pollution-control programs. The State of Colorado 305(b) report is available from the CDPHE (2005c, d).

When credible data on the water quality of a stream or lake indicate that a standard is not met, the State proposes that the stream segment be placed on a list of impaired segments, called the "303(d) list." The Colorado Water Quality Control Commission has a public hearing to consider recommendations and adopts Colorado's 303(d) list as a State regulation. The USEPA accepts the 303(d) list from the State or can list additional segments. The 303(d) list identifies the component(s) (such as nitrate, lead, or sediment) that is (are) causing water-quality concerns for that water body. Some stream segments in the Boulder Creek Watershed have been on the 303(d) list for ammonia and *E. coli* (CDPHE, 2005c, d).

The State is required to prioritize water bodies on the 303(d) list on the basis of the severity of impairment and other factors. It will then determine the causes of the water-quality concern and allocate responsibility for the impairment. This analysis is called the Total Maximum Daily Load (TMDL) process. The State of Colorado also identifies water bodies where there is reason to suspect water-quality impairment, but uncertainty exists about data quality or the cause of impairment. These waters are placed on the Monitoring and Evaluation (M&E) List (CDPHE, 2005c, d). Some stream segments in the Boulder Creek Watershed have been on the M&E list for aquatic life, *E. coli*, selenium, and chromium VI.

Monitoring water quality of Boulder Creek



Segments not meeting designated uses in the Boulder Creek Watershed in 2005 (data from CDPHE, 2005c).

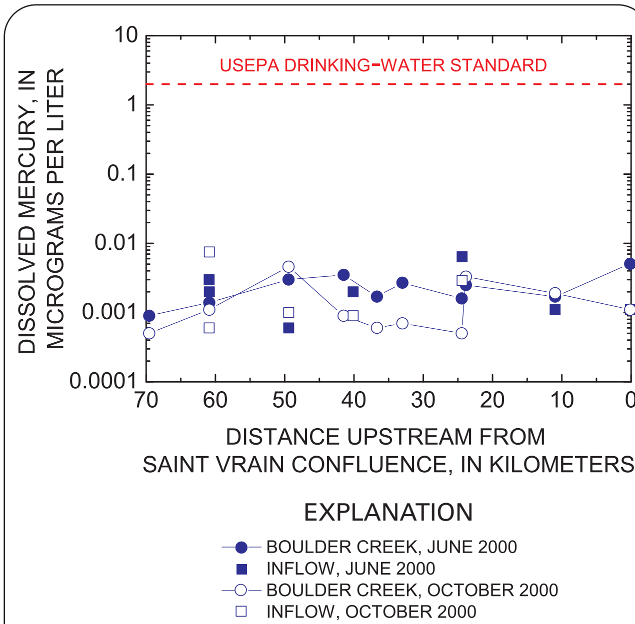
Water Quality of Boulder Creek from Top to Bottom

Water quality in the Boulder Creek Watershed varies substantially. In general, water quality is best in the high-elevation headwaters, where human activity is limited and there are few contaminant sources. Water quality declines downstream as diversions remove water from streams, population density increases, and there are more potential contaminant sources. In lower Boulder Creek, several factors affect water quality, including wastewater, urbanization, and agriculture.

Headwaters and mountains

The headwaters of the Boulder Creek Watershed originate primarily from snowmelt and ground water that has flowed through relatively unreactive bedrock and soil. Therefore, these waters typically have very low concentrations of dissolved solids, alkalinity, and nutrients compared to downstream waters (Murphy and others, 2003, chapters 3, 4, and 8; Verplanck and others, 2003). Surface waters generally have near-neutral pH values, and dissolved oxygen is at or near saturation. The City of Boulder owns a 30-km^2 (12 mi^2) protected watershed property in the headwaters of North Boulder Creek (see map on page 1); public entry is prohibited to protect this high-quality water source. Much of the headwaters of Middle Boulder Creek are within the Indian Peaks Wilderness Area, where motorized vehicles are not permitted. While direct human disturbance is limited, the headwaters are within the "airshed" of the Denver metropolitan area, where coal-fired powerplants, automobiles, and agricultural activities release contaminants (such as sulfate and nitrate) to the atmosphere. These contaminants are carried in the atmosphere to the headwaters area, and returned to the Earth in rain and snow. Deposition of nitrate and sulfate, even in low concentrations, may decrease the pH of the poorly buffered headwaters, causing changes in aquatic ecosystems (Williams and Tonnessen, 2000). Nitrate also can act as a fertilizer, changing the growth rates of plants.

Headwaters of North Boulder Creek (Arapaho Glacier at far left)

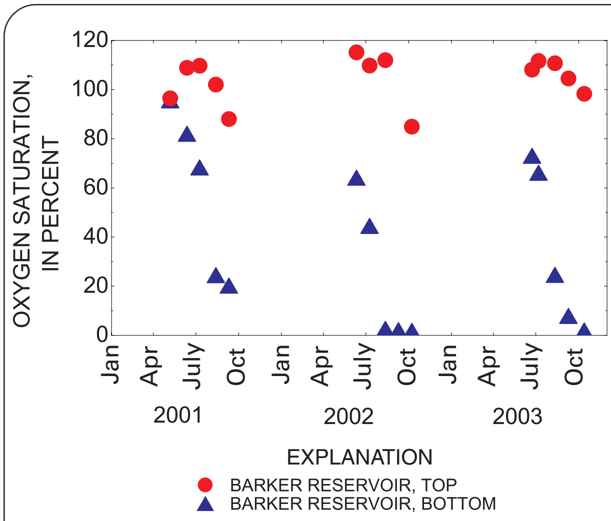


Mercury concentrations in Middle Boulder Creek/Boulder Creek and major inflows, June and October 2000, compared to USEPA drinking-water standard (note logarithmic scale; from Murphy and others, 2003, chapter 4; USEPA, U.S. Environmental Protection Agency).

The upper watershed was mined intensively in the past for gold, silver, tungsten, and other metals. Mining can affect water quality when sulfide minerals in waste rock and tailings interact with water and oxygen to produce sulfuric acid, which leaches metals from rock and increases metal toxicity to aquatic organisms. The ore deposits in the Boulder Creek Watershed usually contain small amounts of sulfides, so runoff from old mines and tailings piles is typically not acidic or metal-rich. Metal concentrations in North Boulder and Middle Boulder Creeks, such as mercury and lead, are usually low (Murphy and others, 2003, chapter 4). Some tributaries of South Boulder Creek are acidic and have elevated metal concentrations, but flow in these tributaries is too small to have a substantial effect on the main stem of South Boulder Creek (Asher-Bolinder, 1995; Colorado Riverwatch, 2001).

Barker Reservoir, on Middle Boulder Creek downstream from the town of Nederland, stores as much as 14,426,000 m^3 (11,700 acre-feet) of water and provides up to 40 percent of the city of Boulder's drinking-water supply (City of Boulder, 2002). The reservoir is usually filled during spring runoff and then drawn off gradually until the next spring. The degree of drawdown varies from year to year depending on water availability and demand. Barker Reservoir generally has near-neutral pH and very low dissolved and suspended solids, ranging from 15 to 40 mg/L and from 0 to 4 mg/L, respectively (City of Boulder, unpub. data, 2004). Dissolved oxygen (DO) concentrations near the surface of the reservoir are typically near saturation because of photosynthesis and contact with the atmosphere. The DO concentrations at the bottom of the reservoir are lower than near the top, reaching their lowest point in late summer when the reservoir becomes stratified and the bottom waters do not mix with surface waters. Low DO can cause release of manganese, iron, and other metals from bottom sediments into the water, which can cause problems for drinking-water treatment.

Barker Reservoir



Dissolved oxygen saturation in Barker Reservoir (data from City of Boulder; reservoir is not sampled November-May due to ice cover).

Nutrients, such as nitrogen and phosphorus, increase rates of plant growth. This increases the amount of organic matter produced and consumed and can contribute to the decline in DO at the bottom of a reservoir. Nederland's Wastewater Treatment Plant (WWTP), an aerated lagoon facility, discharges up to 0.0083 m^3/s (189,000 gallons/day) of treated wastewater to Barker Reservoir (USEPA, 2005). The WWTP is required by a permit from CDPHE to meet certain water-quality standards, such as concentrations of suspended solids, oil and grease, and ammonia. The Nederland WWTP contributes less than 1 percent of the total flow into the reservoir but contributes about 66 percent of the phosphorus and 40 percent of the inorganic nitrogen entering the reservoir (City of Boulder, 2002). In addition, homes using individual sewage disposal systems (ISDSs) are situated on both the north and south sides of the reservoir (Flynn and Barber, 2000). Malfunctioning ISDSs can be a source of nitrate, phosphorus, pathogens, and other constituents to ground water and surface water.

Water-quality data for the Boulder Creek Watershed are available from the Boulder Area Sustainability Information Network (BASIN) Web site, www.BASIN.org

Downstream from Barker Reservoir and Lakewood Reservoir (located on North Boulder Creek and used by the City of Boulder to store water; see location map on page 1), flow in Middle Boulder, North Boulder, and Boulder Creeks can be very low during parts of the year due to diversions. These streams have near-neutral pH values and DO concentrations near saturation (Murphy and Waterman, 2005). Dissolved and suspended solids are generally very low, ranging from 20 to 100 mg/L and from 0 to 10 mg/L, respectively. However, runoff from Highway 119, which parallels Middle Boulder and Boulder Creeks, is a potential source of sediment, automobile fluids, road salts, and debris, and ISDSs in the region are potential sources of bacteria, nutrients, and consumer products to ground water and surface water. Historical mining sites also are potential sources of contaminants; slightly elevated levels of dissolved solids have been detected in Fourmile Creek, which was once at the heart of gold-mining activity in the watershed (Murphy and others, 2003, chapter 4).

Boulder Creek in Boulder Canyon

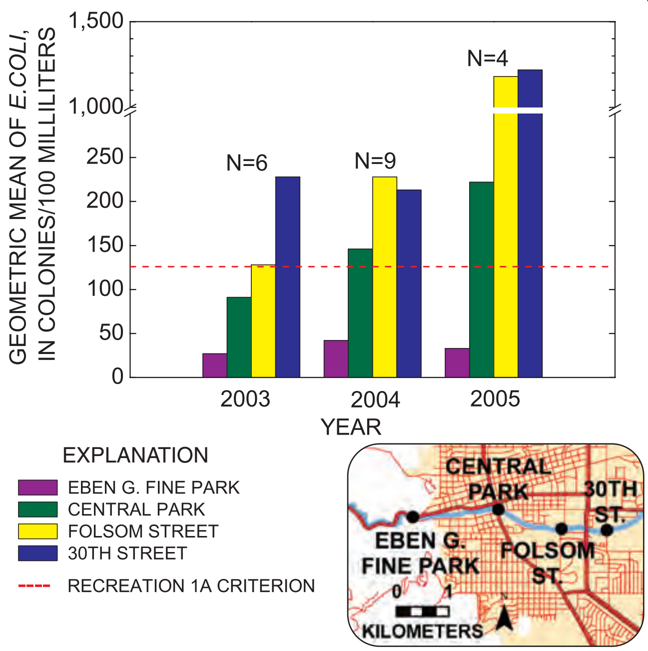
Abandoned mines and mill near Fourmile Creek

Urban

After water in Boulder Creek and its tributaries leaves the mountains, temperature, pH, and dissolved solids increase due to natural and human-related factors. The underlying geology transitions from igneous and metamorphic rocks to more easily eroded sedimentary rocks, increasing dissolved-solids concentrations. Potential contaminant sources increase. Much of the water in South Boulder and Boulder Creeks is diverted in this area, leaving less water for dilution.

Areas of urban development contain many impervious surfaces, such as streets, parking lots, sidewalks, and roofs. Rain and snow cannot percolate into the ground, so large volumes of water enter streams rapidly. This can erode banks, damage stream-side vegetation, and widen stream channels. Also, contaminants from human activities settle and remain on impervious surfaces until a storm washes them, untreated, into nearby storm drains and then into waterways. Common contaminants in urban areas include oil, grease, metals, and road salt from transportation, sediment from construction, and nutrients and pesticides from landscaping. Paulson (1994) found that the metals arsenic, lead, and copper were highest in Boulder Creek during large storms.

Recreation on Boulder Creek



Geometric means of *E. coli* concentrations in Boulder Creek within the City of Boulder, 2003–2005, and CDPHE recreation 1A criterion (data from City of Boulder; N, number of samples; criterion based on a geometric mean of representative samples).

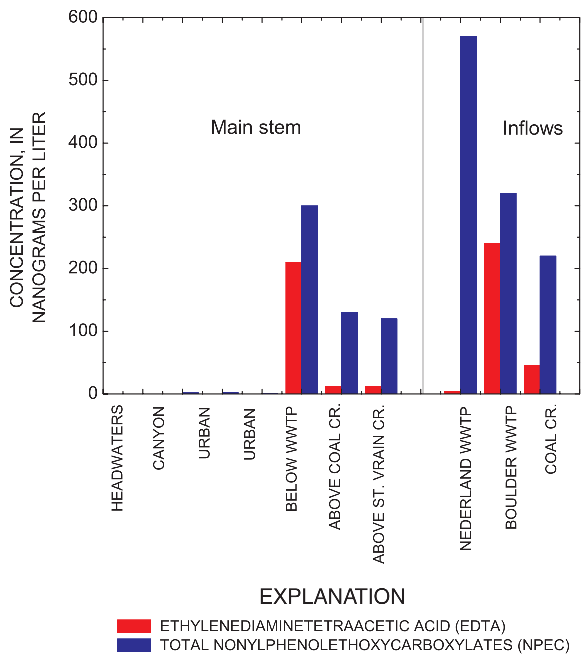
Is it safe to swim in Boulder Creek?
Swimming in any water body involves some degree of risk. During snowmelt runoff, Boulder Creek discharge can be dangerously high; values over 30 m^3/s (1,050 ft^3/s) have been recorded (USGS, 2004). All of the waters in the Boulder Creek Watershed are classified as recreation class 1A, which includes swimming, kayaking, and tubing (CDPHE, 2005b). Water-quality criteria for this classification include dissolved oxygen (DO), pH, fecal coliform, and *Escherichia coli (E. coli)*. DO and pH in surface waters in the watershed are usually within the criteria. Parts of Boulder and Coal Creeks were included on the State of Colorado's 2004 list of water-quality-impaired streams (the 303[d] list) because of high levels of *E. coli* (CDPHE, 2005c).

E. coli and fecal coliform by themselves usually do not cause disease; they are used as indicators, which means they may indicate the presence of other disease-causing microbes. These microbes are typically present in such small amounts that they are difficult and expensive to detect but may cause hepatitis, gastroenteritis, and dysentery. Potential sources of *E. coli* are human (from instream recreation, leaky sanitary sewer lines, and failing septic systems) and animal (raccoons in storm drains, pet waste along the creek, waterfowl). Hundreds of people swim in Boulder Creek each year; Boulder County Public Health has had no reports of serious waterborne illness from this use (written commun., 2005). To minimize contact with bacteria, the USEPA recommends avoiding swimming after a heavy rain, near storm-drain outlets, and in areas with trash or oil slicks in the water (USEPA, 1997).

Lower Boulder Creek

East of the city of Boulder, the Boulder WWTP is permitted to discharge as much as 77,600 m^3 (20.5 million gallons) per day of treated wastewater to Boulder Creek (USEPA, 2005). The wastewater is treated using a trickling filter/solids contact and nitrification process. The amount of wastewater discharged varies over 24 hours, depending on water usage within the city of Boulder. The WWTP is required by a permit from CDPHE to meet certain water-quality standards. However, the WWTP effluent does cause a substantial change in the water quality of Boulder Creek. The effluent contains higher concentrations of dissolved solids and nutrients than Boulder Creek, so these constituents increase downstream from the WWTP (Murphy and Waterman, 2005). Concentrations of suspended solids and fecal coliform in the effluent are often lower than concentrations in Boulder Creek (due to permit requirements), so concentrations of these constituents often decrease downstream from the WWTP.

Discharge point for the Boulder Wastewater Treatment Plant

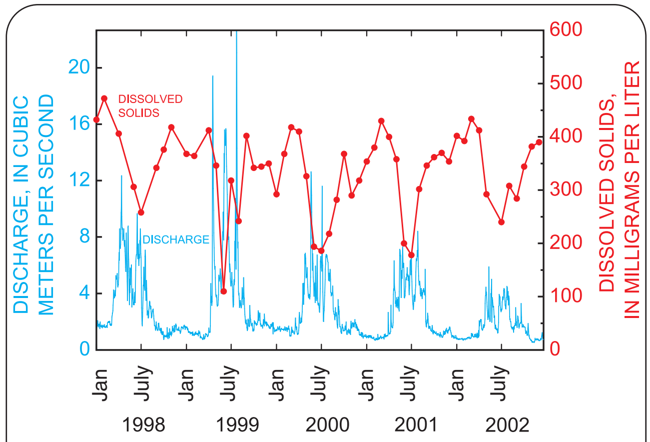


Concentrations of ethylenediaminetetraacetic acid (EDTA) and nonylphenolethoxycarboxylates (NPEC) in Boulder Creek and inflows, October 2000 (Murphy and others, 2003, chapter 5).

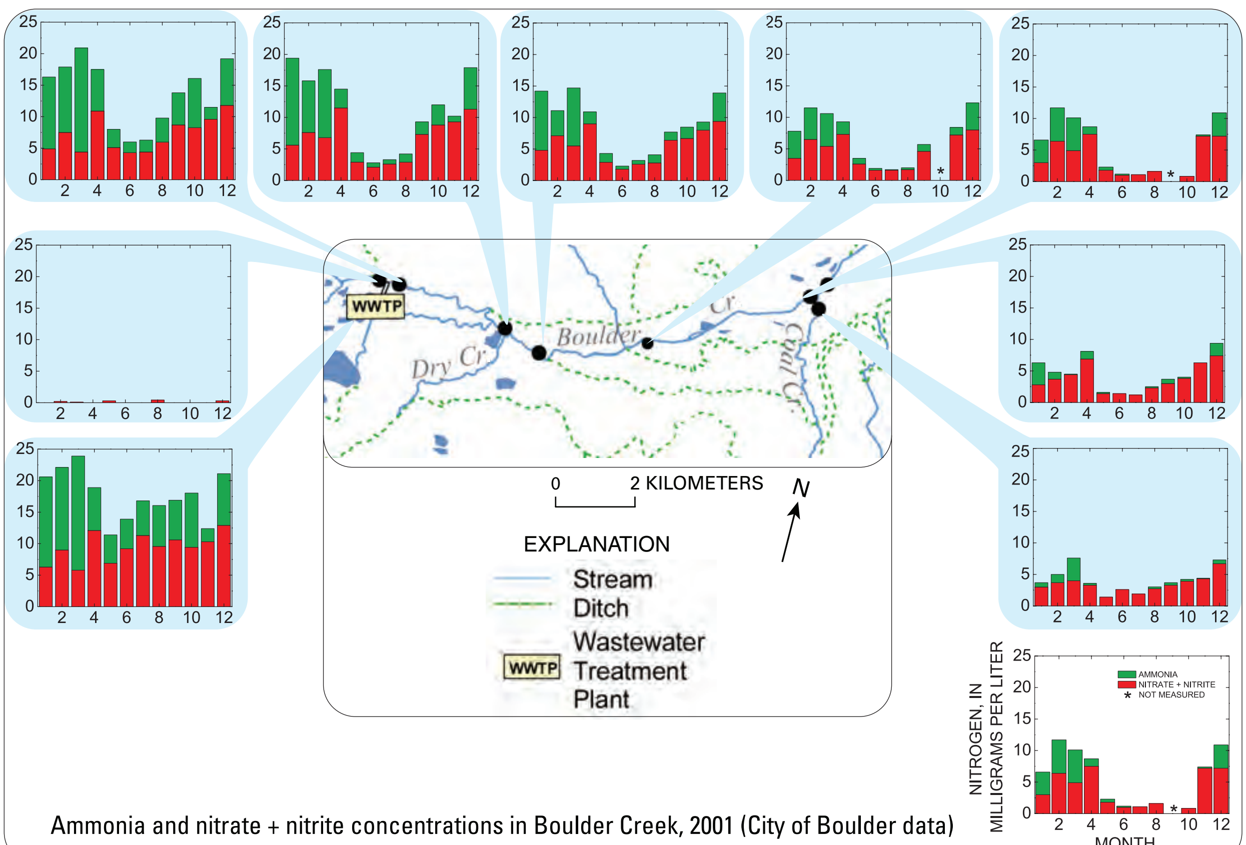
Studies of Boulder Creek downstream from the Boulder WWTP have detected trace organic wastewater compounds such as steroids, hormones, prescription and nonprescription drugs, surfactants, and pesticides (Murphy and others, 2003, chapters 5 and 6; Barber and others, 2006). Recent technological advances have allowed the detection of these compounds at very low levels; some of these compounds were detected at only a few parts per trillion. WWTPs are not required by law to remove these compounds, and their environmental and public health significance is not well understood. The most abundant wastewater compounds detected in 2000 were ethylenediaminetetraacetic acid (EDTA), a metal complexing agent found in shampoo, mayonnaise, and vitamins, and nonylphenolethoxycarboxylates (NPEC), breakdown products from surfactants, which are components of detergents. Concentrations of organic wastewater compounds were highest in Boulder Creek directly downstream from the Boulder WWTP and in Coal Creek; concentrations decreased downstream. In addition to organic wastewater compounds, the rare earth element gadolinium was found to be enriched in the Boulder WWTP effluent and Boulder Creek downstream from the Boulder WWTP (Murphy and others, 2003, chapter 4; Verplanck and others, 2005). Gadolinium has several industrial and medical uses. Because of its magnetic properties, gadolinium is used as a contrasting agent in magnetic resonance imaging (MRI). Organic gadolinium complexes are extremely stable in the human body and in the environment; because of this stability, they are not easily removed during wastewater treatment or instream processes (Bau and Dulski, 1996).

Water quality of Boulder Creek downstream from the Boulder WWTP is affected by a complex combination of sources and processes. The degree of effects from the Boulder WWTP on Boulder Creek depends on the ratio of wastewater effluent to background streamflow. Wastewater effluent has a greater effect on water quality when background streamflow in Boulder Creek is low. During high-flow conditions, snowmelt runoff provides dilution for dissolved constituents. Therefore, concentrations of dissolved solids, nitrogen, and phosphorus in Boulder Creek downstream from the WWTP are typically lowest during late spring and early summer (Murphy and Waterman, 2005).

Several diversions downstream from the WWTP remove a substantial amount of water from Boulder Creek. During some times of the year, the creek is virtually dry in places. These diversions remove much of the wastewater chemical load from the creek. The creek gains water from agricultural irrigation return flows, tributaries, and ground water. These inflows provide dilution for nutrients, metals, and wastewater compounds but can increase some ions, such as sodium, magnesium, and sulfate (Murphy and others, 2003, chapter 4). Nitrogen (nitrate, nitrite, ammonia, and organic nitrogen) and phosphorus also are removed from the water by vegetation uptake, sorption to sediment and organic matter, and bacterial processes. The level of ammonia concentrations that the Boulder WWTP is permitted to discharge varies throughout the year, and typically is highest from November to March and lowest in June (City of Boulder, written commun., 2005).



Discharge and dissolved-solids concentrations in Boulder Creek immediately downstream from the Boulder WWTP (Data from USGS, 2004 and City of Boulder, unpub., 2004).

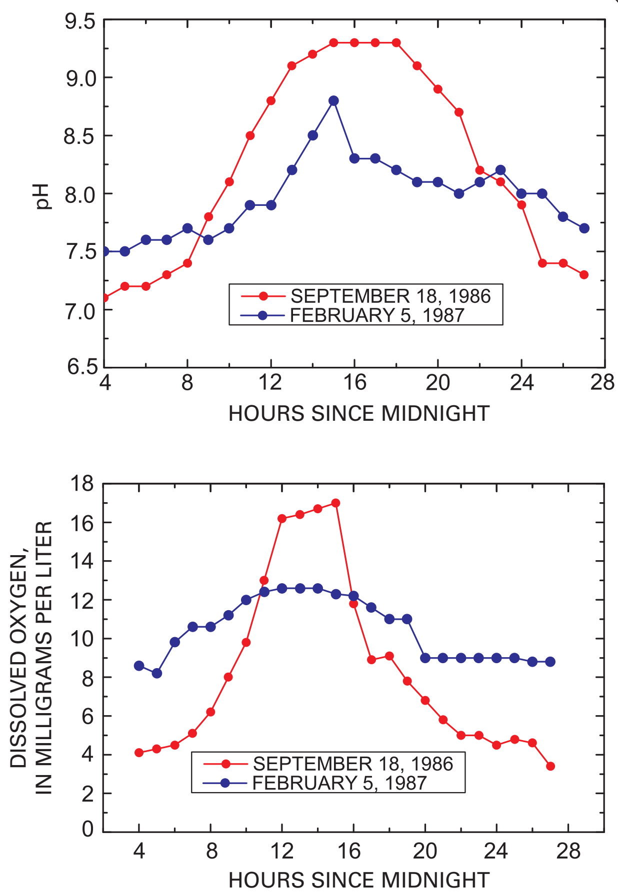


Ammonia and nitrate + nitrite concentrations in Boulder Creek, 2001 (City of Boulder data)

Much of lower Boulder Creek has been channelized and has little riparian vegetation to provide shade, so waters can reach temperatures as high as 30 degrees Celsius in summer months (Murphy and Waterman, 2005). Direct sunlight on the shallow, slow-moving, nutrient-rich water leads to accelerated algal growth and high rates of photosynthesis.

The high rate of photosynthesis during daylight hours produces oxygen and consumes carbon dioxide, causing pH and DO to increase during the day. Respiration and decomposition, which occur 24 hours a day, consume oxygen and produce carbon dioxide, causing lower pH values and DO concentrations at night. Over a 24-hour period, DO and pH have fluctuated as much as 12 mg/L and 2.1 pH units, respectively (Aquatic and Wetland Consultants, 1987).

Boulder Creek near Highway 287



pH and dissolved oxygen over 24 hours in Boulder Creek 13 kilometers downstream from the Boulder WWTP (data from Aquatic and Wetland Consultants, 1987).

In water with high pH and temperature values, ammonia takes the form of un-ionized ammonia, which is toxic to fish. Boulder Creek from South Boulder Creek to Saint Vrain Creek was included in Colorado's 303(d) list of impaired waters in 1992 because of un-ionized ammonia (CDPHE, 2005c, d). The City of Boulder attempted to improve water quality by restoring streambank stability, planting vegetation, and deepening channels, but high un-ionized ammonia concentrations continued. In 2003, a TMDL analysis quantified the amount of ammonia that can be discharged to Boulder Creek without exceeding standards. The analysis was used to assign allowable contaminant loads among ammonia dischargers (CDPHE, 2005e). Some WWTPs in the watershed, including the Boulder and Lafayette WWTPs, have been or will be upgraded to decrease the amount of ammonia discharged (Floyd Bebler, City of Boulder, written commun., 2005; Douglas Short, City of Lafayette, oral commun., 2005).

Lower Boulder Ditch near diversion from Boulder Creek

Coal Creek merges with Boulder Creek about 13 km (8 mi) downstream from the Boulder WWTP. Coal Creek receives wastewater effluent from Erie, Lafayette, Louisville, and Superior WWTPs, which are permitted to discharge a total of 40,882 m^3 (10.8 million gallons) per day of effluent to Coal Creek or its tributary, Rock Creek (USEPA, 2005). Because the natural flow of Coal Creek is very small, the creek is composed almost entirely of wastewater effluent when it enters Boulder Creek. Therefore, concentrations of dissolved solids, nutrients, and organic contaminants in Coal Creek often are elevated relative to Boulder Creek and cause an increase in these contaminants in Boulder Creek (Murphy and others, 2003, chapters 3, 4, and 5; Murphy and Waterman, 2005). Coal Creek also may be affected by agricultural return flows.

Coal Creek near Lafayette

Sunflowers near lower Boulder Creek

Lower Boulder Creek flows through what has historically been an agriculturally dominated area. About 7,890 kilograms (17,400 pounds) of pesticides (active ingredient) were applied to agricultural land in Boulder County in 1997 (Murphy and others, 2003, chapter 6). Samples from Boulder Creek were analyzed for 84 pesticides in June and October 2000. Seven pesticides, including diazinon and atrazine, were detected at one or both of the sampling locations on lower Boulder Creek (upstream from Coal Creek and upstream from Saint Vrain Creek). Agricultural lands in the watershed have rapidly been converted to urban areas in the past decade; one-third (202 square kilometers, or 50,000 acres) of the farm land in Boulder County was converted to nonagricultural uses between 1992 and 2002 (U.S. Department of Agriculture, 2005).

Construction of new housing development near Erie

Rock Creek

What fish species live in Boulder Creek?

Natural conditions in the Boulder Creek Watershed can be harsh for fish and other aquatic life. Streamflow originates primarily as snowmelt and thus varies widely both seasonally and annually. Mountain streams are cold year-round, flow rapidly and turbulently, are low in nutrients, and have little or no aquatic shore vegetation (Ellis, 1914). Plains streams are slower moving and subjected to intense sunlight, causing temperature, dissolved oxygen, and pH to vary drastically, particularly in late summer. These conditions lead to a relatively low number of native fish species able to survive in the watershed (Fausch and Bestgen, 1996). Humans have substantially altered the natural hydrologic regime by diverting water from streams and building reservoirs, straightening stream channels, decreasing flow during high-flow periods, increasing flow during low-flow periods, and causing daily and hourly flow variations. In addition, nutrient loading is higher due to wastewater effluent, habitat has been fragmented, and non-native fish have been introduced.

Much of lower Boulder Creek was channelized for flood control. Channelization removes pools and riffles, which are important habitat for fish. In the 1980s the City of Boulder restored much of Boulder Creek within the city for recreation, esthetics, and fish habitat. About 75 fish habitat structures were built as part of this project, the majority being boulder drops with excavated pools (Steinberger and Wohl, 2003). Banks were stabilized, and riparian areas were revegetated.

About 50 fish species, of which about 18 are non-native, now inhabit the South Platte River Watershed (Fausch and Bestgen, 1996). Introduced species usually fare best in man-made reservoirs; in streams, they generally are not successful because they must compete with species adapted to the watershed (Bluestein and Hendricks, 1974) and fluctuating hydrologic conditions. Non-native trout are an exception. Rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*) were stocked in Boulder Creek soon after settlement and are now the principal fish species in the mountain streams of the watershed and within the city of Boulder (Thorne Ecological Institute, 1972). These fish outcompete the native greenback cutthroat trout (*Oncorhynchus clarki stomias*), a federally listed threatened species. In lower Boulder Creek, native white suckers (*Catostomus commersoni*) and fathead minnows (*Pimephales promelas*), along with non-native common carp (*Cyprinus carpio*), are the most abundant species downstream from the Boulder WWTP (Windell and Rink, 1987). These fish tolerate extreme variations of temperature, dissolved oxygen, and turbidity. Studies of Coal Creek found that native creek chub (*Semotilus atromaculatus*) and fathead minnow were most abundant (Bureau of Reclamation, 1981).

Greenback cutthroat trout (courtesy Colorado Division of Wildlife)

White sucker (courtesy Colorado Division of Wildlife)

New Zealand mudsnail (left, approximate size; right, magnified; courtesy Colorado Division of Wildlife)

Several non-native species are threatening ecosystems in Boulder Creek, including the New Zealand mudsnail (*Potamopyrgus antipodarum*) and the Eurasian watermilfoil (*Myriophyllum spicatum*), an aquatic plant. These species were accidentally introduced, have no natural predators in the watershed, and spread rapidly (City of Boulder, written commun., 2005). They negatively affect aquatic ecosystems by outcompeting native species and reducing biodiversity. A native species of algae, the diatom *Didymosphenia geminata*, also is affecting Boulder Creek. This diatom was once rare and restricted to pristine lakes and streams. In recent years, however, it has formed excessive growths in Boulder Creek, as well as many streams of Western North America (Sarah Spaulding, USGS, oral commun., 2005). Loss of native species and biodiversity can lead to a decline in population and diversity of fish, because their food supply has been affected.

What is the quality of ground water in the Boulder Creek Watershed?

Surface water and ground water are closely connected; contamination of ground water can affect water quality of Boulder Creek and its tributaries.

The mountainous part of the watershed is underlain by crystalline bedrock with generally low water-storage capacity. Ground water is present in fracture zones, with depth to ground water ranging from tens to hundreds of feet (Bruce and McMahon, 1998). Most homes in the mountains are served by wells and individual sewage disposal systems (ISDSs).

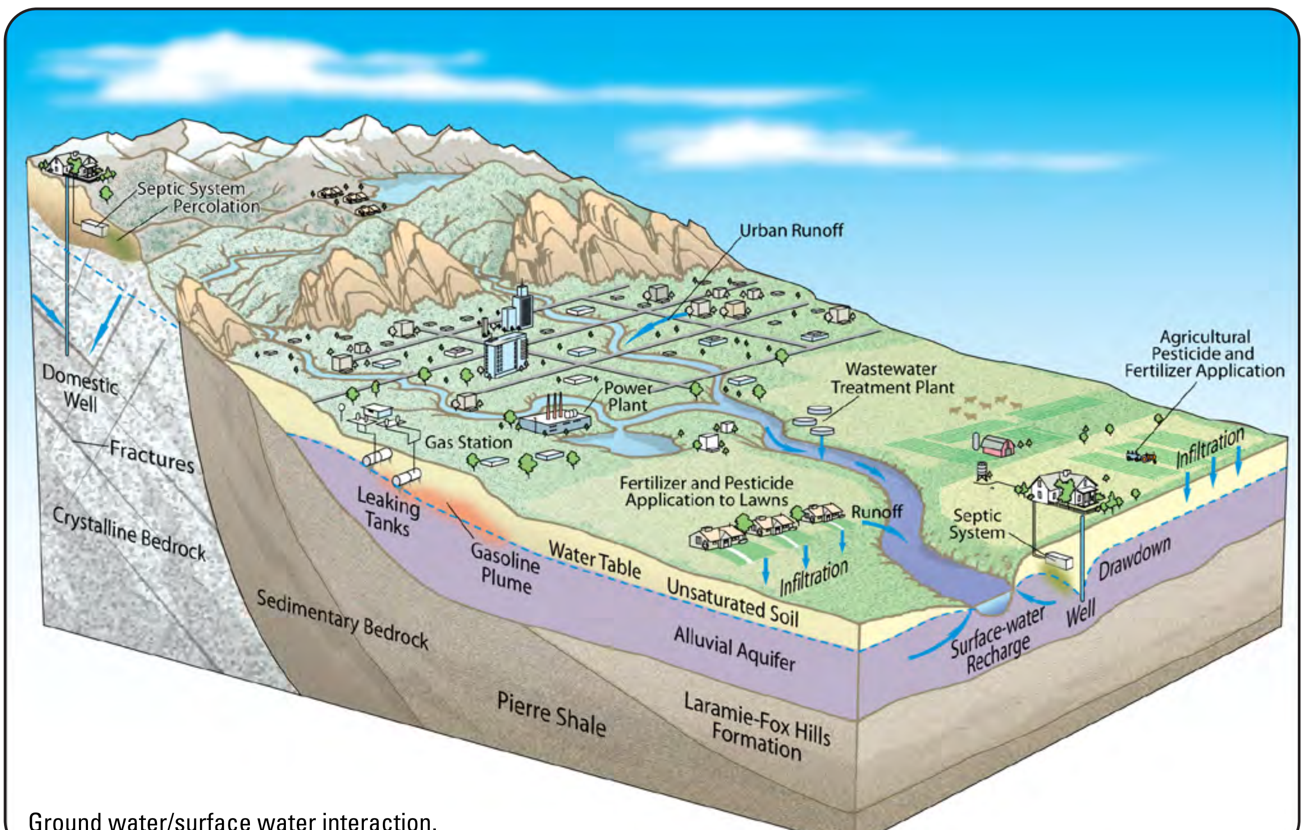
The plains part of the watershed is underlain by sedimentary rock, and ground-water sources are the alluvial aquifer, which underlies valley bottoms, and the Laramie-Fox Hills aquifer (Romero, 1973). The alluvial aquifer is closely connected to surface water.

Ground-water quality in the Boulder Creek Watershed is not well known. Dissolved-solids concentrations generally are lower in the upper watershed because crystalline bedrock is more resistant to dissolution by ground water (Bruce and McMahon, 1998). Ground-water quality can be affected by overlying land use, malfunctioning ISDSs, leaking underground storage tanks (LUSTs), and landfills. Application of pesticides and fertilizers in agricultural or urban settings can introduce these compounds to ground water; the pesticides atrazine and prometon, along with nitrate, have been detected in ground water in the lower watershed (Bruce and O'Riley, 1997). Application of chlorinated drinking water to lawns can introduce chloroform, a byproduct of drinking-water disinfection, to ground water.

Approximately 14,400 onsite wastewater systems (OWSs), which include ISDSs and other systems that treat sewage on a property instead of discharging to a wastewater treatment plant, are in use in Boulder County (Boulder County Public Health, written commun., 2005). About one-half of Boulder County is in the Boulder Creek Watershed. Approximately 6,000 of these OWSs are unapproved, and 8,400 are more than 23 years old. Leaking OWSs have the potential to contribute bacteria, nutrients, and consumer products to ground water and surface water.

There are dozens of underground storage tanks in the Boulder Creek Watershed. After many years, these steel tanks can corrode and leak contents to ground water. These LUSTs can contain gasoline, diesel, and other petroleum products. Methyl tertiary butyl ether (MTBE), which has been added to gasoline since the 1970s and is a potential carcinogen, has been found to be widespread in alluvial ground water of the Denver metropolitan area (Bruce and McMahon, 1998).

Landfills also can be sources of ground-water contamination. The Marshall landfill, which operated from 1965 to 1992, was found to be leaching polychlorinated biphenyls (PCBs), toluene and other organics, and arsenic and other metals to ground and surface water (U.S. Bureau of Reclamation, 1981). The site was added to the USEPA's Superfund List in 1983. A ground-water collection system and water-treatment facility were installed in 1993 and closed in 2004, with monitoring ongoing (Floyd Bebler, City of Boulder, written commun., 2005).

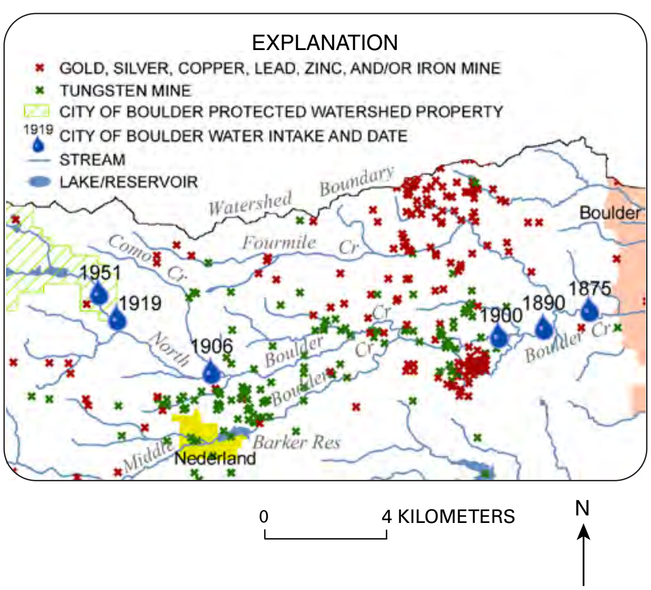


Ground water/surface water interaction.

What was the quality of water in the Boulder Creek Watershed in the past?

Pre-1858

Prior to European-American settlement in 1858, the Boulder Creek Watershed was sparsely populated by Native Americans, who had little effect on the landscape except perhaps in altering fire regimes, leading to changes in erosion from hillsides and channels (Wohl, 2001). Before extensive water management and reservoir development, which began in 1859, streamwater discharge in much of the watershed would have been higher during much of the year. Dissolved solids in surface water would have been low in the mountains, due to crystalline bedrock, and higher on the plains, where bedrock is sedimentary. Dissolved solids would have been lowest during snowmelt runoff. Boulder and Coal Creeks on the plains would have had large temperature variations, as they do today. Bacteria levels in the streams would have been low unless many people or animals were nearby. The first white settlers described streams in the watershed as “pure” and “full of fish” (O.L. Baskin and Company, 1880). Drinking water typically came directly out of streams, shallow wells, or ditches and was not treated.

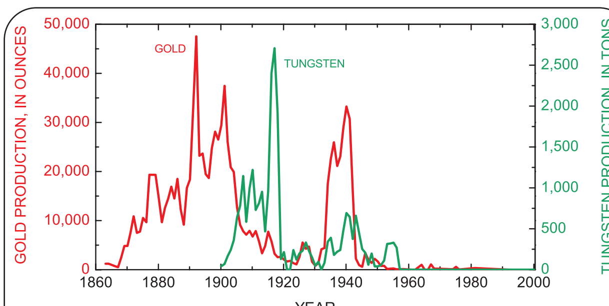


Mine sites and City of Boulder drinking-water intakes (mine data from USGS, 2005b).

1859 to 1920

By 1880, dozens of gold and silver mines were operating in the upper watershed. The first types of mines were placer mines, where sediment was dumped into rocker boxes or sluices, broken apart with water, and processed with mercury. Lode mining followed; this involved crushing chunks of bedrock and processing it with chlorine, mercury, cyanide, and bromide in mills (Cobb, 1988). Lode mining, primarily along Fourmile Creek, allowed much greater production; gold production reached its peak in 1892. Toxic chemicals used in processing were disposed of on the ground or in streams. Mill tailings caused the water in Boulder Creek downstream from Fourmile Creek to have a “milk-like turbidity” (Colorado State Board of Health, 1878) which, when consumed, gave the “sensation of swallowing rope” (Boulder Daily Camera, 1905a). Mining was closely followed by timber harvesting. Boulder Creek was used to deliver lumber downstream, and large boulders and streamside vegetation were blasted to improve passage (Wohl, 2001). Forest fire frequency increased, leading to erosion and release of sediment and dissolved solids to streams.

The City of Boulder fought mines and mills to reduce the discharge of waste to streams (Boulder Daily Camera, 1905b), but in 1890 avoided most contamination by moving its water intake upstream from Fourmile Creek. In 1900, however, tungsten was discovered in the watershed, and many mines operated along Middle and North Boulder Creeks. The population of the upper watershed swelled. In 1907, all of the fish in several miles of Boulder Creek were killed by mill waste (Ellis, 1914). To avoid contamination by mining and sewage, Boulder moved its intake to North Boulder Creek in 1906 and built Lakewood Reservoir and Pipeline. Bacterial contamination continued from work camps and cottages, so in 1919 Boulder added additional water intakes at higher elevations, purchased much of the headwater area of North Boulder Creek, and eventually closed the area to the public (Phelps, 1916; Burns and McDonnell Engineering Co., 1921).



Annual gold and tungsten production in Boulder County (data from Henderson, 1926; Lovering and Tweto, 1953; USGS, 1882–1931, 1933–2000).

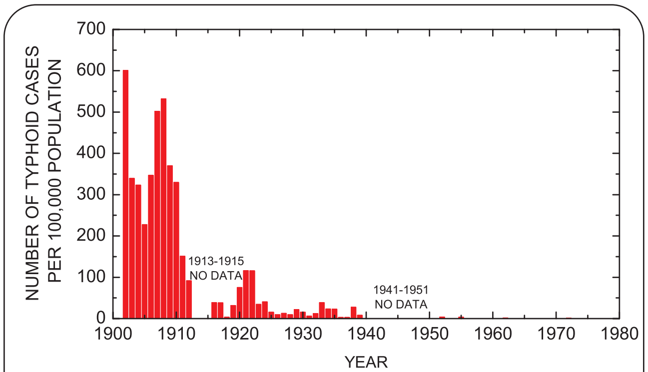
Placer mining on Fourmile Creek, circa 1890–1900 (by J.B. Sturtevant; courtesy Carnegie Branch Library for Local History, Boulder Historical Society Collection)

In the Marshall Coal Mine, near Langford (now Marshall), circa 1880–1893 (by Ira Kneeland; courtesy Carnegie Branch Library for Local History)

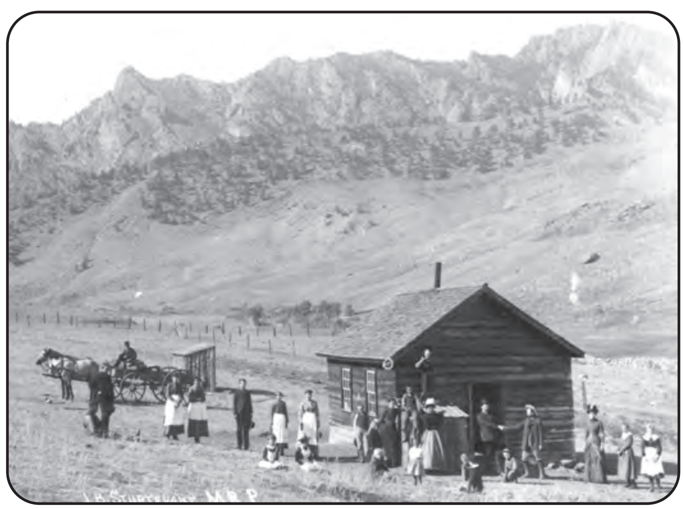
In the eastern part of the watershed, the towns of Erie, Lafayette, Louisville, Marshall, and Superior were founded to support underground coal mines. These communities first obtained drinking water from wells. Eventually, Lafayette, Louisville, and Erie diverted water from South Boulder Creek.

Early in Colorado history, inadequate disposal of human waste was a problem. In 1877, the newly established Colorado State Board of Health reported that "This beautiful land… blessed with good water… free from all contaminations less than two decades since, is now, in many places, sadly changed. The crowded habitations which have sprung up… are in imminent danger of losing their healthfulness… by atmospheric and water pollution" (Colorado State Board of Health, 1877). Outhouses and cesspools were used throughout the Boulder Creek Watershed; many of these were close to drinking-water wells (University of Colorado Extension studies, 1921).

In 1895, the City of Boulder installed its first sewer pipes, which directed sewage to a settling basin and then to Boulder Creek. However, the settling basin had little effect; for a mile downstream, water in the creek resembled sewage, fish were absent, and cattle and horses refused to drink (Bishop, 1908). In 1905, at the same time that Boulder sought an injunction against mill pollution of Boulder Creek, farmers downstream complained about Boulder emptying untreated sewage into the creek (Boulder Daily Camera, 1905b). South Boulder Creek was contaminated by bacterial pollution from the resort community of Eldorado Springs (University of Colorado Extension studies, 1921). High incidence of typhoid, which is carried by water contaminated with human waste, was recorded in Boulder County in the early 1900s.



Annual typhoid cases (including deaths) in Boulder County, 1902–1980 (data from Colorado State Board of Health reports, 1902–1947 and U.S. Public Health Service, 1952–1980).

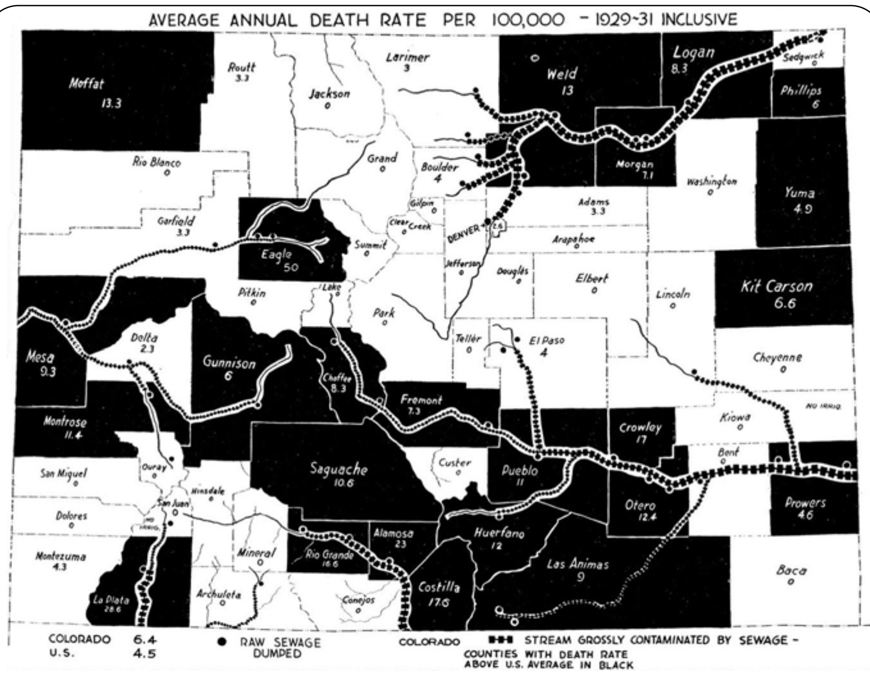


South Boulder School, Eldorado Springs, circa 1886–1890, with outhouse in background (by J.B. Sturtevant, courtesy Boulder Carnegie Branch Library, Boulder Historical Society Collection)

1920 to 1950

When World War I ended, tungsten mining decreased in the Boulder Creek Watershed, and many mining communities became ghost towns. Forest fire suppression began in about 1920 (Wohl, 2001). These factors likely led to an improvement in water quality of the upper watershed. Simultaneously, National and State water-quality regulations, including the first Federal drinking-water standards, were being enacted. Towns and cities within the watershed began to treat drinking-water supplies with chlorination and (or) filtration (U.S. Public Health Service, 1950). However, poor wastewater disposal practices continued to result in contamination of the watershed. Statewide, the practice of discharging untreated sewage to rivers, which were then used to irrigate crops, was tied to typhoid fever and dysentery when people consumed the crops. This led several neighboring States to boycott produce from the South Platte Valley (Colorado State Board of Health, 1930, 1960; Chapman, 1934). Between 1934 and 1939, the population in Colorado served by sewage-treatment facilities increased from 6 to 84 percent (Colorado State Board of Health, 1939). The City of Boulder built its first WWTP in 1934, but it did little to treat sewage effectively (U.S. Public Health Service, 1950). Gold and tungsten mining in the upper watershed boomed again when the price of gold rose in 1934 and World War II began in 1939.

Contamination of water resources nationwide led to the Water Pollution Control Act of 1948, which established that States were primarily responsible for water-pollution control and that the Federal government would provide financial and technical assistance (Stoddard and others, 2002). That same year, a study of the South Platte River Basin found that Boulder Creek, like most streams in the basin, contained high amounts of coliform bacteria, high biological oxygen demand (BOD), and low dissolved oxygen downstream from the two existing WWTPs in the watershed (Boulder and Lafayette), particularly during low-flow conditions (U.S. Public Health Service, 1950). Erie, Louisville, Nederland, and Superior were still using outhouses and septic systems.

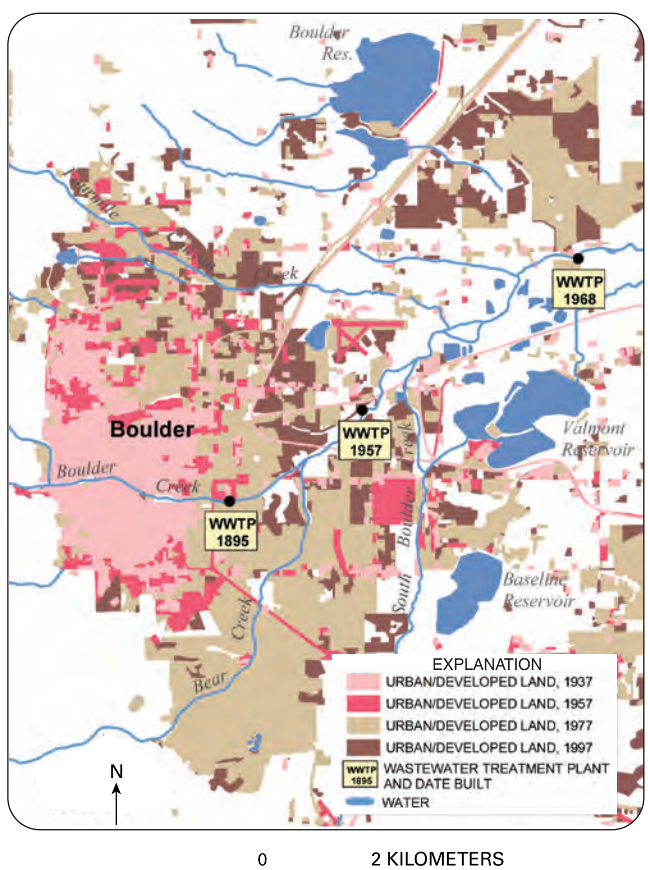


Map showing Colorado rivers polluted with sewage and counties with typhoid deaths over national average in 1929–1931 (from Chapman, 1934).

1950 to present

The population of the City of Boulder doubled between 1940 and 1960, increasing wastewater load. The City of Boulder built a new WWTP with secondary treatment (trickling filter and chlorination) on East Pearl Street in 1957. Coliform output decreased substantially, but due to continuing rapid population growth, the WWTP was quickly overloaded and released sewage with high suspended solids content and high biological oxygen demand (BOD) (U.S. Department of the Interior, 1967a, b). Below the WWTP, Boulder Creek was murky and gray, with only a small number of tolerant organisms living in the creek. In 1968, Boulder constructed an additional WWTP on 75th Street, downstream from the Boulder Creek Supply Canal. Both WWTPs discharged to Boulder Creek until 1975, when the East Pearl WWTP began diverting primary effluent to the 75th Street WWTP for secondary treatment (the East Pearl WWTP closed in 1980). Water quality of Boulder Creek improved, but dissolved-oxygen concentrations were still low and the water was murky and smelled of sewage (USEPA, 1972).

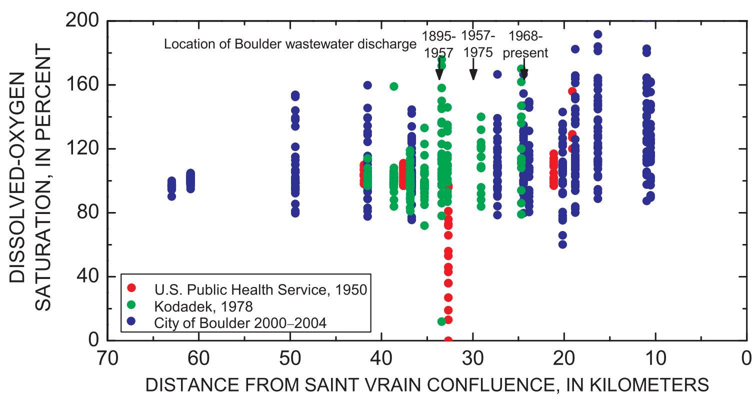
By 1965, Erie and Louisville had built WWTPs, which along with Lafayette discharged to Coal Creek (U.S. Department of the Interior, 1967a). The USEPA (1972) found that Coal Creek was contaminated with coliform bacteria, and was chemically and bacteriologically degrading lower Boulder Creek. Contamination of ground-water supplies by inadequate septic systems also was becoming a problem in mountainous parts of the watershed (Boulder Daily Camera, 1973).



Growth of urbanized areas and wastewater discharge locations, Boulder (data from USGS, 1998).

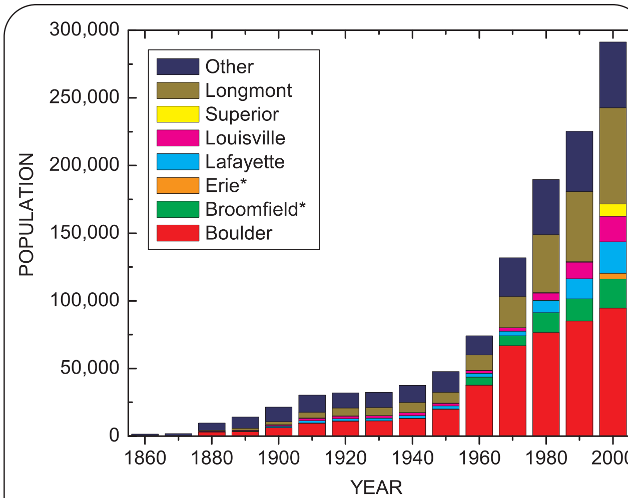
In 1972, the Federal Water Pollution Control Act Amendments (now known as the Clean Water Act) were passed, with the goal to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" and to attain "fishable and swimmable" waters throughout the Nation. The act required that every point-source discharger of pollutants obtain a permit and meet water-quality standards, and that all publicly owned WWTPs must perform a minimum of secondary treatment (Stoddard and others, 2002). Several of the WWTPs in the watershed were upgraded.

Since the Clean Water Act was passed, additional regulations and stricter water-quality standards have required WWTPs in the watershed to upgrade several times in the past 30 years. These improvements decreased the amount of BOD, suspended solids, ammonia, coliform bacteria, and chlorine being discharged to Boulder and Coal Creeks, and increased dissolved oxygen concentrations below WWTPs (Arthur Dike, City of Boulder, written commun., 1985; Murphy and others, 2003, chapter 3). Industrial pretreatment programs now regulate the waste that industries can discharge to WWTPs. In 2005, the Boulder WWTP was being upgraded to improve ammonia removal (Floyd Bebler, City of Boulder, written commun., 2005).



Dissolved-oxygen saturation along Middle Boulder Creek/Boulder Creek in 1950, 1978, and 2000–2004, and locations of wastewater discharge (from 1968 to 1975, there were two WWTPs discharging to the creek; data from U.S. Public Health Service, 1950; Kodadek, 1978; City of Boulder).

Population growth in the watershed continued to increase rapidly. The combined populations of the four communities discharging to Coal Creek, historically a very low flow stream, increased from 7,168 in 1970 to 57,436 in 2000 (U.S. Census Bureau, 2001). All of these communities (Erie, Lafayette, Louisville, and Superior) upgraded or built new WWTPs in the past 20 years to accommodate this growth.



Population of Boulder County, 1860–2000 (data from U.S. Census Bureau, 2001; *Erie and Broomfield populations include only portions within Boulder County; Broomfield became a separate county in 2001).

Water Resources

Water resources have always been of utmost importance in the Boulder Creek Watershed. The extreme variation in streamflow requires extensive management to support human activity. Early settlers needed water for mining, agriculture, and household use. All of these activities affected water quantity and quality, and conflicts occurred frequently. Over time, water use by mines decreased, while new hydroelectric and powerplant facilities required water. Rapid population growth in the watershed since the 1950s has shifted water use to domestic supply and has increased stress on water resources.

- 1859- First ditch in watershed completed (Lower Boulder Ditch)
- 1859-1875- Boulder residents carried water from creek and ditches for household use
- 1875- Boulder's first water works constructed: diversion from Boulder Creek one mile upstream from city to reservoir
- 1877- Stormwater diversion built from downtown Boulder to Boulder Creek
- 1885-1939- Artesian wells supplied Erie's drinking water
- 1890- Lafayette began diverting water from South Boulder Creek
- 1894- Worst recorded flood on Boulder Creek
- 1895- First sewer main laid in Boulder; sewage settling basin and garbage dump installed at Scott Carpenter Park (then Valderdan Park)
- 1904- Louisville began diverting water from South Boulder Creek
- 1906- City of Boulder's Lakewood Reservoir & Pipeline built
- 1910- Barker Dam and Boulder Canyon Hydroelectric Plant completed
- 1915- Nederland water system built
- 1914-1917- Paving of Boulder streets began; storm sewers laid down first
- 1918- Liquid chlorination plant installed at Lakewood Reservoir, used intermittently when coliform bacteria were detected
- 1919- City of Boulder's Silver Lake Pipeline built (from Lakewood Reservoir to Upper Boulder Falls)
- 1920- Boulder-owned watershed closed to public
- 1923- Lakeside [Valmont] Power Plant built
- 1928- City of Boulder purchased Arapaho Glacier from U.S. Government
- 1934- Boulder's first wastewater treatment plant (WWTP) completed over former sewage settling basin; nearby garbage dump closed
- 1937-39- Louisville, Lafayette, Erie built new water treatment plants (WTPs); Erie abandoned wells for South Boulder Creek
- 1940s- Lafayette's first WWTP built
- Late 1940s- several States boycotted South Platte Valley produce because crops irrigated with sewage
- 1949- Boulder began chlorinating drinking water year-round
- 1951- Boulder moved Silver Lake Pipeline intake to city-owned watershed
- 1952- Louisville's first WWTP constructed
- 1955- Boulder and Gross Reservoirs and Boulder Creek Supply Canal completed
- 1957- Boulder WWTP replaced with East Pearl WWTP
- 1959- "Blue Line" ordinance passed in Boulder to prevent development in foothills
- 1963- Boulder's Betasso WTP built
- 1964- Lafayette built new WWTP (secondary treatment)
- 1965- Louisville WWTP expanded
- 1965- Marshall landfill built
- 1968- Boulder 75th St. WWTP constructed; East Pearl WWTP continued to operate
- 1970- Nederland WWTP built next to Barker Reservoir
- 1971- Erie built new WTP
- 1972- Boulder 75th St. WWTP upgraded
- 1972- Boulder Reservoir WTP built
- 1978-1980- Improvements to Boulder 75th St. WWTP; East Pearl WWTP closed
- 1982-1989- Improvements to Boulder and Louisville WWTPs
- 1983- Marshall Landfill added to Superfund List due to ground water pollution
- 1988- Superior built WTP
- 1992- Superior built WWTP
- 1993- Cleanup activities initiated at Marshall Landfill
- 1998- Erie built new WWTP
- 1999- Improvements to Louisville WWTP
- 2000- Erie built new WTP
- 2001- Boulder acquired Barker Reservoir and Boulder Canyon Hydroelectric Plant
- 2003- Lafayette WWTP expanded and improved
- 2003- Pipeline built from Boulder Creek at 75th St. to Lafayette; Boulder WWTP outlet moved downstream
- 2003- Colorado stormwater-quality permits issued to Boulder, Erie, Lafayette, Louisville, Superior, and Boulder County
- 2004- Marshall Landfill ground-water treatment plant shut down; monitoring ongoing

National and Regional History

National and regional history shaped the evolution of the watershed and affected water use and quality. Establishment of roads and railroads enabled the development and transport of mining and agricultural products. World wars affected mineral production.

- 14,000 B.C.- First evidence of humans arriving in Colorado
- 1494-1800- Boulder area in territory claimed by Spain
- 1776- Declaration of Independence written
- 1800-1803- Boulder area in territory claimed by France
- 1803- Boulder area became part of United States by Louisiana Purchase
- Early 1800s- Beaver trapping in upper watershed
- 1820- Area explored by Stephen Long
- 1858- First permanent white settlers in watershed
- 1859- Towns of Boulder and Gold Hill founded
- 1861- Territory of Colorado and Boulder County established
- 1861-1865- U.S. Civil War
- 1865- First road in Boulder Canyon built from Boulder to confluence of Boulder and Fourmile Creeks
- 1871- Town of Erie founded
- 1873- Railroad extended from Denver to Boulder
- 1876- Colorado became a State
- 1878- Town of Louisville founded
- 1877- University of Colorado established
- 1888- Town of Lafayette founded
- 1896- Town of Superior founded
- 1914-1918- World War I
- 1929- The Great Depression began
- 1939-1945- World War II
- 1950-1953- Korean War
- 1951- Denver-Boulder Turnpike opened
- 1952- Rocky Flats Nuclear Weapons Factory opened
- 1960-1965- Civil rights movement
- 1964-1975- Vietnam War
- 1969- Humans first landed on the moon
- 1970- First Earth Day

Pre-1850 | 1850 | 1860 | 1870 | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010

Water-Quality Regulations

Federal and state lawmakers first began instituting water regulations regarding drinking water supply. Regulation of point-source discharge of wastewater and other pollutants followed. Over time, additional regulations were added, with the ultimate goal of all waters being swimmable, fishable, and drinkable. These regulations have led to greater control over contaminants discharged to Boulder Creek.

- 1876- Colorado State Board of Health established
- 1890- Federal Rivers and Harbors Act
- 1902- Colorado State Board of Health began requiring reporting of typhoid and that new public water supplies must have Board approval
- 1912- U.S. Public Health Service Act authorized Federal Government to investigate waterborne disease and water pollution
- 1914- U.S. Public Health Service established first Federal drinking water standards (applied primarily to passenger trains)
- 1925- Drinking-water standards adopted by U.S. Treasury Department; refer to source, treatment, and protection of water
- 1947- Colorado Department of Public Health given power to establish and enforce sewage water-quality standards
- 1948- U.S. Water Pollution Control Act
- 1956- Federal Water Pollution Control Act
- 1965- U.S. Water Quality Act (required States to establish water-quality standards)
- 1966- Colorado Water Pollution Control Act (created authority to establish water-quality standards)
- 1970- U.S. Environmental Protection Agency established
- 1972- Federal Water Pollution Control Act Amendments (Clean Water Act)
- 1973- Colorado Water Quality Control Act
- 1974- U.S. Safe Drinking Water Act
- 1976- U.S. Toxic Substances Control Act
- 1987- U.S. Water Quality Act

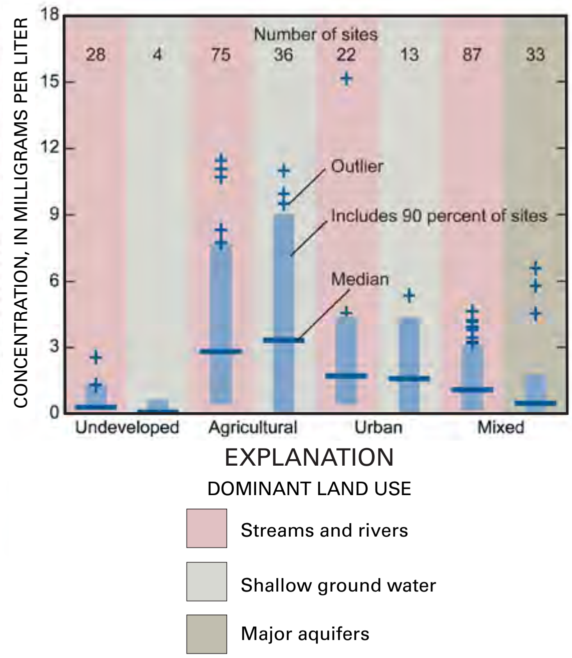
Timeline for the Boulder Creek Watershed, Colorado

How does water quality in the Boulder Creek Watershed compare to other Front Range watersheds and to watersheds nationwide?

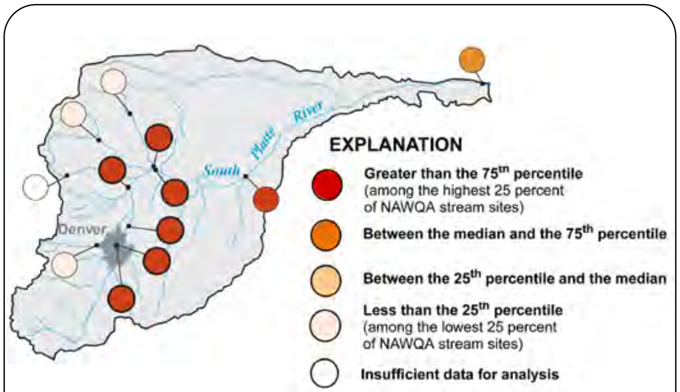
The National Water-Quality Assessment (NAWQA) Program of the USGS assesses water quality of watersheds across the United States. NAWQA studies indicate that contaminants are widespread, albeit commonly at low concentrations, across a wide range of landscapes and land uses (Hamilton and others, 2004). The highest nutrient and pesticide concentrations were detected in agricultural and urban streams. These streams usually contain complex mixtures of nutrients and pesticides. Nationally, at least one pesticide was found in 94 percent of all surface-water samples. Contaminant concentrations varied with seasons, typically with long periods of low or nondetectable concentrations and brief periods of much higher concentrations.

The South Platte River Watershed, which includes the Boulder Creek Watershed, has been studied as part of the NAWQA Program. The NAWQA study evaluated data based on five land-use categories: forest, agricultural, urban, mixed urban/agricultural, and rangeland. The study found that water quality in the forested mountain region of the South Platte River Watershed was generally good, while water quality in urban and agricultural areas was degraded (Dennehy and others, 1998). Most surface-water sampling sites located in urban, agricultural, and mixed urban/agricultural land-use areas had nutrient concentrations that were among the highest 25 percent of all 20 NAWQA study units sampled during 1992–95 (that is, 75 percent or more of samples from each site had total nitrogen concentrations greater than 7.3 mg/L as N and total phosphorus concentrations greater than 0.87 mg/L as P). Total nitrogen concentrations in streams along the Colorado Front Range were substantially greater downstream from WWTPs. Nutrient levels in mountain and rangeland sampling sites in the South Platte River Watershed, however, were among the lowest nationally.

Water-quality data for Boulder Creek are similar to data from the South Platte River Watershed NAWQA study in the same land-use categories. Nutrient concentrations in forested headwater and mountain regions are low or undetectable; downstream from urban areas, nutrient concentrations are within the range of the highest 25 percent of the NAWQA study units (Murphy and Waterman, 2005).



Total nitrogen in streams and nitrate in ground water for all USGS NAWQA study units (from USGS, 1999).



Ranking of nutrient concentrations in the South Platte River Watershed relative to all NAWQA stream sites (bold outline of circle indicates one or more aquatic-life criteria were exceeded; from Dennehy and others, 1998).

Information about the USGS NAWQA program is available at http://water.usgs.gov/nawqa/

What will be the water-quality issues in the Boulder Creek Watershed in the future?

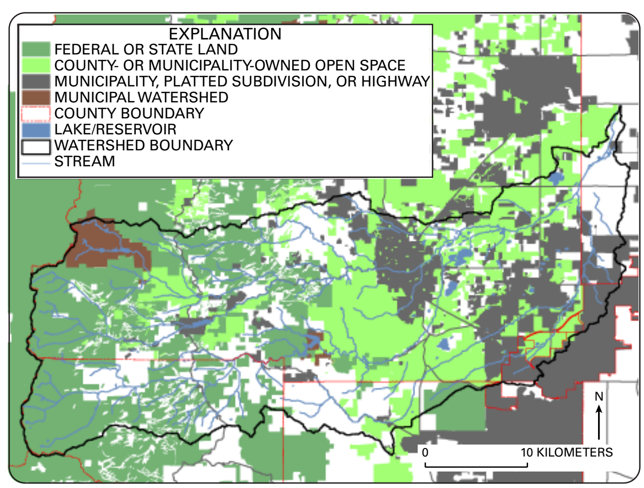
As population has grown in the Boulder Creek Watershed, potential water-quality effects from urbanization have increased. Conversion of forest and agricultural land to urban land use has resulted in increased impervious surface area, which causes rain and melted snow to travel quickly to streams as surface-water runoff, carrying sediment and accumulated contaminants. Construction also contributes sediment to streams if runoff is not controlled. In 2001, CDPHE enacted regulations that require urban areas with populations over 10,000 to manage stormwater to reduce pollutant loading (CDPHE, 2005f). These regulations require public education, illicit discharge detection and elimination, construction site stormwater runoff control, and pollution prevention for municipal operations. In the Boulder Creek Watershed, these regulations affect Boulder County and the cities of Boulder, Erie, Lafayette, Louisville, and Superior. The listing of Boulder Creek through the city of Boulder as an impaired stream because of high levels of *E. coli* has also focused attention on urban runoff. Identifying sources of bacteria is difficult, and research is ongoing (Stoeckel and others, 2004).

Information about stormwater programs in the watershed is available from the Watershed Approach to Stream Health (WASH) program at www.BASIN.org/WASH

Increased population means more wastewater, which contributes nutrients and organic wastewater contaminants to streams. However, WWTP expansions to accommodate growth usually improve nutrient removal. The Boulder WWTP, the largest contributor of ammonia to the watershed, is being upgraded to improve ammonia removal. Organic wastewater contaminants, such as pharmaceutical drugs, hormones, and cleaning products, which are generally not regulated, have been found in effluent from the Boulder WWTP and WWTPs and rivers throughout the Nation (Kolpin and others, 2002; Murphy and others, 2003, chapter 5). The effects of many of these compounds are unknown, and there are no water-quality standards for most of them. Potential concerns include abnormal physiological processes and reproductive impairment (Daughton and Ternes, 1999). Studies of fish in Boulder Creek and the South Platte River downstream from WWTPs detected a high female to male ratio and reproductive abnormalities (Vajda and others, 2004). New analytical research into the ecological effects of these emerging contaminants is needed to fully understand human health and ecosystem implications.

While population growth and urbanization in the Boulder Creek Watershed has been rapid in recent years, the rate of growth will likely be lower in the future. Boulder County and communities within the county have preserved about 445 square kilometers (110,000 acres) of land as open space or conservation easements (Boulder County Parks and Open Space, written commun., 2005). There is also open space in Broomfield, Jefferson, and Weld Counties within the watershed. Much of the upper watershed is national forest or city-owned protected watershed property.

Cleaning products



Land ownership in the Boulder Creek Watershed in 2005 (data provided by U.S. Forest Service, Boulder County, and Jefferson County).

Summary

Boulder Creek and its tributaries are vital for providing drinking water, agricultural irrigation, aquatic habitat, recreation, and power generation. The suitability of water for these uses is commonly determined by water quality. Water quality in the Boulder Creek Watershed is affected by natural factors such as geology, climate, and physiography, and human-caused factors, such as wastewater effluent, runoff from roads and urbanized areas, agricultural practices, atmospheric contaminants, and other sources. Water-quality effects are compounded by the many water diversions in the watershed, which often leave little water in streams to provide dilution. The relative effect of these factors on water quality has changed over time and will continue to shift with changes in land and water use. Knowledge of water quality is important for effective water-resource and land-use planning. This report provides an assessment of water quality in the Boulder Creek Watershed at the beginning of the 21st century and how it has changed over the past 160 years. The information can be used as a baseline for evaluating water-quality changes in the future.

Middle Boulder Creek

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For more information

About the Boulder Creek Watershed:

Boulder Area Sustainability Information Network:
www.BASIN.org

USGS studies on the Boulder Creek Watershed:
http://wwwbrr.cr.usgs.gov/projects/SWC_Boulder_Watershed/

About communities within the watershed:

Boulder County
Post Office Box 471
Boulder, CO 80306
(303) 441-3131
http://www.co.boulder.co.us

City of Boulder
1739 Broadway
Boulder, CO 80302
(303) 441-3266
http://www.ci.boulder.co.us

City and County of Broomfield
One DesCombes Drive
Broomfield, CO 80020
(303) 438-6390
http://www.ci.broomfield.co.us/

City of Lafayette
1290 South Public Road
Lafayette, CO 80026
(303) 665-5588
http://www.cityoflafayette.com

City of Louisville
749 Main Street
Louisville, CO 80027
(303) 666-6565
http://www.ci.louisville.co.us/

Gilpin County
203 Eureka Street
Central City, CO 80427
(303) 582-5214
http://co.gilpin.co.us/

Jefferson County
100 Jefferson County Pkwy
Golden, CO 80419
(303) 279-6511
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Town of Erie
645 Holbrook, PO Box 750
Erie, CO 80516
(303) 926-2700
http://www.ci.erie.co.us/

Town of Nederland
P.O. Box 396
Nederland, CO 80466
(303) 258-3266
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Town of Superior
124 E. Coal Creek Drive
Superior, CO 80027
(303) 499-3675
http://www.townofsuperior.com/

Weld County
1555 N. 17th Ave.
Greeley, CO 80631
(970) 356-4000
http://www.co.weld.co.us/