City of Boulder

Source Water Protection Plan

2023 Update

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Acknowledgments

The City of Boulder respectfully recognizes and acknowledges the original inhabitants and caretakers of the water and land in the source water watersheds: the Di De'i (Apache), Hinono'eiteen (Arapaho), Tsistsistas (Cheyenne), N~~u~~mu~~n~~u~~u~~ (Comanche), Kiowa (Caiugu), Čariks i Čariks (Pawnee), Sosonih (Shoshone), Oc'eti S'akowin (Sioux) and Núuchiu (Ute), and the indigenous peoples and all of their ancestors and descendants, past, present, and future.

Boulder is grateful to the many stakeholders who took the time to provide written and verbal input and attend several in-person meetings to update this Plan. Each of you provided valuable feedback on the Plan and identified priority projects that Boulder and stakeholders can work together on implementing to help ensure short- and long-term source water protection.

Key stakeholders who contributed to this plan include: Boulder County Public Health – Erin Dodge, Celeste Gleason, Stephanie Fontanini; Boulder Office of Disaster Management – Kim Scott; Town of Nederland – Miranda Fisher; Northern Colorado Water Conservancy District – Anna Hermes, Kimberly Mihelich; Colorado Department of Public Health and Environment – Kirsten Hughes, Robert Murphy; Colorado Rural Water Association – Paul Hempel, Naia Sottile, Mallory Hiss; U.S. Geological Survey – Sheila Murphy; University of Colorado and the Institute of Arctic and Alpine Research – Noah Molotch, Eve Hinckley, Jennifer Morse; Colorado State Forest Service – Ben Pfohl; Colorado Department of Transportation – Nick Schipanski; Boulder Watershed Collective – Maya MacHamer, Cat Price; The Watershed Center – Deb Hummel, Yana Sorokin. And thank you to the many city staff involved in the process: Utilities Department – Kate Dunlap, Michelle Wind, Meghan Wilson, Kim Hutton, Robby Glenn, Eric Johnson, Darroll Meddaugh, Michael Lawlor, Kevin Koryto, Jon Stoddard; City Attorney's Office – Leila Behnampour; Parks and Recreation Department – Regina Elsner, Stacy Cole; Open Space and Mountain Parks Department – Chris Wanner, Cat McIntyre, Andy Pelster; Climate Initiatives – Brett KenCairn.

Acronyms

Acronym	Definition
ANS	Aquatic Nuisance Species
BCPH	Boulder County Public Health
BWC	Boulder Watershed Collective
C-BT	Colorado-Big Thompson
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CFRI	Colorado Forest Restoration Institute
CPW	Colorado Parks and Wildlife
CRWA	Colorado Rural Water Association
CSFS	Colorado State Forest Service
CWCB	Colorado Water Conservation Board
DRMS	Colorado Division of Reclamation and Mining Safety
EPA	U.S. Environmental Protection Agency
LTER	Long Term Ecological Research Site (Niwot Ridge)
MGD	Million gallons per day
Northern Water	Northern Colorado Water Conservancy District
NRCS	U.S. Department of Agriculture's Natural Resources Conservation Service
ODM	Boulder County Office of Disaster Management
OWTS	Onsite Wastewater Treatment System
PFAS	Per- and polyfluoroalkyl substances
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WESTT	Wildfire Erosion and Sediment Transport Tool
WTP	Water Treatment Plant
WWTF	Wastewater Treatment Facility

Executive Summary

Protecting water supplies at the source is critical to ensuring that Boulder can provide safe and high-quality drinking water to community members and visitors. Boulder's drinking water originates from alpine lakes, reservoirs and headwater streams near the Town of Nederland and the Continental Divide, as well as from diversions from the upper Colorado River via Carter Lake in the foothills north of Boulder. These sources are piped to either of Boulder's two water treatment plants before being delivered to customers for drinking water or irrigation use.

While the Silver Lake Watershed is owned by Boulder and prohibited from public access to protect the water supply, the majority of the source water watersheds are owned or managed by the United States Forest Service, Boulder County, the Town of Nederland, and private landowners. City staff have a long history of working closely with the landowners and managers to assess potential risks to the water supply and identify and implement projects designed to protect water quality. With the assistance of more than 40 stakeholders, Boulder built upon previous efforts by developing the 2017 Source Water Protection Plan (Plan) through Colorado's Source Water Assessment and Protection Program. The 2017 Plan identified more than 50 voluntary strategies and projects that Boulder and its partners could implement to protect the water supply. Since that time, most of those identified projects have been implemented, and there have been some changes to Boulder's water supply. Boulder used this as an opportunity to re-engage stakeholders more formally in 2022 to update the Plan.

This 2023 Source Water Protection Plan is the final product from the stakeholder group and will be used to help guide Boulder's Source Water Protection Program over the coming years (similar to the 2017 Plan). All strategies are voluntary and most involve working and coordinating with partners. The strategies identified in this Plan (see Section 5.2) range from continuing to implement forest health projects to mitigate post-fire impacts to water resources; to better leveraging Niwot Ridge research to help inform water supply policy and management decisions; to working with Boulder County and several state agencies to assess and mitigate potential impacts from upstream mining operations. Boulder staff will continue to track project implementation and will assess effectiveness through Boulder's ongoing water quality monitoring program.

1 Introduction

Source water protection is central to Boulder's water supply planning program. The water supply is vast (spanning both sides of the Continental Divide) and is predominantly outside of Boulder's jurisdictional boundaries. To ensure short- and long-term high quality water supplies, Boulder has fostered partnerships with landowners and stakeholders to mitigate potential impacts and implement source water protection projects and policies.

While source water protection has been ongoing for decades, Boulder formalized these efforts in the first Source Water Protection Plan (Plan) in 2017 in coordination with the Colorado Department of Public Health and Environment (CDPHE) via their Source Water Assessment and Protection Program. With assistance from the Colorado Rural Water Association, nearly 50 stakeholders representing local, state, and federal agencies and organizations, water providers, developers, business owners, and ranch owners were invited to participate in the 2017 Plan development. Five years have passed, and in that time most of the protection strategies identified in the 2017 Plan have been implemented. Boulder set out to update the Plan for the following reasons:

- **Source water updates** – Since 2020 the Boulder Reservoir Water Treatment Plant (WTP) can treat water from Carter Lake Reservoir directly (via the Carter Lake Pipeline), in addition to Boulder Reservoir and Boulder Feeder Canal (both fed by Carter Lake).
- **Protection zones** – This update reflects modified source water protection zones aimed at prioritizing protection for Boulder's primary drinking water intakes.
- **Stakeholder engagement** – Developing and updating the Plan serves as a gateway for enhancing stakeholder involvement in source water protection. Fostering these positive working relationships is the primary way in which Boulder is able to implement source water protection projects.
- **Protection strategies** – Nearly all of the protection strategies identified by stakeholders in the 2017 Plan have been implemented. Through this Plan development, stakeholders developed an updated set of voluntary strategies to help guide Boulder's source water protection efforts moving forward.
- **Potential contaminant sources** – Stakeholders re-evaluated each of the potential contaminant sources to assess possible impacts and risks to the water supply. There have been some changes to land use since the 2017 Plan was developed, and those changes are reflected in this Plan.

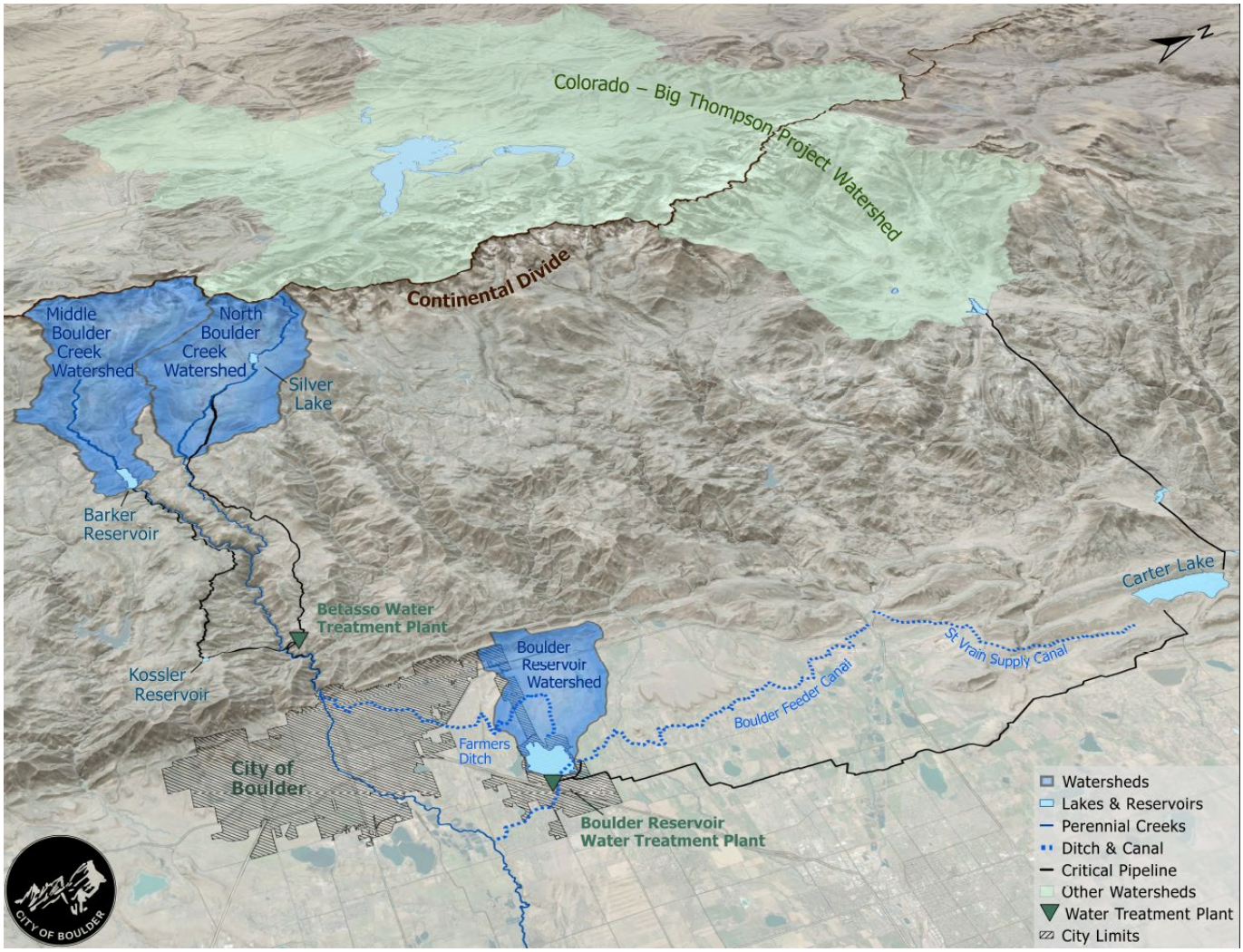
Source water protection is a component of Boulder's multi-barrier approach to providing clean, safe drinking water. This Plan is just one of many tools Boulder uses to help ensure reliable and high-quality drinking water sources for current and future generations. This Plan is organized as follows:

1. **Introduction.** Background and Plan goals
2. **Water System Overview.** A description of the source water system, water quality and water supply demands
3. **Source Water Protection Area.** Description and maps of the source water protection zones and land use
4. **Potential Contaminant Sources.** Assessment of potential water supply contaminant sources and other risks
5. **Protection Strategies.** Strategies to further protect the water supply, including a review of some of the mitigation measures implemented since the 2017 Plan

2 Water System Overview

Boulder's source water originates from three distinct areas: Barker Reservoir on Middle Boulder Creek; Silver Lake and Lakewood Reservoir on North Boulder Creek; and diversions from Northern Colorado Water Conservancy District's (Northern Water) Colorado-Big Thompson (C-BT) and Windy Gap systems via the Carter Lake Pipeline, Boulder Reservoir, and Boulder Feeder Canal. These water sources are treated at two different WTPs — Betasso WTP and Boulder Reservoir WTP. A map of Boulder's source water system is shown in Figure 1. Developing multiple water sources provides Boulder with redundancy, resilience in the face of climate change and associated extreme weather events, and operational flexibility.

Figure 1. Map of City of Boulder's source water supply and water treatment plants.



2.1 Water Treatment

Betasso Water Treatment Plant

The Betasso WTP is located in the foothills west of Boulder (see Figure 1) and treats water from Barker Reservoir (via Kossler Reservoir) and North Boulder Creek (via Lakewood Reservoir). The treatment capacity of the Betasso WTP is 40 million gallons per day. Boulder operates eight hydroelectric facilities that generate electricity off of both raw source water and treated water pipelines prior to distribution throughout Boulder.

A key component of the North Boulder Creek source is the Silver Lake Watershed near the Continental Divide. This area is owned by Boulder and has been prohibited from public access since 1920 to protect source water quality and the long-term ecological and climatological research taking place at Niwot Ridge. Public access to Lakewood Reservoir and Kossler Reservoir is prohibited, and contact recreation, watercraft use, and dogs are prohibited on Barker Reservoir to protect the water supplies and prevent the introduction of aquatic invasive or nuisance species.

Boulder Reservoir Water Treatment Plant

The Boulder Reservoir WTP treats water delivered via the C-BT system managed by Northern Water (see Figure 1). The treatment capacity of the Boulder Reservoir WTP is 16 million gallons per day. The Carter Lake Pipeline delivers water from Carter Lake directly to the WTP year-round. During planned and unplanned pipeline outages or maintenance, the WTP can treat water from Boulder Reservoir (any time of the year) or Boulder Feeder Canal (April through September, or when flowing).

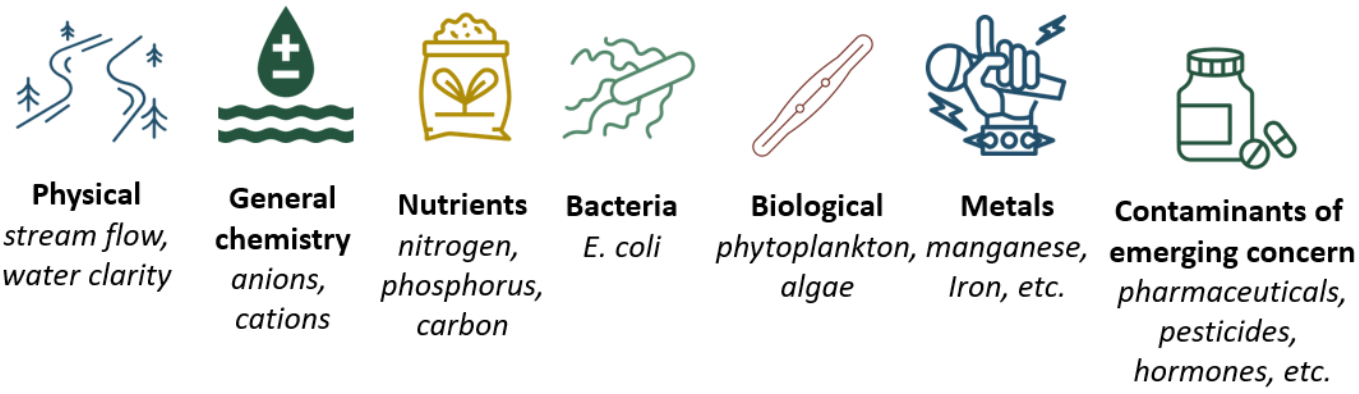
Water Supply Redundancy and Flexibility

Having multiple distinct sources of drinking water provides operational flexibility and system redundancy. Boulder can change sources if needed and can also control some ditch flows to drinking water reservoirs as needed. Overall, Boulder has a diverse water supply portfolio, consisting of water storage, direct flow and water exchange rights extending from the Continental Divide to the Wittemyer Ponds off Boulder Creek, east of Boulder. Boulder's water rights (not including infrastructure) are valued at more than $400 million.

2.2 Water Quality

Boulder implements a robust water quality monitoring program. Since the 1990s, staff has been sampling at the source water reservoirs and tributaries and analyzing for a suite of compounds and analytes (Figure 2). This sampling is in addition to the routine and continuous water quality monitoring at both WTPs and throughout Boulder's water distribution system to monitor treated drinking water quality and ensure regulatory compliance.

Figure 2. Boulder routinely monitors water quality in the source water reservoirs and tributaries for the following types of analytes.

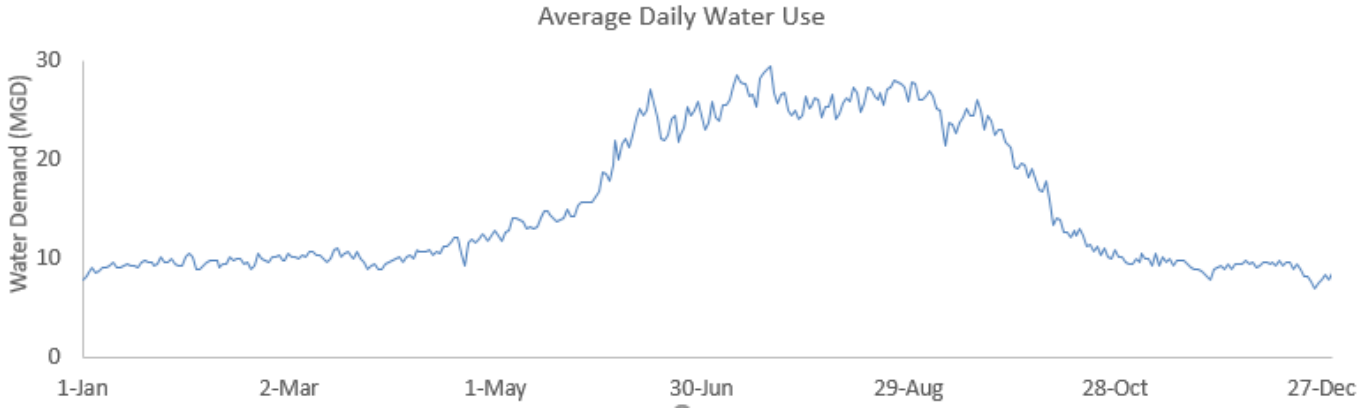


Source water data are analyzed to characterize baseline conditions, seasonal and spatial differences in water quality, and long-term trends; ensure compliance with federal and state water quality regulations and city goals; and inform water treatment. The data also allow staff to understand water quality improvements or degradation from watershed activities and to detect potential sources of contamination. The monitoring program is evaluated and updated annually. Since 2009, Boulder has also participated in a collaborative led by Northern Water to monitor for more than 100 contaminants of emerging concern, including pharmaceuticals, pesticides, hormones, organic chemicals, and wildfire compounds, among others. These contaminants are typically not detected in Boulder's source waters.

2.3 Water Supply Demands and Growth Projections

Boulder's water system service area covers approximately 28 square miles and serves an estimated 120,156 residents and commuters (City of Boulder 2022). Average annual treated water use in Boulder is approximately 5.6 billion gallons, or equivalent to approximately 126 gallons per capita per day. Average daily water use more than doubles in the summer months, as shown in Figure 3. As further described in Boulder's Water Efficiency Plan, per capita water use has significantly declined since the early 2000s. However, population and employment growth combined with climate change impacts (e.g., warmer temperatures leading to reduced streamflows) could add additional pressure to water demands. Preserving and protecting existing source water quality is a crucial component in Boulder's ability to meet buildout water demands.

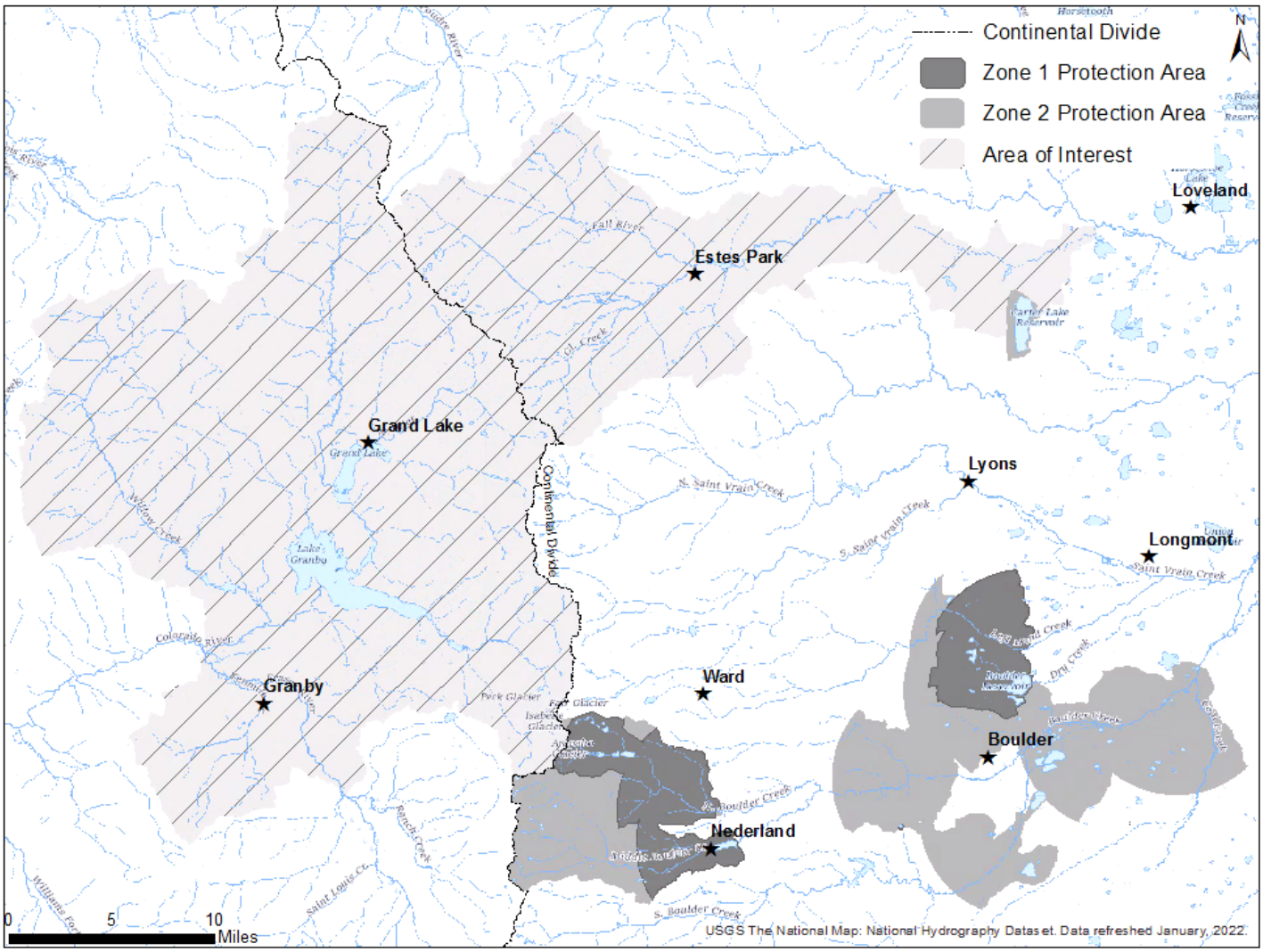
Figure 3. Average daily water use in Boulder, shown in units of million gallons per day - MGD.



3 Source Water Protection Area

Source water protection areas consist of the surface and subsurface areas within which contaminants are reasonably expected to reach a water source. Boulder's source water protection areas consist of two zones and an Area of Interest (see Figure 4). In this Plan, maps show land use and potential contaminant sources for both Zones 1 and 2, but discussion focuses primarily on Zone 1 – the highest area of vulnerability.

Figure 4. Source water protection zones and area of interest.



3.1 Protection Zones

Zone 1

The primary zone of protection is the direct watershed drainage area. This is the 12-digit hydrologic unit code as defined by the U.S. Geological Survey up to five-miles upstream from water supply diversions. This approach is consistent with Colorado Revised Statute 31-15-707(1)(b), which allows water providers to implement rules to protect source water up to five miles from where the water is taken. Zone 1 is the area of highest vulnerability and is therefore afforded the highest level of protection.

Zone 2

The secondary zone of protection is the remaining portion of the watersheds for Boulder's water supply diversions, outside of Zone 1. Zone 2 also includes the Carter Lake watershed and the five-mile drainage areas associated with Boulder's water supply exchange water rights.

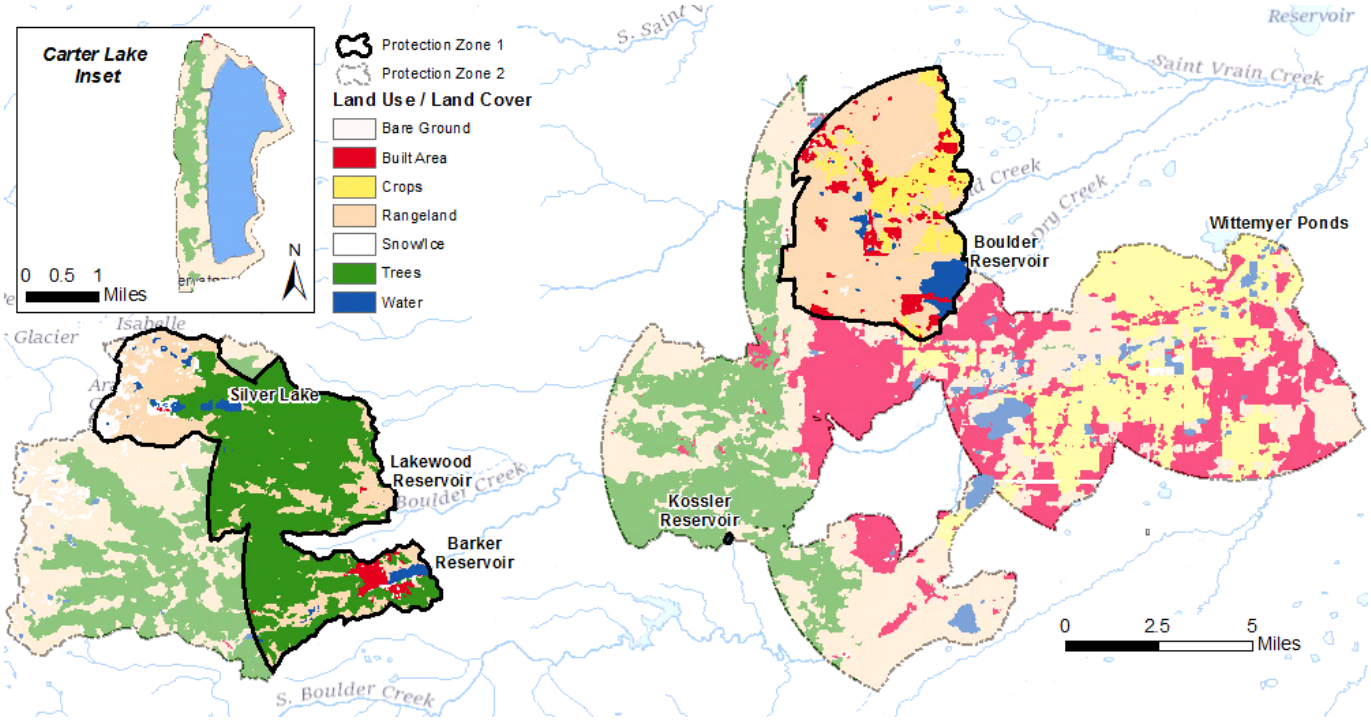
Area of Interest

The area of interest encompasses the larger C-BT system upstream from Carter Lake. Boulder will continue partnering with Northern Water, other C-BT water users, and west slope communities to promote watershed protection in that area. Learn more about Northern Water's source water protection program on their website.

3.2 Land Use and Land Cover

Land use and land cover are variable throughout Zones 1 and 2 of the source water protection area, which ranges from alpine lakes and steep slopes near the Continental Divide, through sub-alpine forests to flatter grassy foothills near the Wittemyer Ponds east of Boulder. Carter Lake is north of Boulder where subalpine forests meet the grassy foothills. Land use and land cover are shown in Figure 5 and further described below. Additional details on watershed characteristics for Boulder's source water system may be found in City of Boulder (2012), MWH and AMEC (2009), and Brown and Caldwell (1992).

Figure 5. Land use and land cover in the source water watersheds. Data source: Esri Sentinel-2 10m land cover time series of the world from 2017-2021 (published January 2022).



The Barker Reservoir Watershed (i.e., the Middle Boulder Creek watershed) and North Boulder Creek watersheds are heavily forested and within the U.S. Forest Service's (USFS) Arapaho and Roosevelt National Forests, including the Indian Peaks Wilderness. Development is concentrated west of Barker Reservoir in the Town of Nederland and also in Eldora Village (populations of 1,471 and 140, respectively [U.S. Census 2020]). The Eldora Ski Resort is located along Middle Boulder Creek on USFS land.

A significant portion of the North Boulder Creek watershed upstream from Lakewood Reservoir is owned by Boulder, including the entire Silver Lake Watershed. The Niwot Ridge Long-Term Ecological Research site is within

and adjacent to the Silver Lake Watershed, where researchers have monitored the climate, ecosystem and water quality for decades. The Silver Lake Watershed is prohibited from public access to protect water quality and long-term research. Downstream from Silver Lake near Lakewood Reservoir is Caribou Ranch, which is an agriculturally managed tract of land where cattle graze during the summer months.

The Kossler Reservoir Watershed is not much bigger than the lake itself and is completely forested and owned by Boulder. Kossler Reservoir is fed by Barker Reservoir via pipeline. Access to the reservoir and watershed are prohibited to protect source water quality.

The Carter Lake Watershed (shown as an inset in Figure 5 for scale) is relatively small compared to the reservoir size. The direct watershed is primarily forested with recreational trails throughout. Carter Lake source water is a mixture of diversions from the Upper Colorado River on the west slope and from the Big Thompson River on the east slope of the Continental Divide. Carter Lake is the second largest waterbody in Northern Water's C-BT distribution system.

Boulder Reservoir Watershed and the lower portion of the Boulder Feeder Canal are predominantly used for agricultural purposes, open space, and residential (Figure 5). Residential development is primarily in the homeowner's association Lake Valley Estates and Golf Course west of Boulder Reservoir. A significant portion of the land in Boulder Reservoir Watershed is owned by Boulder, and much of it is leased for agricultural use.

4 Potential Contaminant Sources

The stakeholder group identified 15 potential sources of contamination or risks to Boulder's water supply. This section of the Plan is organized by contaminant source, providing a general description of the contaminant in the "General Summary" subsections, followed by the "Watershed Details" subsections describing specifics in Boulder's source water protection zones. Contaminant source descriptions are not presented in any ranked order. Overall, the water system's susceptibility to each contaminant source reflects the potential impact to the water system (e.g., human health concerns, volume of the contaminant source) the probability or likelihood of impact (e.g., proximity to the water source, number or quantity of the contaminant source), and water system controls (e.g., Boulder's ability to take measures to prevent water contamination by diverting a source or implementing other strategies). This section describes each potential contaminant source and relevance to the water supply.

4.1 Climate Change and Extreme Weather Events

General Summary

Planning for and responding to climate change is a critical component of source water protection as it directly affects both water quantity and quality. Climate change is fundamentally altering the water cycle and air temperatures and is a driving force behind the increased frequency of extreme weather events including flooding, drought, heat waves, etc. (Box et al. 2017, Madakumbura 2019, Allan et al. 2020, Woolway 2020). Water supply impacts related to climate change include, for example: flooding and heavy snow events that can damage water delivery infrastructure; peak flow precipitation events that can increase water turbidity (i.e., muddy water) making water treatment challenging; heat waves that can trigger source water algal blooms leading to taste and odor issues in drinking water; and prolonged drought conditions that can reduce water supply availability. Extreme weather events are expected to continue in Colorado with the changing climate and warming temperatures (Childress et al. 2015). Wildfire frequency and severity related to climate change are also increasing in Colorado (details in Section 4.2).

Watershed Details

Climate change and associated impacts have been incorporated into Boulder's water supply planning since 2003 following a significant drought year. In recent years, Boulder analyzed seven climate projections and greenhouse gas emissions scenarios – representative of the range of climate change scenarios available. All of the scenarios project a warmer future but vary on changes in annual and seasonal precipitation. Boulder has been working to ensure a reliable future water supply by evaluating system operations, updating its Drought Plan, and working to maximize Boulder's reusable water rights.

The Silver Lake Watershed is home to an alpine tundra Long-Term Ecological Research site, allowing Boulder direct insight into climate-related changes occurring and expected to occur in a portion of the water supply. The extensive and long-term monitoring and analysis at Niwot Ridge have revealed some trends and impacts attributed to the changing climate:

- Portions of the permafrost in the watershed appear to be melting, affecting runoff, vegetation, etc. (Knowles et al. 2015, 2019).
- The tree line is moving to higher elevations (Bourgeron et al., 2015; Suding et al., 2015).
- The type of vegetation is shifting due to the warming climate and precipitation changes (Suding et al., 2015).
- Potential shifts in precipitation type (i.e., rain vs. snow) (Jennings and Molotch 2020).
- The melt-out, or ice-off date of lakes in the watershed has moved earlier each spring compared to the past (Preston et al., 2016).

- Possible changes in lake and stream water chemistry and with biological community make-up (e.g., Crawford et al., 2019; Scharnagl et al., 2019).

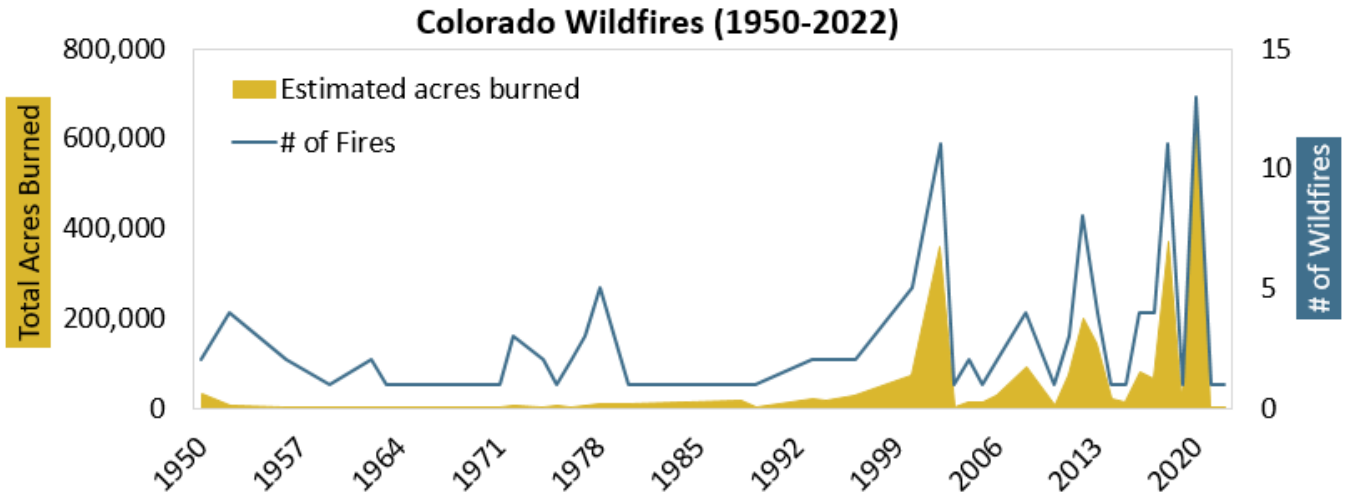
City staff and Niwot Ridge researchers have been partnering to increase information sharing. Understanding changes to water chemistry, snowpack, lake ice cover, and precipitation helps to inform Boulder's water quality monitoring and analysis program and water supply planning.

4.2 Wildfire

General Summary

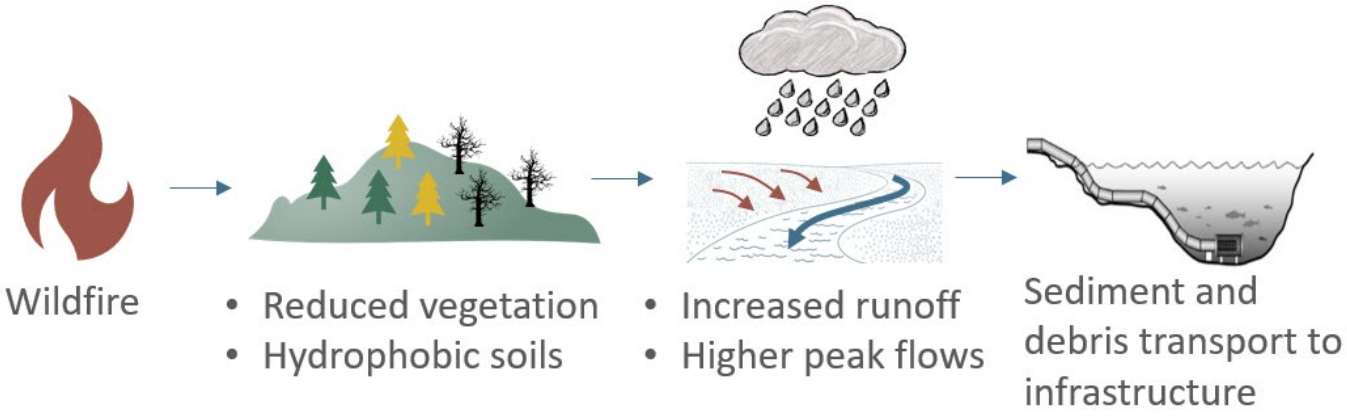
Wildfires are a natural component of Colorado's forested and grassland ecosystems. However, wildfire frequency and extent have been increasing since the 1990s (and particularly since the 2002 drought), and wildfires are now a year-round concern in Colorado (Figure 6). Nine of the 20 largest fires in the state's recorded history have occurred since 2018 (CO DFPC 2022). The primary reasons for increasing wildfires in the state are drought conditions, warming temperatures, more people visiting and living in the Wildland Urban Interface, and declining forest health (bark beetle, parasites, and historic fire suppression leading to high forest density) (CO DFPC 2022).

Figure 6. Large wildfires in Colorado between 1950 and 2022. Data source: Inciweb.nwcg.gov. Dataset may not include all small fires less than 400 acres.



Wildfire and post-wildfire impacts can damage drinking water infrastructure and lead to short- and long-term water quality impacts. These impacts are primarily from post-fire sediment and debris runoff to water supplies as shown in Figure 7. The level of impacts depends on wildfire location, extent and intensity, post-wildfire precipitation, topography, and local soils and vegetation. Hillside erosion and sediment/debris transport to waterbodies contributes to reservoir water storage capacity loss and water quality impacts; damage to collection and controls infrastructure; temporary WTP shutdowns; changes in the amount and timing of snowmelt runoff; increased water treatment costs; and drinking water taste and odor issues. Nutrients (nitrogen and phosphorus) are bound to sediment, and it's not uncommon for algal blooms to occur in reservoirs in the growing season after a wildfire.

Figure 7. Graphic summarizing post-fire impacts to water supplies.



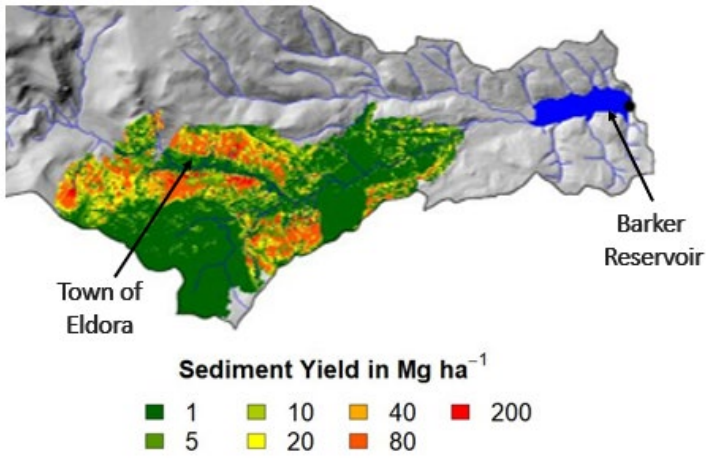
Watershed Details

To better understand potential post-fire impacts to the source water system and facilitate watershed recovery, Boulder partnered with the Colorado Forest Restoration Institute to develop a customized wildfire planning tool—the Wildfire Erosion and Sediment Transport Tool (WESTT). The tool is designed to:

- Predict post-fire erosion and sediment transport to Boulder's drinking water diversions,
- Determine the most effective type and placement of post-fire rehabilitation strategies to stabilize hillslopes and trap sediment, and
- Estimate watershed rehabilitation costs.

The WESTT tool indicates that the largest, most impactful fires to Boulder's water supply are predicted along Middle Boulder Creek. Figure 8 shows a worst-case scenario for Barker Reservoir. In this hypothetical burn scenario, WESTT recommends targeted wood mulch application along the red (high sediment yield) areas on both sides of Middle Boulder Creek, combined with straw mulch application in the yellow (medium sediment yield areas). In the event of a fire in the Barker Reservoir or North Boulder Creek watersheds, Boulder will collaborate with USFS and other primary landowners and will use WESTT to predict potential impacts and help inform post-fire rehabilitation.

Figure 8. A screenshot from the Wildfire Erosion and Sediment Transport Tool. Here, an example modeled burn perimeter along Middle Boulder Creek demonstrates where the majority of post-fire erosion and sediment transport to Barker Reservoir is likely to occur (red areas). Units are in Megagrams per hectare, which is equivalent to a metric ton of sediment.



Wildfires in Colorado will continue to occur and have significant associated costs. In addition to financial planning as a step towards wildfire preparedness and source water protection, the following steps have been taken to actively plan for and address wildfire risk:

- **Forest Health Projects** – Using WESTT and other data, Boulder partnered with Bluestem Conservation and the Boulder Watershed Collective to identify priority areas for forest health and forest thinning projects. These projects are designed to thin out overgrown lodgepole pine, restoring meadows and allowing for ponderosa and aspen regeneration. These projects also improve access for firefighters and reduce fire spread and burn severity. To implement these projects, Boulder has been working with the Town of Nederland, USFS, Colorado State Forest Service, and private landowners.
- **Colorado Post-Fire Playbook** – City staff took an active role in the collaborative effort to develop the Colorado Post-Fire Playbook. This concise and action-oriented resource for water providers and local governments includes 11 specific steps to implement before, during and within 30 days of a fire to plan for and facilitate watershed recovery.
- **Smoke/Ash Water Quality Analyses** – Following the Cameron Peak and East Troublesome wildfires in 2020, the contaminants of emerging concern collaborative, which Boulder participates in, sampled water quality throughout the C-BT system, including Carter Lake, to analyze concentrations and trends in compounds associated with wildfire smoke and ash. The study found that these compounds can be prevalent during rain events in streams and rivers receiving burn-scar runoff, but that concentrations dissipate within 24 hours and in larger reservoirs and lakes.
- **Water Infrastructure in USFS' Database** – City staff worked with CDPHE to integrate Boulder's primary drinking water infrastructure information into the USFS Wildfire Decision Support System. This may help to ensure protection of the water supplies and infrastructure in the event of a fire in the Barker Reservoir or North Boulder Creek watersheds.

4.3 Aquatic Nuisance Species

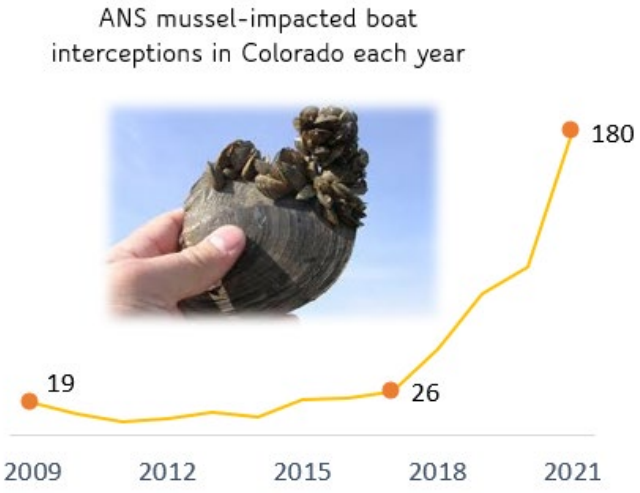
General Summary

Animal and plant aquatic invasive or nuisance species (ANS), including zebra and quagga mussels, the rusty crayfish, New Zealand mudsnails, and Eurasian watermilfoil are priority species of concern in Colorado because they are nearly impossible to eradicate once introduced. Depending on the species, ANS can have aquatic life, water quality, recreational and economic impacts once introduced to a waterbody. ANS mussels, for example, attach to all hard surfaces including water infrastructure and boats, cover swim beaches and impact recreational and water supply uses. A 2018 study commissioned by the City of Westminster found that if their water supply were to become infested with zebra mussels, it would cost the municipality an estimated $10 million in capital improvements plus an additional $3 million annually in water utility operational and maintenance costs.

Preventing the transport and introduction of ANS is critical to waterbody protection and this is performed primarily via public education and watercraft inspection and decontamination programs. Colorado Parks and Wildlife and partners such as Boulder implement these programs at waterbodies throughout the state in an effort to prevent the spread of ANS. Over the past few years there has been a dramatic increase in the number of interceptions of ANS mussel-impacted boats[1] in Colorado's lakes and reservoirs (Figure 9), and in fall 2022 Highline Lake on the western border of Colorado was found to be infested with zebra mussels.

[1] An "interception" refers to a case where prior to entering a waterbody, a watercraft is inspected and ANS are detected on or within the boat.

Figure 9. The number of invasive mussel-impacted boats intercepted by boat inspectors in Colorado has been increasing. In 2021, 180 boats were intercepted, compared with 10-20 boats per year before 2017. Most impacted boats are coming from Lake Powell. Data from Colorado Parks and Wildlife.



Watershed Details

All of Boulder's source water reservoirs except for Boulder Reservoir and Carter Lake are prohibited from public access to protect water quality and prevent the introduction of ANS. Boulder has implemented a watercraft inspection and decontamination program at Boulder Reservoir since 2009 to prevent ANS introduction. Every year the program is re-evaluated and improved based on new information and improved detection and disinfection methods. In summary, all watercraft are inspected and decontaminated, or quarantined prior to launching on the reservoir. Details on Boulder Reservoir's watercraft permit and ANS protocols and decontamination program are online.

Eurasian watermilfoil was detected and confirmed to be established in Boulder Reservoir in late summer 2022 (details on the City's website). At the time of publication of this Plan, the ANS plant is established in shallow areas primarily in the western coves of the reservoir. At current plant density levels, there are no immediate impacts to the reservoir's recreational or water supply uses. Boulder is partnering with Colorado Parks and Wildlife, the Colorado Department of Agriculture, Northern Water (which co-manages the waterbody), and others to explore and implement options to control plant growth in the reservoir. Because this plant is established in other waterbodies in the county and throughout the state, and because the plant can reproduce and establish from just one floating fragment, it could have been introduced from any number of ways such as wind, waterfowl, connected waterways, watercraft, dogs, or recreational users.

While not currently known to be established in Boulder Reservoir, New Zealand mudsnails also have established populations in nearby and connected waterways. Given that these ANS mudsnails self-propagate and are easily transportable, it is likely that they will also eventually make their way into Boulder Reservoir regardless of preventative measures taken. Importantly, while both Eurasian watermilfoil and New Zealand mudsnails are a nuisance, they are not nearly as detrimental to waterbodies as zebra or quagga mussels. Therefore, Boulder continues to maintain and enhance the watercraft inspection and public education programs at Boulder Reservoir to prevent the introduction of these species.

Carter Lake also has a boat inspection program that is managed by Larimer County with funding support from Northern Water. Any boat with a motor or trailer is inspected (and potentially decontaminated) prior to launching in the reservoir. Over the years, Larimer County has made efforts to reduce illegal launch sites and prevent boat entry after-hours.

In Kossler Reservoir, a native but nuisance plant species– *Elodea Nuttallii* – began to dominate aquatic plant life in the reservoir in 2019, leading to water operational issues. Staff has been working diligently with several consulting firms to manage the plant growth, which generally peaks July through September. Several methods that Boulder has used to control plant growth include stocking triploid (sterile) grass carp in the reservoir to consume the vegetation, installing temporary booms and a permanent "trash rack" to keep vegetation out of the outlet corridor, and adjusting reservoir volume to minimize plant spread.

4.4 Wildlife and Geese

General Summary

Water quality concerns associated with wildlife and geese include elevated bacteria levels, nutrient and organic matter loading from fecal waste, and degraded riparian areas, leading to erosion and higher turbidity. In many areas of Colorado, including Boulder, geese often no longer migrate and remain within the state year-round.

Watershed Details

Wildlife is an essential component of the ecosystems along Middle Boulder Creek and North Boulder Creek, which support healthy herds of elk, mule deer, and moose, as well as mountain lions, black bear, and small mammals such as the pika. The Winiger Ridge elk herd resides in the Middle and North Boulder Creek watersheds, moving between Arapaho Ranch, Caribou Ranch, and the Silver Lake Watershed. The herd size can be in the hundreds. When the elk settle along Delonde Creek, their presence can be detected by elevated bacteria levels in Boulder's water quality samples collected downstream on North Boulder Creek. An increasing moose population is scattered between the high country, Caribou Ranch, Arapaho Ranch, and Gross Reservoir. Mountain lions appear to be the primary check on the moose, elk, and deer populations in the upper watersheds. Moose and elk populations are also maintained, to a more limited degree, by hunting.

The Boulder Reservoir watershed supports coyotes, bobcats, prairie dogs, and 70 bird species, including four Boulder County Birds of Special Concern. A large population of Canada geese reside year-round at Boulder Reservoir on the swim beach, docks, marina, and grassy areas. Goose waste contributes to nutrient and organic matter loading in the reservoir, which can adversely impact water quality and promote algal growth. As part of the 2017 Plan development, Boulder received a grant from the Colorado Rural Water Association to partially fund a "till and collect" device that facilitates and expedites goose waste removal at Boulder Reservoir. Since 2017, the device has been used to collect an estimated 1,800 pounds of goose waste around the swim beach and marina each summer – see Daily Camera article for details. This translates to an estimated 91 pounds of nitrogen and 28 pounds of phosphorus removed from the reservoir watershed annually. In some years, this waste is used by Boulder's Open Space and Mountain Parks Department to amend and enhance soils for agricultural use.

4.5 Recreational Activities

General Summary

Recreation encompasses both terrestrial and aquatic activities ranging from hiking to dog walking to fishing to backcountry camping and skiing. With the increasing number of visitors to wilderness and outdoor recreational areas, it is critical that everyone do their part to minimize their impact. Staying on designated trails protects wildlife habitat and minimizes riparian erosion and sediment degradation to streams. Bagging and removing pet and human waste reduce the risk for spreading diseases and invasive species and protects nearby water quality from bacteria and nutrient contamination. Packing out all trash, including food waste, protects wildlife and water quality. Tips and tricks on reducing your environmental impact when spending time in the outdoors are available online – visit "Leave No Trace" for examples.

Watershed Details

The Indian Peaks Wilderness and other parts of the Arapaho and Roosevelt National Forests within Barker Reservoir and North Boulder Creek watersheds are high use recreational areas. Primary destination areas are the Rainbow Lakes, the Fourth of July Trail, and West Magnolia. In recent years, USFS has placed restrictions on backcountry dispersed camping in the area due to damaged vegetation, impacted water quality from trash and feces, and the risk for wildfire from illegal camp fires (USFS 2021, Swearingen 2021).

More than 270,000 people visit Eldora Mountain Ski Resort in the Barker Reservoir Watershed annually (USFS 2015). Impacts from this high number of skiers within the watershed may be more associated with vehicle use and commuting (see Section 4.6 and 4.9) as opposed to human waste and trash, since the Resort treats wastewater (see Section 4.10) and has trash receptacles throughout.

Aside from Boulder Reservoir and Carter Lake, contact recreation and watercraft use are prohibited at all of Boulder's source water reservoirs. Boulder Reservoir has a public swim beach that is open from Memorial Day through Labor Day. The reservoir area is used for boating, biking, pedestrians, and dog walkers, as well as special events including races and triathlons. To minimize water quality impacts from dog walkers, Boulder's Parks and Recreation Department provides bags for dog owners to pick up and properly dispose of dog waste. City Parks and Recreation staff also implement one of the most robust watercraft and ANS inspection and decontamination programs in the state (see Section 4.3). Boulder goes above and beyond to monitor Boulder Reservoir during high-use days and several times per year for boat oil-related compounds, personal care products such as sunscreen and insect repellent, among others. These compounds are generally not detected in the reservoir.

4.6 Stormwater Runoff and Road Maintenance

General Summary

Stormwater runoff from paved surfaces, packed dirt roads, parking lots, residential lawns, agricultural land, and construction areas can transport pollutants to water resources unless proper control measures are installed. Typical pollutants from stormwater include sediment, sand, nutrients, bacteria, metals, oils, synthetic organics and microplastics. These generally originate from soil erosion, fertilizers, pesticides, human and animal/bird waste, trash, deicers, vehicles, tire wear, and road paints. Sediment detention and filtration basins, grass buffers and swales, stream stabilizers, and other methods can be employed to reduce the volume of stormwater runoff, filter out pollutants, and protect waterbodies. Mile High Flood District provides guidance on what type of control measures to install to reduce stormwater impacts.

Watershed Details

Barker Reservoir receives stormwater from several culverts along Route 119, Boulder Canyon Drive, and from culverts or swales draining East Street and the Town of Nederland post office parking lot near the western side of the reservoir. Most streets within the Town of Nederland drain into Beaver Creek, with some culverts discharging to Middle Boulder Creek upstream from Barker Reservoir. Many of the storm drains in Nederland read "Dump No Waste- Drains to River." Vehicles overturning into Barker Reservoir from Route 119 is a concern but occurs infrequently. According to the Colorado Department of Transportation, 2020 average annual daily traffic was 3,200 vehicles on Route 119 at Barker Reservoir. Traffic is expected to increase approximately 19% by the year 2041 (CDOT 2022).

Stormwater discharges to North Boulder Creek and Kossler Reservoir are minor or non-existent given their location and elevation compared to nearby roads.

Boulder Reservoir receives runoff from the swim beach parking area; the boat storage lot, which includes a filling station; and the irrigated grass areas near the swim beach. Stormwater and field drainage is discharged directly to

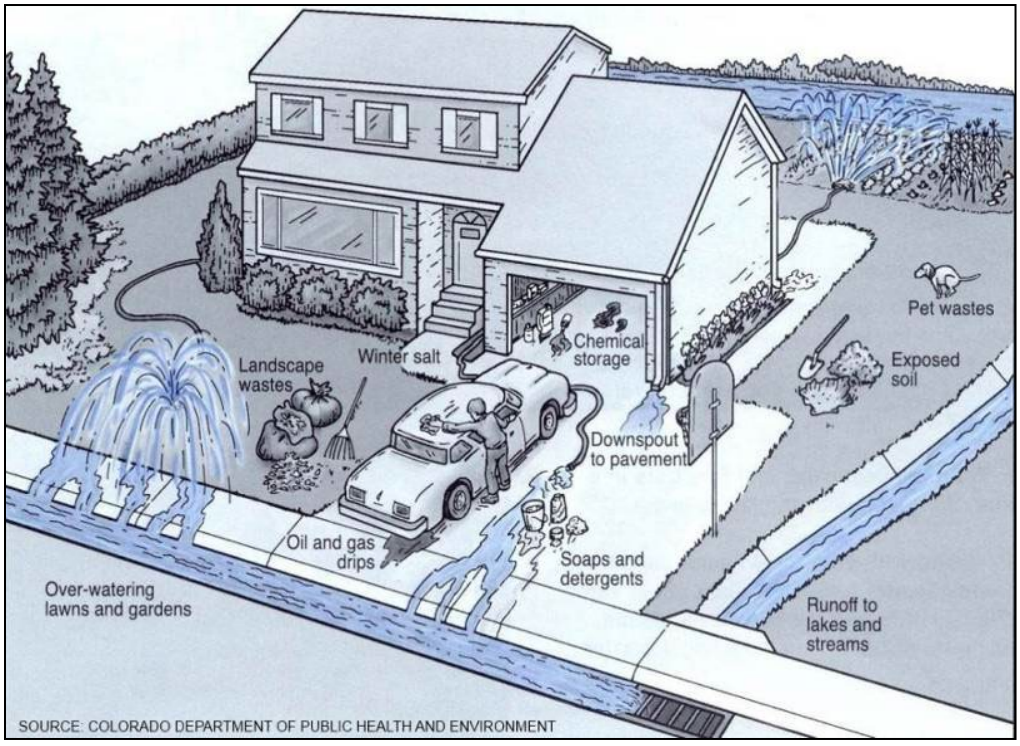
Boulder Feeder Canal via several outfalls along the length of the canal. Over the years, Northern Water and Boulder have partnered to divert outfalls away from Boulder Feeder Canal to minimize water quality impacts to the Canal and Boulder Reservoir. Runoff can also reach Boulder Feeder Canal through several road crossings and parallel roads along the 21-mile length of the canal.

4.7 Residential and Business Practices

General Summary

Without proper precautions, residential and business practices can have adverse impacts to downstream water quality – both during construction and in everyday use. Figure 10 shows a graphic depiction of key contaminant sources from a residential property.

Figure 10. Potential sources of contamination from residences (Hill 2013).



Stormwater and wind on construction sites can transport sediment, trash and other debris to nearby waterways via storm drains or overland flow. Runoff on properties can transport pet waste, soaps and detergents from car washing, lawn fertilizers, pesticides, oil and gas from driveways, and winter salt and sand applications to nearby waterways without prior treatment.

When businesses or homeowners improperly dispose of pharmaceuticals by flushing them down toilets or sink drains, these emerging contaminants make their way to wastewater treatment facilities (WWTF) and often cannot be adequately treated or filtered out prior to discharging to surface water and downstream source water supplies. Visit Boulder County's website to learn about safe medication and syringe disposal.

Any fats, oils, or grease dumped down sink drains at restaurants, homes, and businesses can cause pipe blockages, lead to city sanitary sewer overflows, and leaching from onsite wastewater treatment systems, polluting nearby waterways. Details on regulations pertaining to fats, oils and grease are here.

Per- and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals found in a variety of industrial and consumer products. They also may be found in certain firefighting foams. These persistent chemicals can leach into groundwater and surface water systems, and have been associated with public health effects if concentrations are elevated and prolonged.

Watershed Details

In the Barker Reservoir watershed, residential and business development are primarily centered in the Town of Nederland and the Village of Eldora (see Figure 5 for land use and development). The majority of stormwater from Nederland drains into Beaver Creek or Middle Boulder Creek, just before entering Barker Reservoir. Stormwater from the Barker Meadows park area (near Nederland's WWTF and the post office) flows into Barker Reservoir directly. The Town of Nederland has been working to implement a Fats Oils and Grease program to educate the community about proper disposal of grease and oils to protect the wastewater treatment process and wastewater pipe system. There is little information on pesticide use within the Barker Reservoir watershed. In the past, Eldora Mountain Resort applied chemicals such as carbaryl to control bark beetles, but that practice has long been discontinued. Instead, the ski resort debarks, fells, and removes dead or impacted trees as a mitigation approach. To control invasive terrestrial plants, Boulder occasionally applies approved herbicides around Barker Reservoir and Kossler Reservoir following regulatory limits and requirements.

In the Boulder Reservoir watershed, residential development is concentrated in the Lake Valley Estates suburban development, and along 51st street just west of Boulder Reservoir. Northern Water applies herbicides to Boulder Feeder Canal to control algae and aquatic and terrestrial plant growth. The Boulder County Public Health Mosquito Control program applies permethrin in specific areas throughout Boulder County via ultra-low volume spray. Details on the program, including annual reports, are online.

Boulder routinely monitors both raw source and treated drinking water for more than 100 contaminants of emerging concern, including pharmaceuticals, hormones, household products, and pesticides. Boulder tracks drinking water regulations and reviews and updates the list of monitored emerging contaminants annually. The data from the emerging contaminant monitoring program help city staff better understand the types of contaminants in the raw water and removal efficiency during the water treatment process. Treated drinking water data are posted online in a document titled "Drinking Water Quality Results and a List of Non-Detect Substances" for customer transparency.

Boulder has also monitored for and, as of the publication date of this Plan, has not detected PFAS in the source water and treated water systems (see CDPHE's map for details). Through conversations with several fire districts in the source water watersheds, firefighting foams containing PFAS have not been used. In 2023, Boulder is conducting quarterly PFAS sampling in drinking water as part of EPA's Fifth Unregulated Contaminate Monitoring Rule, with results expected in summer 2023. Visit Boulder's website for updated information.

4.8 Agricultural Activities

General Summary

Agricultural crop and livestock production can be beneficial to the landscape, but without proper management, these activities can also adversely impact water quality. Keeping cattle out of waterways protects riparian habitat and reduces pollutant loading (e.g., nutrients, bacteria, sediment, and emerging contaminants including hormones and compounds associated with antibiotics). Limiting pesticide and fertilizer applications to cropland and avoiding application prior to precipitation minimizes transport of these chemicals to downstream waterways. Rotational cattle grazing on pastures has been shown to reduce wildfire fuels and can minimize erosion.

Watershed Details

There are several ranches and agriculturally managed tracts of land within the source water supply watersheds. The privately owned Indian Peaks LLC tract, also known as Caribou Ranch, is located near Lakewood Reservoir. In most years, roughly 20-50 cattle reside on the property between Memorial Day and Labor Day. The ranch managers practice rotational grazing, which minimizes erosion and provides some level of wildfire protection near Lakewood Reservoir. Depending on their location on the property, the cattle can have direct access to either Como Creek or North Boulder Creek upstream from Lakewood Reservoir. Runoff from the irrigated meadows generally drains to a series of trout ponds on the property that discharge into North Boulder Creek.

There are also agricultural activities in the Boulder Reservoir Watershed. Some residents practice hobby farming, keeping a small number of farm animals on their property. Boulder's Open Space and Mountain Parks Department owns a significant portion of the watershed including Boulder Valley Ranch. This ranch is leased and used for perennial hay production and year-round cattle production (roughly 60 head on average). Several horses are also on the property. The cattle have access to Little Dry Creek and Farmers Ditch, which are tributaries to Boulder Reservoir. On another separate city property north of the reservoir, the lessee generally keeps 150 cattle during the winter and spring (December through early May). The property is also used for hay production and irrigated pasture during the summer. Tail waters from this area have mostly been diverted over Boulder Feeder Canal, and for those that have not been, Boulder staff tend to keep the outfalls closed unless there is an immediate threat of flooding or standing water that could damage the northern Boulder Feeder Canal dike. Flood irrigation is the primary form of irrigation in the watershed, and fertilizer is applied annually or via split application on the cropland.

4.9 Atmospheric Deposition

General Summary

Atmospheric deposition can contribute nitrogen oxides and sulfur oxides to the alpine and subalpine regions of the Rocky Mountains. Recent research by Heindel et al. (2022) also suggests elevated reactive nitrogen (primarily ammonium) deposition along the foothills and wildland urban interface. Sources of nitrogen and sulfur oxides are from within and outside Colorado, including car emissions, agricultural fertilizers, livestock operations, and coal combustion from power plants. There is increasing concern among the research community about the shift toward ammonia-dominated nitrogen deposition and associated adverse ecological and water quality impacts (e.g., Clow et al. 2015, Crawford et al. 2020, Heindel et al. 2022). Ammonia is one of the more biologically available forms of nitrogen and can spur biological growth including algal blooms in waterways.

Watershed Details

Research at Niwot Ridge in and near the Silver Lake Watershed has provided a plethora of data and published research on atmospheric deposition. Williams and Tonnesson (2000) report that annual wet inorganic nitrogen deposition nearly doubled at Niwot Ridge during the 1984 to 1996 period. More recent research from Crawford et al. (2019 and 2020) indicates that as a result of air quality regulations, atmospheric nitrate and sulfate deposition have been decreasing in the alpine region since the early 2000's. Emissions from agriculture are less regulated, and this same research has found that ammonium concentrations in alpine precipitation and in stream water have been steadily increasing since the mid-1980s, likely attributable to feedlots in eastern Colorado.

4.10 Domestic Wastewater Treatment Facility Discharges

General Summary

Treated domestic wastewater discharges contribute nutrients, organic matter, chemicals from personal care and household products, pharmaceuticals, hormones, and bacteria to surface waters. Discharges can also elevate receiving water temperature and turbidity, and the increased nutrient loading can facilitate algal growth.

Watershed Details

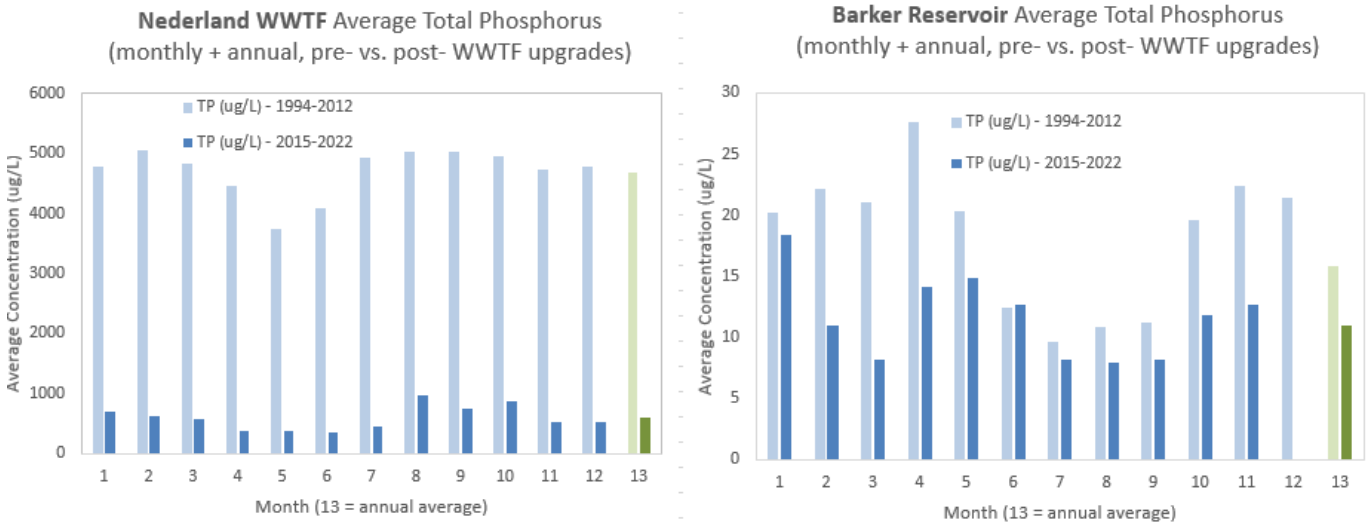
There are several permitted domestic WWTFs in the source water protection area, as further described below.

Town of Nederland WWTF

The Town of Nederland's WWTF (permit CO0020222) discharges treated effluent into Middle Boulder Creek near the west end of Barker Reservoir. Prior to April 2013, Nederland's WWTF was an aeration lagoon system providing secondary treatment. Despite contributing relatively little flow (i.e., less than 1% of the total) to Barker Reservoir, the WWTF effluent was responsible for roughly 75% of the phosphorus loading. To improve effluent quality and minimize phosphorus loading to Barker Reservoir, Boulder contributed capital funding to incorporate phosphorus removal in the treatment process and reimburses the Town of Nederland annually, under a 2009 Intergovernmental Agreement, to continue phosphorus treatment. Phosphorus removal at the Nederland WWTF has been in place since 2013. Since that time, Nederland WWTF effluent water quality has significantly improved, lowering nutrient levels in Barker Reservoir (see Figure 11 for phosphorus concentrations). Boulder staff continue to monitor treated effluent and reservoir water quality to better understand trends.

In addition to WWTF upgrades, the Town of Nederland has been working to reduce sewer infiltration and inflows (i.e., seepage from sewer pipes through town). A professional contractor will conduct a full inspection and cleaning of the sewer system in 2023 and every five years thereafter per the Town's Master Infrastructure Plan. The camera-based inspection will help to identify repair needs.

Figure 11. Nederland WWTF effluent (left) and Barker Reservoir (right) total phosphorus levels pre- and post- phosphorus removal at the Nederland WWTF. "Month 13" shows the annual average, with the darker green attributed to the 2015-2022 period. Years 2013 and 2014 are not included in the figures because those were transition years and not indicative of longer-term concentrations. Barker Reservoir is generally frozen in the winter months and the sample numbers are low, and in some cases, none.



Lake Eldora WWTF

The Lake Eldora Water and Sanitation District has two sewage treatment lagoons at Eldora Mountain Resort (discharge permit CO0020010). Treated effluent discharges into an unnamed ditch which flows into Peterson Lake, Peterson Creek, and eventually into Middle Boulder Creek. The lagoons were emptied and re-lined in 2012. The facility is designed to serve a population of 24 part-time employees and 1,500 ski resort visitors. The permitted 30-day average discharge is 0.03 million gallons per day.

Mountain Research Station WWTF

The Mountain Research Station WWTF (permit COX631000) is located along upper Como Creek in the Lakewood Reservoir Watershed. Installed in August 2001, the Cycle-Let/ZenoGem WWTF consists of a three chamber 10,000-gallon tank for biological processing with membrane filters and ultra-violet disinfection. The tank discharges into a pond with a storage capacity of 28,000 gallons. The pond is unlined and flows via groundwater into Como Creek, which is about 60 feet away and 20 feet lower in elevation. Treatment capacity is 14,400 gallons per day, though the average is 2,000 gallons per day during the June through August busy season (Pfeifer, G., email communication, 2017). Pending a construction permit from CDPHE, the facility will begin construction in summer 2024 (at the earliest) to begin discharging to an exfiltration bed instead of a pond (Hess, K., email communication, 2023). The new exfiltration bed would be more than 200 feet from Como Creek to help protect water quality.

Fairways Metropolitan District WWTF

Lake Valley Estates' Fairways Metropolitan District WWTF (permit CO0048411) is approximately one mile upstream from Boulder Reservoir and serves 339 single family homes and a golf course club house. The facility conducts basic wastewater treatment via chlorine gas. The chlorinated effluent is then pumped to several aerated ponds for storage and irrigation use on the golf courses. All overland runoff and flows from the District flow into Dry Creek, a tributary of Boulder Reservoir's. The WWTF's permit provides for direct discharge to Dry Creek; however, according to WWTF staff, their permit water quality limits could not be achieved with their current treatment approach. Therefore, unless there is an emergency event, water is pumped to the irrigation ponds.

When the ground is saturated due to heavy rain/snowfall, raw sewage can overflow from surcharges in the collection line. Overflows occurred for this reason most recently in May 2015 and May 2017. In December 2018 the facility's emergency discharge valve was accidentally left open for a week, resulting in minimally treated effluent flowing into Dry Creek. In August and September 2022 all six of the aerators in the ponds clogged due to non-flushable items in the wastewater stream. In early January 2023, the Fairways Metro District Board approved expanding the board from two to four elected volunteers and funding two new aerators. Per discussions with WWTF staff, there is an unknown quantity of sludge in the irrigation ponds, which have not been pumped since 2016/2017. To protect the aerators, the District is kicking off an educational campaign for residents regarding which types of items can be flushed. Educational flyers, door hangers, informational items in quarterly invoices, and laminated posters of information are expected to be disseminated by District staff in early 2023.

4.11 Onsite Wastewater Treatment Systems

General Summary

Onsite wastewater treatment systems (OWTS) are most commonly referred to as septic systems, which are a type of OWTS consisting of a tank that collects sewage and allows solids to settle and greases/fats to float before discharging liquid to a soil treatment area or leach field for final filtration. The tanks must be regularly maintained and inspected to ensure that they are properly functioning. Non-functioning or inadequately maintained OWTS can contribute a variety of contaminants to groundwater, including bacteria, pathogens, nutrients, organic matter, and pharmaceuticals and household products.

Watershed Details

Boulder County Public Health implements a comprehensive OWTS regulatory program and runs the SepticSmart campaign to help ensure OWTS' are permitted, routinely maintained, and operating safely and effectively. Within Boulder's source water supply system, the highest concentration of unapproved and high-risk OWTS is in the Town of Eldora and along the north fork of Middle Boulder Creek. There are also several unapproved OWTS south of Barker Reservoir in the Big Springs neighborhood and upstream from Lakewood Reservoir.

4.12 Storage Tanks

General Summary

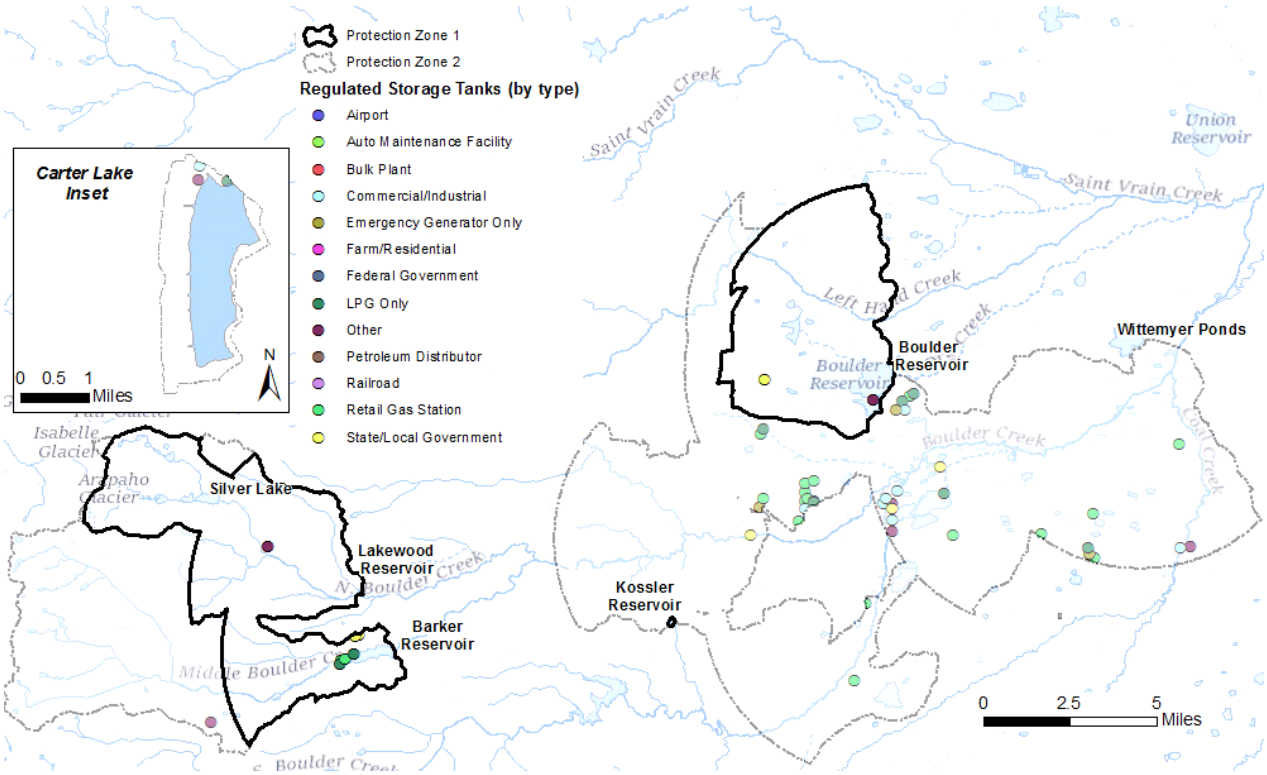
Colorado's Department of Labor and Employment, Division of Oil and Public Safety regulates certain above- and underground- storage tanks that contain petroleum substances (except some compressed and liquefied gases). Regulated tanks include underground storage tanks greater than or equal to 110 gallons and aboveground storage tanks with capacities ranging from 60 to 40,000 gallons (CO DLE 2017).

Watershed Details

There are nine facilities with regulated storage tanks in Zone 1 and 44 facilities in Zone 2 (see Figure 12). The facilities that have tanks in the Barker Reservoir Watershed include Amerigas (5 liquid propane gas tanks), Indian Peaks Ace Hardware, two retail gas stations in Nederland, the Nederland road maintenance facility and the Nederland Bus Barn. The Mountain Research Station has one regulated tank at their facility in the North Boulder Creek watershed. In the Boulder Reservoir watershed, Boulder's Marina Fueling Area has a tank, and there is also a tank at the Boulder County Longhorn Transportation Facility. The 1,000-gallon fueling tank at the Boulder Reservoir marina is used for fueling city boats and vehicles and private watercraft. The tank is aboveground and has a concrete liner around it.

Since 1986, when data collection began, there have been three documented petroleum releases from storage tanks in the Zone 1 protection area – all three of which were in the Barker Reservoir Watershed in Nederland (see online map). The most recent release was reported in 2015 at the Gasamat/Cigarette Store #127 (Event ID 12361). That release was actually a historical impact that was identified in 2015 during a tank removal and replacement project. The site was fully cleaned, and the case was closed in January 2022 (Campbell, K., phone conversation, 2022).

Figure 12. Regulated storage tanks (colored by type) in Source Water Protection Zones 1 and 2. Data are from the Colorado Department of Labor and Employment, Division of Oil and Public Safety. Data downloaded on 5/23/2022 from https://data.colorado.gov/Energy/Regulated-Storage-Tank-Facilities-in-Colorado-Oil-/iazk-c8xj



4.13 Mining Activities

General Summary

Active and historic mines and mining-related activities can have adverse impacts on water quality, aquatic life, and public health if not properly operated. Impacts are generally related to discharges of heavy metals, sediment, and other byproducts of mining. Also, drainage leaching through mine tailings can be laden with metals and chemicals that were used during the milling process. Placer mining and other in-stream mining can have direct water quality and water treatment-related impacts by elevating in-stream turbidity, sediment, and metals.

Watershed Details

During the late 1800s and early 1900s, the Barker Reservoir and North Boulder Creek watersheds were heavily mined for tungsten, gold, silver, and other metals. Ores were discovered in Caribou Hill in 1869 and the area was mined until the price of silver dropped in 1893. Gold mining was initiated around 1882 in Happy Valley near what is now the town of Eldora, southwest of Caribou Hill. A second mining boom was sparked in Caribou Hill in 1915, when tungsten, a steel-hardening alloy, was discovered. By 1920, mining had significantly declined due to lower demand and prices and was limited primarily to individuals sporadically reactivating abandoned mines into the mid-1900s (Moore et al. 1957, Nederland Area Historical Society 2016). Further background on the mining history in the upper reaches of Boulder Creek (and Boulder's multiple water intake movements to limit drinking water contamination) has been published by Murphy (2006) available online. The mines of Caribou Hill, subsequently called Wolf Tongue Mill, have been out of operation since 1972 (City of Boulder 1992). There are several mines of particular interest in the Zone 1 protection area, upstream from Barker Reservoir (see map here).

Cross and Caribou Mines

Cross and Caribou Mines (DRMS permit ID M1977410; CDPHE discharge permit CO0032751) are located west of the Town of Nederland, near the top of Caribou Road. The Cross Gold Mine is an active 9.99-acre hard rock mine with a surety of $546,751. The Caribou Mine is permitted for one acre and there is no surety. A surety is a financial obligation, or collateral, to help pay for reclamation in case the mine permittee defaults.

Effluent from the Caribou Mine and Cross Mine (adjacent to one another on the same property) is required to be treated prior to discharge into Coon Track Creek, roughly four miles upstream from Barker Reservoir. Due to water quality violations, Cease and Desist orders were issued to the mine operators in late 2021 by both CDPHE and the Colorado Division of Reclamation and Mining Safety (DRMS). Boulder submitted public comments to CDPHE and DRMS in January 2022 expressing concern about the mine effluent and potential impacts to Boulder's water supply. Boulder has increased water quality monitoring and metals analyses at Beaver Creek to track any changes in water quality that could be attributed to the mines. Boulder is also maintaining communication with Boulder County Public Health, DRMS and CDPHE staff to keep informed about the status of the mining operation, permitting, mining effluent treatment, and water quality testing performed by mine operators. At the time this Plan was published, DRMS had made the determination that the mines should be a "Designated Mining Operation," and the mine owner – Grand Island Resources - is therefore responsible for submitting a Designated Mining Operation application by July 2023.

New Cardinal Mill

The New Cardinal Mill mine is downstream from the Cross and Caribou Mines and is also off of Caribou Road west of Nederland. The inactive mine is owned by Boulder County. Opened in 1903, the site was used to mine and mill primarily tungsten and gold until 1914. After that point, the mine was in and out of operation until 1942. The mine discharges continuously, and the un-treated effluent is sampled monthly by Boulder County for metals per their CDPHE discharge permit (COG603078). The effluent discharges to Coon Track Creek, upstream from the confluence with Hicks Gulch Creek. The permitted discharge rate is 30 gallons per minute.

Swathmore

The Swathmore mine is near the Town of Eldora and was secured by DRMS after it temporarily breached in September 2015. At the time, the mine discharged an estimated 4,500 gallons of mine-impacted water within an hour into Middle Boulder Creek, turning the creek orange. As a precaution, Boulder temporarily shut off the downstream Barker Reservoir intake. Staff from Boulder, Nederland, and EPA monitored in-stream water chemistry and sampled the creek for metals analyses. DRMS staff implemented a monitoring program at the mine to characterize the mine discharge quality. There have been no known discharges from the mine since 2015.

4.14 Oil and Gas Development

General Summary

Without proper management and containment, oil and gas production, including hydraulic fracturing and horizontal drilling, can impact water resources. Contamination can stem from spills or discharges of hydraulic fracturing fluids, chemicals and produced water; injecting hydraulic fracturing fluid into wells with compromised integrity, allowing gases and liquids to contaminate groundwater resources; or storing hydraulic fracturing wastewater in inadequately lined or unlined pits, allowing liquids to leach into ground water resources (refer to EPA (2016) for more details).

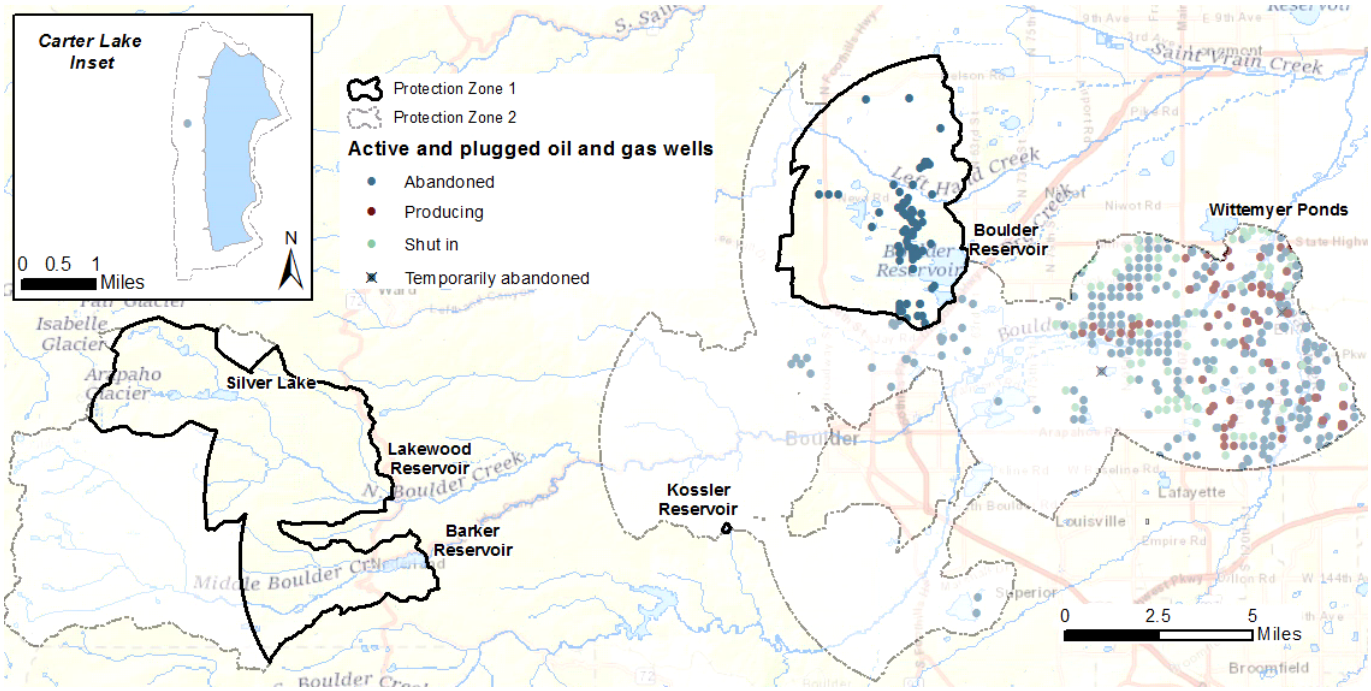
Public surface drinking water sources have modest protections from oil and gas operations under Colorado Oil and Gas Conservation Commission Rule 317B. For classified water supply segments, Rule 317B protects up to five miles upstream from the WTP intake. Additional protections on oil and gas development are required within a half-mile of the source water. Further details on the state's regulations as they pertain to source water protection can be found at COGCC (2016) and AirWaterGas et al. (2016).

Watershed Details

Consistent with other Front Range communities and Boulder County, Boulder adopted local regulations on oil and gas operations on December 14, 2021. The regulations are found within Chapter 6 of Boulder's land use code. The regulations require Planning Board approval of a Use Review application and include extensive regulations on protecting the public health, welfare and safety, and the environment. Detailed studies, reports and plans are required for any applicant to demonstrate a range of criteria that would have to be met for approval. Given the minimum distance requirements to residential and other uses, there are few properties within the city limits that are eligible for new operations. Details on Boulder's regulations are online.

As shown in Figure 13, oil and gas production is primarily east of Boulder and in the Zone 2 Source Water Protection Area within Boulder County. All of the oil and gas wells within the Boulder Reservoir and Boulder Feeder Canal Zone 1 protection area are abandoned. Any new wells in these areas would be subject to Boulder County's comprehensive oil and gas regulations, which include setbacks and protections for water and air quality, natural features and soils, odor, noise, etc. The regulations closely follow the local regulatory authority granted in SB 19-181.

Figure 13. Active and abandoned oil and gas wells in the source water protection zones. Well surface location data "Well Spots" downloaded from COGCC on 4/29/2022.



4.15 Hazardous Waste and Inactive Dump Sites

General Summary

Any hazardous waste, chemical dumping, or leaching dump sites are a risk to water resources. Depending on the chemical or waste product, there could be public health risks associated with exposure and/or consumption.

Watershed Details

The extent to which spills and illegal chemical dumping occurs in the source water protection zones is largely unknown, though there have been resident reports of such incidents to local and state authorities. One known illegal dump site is Gordon Gulch north of Lakewood Reservoir on USFS land. In 2015, EPA performed an emergency cleanup and excavation of two pits containing unknown chemicals (for details see EPA's website). Below are several other known former dumps sites.

Inactive Nederland Landfill

This former Nederland landfill is located east of CO-119 on upper East Magnolia in Barker Reservoir Watershed. The landfill was closed in the 1970s, though the area has at times been used as an illegal shooting range. While the site is in the Barker Reservoir Watershed, drainage runs through the Big Springs subdivision and forested areas before reaching the reservoir. Potential impacts from runoff or groundwater seepage are unknown, but are expected to be minor, if any.

Inactive North Boulder Dump

The 105-acre historic North Boulder Dump was located on the northern end of 26th Street, near the current Boulder Rifle Club in the Boulder Reservoir Watershed. The dump site was used for approximately forty years, closing in 1965. While in operation, it received chemical waste from Syntex Inc., and chemical waste had been observed flowing off-site into a stream (Ecology and Environment, 1988). The site's Superfund eligibility was evaluated in

1988 by the firm Ecology and Environment, Inc. and at the time, the dump site was not expected to impact Boulder Reservoir (Ecology and Environment, 1988). Boulder has a routine monitoring program on Boulder Reservoir and associated tributaries, and water quality data suggest no long-term impact from the former dump site.

Raytheon Site

The Raytheon Aircraft Company facility (also referred to as Raytheon Technologies – Boulder, Facility ID COD007068646), formerly Beech Aircraft Corporation, is located within the Boulder Reservoir Watershed, immediately west of U.S. 36. Aerospace, fueling, and missile subassemblies were conducted onsite between 1967 and 1999, and since that time the site has been used for industrial purposes. Groundwater monitoring during the early 1990s revealed low residual concentrations of volatile organic compounds in the groundwater on the property (Williams 2010). In accordance with an EPA Corrective Action Order issued in 2000, Raytheon has been monitoring groundwater quality and reinjecting treated groundwater through EPA's Underground Injection Control program.

Two seeps also covered under Raytheon's CDPS permit since 1997 continue to discharge untreated groundwater on the eastern side of U.S. 36 to an ephemeral tributary, eventually discharging into Left Hand Valley Reservoir. Raytheon's discharge permit numbers are COG315000 and COG318000. In January 2023, CDPHE issued a Notice of Violation and Cease and Desist Order to Raytheon for failing to comply with discharge permit limits for total and dissolved iron, dissolved manganese, 1,2-cis-dichloroethylene, trichloroethylene, vinyl chloride, total suspended solids, and failing to comply with flow monitoring requirements. Boulder staff conducted a site visit with Raytheon staff and contractors in February 2023 and continue to monitor the situation and analyze our water quality monitoring data at Boulder Reservoir.

5 Protection Strategies

The primary goals of this Plan are to assess potential contaminant sources and identify strategies that Boulder and partners can implement to protect Boulder's water supply. These strategies are non-binding and non-regulatory but do help to guide Boulder's Source Water Protection Program.

5.1 2017 Recap of Protection Projects

The 2017 Plan included 54 strategies identified by the stakeholder group. These projects, which were prioritized based on need, impact, cost, and feasibility, have largely been implemented since the 2017 Plan was finalized. Table 1 highlights some examples of the projects and strategies implemented from the 2017 Plan.

Table 1. Primary source water protection projects and strategies implemented since the 2017 Source Water Protection Plan. Note that Collaborators also generally includes multiple City of Boulder Departments, even if they are not all specifically identified.

Area of Interest	Summary of the Project Implemented Since the 2017 Plan	Collaborators
Wildfire	Partnered with the Colorado Forest Restoration Institute to develop the Wildfire Erosion and Sediment Transport Tool.	CFRI, Town of Nederland
Wildfire	Imported Boulder's ranked critical drinking water infrastructure data into USFS' database to help first responders protect Boulder's water supply assets during a wildfire.	CDPHE, Colorado Rural Watershed Association, USFS, Coalitions and Collaboratives
Wildfire	Scaling up forest health projects in the Barker Reservoir and North Boulder Creek Watersheds, as well as around water infrastructure.	Bluestem Conservation, Boulder Watershed Collective, USFS, CSFS, Town of Nederland, Arapaho Ranch
Wildfire	Coordinated the effort to develop the Colorado Post-Fire Playbook, a resource for water providers, tribes, counties, and municipalities in Colorado to more efficiently and effectively plan for and mitigate wildfire impacts.	Multiple CO water providers, CDPHE, NRCS, USFS, CSFS, Coalitions and Collaboratives
Wildlife and Geese	Purchased a Till and Collect, which facilitates and expedites routine goose waste removal at Boulder Reservoir.	CDPHE, CRWA
Wildlife and Geese	Conducted analyses to understand contributors to periodic elevated bacteria levels at Boulder Reservoir's swim beach. Used findings to implement projects and adjust reservoir operations, ultimately reducing bacteria loading.	Northern Water
Aquatic Nuisance Species	Boulder has significantly enhanced the ANS prevention program at Boulder Reservoir. This includes a more robust watercraft inspection program and implementing a ranger program at Boulder Reservoir to help enforce regulations related to ANS and dogs and protect water quality.	City of Boulder Parks and Recreation Department, CO water providers
Mining Activities	Conducted site visits and performed water quality sampling and analyses to characterize effluent water quality from the Cross and Caribou Mines, and the New Cardinal Mill Mine.	Local mine operators, Boulder County, U.S. Geological Survey, DRMS
Stormwater Runoff and Road Maintenance	Obtained data on deicer application from the Colorado Department of Transportation and Boulder County and evaluated chloride concentrations in the source water to assess potential impacts and long-term trends.	Colorado Department of Transportation, Boulder County
Emergency Response Planning	Updated Boulder's Drinking Water Emergency Response Plan to facilitate and coordinate staff response to emergency events in the drinking water supply.	Boulder ODM, Boulder County
Emergency Response Planning	Developed a Source Water Emergency Monitoring Annex to facilitate staff response to source water contamination events.	CDPHE, EPA
Emergency Response Planning	Updated Boulder's Algae and Cyanotoxin Monitoring and Response Plan to guide response efforts in the event of a harmful algae bloom in any city waterbody, including the source water system	CDPHE

5.2 2023 Plan Protection Projects

For this Plan update, Boulder staff and stakeholders worked to identify a new set of projects and strategies that could be implemented to help ensure short- and long-term source water protection. Similar to the process used in 2017, these projects were identified by the stakeholder group and refined based on need, impact, cost, and feasibility. These projects were then categorized based on level of effort (i.e., city staff time and resources) versus value (i.e., positive impact related to protecting Boulder's water supply) – see Figure 14. In most cases, Boulder will be working with land managers and other partners to collaborate on project implementation. The projects identified by the stakeholder group in this 2023 Plan are in Table 2.

Figure 14. Graphic demonstrating how the stakeholder group categorized each of the proposed source water protection projects.

Table 2. New source water protection strategies to implement per this 2023 Plan update. Note that Collaborators also generally includes multiple City of Boulder Departments, even if they are not all specifically identified.

Objective	Strategy Summary and Ideas	Collaborators	Project Planning (Effort and Value)
Identify hotspots for contaminant loading; work with partners to identify and implement projects designed to reduce pollutant loading and mitigate impacts	• Develop a data analysis tool to facilitate environmental data quality assurance/ quality control, view seasonal trends in water quality and stream flows, and assess tributary and reservoir compliance with water quality standards.	Consultant	4
	• Conduct long-term trend analyses to characterize stream flow and water quality trends and pollutant loading from point and non-point sources. Explore possible use of tools such as USGS' R packages EGRET and WRTDS. The project would include using a program that is repeatable and training for staff to allow for ongoing, updated trend and loading analyses internally.	USGS, CU Boulder, consultant, Keep It Clean Partnership, Town of Nederland	4
	• Using the water quality data analyses tools and results, explore funding opportunities for and implement projects to protect water quality and/or mitigate impacts. For any implemented projects, assess effectiveness and adjust as needed. Coordinate projects and work planning efforts with watershed groups.	Town of Nederland, consultant, USGS, NRCS, EPA, CWCB, ASDWA, BCPH, BWC	4
	• Partner with CU's undergraduate and graduate water quality course (or other relevant college courses) to perform preliminary analyses and provide applied research opportunities for future water professionals.	CU Boulder, CU's MENV program, CU's Center for Sustainable Landscapes and Communities	2

Objective	Strategy Summary and Ideas	Collaborators	Project Planning (Effort and Value)
	• Maintain communication with and conduct frequent check-ins on any efforts conducted by BWC and The Watershed Center to assess habitat potential for beavers in the Boulder Creek Watershed. If a strong re-introduction potential is there, support efforts to identify strategic locations for installing beaver dam analogues, considering potential impacts to water utility infrastructure and operations. Assess benefits and drawbacks associated with beaver dam analogues.	The Watershed Center, Boulder County, BWC	1
Leverage research and long-term trends to help inform source water availability, treatment, and water quality changes (particularly associated with the changing climate)	• Remain an active participant in the Niwot Ridge Mountain Consortium. Support Niwot Ridge staff's efforts to increase the accessibility of their data. Leverage research from Niwot Ridge to help inform policy and management decisions.	Niwot Ridge LTER researchers and staff	2
	• Continue partnering with Niwot Ridge researchers and staff to host the water quality and climate change summit every two years.	Niwot Ridge LTER researchers and staff, City's Climate Change Initiatives	2
Review regulatory requirements and implement policies and programs to help ensure long-term water quality protection	• Update Boulder's Algae and Cyanotoxin Monitoring and Response Plan and explore opportunities with Northern Water to incorporate Carter Lake into the Plan.	Northern Water, CPW	1
	• Continue to track legislation relevant to source water quality, including developments in PFAS and the potential need for additional sampling.	CDPHE, BCPH, Northern Water, Fire Districts	3
	• Continue to be an active partner in Northern Water's Contaminants of Emerging Concern Collaborative to sample and analyze for these contaminants throughout the C-BT system and within Boulder's source water watersheds.	Northern Water and collaborating Utilities	2
	• Help to ensure long-term water quality protection by implementing a Watershed Protection Ordinance pursuant to C.R.S. § 31-15-707(1)(b).	Boulder County, Town of Nederland	4
	• Leverage existing resources from Keep it Clean, Leave No Trace, Let's Doo to educate visitors to Barker Reservoir and Boulder Reservoir about reducing impacts from dog waste, trash, and human impacts.	BCPH, Town of Nederland	4
Support and implement forest health projects to minimize post-fire impacts to the water supply	• Identify and prioritize near- and long-term forest health projects in the Source Water Protection Zones to increase landscape-scale resilience during wildfire. Specific projects to work on with partners include: Arapaho Ranch, Kossler Reservoir, Boulder Canyon Hydro, Boulder County's properties near Nederland.	BWC, private landowners, Town of Nederland, Xcel Energy, CSFS, Northern Colorado Fireshed, Boulder Valley and Longmont Conservation Districts, USFS, CSFS, CFRI	4
	• Track wildfire mitigation and funding legislation and opportunities. Apply for grants with partners to facilitate forest health project planning and implementation.	Various state and federal agencies	4
	• Support and enhance existing efforts to educate and work with the public on the importance and purpose of forest health projects and home mitigation efforts. This may include inviting the public to visit forest health projects, developing Utility bill inserts on wildfire impacts to water supplies, presenting to the Water Resources Advisory Board, and working with BWC on community outreach in the Source Water Protection Zones.	BWC, Boulder County Wildfire Partners, Town of Nederland, Fire Districts, CSFS, CFRI, Wildfire Watershed Protection Group, Boulder County Fireshed	1

Objective	Strategy Summary and Ideas	Collaborators	Project Planning (Effort and Value)
Estimate and assess post-fire water quality impacts to help inform water treatment and water resources operations	• Continue to participate in Northern Water's East Slope C-BT Water Quality Network, designed to understand and characterize downstream impacts from the East Troublesome and Cameron Peak fires.	Northern Water	2
	• Utilize WESTT and other data and information sources to identify and prioritize sediment catchment river restoration projects that could benefit water quality and build watershed resilience in the face of flood, fire, drought conditions.	BWC, The Watershed Center, consultant, BCPH, private landowners, USFS, CSFS	3
	• Partner with the County, BWC, Boulder County Fireshed participants, and the Colorado Water Conservation Board on the Wildfire Ready Watersheds assessment. Compare results to Boulder's WESTT tool, and utilize information to help inform wildfire preparedness and prioritize forest health projects.	CPW, CFRI	2
Protect water quality and water infrastructure by reducing the potential for introduction or spread of ANS to Boulder's source water supplies	• Explore opportunities for furthering ANS and water quality education and outreach to anglers, dog owners and potential illegal watercraft launchers around Barker Reservoir and Boulder Reservoir. Conduct research (from within and outside of Colorado) to understand which approaches are most effective when it comes to educating the public about protecting source waters. Explore opportunities for seasonal staffing at Barker Reservoir (similar to Boulder Reservoir) to educate the public about source water protection and ANS, and enforce water supply protection regulations.	Town of Nederland, CPW, CU's Center for Creative Climate Change Communication and Behavior Change	2
	• Collaborate across city departments and with Boulder County to assess and characterize the spread of New Zealand mudsnails and potential source water impacts in the future.	Boulder County, Watershed Center, Ditch companies	1
	• Conduct annual aquatic vegetation surveys at Boulder Reservoir to map any potential changes in Eurasian Watermilfoil density and extent, and allow for early detection of any newly introduced ANS.	CPW, Boulder County, and Colorado Department of Agriculture	4
	• Collaborate with consultant to assess *Elodea nuttallii* plant growth changes at Kossler Reservoir, effectiveness of the triploid grass carp, and coordinate fish and vegetation surveys as needed.	Consultant, CPW, hatchery	4
Assess and minimize impacts from wastewater to source water quality	• Work with BCPH to map OWTS status in the County and identify hotspots or unapproved systems in the protection zones. Identify priority OWTS near Barker Reservoir. Work with BCPH to provide educational materials on the proper use of OWTS for short-term rentals in the Nederland area. As needed, partner with BCPH on any potential tracer (or similar) studies to assess potential water quality impacts from failing OWTS upstream from Barker Reservoir.	BCPH, Town of Nederland	3
	• Update and extend the City of Boulder and Town of Nederland Intergovernmental Agreement to continue to reimburse Nederland for phosphorus removal at their WWTF to protect Barker Reservoir from eutrophication.	Town of Nederland	4
	• Meet with staff from Eldora Mountain Ski Resort and CU's Mountain Research Station to keep up to speed on WWTF upgrades and improvements at both sites.	Eldora Mountain Ski Resort, CU's Mountain Research Station	1

Objective	Strategy Summary and Ideas	Collaborators	Project Planning (Effort and Value)
	• Support USFS in installing more portable toilets or standalone vaulted bathroom facilities at heavily used recreational sites to minimize nutrient and bacteria loading to surface and groundwater.	USFS, BWC, BCPH	3
Mitigate construction and road maintenance stormwater runoff to source waters	• Explore options/feasibility for filtration basins along CO 119 to filter pollutants and retain sediment and salts prior to discharge into Barker Reservoir.	CDOT	4
	• Partner with Nederland, Boulder County, and the Colorado Department of Transportation to investigate potentially developing an inventory of stormwater outfalls within the watershed. As needed, seek grant funding to assess potential impacts and pollutant loading and prioritize as need for implementing stormwater best management practices.	Town of Nederland, BCPH, CDPHE	4
Protect water quality from active mining activities and legacy mines and dump sites	• Support mining reclamation efforts on private land within the source water protection zones. Support includes periodic check-ins, and identifying and mitigating potential risks.	BWC, DRMS, Trout Unlimited, U.S. Bureau of Land Management	1
	• Support BCPH on their efforts with identifying, mapping, and cleaning legacy dump sites within the source water protection zones. Support includes reviewing BCPH data and maps to understand potential risks and determine next steps.	BCPH	1
	• Conduct quarterly reviews of the U.S. Bureau of Land Management's website for any new mining claims in Boulder County. Review any proposed mining claims, assess potential risks to the water supply and work with partners to determine next steps.	U.S. Bureau of Land Management, Boulder County	1
	• Conduct quarterly check-ins with staff from BCPH, DRMS and CDPHE on any mining permits or discharge-related issues.	BCPH, DRMS, CDPHE	2

References

AirWaterGas, Colorado Rural Water Association, Intermountain Oil and Gas BMP Project, and Western Resource Advocates. 2016. Protecting Source Water in Colorado During Oil and Gas Development. August 2016. http://westernresourceadvocates.org/publications/protecting-source-water-colorado-oil-gas-development/

Allan, R.P., Barlow, M., Byrne, M.P., Cherchi, A., Douville, H., Fowler, H.J., Gan, T.Y., Pendergrass, A.G., Rosenfeld, D., Swann, A.L. and Wilcox, L.J., 2020. Advances in understanding large-scale responses of the water cycle to climate change. Annals of the New York Academy of Sciences, 1472(1), pp.49-75.

Bourgeron, P.S., Humphries, H.C., Liptzin, D. and Seastedt, T.R., 2015. The forest–alpine ecotone: a multi-scale approach to spatial and temporal dynamics of treeline change at Niwot Ridge. *Plant Ecology & Diversity*, *8*(5-6), pp.763-779.

Box, J.E., Colgan, W.T., Christensen, T.R., Schmidt, N.M., Lund, M., Parmentier, F.J.W., Brown, R., Bhatt, U.S., Euskirchen, E.S., Romanovsky, V.E. and Walsh, J.E., 2019. Key indicators of Arctic climate change: 1971–2017. Environmental Research Letters, 14(4), p.045010.

Brown and Caldwell 1992. Water Source Impact Assessment.

Campbell, K. 2022. Phone conversation with Kate Dunlap. June 2, 2022. Kyle.campbell@state.co.us

Childress, A., E. Gordon, T. Jedd, R. Klein, J. Lukas, and R. McKeown. 2015. Colorado Climate Change Vulnerability Study: A Report by the University of Colorado Boulder and Colorado State University to the Colorado Energy Office. Edited by E. Gordon and D. Ojima.

City of Boulder 2022. Boulder Community Profile.

CDOT (Colorado Department of Transportation). 2022. Traffic Data Explorer. Station 104337 (on Rt. 119 at Barker Reservoir) and Station 104332 (on Rt. 119 west of Nederland). Accessed June 28, 2022.

CO DFPC (Colorado Division of Fire Prevention and Control). 2022. 2022 Wildfire Preparedness Plan.

CO DLE (Colorado Department of Labor and Employment). 2017. Storage Tank Regulations 7 C.C.R. 1101-14. May 1, 2017. Division of Oil and Public Safety.

COGCC (Colorado Oil and Gas Conservation Commission). 2016. Series Drilling, Development, Production, and Abandonment. Rule 317B.

CPW (Colorado Parks and Wildlife). 2020. State of Colorado Aquatic Nuisance Species Management Plan.

Crawford, J.T., Hinckley, E.L.S., Neff, J.C., Brahney, J. and Litaor, I., 2019, December. Evidence for accelerated climate-driven weathering and sulfate export in high alpine environments. In AGU Fall Meeting Abstracts (Vol. 2019, pp. H43G-2081).

Crawford, J.T., Hinckley, E.L.S. and Neff, J.C., 2020. Long-term trends in acid precipitation and watershed elemental export from an alpine catchment of the Colorado Rocky Mountains, USA. *Journal of Geophysical Research: Biogeosciences*, *125*(11), p.e2020JG005683.

Clow, D.W., H.A. Roop, L. Nanus, M.E. Fenn, and G.A. Sextone. 2015. Spatial patterns of atmospheric deposition of nitrogen and sulfur using ion-exchange resin collectors in Rocky Mountain National Park, USA. Atmospheric Environment. 101:149-157.

Ecology and Environment, Inc. 1988. Analytical Results Report, North Boulder Dump. Located in: Brown and Caldwell 1992. Water Source Impact Assessment.

EPA (U.S. Environmental Protection Agency). 2016. Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States.

Essential Management Solutions. 2016. Construction Report – CS010 Outfall 002A and 003A Trichloroethylene, cis-1,2 Dichloroethylene, and Vinyl Chloride, Methylene Chloride, Dissolved Manganese, Dissolved and Total Recoverable Iron, and Chloroform Limitation Progress Summary (2nd Quarter 2016) CDPS Permit Number COG-315176 Former Beech Aircraft Facility, Boulder, Colorado. June 30, 2016. To Ms. Andrea BeeBout (CDPHE) from Scott Andrews.

Heindel, R.C., S.F. Murphy, D.A. Repert, G.A. Wetherbee, A.E. Liethen, D.W. Clow, and T.A. Halamka. Elevated nitrogen deposition to fire-prone forests adjacent to urban and agricultural areas, Colorado Front Range, USA. Earth's Future, 10, e2021EF002373. https://doi.org/10.1029/2021EF002373

Hill, M. 2013. Source Water Protection for the Colorado River Partnership Source Water Protection Plan. Morgan Hill, Garfield County Public Health.

Jennings, K.S. and N.P. Molotch, Snowfall fraction, cold content, and energy balance changes drive differential response to simulated warming in an alpine and subalpine snowpack, Frontiers in Earth Science, Vol. 8, 10.3389/feart.2020.00186, 2020.

Knowles, J.F., 2015. Spatio-temporal patterns of soil respiration and the age of respired carbon from high-elevation alpine tundra. PhD, Department of Geography, University of Colorado, Boulder, Boulder, Colorado, USA.

Knowles, J.F., Blanken, P.D., Lawrence, C.R. and Williams, M.W., 2019. Evidence for non-steady-state carbon emissions from snow-scoured alpine tundra. Nature communications, 10(1), pp.1-9.

Madakumbura, G.D., Kim, H., Utsumi, N., Shiogama, H., Fischer, E.M., Seland, Ø., Scinocca, J.F., Mitchell, D.M., Hirabayashi, Y. and Oki, T., 2019. Event-to-event intensification of the hydrologic cycle from 1.5 C to a 2 C warmer world. Scientific Reports, 9(1), pp.1-7.

Moore, F.B., W.S. Cavender, and E.P. Kaiser. 1957. Geology and Uranium Deposits of the Caribou Area, Boulder County Colorado. U.S> Department of the Interior. Geological Survey Bulletin 1030-N.

MWH and AMEC. 2009. Water Utility Master Plan: Volume 4 Source Water Master Plan.

Nederland Area Historical Society. 2016. Timeline. Accessed November 4, 2016.

Preston, D.L., Caine, N., McKnight, D.M., Williams, M.W., Hell, K., Miller, M.P., Hart, S.J. and Johnson, P.T., 2016. Climate regulates alpine lake ice cover phenology and aquatic ecosystem structure. Geophysical Research Letters, 43(10), pp.5353-5360

Scharnagl, K., Johnson, D. and Ebert-May, D., 2019. Shrub expansion and alpine plant community change: 40-year record from Niwot Ridge, Colorado. Plant Ecology & Diversity, 12(5), pp.407-416.

Suding, K.N., Farrer, E.C., King, A.J., Kueppers, L. and Spasojevic, M.J., 2015. Vegetation change at high elevation: scale dependence and interactive effects on Niwot Ridge. Plant Ecology & Diversity, 8(5-6), pp.713-725.

Swearingen, D. 2021. Forest Service Closing Several Boulder County Dispersed Camping Spots. Daily Camera.

U.S. Census. 2020. Nederland Town, Colorado and Eldora CDP, Colorado Populations and People. Accessed June 3, 2022.

USFS (U.S. Forest Service). 2015. Eldora Mountain Resort Ski Area Projects Final Environmental Impact Statement: Appendices. February 2015. USDA Forest Service, Rocky Mountain Region, Roosevelt National Forest.

USFS (U.S. Forest Service). 2021. Forest Service Targets Five Areas for Dispersed Camping Closures.

Williams, M., and K.A. Tonnesson. 2000. Critical loads for inorganic nitrogen deposition in the Colorado Front Range, USA. Ecological Applications. 10(6):1648-1665.

Woolway, R.I., Kraemer, B.M., Lenters, J.D., Merchant, C.J., O'Reilly, C.M. and Sharma, S., 2020. Global lake responses to climate change. Nature Reviews Earth & Environment, 1(8), pp.388-403.