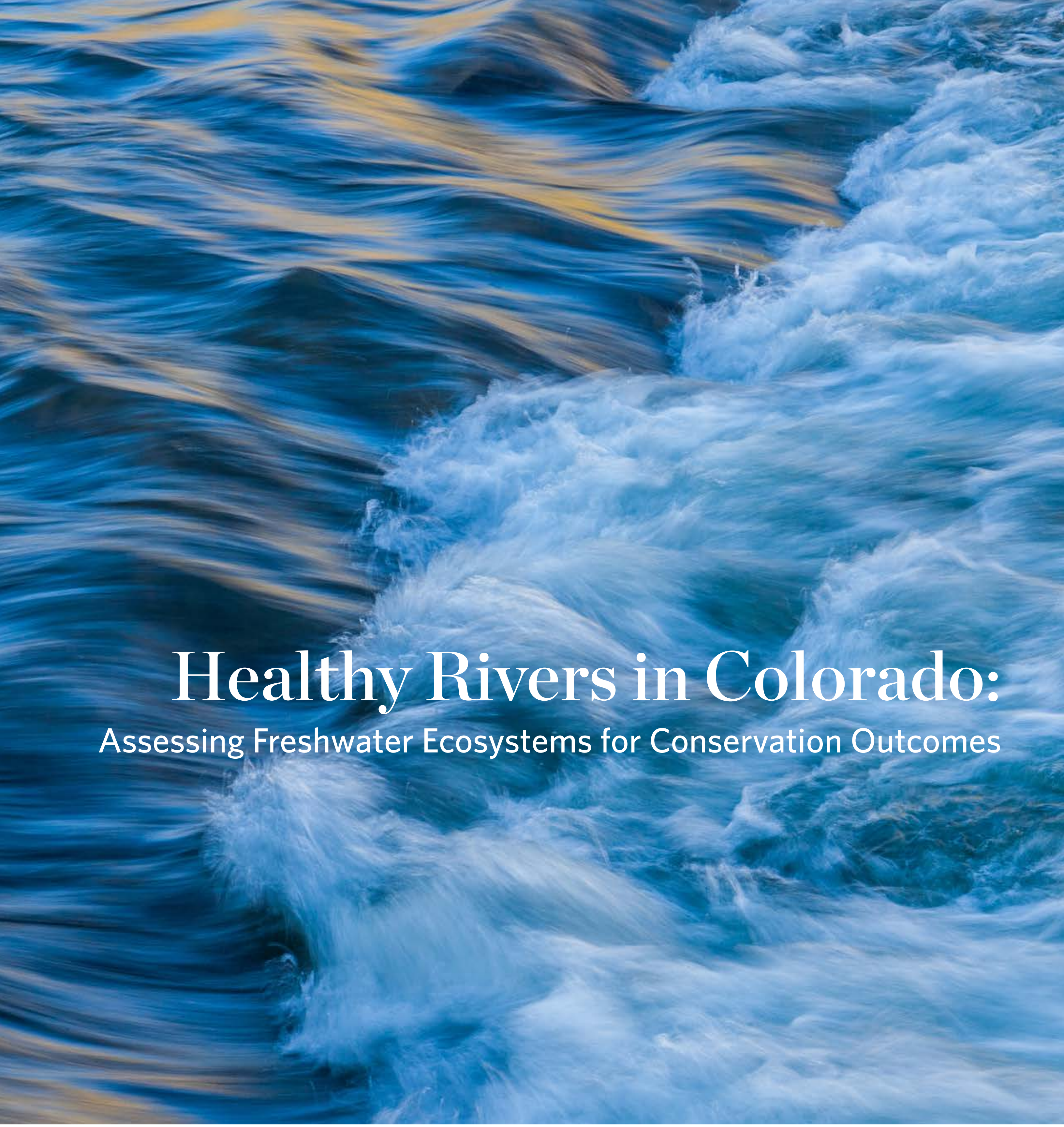

# Healthy Rivers in Colorado:

## Assessing Freshwater Ecosystems for Conservation Outcomes

The Nature Conservancy
Colorado

By Meg White, Teresa Chapman, Brian G. Tavernia, and John Sanderson

July 2017

## Cover image:

Animas River © Erika Nortemann/TNC


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# 1. Executive Summary

Water is the lifeblood of Colorado's economy and quality of life. The water we use—for drinking, to irrigate fields and gardens, to generate electricity and sustain our communities—is water that we share with the natural environment. However, today's freshwater ecosystems experience a wide variety of anthropogenic stressors that can lead to changes in runoff patterns, directly alter flow regimes and rates of groundwater infiltration, and impact the quality of water and habitat. These alterations fundamentally impact the chemical, physical, and biological conditions of Colorado's rivers, streams, and wetlands. Further exacerbating these conditions, shifts in climate increase frequencies of weather extremes including flooding and droughts, which amplify uncertainty for how to most effectively manage water to meet the needs of both people and nature.

With the completion of Colorado's Water Plan, practitioners, managers, and decision makers working in water in Colorado need baseline information and frameworks to help assess current conditions and plan projects that will maximize freshwater conservation outcomes. The objective of the Healthy Rivers Assessment is to serve as a resource and guidance document to provide current freshwater ecosystem baselines and inform project design and prioritization. This analysis offers a comprehensive assessment of freshwater ecosystems in Colorado, scaled to the HUC 12 subwatershed level, and offers insight into opportunities to maintain, protect, and restore rivers and streams throughout Colorado.

We analyzed 22 variables across five different indicator categories to generate maps that highlight the resilience of freshwater ecosystems based on physical, biological, and social conditions, and stressors to those conditions. The first category captured freshwater biodiversity and flow indicator species of conservation value in Colorado. Next, we investigated a suite of seven physical conditions —ranging from elevation and gradient to linear connectivity—that shape the structure and function of stream and river systems across Colorado. We then examined eight variables that account for current habitat conditions, representing human influence on waterways and in watersheds that can impact the flow of materials and energy (i.e., the power produced when water moves down a slope) into and out of a watershed.

Yampa River © *Mark Godfrey*

Finally, we also included two risks and threats variables—nonnative species and drought—and three protections variables (e.g., instream flow protections) to more completely capture current conditions for rivers and streams in Colorado. It is important to note that we chose not to include water quality parameters in this analysis due to data and time constraints. We acknowledge the importance of water quality to overall river health, and that it is inextricably linked to both water quantity and flow conditions.

These variables were aggregated into a final index—the Healthy Rivers Index. The Healthy Rivers Index provides a resiliency score for each subwatershed, offering guidance for freshwater conservation opportunities. The Healthy Rivers Index is designed to highlight current freshwater conditions and inform future decision making and management prioritizing the protection, maintenance, and restoration of river and stream ecosystems in Colorado.

Dolores River © *Lauryn Wachs/TNC*

# 2. Introduction

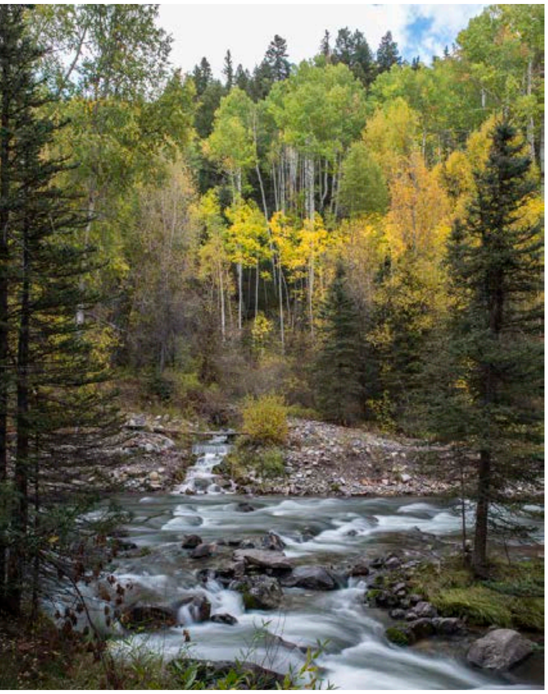
Colorado, famous for its snowcapped mountains, cascading waters, and rolling, open prairies, is home to nearly 110,000 miles (~177,000 kilometers) of streams and rivers including the headwaters of the Platte, the Arkansas, the Rio Grande and the Colorado. These rivers and their tributaries serve as the lifeblood of the state's landscapes, supporting fish and other aquatic life, maintaining healthy riparian corridors for wildlife, fueling recreation and tourism industries, sustaining cities and agriculture, and contributing to Colorado's high quality of life. Yet Colorado is a semi-arid state, averaging only 17 inches of precipitation annually. This limited precipitation generates roughly 15 million-acre feet (MAF) annually to replenish and sustain flowing rivers in eight primary river basins (Colorado Water Plan, 2015). Of those 15 MAF, Colorado consumes roughly 5 million acre-feet through agriculture, municipal, and industrial uses to meet the needs of more than 5 million people. The remaining 10 MAF flows out of Colorado to neighboring states. Most the surface water in Colorado comes from snowmelt in the high mountains, and about 70% of the water available for use each year comes during a short window: during the spring runoff period from May to July (CWCB, 2015). Colorado's plants and animals are adapted to thrive in these dynamics. Alterations to flow patterns—e.g., the size and timing of spring floods, the amount of water in a stream in August—can drastically impact the ability of plants and animals to survive.

In addition to the natural physical and climatic factors shaping flows in Colorado's river basins, legal and policy drivers also guide how water moves through these systems and out of the state. At the headwaters of the Continental Divide, all of Colorado's major rivers flow downstream to eighteen states and Mexico. Nearly two-thirds of the surface water generated in Colorado is legally obligated to downstream users. These obligations significantly influence how water moves through the landscape. More than 8.5 MAF of water flows to states west of the Continental Divide, including Utah, Nevada, California, New Mexico, Arizona, and Mexico. Colorado supplies another 1.4 MAF of water to states on the Atlantic side of the Divide, including Nebraska, Kansas, and Wyoming (CWCB, 2015). Within the state boundaries 80% of water consumed is diverted directly out of rivers. The remaining 20% is pulled from groundwater and aquifers (Cohen, 2011). Of the water

Arkansas River headwaters © *Larry Lams*

Coloradoans use, approximately 80% is used to meet agricultural needs, 10% to meet municipal demands, 2% for industrial needs, 2% to recharge groundwater and aquifers, and 3% for environmental and recreational needs (CWCB, 2010).

The last two decades have brought many changes to Colorado's water supply outlook. The state has experienced significant population growth, with the population expected to nearly double within the next 40 years. Additionally, Colorado's water supply is under pressure from severe drought, multiple end uses (e.g., municipal, industrial, environmental, and recreational), and impacts to agriculture due to water shortages, urbanization, and transfers to new users (CWCB, 2011). Consequently, Colorado faces significant and immediate water supply challenges that require assessment of future water needs and development of plans to meet those needs.



In response to these challenges, Colorado finalized its first-ever statewide water plan in November 2015. Designed to provide a roadmap for future water management in Colorado, Colorado's Water Plan (the Plan) identified the need to secure and manage water resources to support an economy that provides for vibrant and sustainable cities; viable and productive agriculture; and river recreation, and tourism industries; efficient and effective water infrastructure; and a thriving, resilient environment that includes healthy watersheds, rivers, streams, and wildlife. The Plan established a statewide water conservation target of approximately 400,000 acre-feet and set forth measurable objectives, goals, and actions by which Colorado can address its projected future water needs and measure progress. The Plan also included guidelines for making decisions about new supply projects.

While conservation plays a critical role in stretching existing supplies for consumption as well as environmental and recreational needs, conservation alone will not be sufficient to meet future water demands. Colorado still must plan for new reservoirs and dams, potential expansion of existing storage projects, and potential inter-basin transfers and agricultural withdrawals—while still providing flows for recreational uses and the natural environment. Historic management practices have emphasized the diversion of significant flows, storage for future release, and groundwater pumping without considering environmental and recreational needs. However, with information and planning that includes protection of flows, design features and infrastructure operations can often be much less impactful to the natural environment. For example, the Coordinated Reservoir Operations program in 1995 was designed to enhance spring peak flows in a section of the Colorado River upstream of Grand Junction determined critical to the survival of the four endangered fishes found only in the Colorado River system. Colorado's Water Plan sets the stage to improve water management with practices that include protecting rivers and streams, while providing for human needs. However, there are still gaps in knowledge regarding the current state of freshwater ecosystems in Colorado and how to make informed decisions for their protection and restoration, particularly regarding the flows that sustain them.

San Miguel River © *Todd Warnke,* Fly fishing the Gunnison River © *Mark Skalny,* Farms using water from the Colorado River © *Ken Geiger/TNC*

The altered flows that have resulted from a long history of water development have had consequences for the ecological integrity, and resilience, of freshwater ecosystems. Ecological integrity is defined as 'the ability of an ecosystem to support and maintain ecological processes and a diverse community of native organisms.' Often measured as the degree to which a diverse community of native organisms is maintained, ecological integrity can be used as a proxy for ecosystem resilience. Ecosystem resilience is the ability of an ecosystem to retain essential processes and support native diversity in the face of disturbances or shifts in conditions (Gunderson, 2000). Resilient stream systems are those that will support a full spectrum of biodiversity and maintain functional integrity even as species compositions and hydrologic properties change in response to shifts in conditions (Anderson et al., 2013). Recent research suggests that the resilience of freshwater systems can largely be characterized by a set of measurable elements including: level of biodiversity, physical settings in a watershed, adjacent land uses, degree of connectivity, and alterations to instream flow regime (Anderson et al., 2013; Rieman and Isaak, 2010; Palmer et al., 2009). For example, the presence of a diverse portfolio of species increases the probability that at least some of these species have the traits required to survive and maintain a suite of ecosystem functions in the face of climate change. Because native animals and plants evolved in conjunction with the dynamic nature of the river, much of their life history depends on the flow regime remaining in its natural state. A healthy, resilient river or stream can accommodate a certain level of alteration with negligible impacts to its structure and function.

The Healthy Rivers Assessment shows the current state of freshwater ecosystems and identifies priority watersheds where protection and restoration opportunities are most critical for maintaining and improving river flows and ecosystem structure. By producing this index, practitioners, managers, and decision makers have access to a comprehensive assessment of freshwater conditions from which they will be able to identify where conservation efforts are most critical and monitor progress toward those goals on a statewide level. This report includes:

- **Coarse scale, statewide, replicable baseline measures** of the ecological integrity of Colorado's freshwater systems. The effectiveness of conservation strategies may be measured against these baseline measures using updated information and databases.
- An **index highlighting past and present water management practices** that may negatively impact river flows, freshwater habitat, and native species.
- **Common metrics** for individual Colorado watersheds to achieve a comprehensive view of the impacts to our freshwater systems.
- **Spatially explicit datasets** to map watershed conditions and identify potential for freshwater conservation outcomes.
- Potential **drivers and challenges** to **river flows and function.**
- Analysis to **help prioritize funding for restoration and conservation** and **guide effective management actions and water transactions.**

San Miguel River © *Todd Warnke*, Great Blue Heron © *Steve Thompson*

# 3. Methods

Maintaining and improving river health requires a comprehensive assessment of the current state of river ecosystems. Assessing river function can involve consideration of all elements of a river ecosystem including the structure, abundance and condition of flora and fauna, hydrology, levels of catchment disturbance, physical form of the channel system, and water quality. These metrics individually address unique aspects of river health. Combined, they offer a more complete picture of the current state of freshwater ecosystem function. To develop these metrics, we made a spatially explicit database that generates an index of scores that depict freshwater health and can serve as a roadmap to inform freshwater conservation projects throughout Colorado.

## GIS Map Layers

We analyzed 22 variables across five different indicator categories to generate maps that address physical and biological conditions as well as stressors to those conditions. Combined, these maps provide a summary index of watershed conditions and freshwater health. Each map offers scores at the HUC 12 subwatershed (hereafter "subwatershed") level that provide insights on existing challenges and opportunities to maintain, protect, or restore river health across Colorado. The five indicator categories capture the physical, ecological, and management conditions that influence river structure and function. All variables were analyzed and calculated at the subwatershed level across the state of Colorado to provide a comprehensive assessment of Colorado's freshwater ecosystems.

Mountain streams that form the beginnings of the Uncompahgre River © Bob Wick/BLM

## Study Area and Unit of Analysis

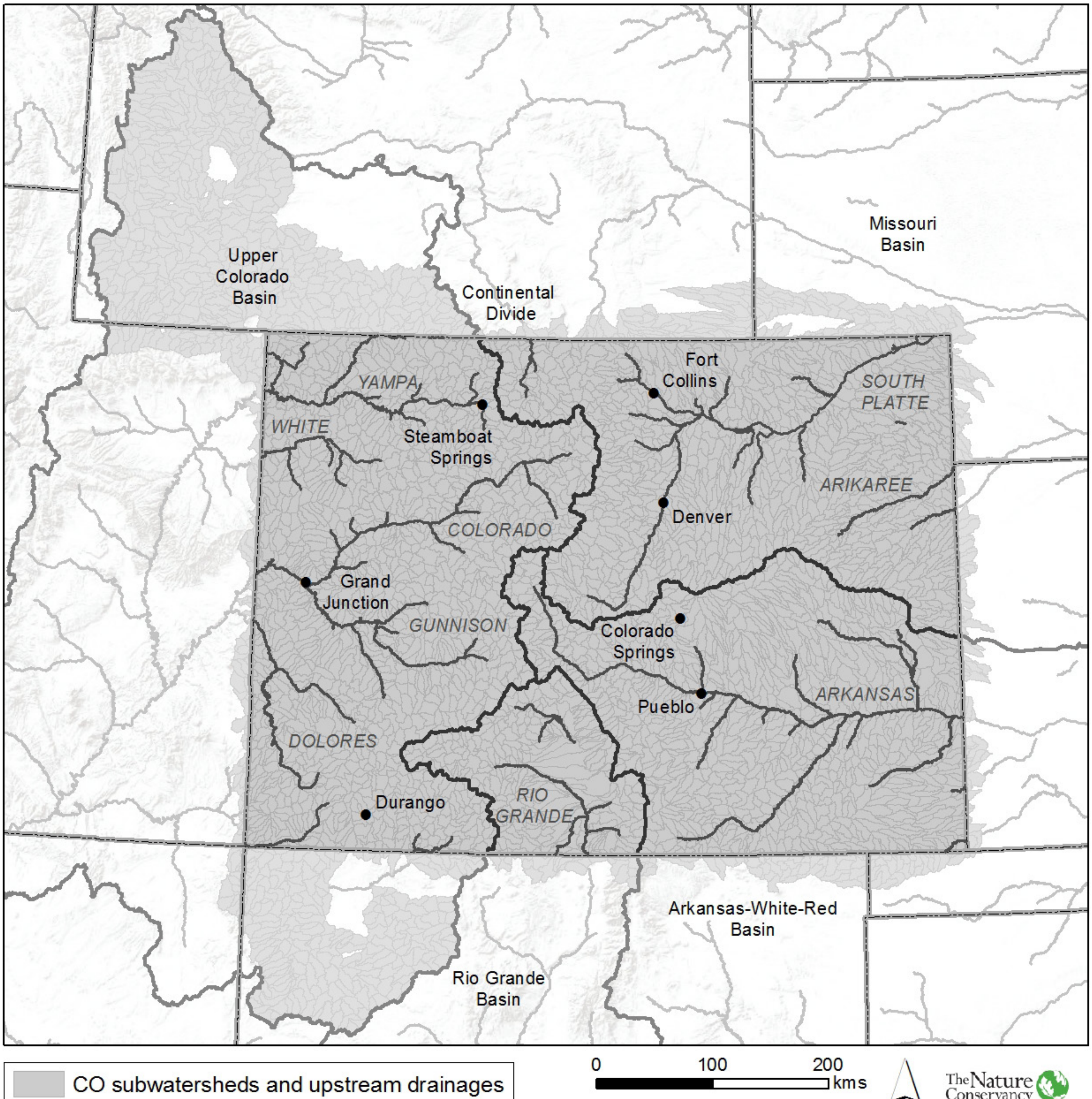
The unit of analysis for this assessment was the United States Geological Survey's (USGS) subwatershed boundaries (Seaber et al., 2007). Each subwatershed is uniquely identified by a 12-digit number sequence referred to as its Hydrologic Unit Code (HUC). These subwatershed boundaries represent the finest spatial resolution within a hierarchy of hydrologic units also including regions, subregions, basins, subbasins, and watersheds. Table 1 describes the system's hydrologic unit levels and their characteristics, along with example names and codes. HUC 12-digit is the finest resolution of watershed which currently exists for the study region, and is the unit of analysis for this assessment.

***Table 1.*** USGS Classification System for Hydrologic Unit Code (HUC)

| Name | Level | Digits | Average size (square miles) | Number of HUs (approximate) | Example name | Example code (HUC) |
|---|---|---|---|---|---|---|
| Region | 1 | 2 | 177,560 | 21 | Pacific Northwest | 17 |
| Subregion | 2 | 4 | 16,800 | 222 | Lower Snake | 1706 |
| Basin | 3 | 6 | 10,596 | 370 | Lower Snake | 170601 |
| Subbasin | 4 | 8 | 700 | 2,200 | Imnaha River | 17060102 |
| Watershed | 5 | 10 | 227 (40,000-250,000 acres) | 22,000 | Upper Imnaha River | 1706010201 |
| Subwatershed | 6 | 12 | 40 (10,000-40,000 acres) | 160,000 | South Fork Imnaha River | 170601020101 |

Poudre Canyon © *USDA,* Cache la Poudre River near Greeley, CO © *City of Greeley,* N. Fork of the Cache la Poudre © *John Fielder*

Map 1 depicts the study area, which is comprised of all subwatersheds within Colorado. We also included upstream contributing subwatersheds within the regions Upper Colorado (#14), Lower Missouri (#10L), Arkansas-Red-White (#11), and Rio Grande (#13) where appropriate. The subwatersheds averaged 23,204 acres in size (minimum 4,742 acres - maximum 117,183 acres) for the study region. Streams and rivers (flowlines in the USGS National Hydrography Dataset [NHD]) and waterbodies of the subwatersheds within the study area were used to calculate variables and metrics. These flowlines were generated at a scale of 1:100,000 (i.e., medium resolution NHD). All the attributes of the subwatersheds, flowlines, and waterbodies were generated through the NHD PLUS version 2.




***Map 1.*** Study Area for Colorado Healthy River Assessment

## Variable Types

Two different types of variables were included in this analysis: local and accumulated upstream. A local variable calculation captures data and depicts patterns within a subwatershed. In other words, a local variable only considers the data and patterns that are occurring within each subwatershed boundary. An accumulated upstream variable calculation accounts for upstream watershed influences. In other words, an accumulated upstream variable includes the interconnected nature of materials, water, energy, and human influence from upstream watersheds in its calculation.

## Scoring and the Healthy Rivers Index

Each variable was calculated using raw data and then standardized to a summary index reflecting the relative resilience of freshwater conditions based on outputs and evidence from statistical analysis, literature review, and expert opinion. Each variable included in the index of freshwater resilience received a score of that could range from low resiliency (1) to the highest resiliency (4). All variables were scored using the same index scale.

To generate the comprehensive Healthy Rivers Index, the variables were summed to generate a total relative resilience score at the subwatershed level. Thresholds were identified using quartiles. Subwatersheds with scores below 41 were labeled as having a "low" resilience score; between 42 and 49 were "moderate"; between 50 and 55 were "high;" and the most resilient—"very high"—subwatersheds had scores greater than 56. The maximum score a subwatershed could receive was 84.

Purgatoire River © *John Fielder*

***Table 2.*** Map Categories, Variables, and Data Sources Included in Healthy Rivers Analysis

| Category | Variable Name | Variable Type* | Data Sources | Description (Unit of Analysis = HUC 12 subwatershed) |
|---|---|---|---|---|
| **Freshwater Biodiversity** | Freshwater Species/ Communities of Conservation Value | L | CNHP<br>CPW<br>USFWS | Freshwater species and communities listed as federally or state endangered, threatened, imperiled, or state species of special concern |
| | Flow Indicator Species | L | CNHP<br>CPW<br>USFWS | A subset of native fish species that are dependent upon flows and are federally or state endangered, threatened, imperiled, or of state special concern or conservation status |
| **Physical Setting** | Network Complexity | L | NHDPlus V2 | A measure of stream order richness.<br>The variety of different rivers and streams |
| | Watershed Area | A | NHDPlus V2 | Total Land Area above the lowest point in the subwatershed. |
| | Linear Connectivity | L | NHDPlus V2<br>GRanD | Maximum length of stream or river miles (uninterrupted by large dams) |
| | Elevation | L | NHDPlus V2 | Elevation class richness; number of elevation classes |
| | Gradient | L | NHDPlus V2 | Gradient class richness; number of gradient classes |
| | Air Temperature | L | NHDPlus V2<br>PRISM | Air Temperature patterns, measured as 30-year average |
| | Precipitation | L | NHDPlus V2<br>PRISM | Precipitation patterns, measured as 30-year average |
| **Habitat Conditions** | Floodplain Riparian Cover | L | NHDPlus V2<br>FEMA<br>NLCD<br>Landfire<br>NWI | Amount of natural (riparian) cover in the floodplain |
| | Agricultural Land Use | L | NHDPlus V2<br>NLCD<br>CDSS | Extent of agricultural cover in the watershed |
| | Urban Land Use | L | NHDPlus V2<br>NLCD | Extent of impervious surface/urban development in the watershed |
| | Instream Fish Barriers | L | NHDPlusV2<br>CDSS | Density of diversion structures per river miles in watershed |
| | Reservoir Storage Index | A | CDSS<br>GRanD<br>NHDPlusV2 | Ratio of reservoir storage volume to mean annual flow |

** L = Local; A = Upstream Accumulated*

| Category | Variable Name | Variable Type* | Data Sources | Description (Unit of Analysis = HUC 12 subwatershed) |
|---|---|---|---|---|
| **Habitat Conditions** | Index of Local Depletions | L | CDSS<br>EROM<br>NHDPlusV2 | All diversion volumes in a subwatershed/mean annual natural flow |
| | Total Water Use | L | NLCD<br>CDSS<br>USGS | Agricultural water use + municipal water use |
| | Degree of Flow Alteration | A | NHDPlusV2<br>NLCD<br>CDSS<br>Census<br>CWCB<br>EROM | Degree of departure from natural flow regime, calculated as: consumptive use (agriculture and municipal) +/- transbasin export & imports (HUC 8)/mean annual natural flow |
| **Risks/Threats** | Non-Native Aquatic and Riparian Species | L | CPW<br>USGS<br>EDDMS | Presence of nonnative aquatic and riparian species |
| | Drought Conditions | L | PDSI | Number of years between 2000-2015 recorded as a severe drought on the Palmer Drought Severity Index (PDSI) |
| **Protections** | Instream Flows | L | CDSS<br>CWCB | Existing instream flow protections in Colorado |
| | Critical Habitat | L | NHD Plus V2<br>USFWS | Federally designated endangered species critical habitat |
| | Other Protection Measures | L | CWCB | Voluntary flow agreements; federal mandated bypass flows |

***L = Local; A = Upstream Accumulated***

# 4. Map Layers

The following series of variables were calculated and mapped because each influence freshwater ecosystem function. The maps are organized into five categories based on variable type: Category 1 variables capture freshwater biodiversity; Category 2 includes variables that depict the physical setting of individual watersheds; Category 3 variables show habitat conditions and human influence; Category 4 variables highlight widespread risks and threats; and Category 5 variables identify existing protections for freshwater ecosystems. Each map is designed to serve as a stand-alone analysis, and each is also rolled up into a final summary measure of resilience, the Healthy Rivers Index. It should be noted that of the 22 variables assessed, only 21 were included in the final Healthy River Index measure. Air Temperature was excluded from the final rank calculations.

## CATEGORY 1: FRESHWATER BIODIVERSITY VARIABLES

The two Freshwater Biodiversity variables offer an inventory of freshwater species and communities that have conservation value in Colorado. The flow indicator species focus on a subset of aquatic species that are especially sensitive to specific components of a natural flow regime. The species and communities included in the Freshwater Biodiversity category are classified by United States Fish and Wildlife Service (USFWS), Colorado Parks and Wildlife (CPW), and the Colorado Natural Heritage Program (CNHP) as federally or state endangered, threatened, imperiled, or species of special concern. A full list of the freshwater species is in Appendix A.

North Platte River © *Mark Godfrey*

## Freshwater Species and Communities of Conservation Value

The Freshwater Species and Communities of Conservation Value variable captures the diversity of freshwater species and communities of conservation concern in Colorado. This variable shows where there are concentrations of freshwater species and communities and provides a count of the richness of different species and communities present in a subwatershed. These data depict freshwater species and communities associated with rivers and streams, wetlands, and associated floodplain habitats, providing the foundation for setting freshwater conservation targets throughout Colorado. To calculate this variable, we gathered data from CPW and CNHP and intersected those data with floodplains to generate an updated, and comprehensive, dataset of freshwater species and communities present in every subwatershed. The values for calculated richness, or the number of freshwater species and communities of conservation per subwatershed, ranged from 1 - 37.

### Scoring the Subwatersheds

Because the freshwater species and communities of conservation data are opportunistic (i.e., based on best available data; not a completely comprehensive dataset) and correlated with aquatic ecosystems and their associated floodplain areas, we ranked these data based on quartiles, dividing the dataset into four equal-size groups. The underlying rationale is that rivers and streams with higher species diversity are more resilient. Therefore, subwatersheds with fewer than 2 freshwater species or communities received a low score (1) and those with more than 9 species received the highest score (4). Table 3 depicts the freshwater species and communities values and associated scores.

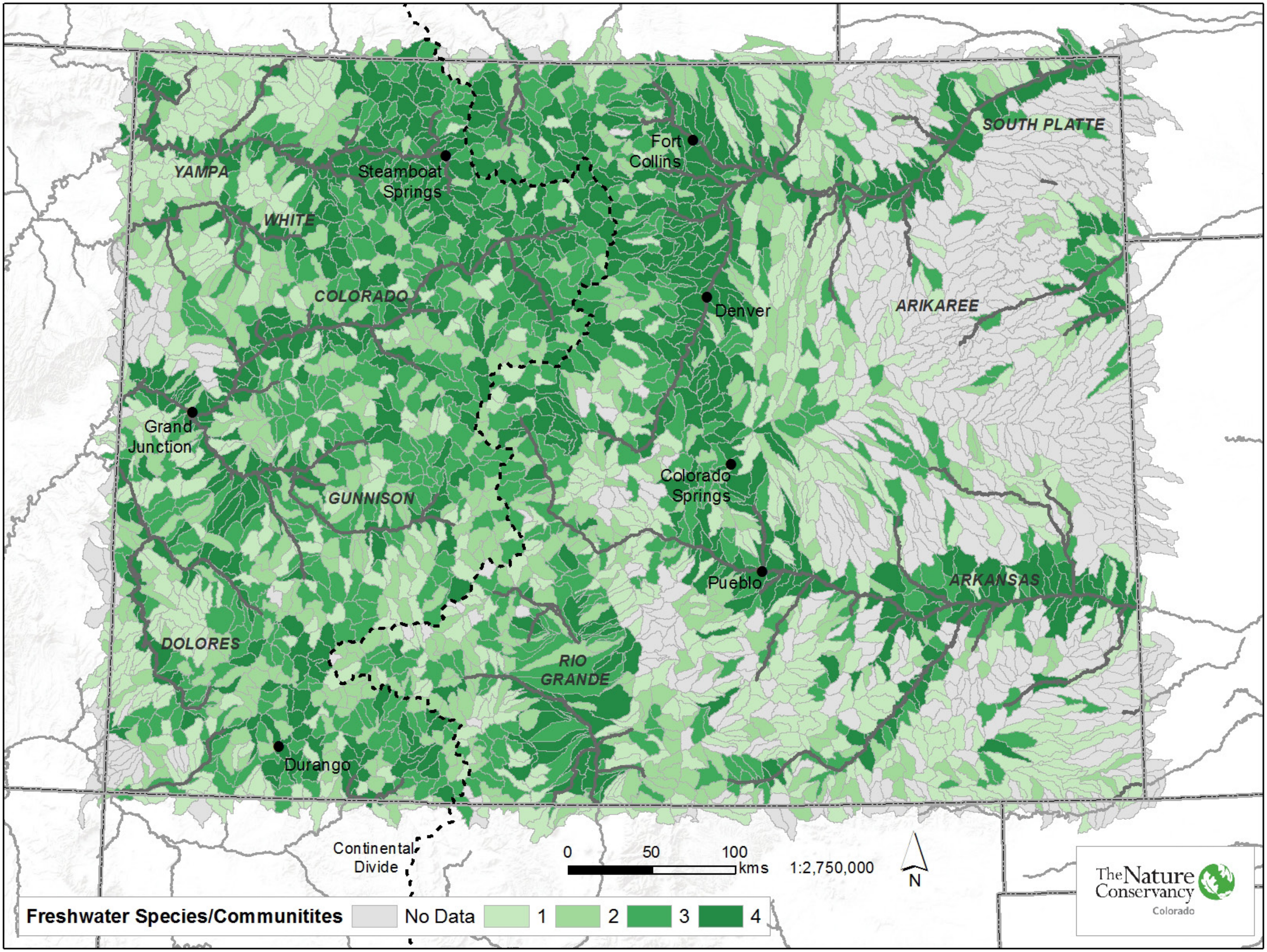
***Table 3.*** Scoring for Freshwater Species and Communities of Conservation Value

| # (Count) in subwatershed | Healthy Rivers Index |
|---|---|
| <2 | 1 |
| 3-4 | 2 |
| 5-8 | 3 |
| >9 | 4 |

### Interpreting the Results

Map 2 depicts patterns of freshwater species and communities of conservation value by subwatershed across Colorado, and helps establish baselines for identifying freshwater conservation targets. Based on the analysis, larger river systems in Colorado tend to have stronger concentrations of freshwater biodiversity and conservation values. Investing efforts into subwatersheds with higher density of freshwater diversity may offer more opportunities for conservation outcomes and greater return on investment.

Razorback Sucker © *Erika Nortemann/TNC*




***Map 2.*** Healthy River Scores for Freshwater Species/Communities of Conservation Value in HUC 12 subwatersheds.
1 = low species count, 4 = high species count

## Flow Indicator Species

The Flow Indicator Species variable provides a subset of fish species from the freshwater species and communities of conservation value dataset. Thirty native fish species were selected based on geographic distribution, and have components of their life cycles linked to the natural flow regime, making them dependent upon natural flow variability associated with healthy river ecosystems. Because of this, these fish species serve as indicators of flow alteration that help to prioritize river protection and restoration efforts. Like the Freshwater Species and Communities of Conservation Value variable, species occurrences were summed to determine the total number of flow indicators present in the subwatershed. Species were filtered to include species categorized as federally and state threatened and endangered; Tier 1 and 2 species in Colorado's State Wildlife Action Plan; and State species of concern and other conservation status. Flow indicator species are indicated with an asterisk (*) in the species list found in Appendix A.

### Scoring the Subwatersheds

Flow indicator species were ranked to capture the distribution of species across the state and were informed by quartiles. The underlying rationale is that rivers and streams with more flow dependent species present highlight systems that may have greater vulnerability to flow alteration. Therefore, subwatersheds with fewer flow indicator species receive a low score and those with higher concentrations of flow indicator species received the highest score. Table 4 depicts the flow indicator values and associated scores.

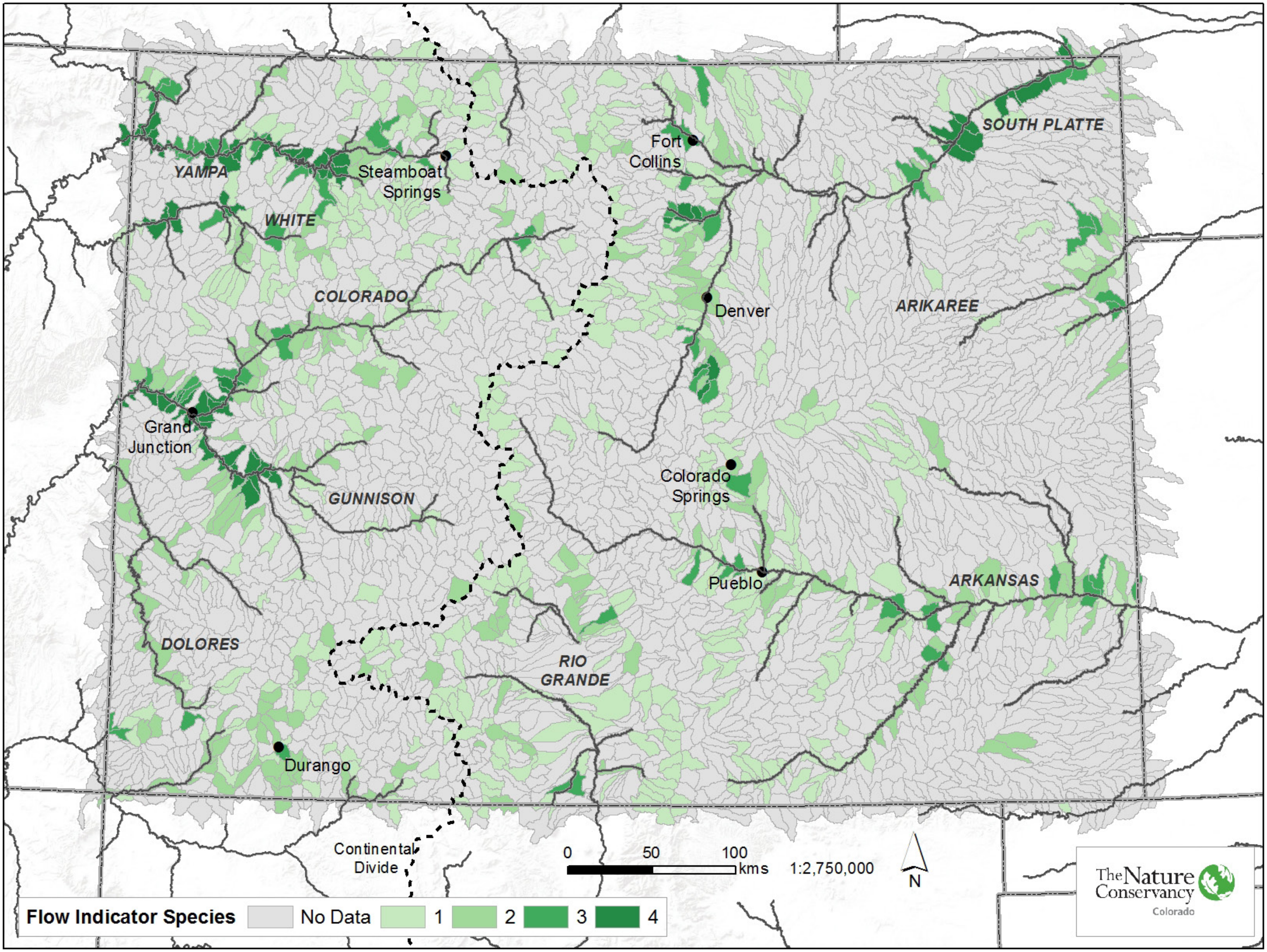
***Table 4.*** Scoring for Flow Indicator Species

| # (count) in subwatershed | Healthy Rivers Index |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| >3 | 4 |

### Interpreting the Results

Like Map 2, Map 3 depicts the subwatersheds with the greatest numbers of flow indicator species, but with specific focus on fish species that would respond to flow management outcomes. The Flow Indicator patterns illustrate where ecological flow management will be particularly important for sustaining native fish populations. On the west slope, there are several important tributaries to the Colorado River (e.g., Yampa, White, Colorado, Dolores Rivers) that support endangered fish and native fish populations that are declining in Colorado and may be especially vulnerable to changes in flow and flow management.

White River © *Harold E. Malde*




***Map 3.*** Healthy River Scores for Flow Indicator Species in HUC 12 subwatersheds. 1 = low species count, 4 = high species count

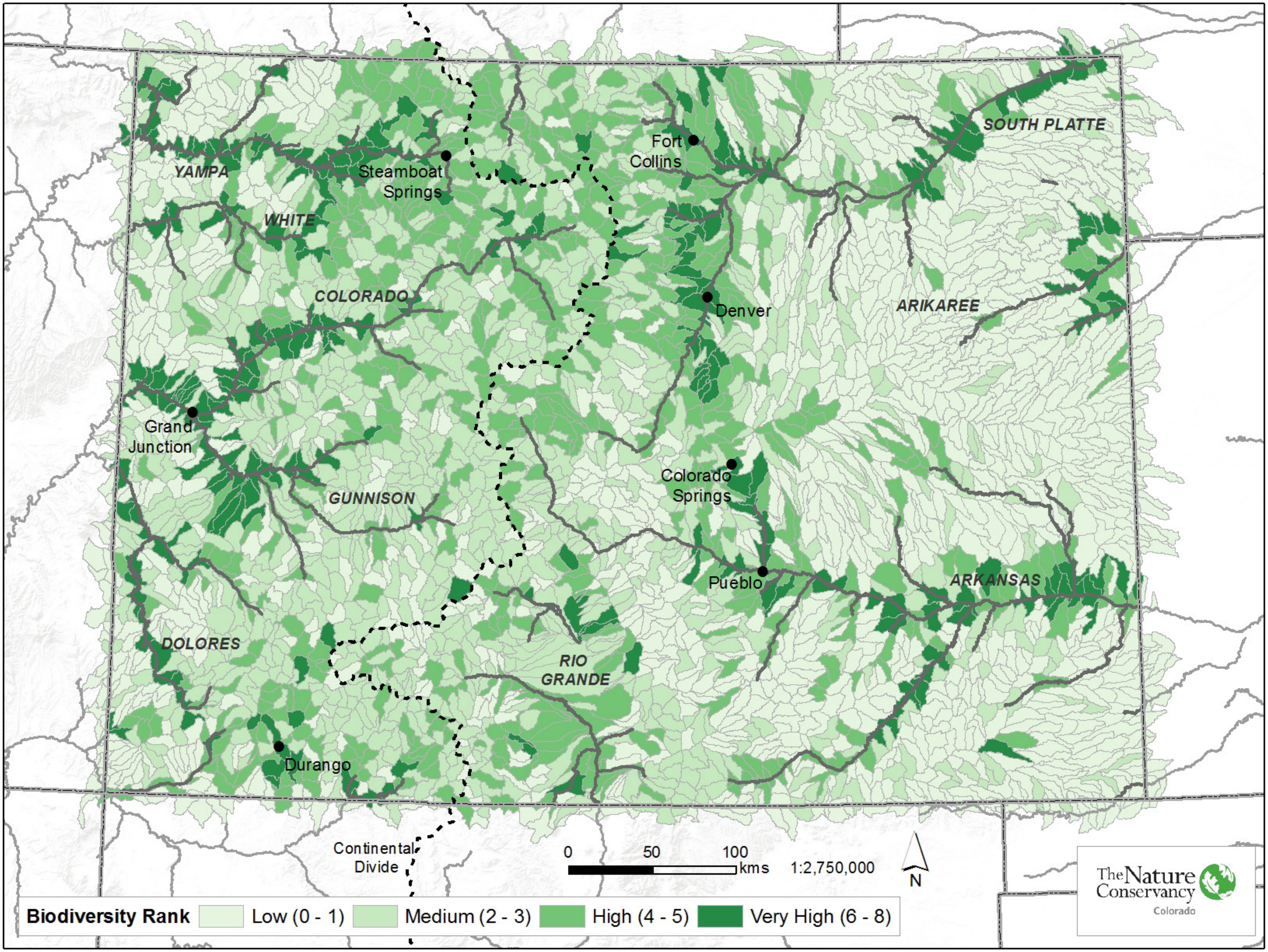
## Summary Index of Freshwater Biodiversity Variables

The combined summary index for the Freshwater Biodiversity variables highlights subwatersheds that support the highest numbers of freshwater species. Scores were based on quartiles, dividing the dataset into four equal-size groups. Subwatersheds with higher numbers support greater variety of freshwater biodiversity and flow indicator species. Many of the subwatersheds adjacent to bigger river systems support the highest levels of biodiversity, and may be places to prioritize when implementing projects for protecting, maintaining, and restoring river flows for conservation outcomes.

***Table 5.*** Scoring for Freshwater Biodiversity Variables

| Freshwater Biodiversity Variables Score | Healthy Rivers Index |
|---|---|
| 0-1 | Low |
| 2-3 | Medium |
| 4-5 | High |
| 6-8 | Very High |

Yampa River © *Mark Godfrey,* San Miguel River © *Lynn McBride,* Fly fishing on the Big Thompson River © *Nick Hall*




***Map 4.*** Summary scores for combined Freshwater Biodiversity variables.
"Very High" = most resilient "Low" = least resilient

## CATEGORY 2: PHYSICAL SETTING VARIABLES

Recent research has suggested that physical landscape characteristics, such as connectivity and the diversity of geophysical settings, serve as important measures of resilience for freshwater systems (Anderson et al, 2013; Rieman and Isaak, 2010; Palmer et al., 2009). Based on this, we selected seven Physical Setting variables: Network Complexity, Watershed Area, Linear Connectivity, Elevation, Gradient, Air Temperature, and Precipitation. These variables provide a baseline of the physical conditions of the river and stream ecosystems across the state and highlight opportunities and constraints in the natural landscape. The Physical Setting variables also help identify watersheds with the physical capacity and heterogeneity to maintain similar biodiversity characteristics and functional processes in the face of environmental pressures critical to protecting healthy freshwater systems (Anderson et al., 2013).

### Network Complexity

Network complexity refers to the variety of different sized rivers and streams - or functionally connected networks— contained in a subwatershed. Using the NHD medium scale (1:100,000) data, we calculated the number of different size classes, or stream orders, in a subwatershed. Stream order is a measure of the relative size of rivers and streams. The smallest tributaries, or headwaters, are referred to as first-order streams, while the some of the largest rivers in the world are twelfth-order waterways. As stream size increases, changes in physical habitat, water volume, and energy sources are correlated with predictable patterns of variation in the aquatic biological communities (Anderson et al, 2013; Hitt and Angermeier, 2008; Vannote et al, 1980). Because biota and physical processes change with stream order, our rationale is that subwatersheds with higher network complexity provide varied potential habitat, including refugia.

#### Scoring the Subwatersheds

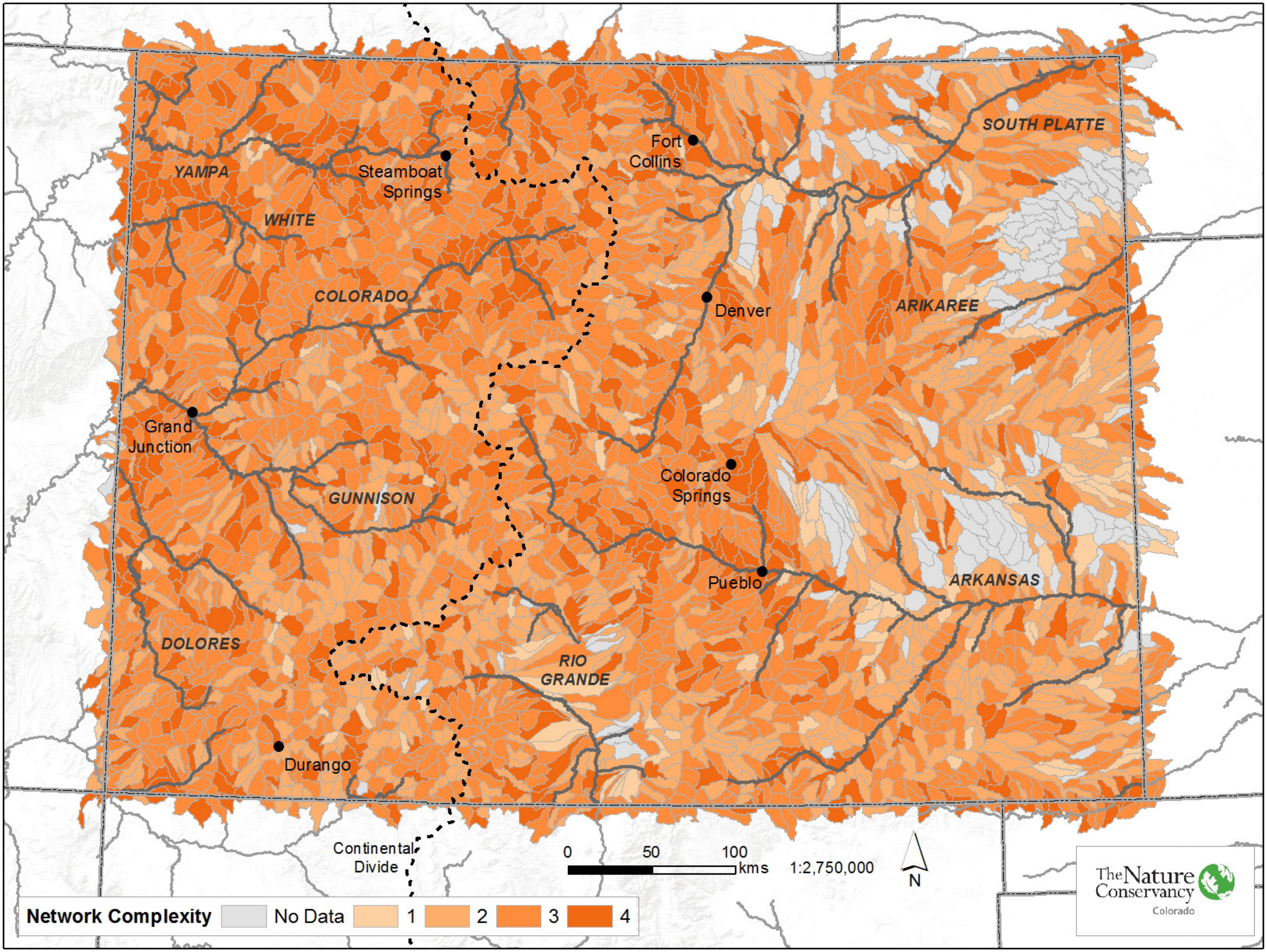
Using quartiles, network complexity was ranked to best capture the range of complexity across subwatersheds. The underlying rationale is that watersheds with more network complexity will offer higher resiliency. Table 6 depicts the network complexity thresholds and associated index scores.

***Table 6.*** Scoring for Network Complexity

| Stream Orders (#) | Healthy Rivers Index |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| >4 | 4 |

#### Interpreting the Results

The network complexity patterns in Map 5 offer insight into which watersheds encompass the complexity critical to supporting aquatic biological assemblages. Changes in physical habitat, water volume, and energy source with increasing stream size are correlated with predictable patterns of change in the aquatic biological communities (Vannote et al., 1980; Olivero and Anderson, 2008). Differences in the physical size of the catchment relate to differences in stream characteristics, from small headwater streams draining local catchments to large rivers draining even larger basins.




***Map 5.*** Healthy River Scores for Network Complexity in HUC 12 subwatersheds. 1 = low complexity, 4 = high complexity

## Watershed Area

The Watershed Area variable captures cumulative upstream watershed volumes and overall influence of a watershed ($km^2$). Using NHD data, we determined the maximum cumulative upstream drainage area across all flowlines with an end point occurred within a downstream subwatershed. This upstream accumulated drainage area is defined as watershed area for our analysis, which means the calculation reflects the materials and energy flowing into each subwatershed from those upstream. Based on these calculations, using stream size classes and literature, we classified watersheds into four size classes: extra small watersheds that contain small (i.e., headwater) streams = 10-100 $km^2$; small watersheds which contain larger streams = 100-1,000 $km^2$; medium watersheds with small rivers = 1,000-10,000 $km^2$; and large watersheds with larger rivers = > 10,000 $km^2$.

### Scoring the Subwatersheds

Watershed area thresholds were based on literature and expert opinion (Theobald et al., 2006; Hitt and Angemeier, 2008). The underlying rationale is that larger watersheds offer greater resiliency because they can support more freshwater habitat and higher numbers of stream networks, which can offer greater buffering, or capacity, to water withdrawals. Additionally, this calculation reflects inputs from upstream accumulated drainages. Table 7 depicts the watershed area thresholds and associated scores.

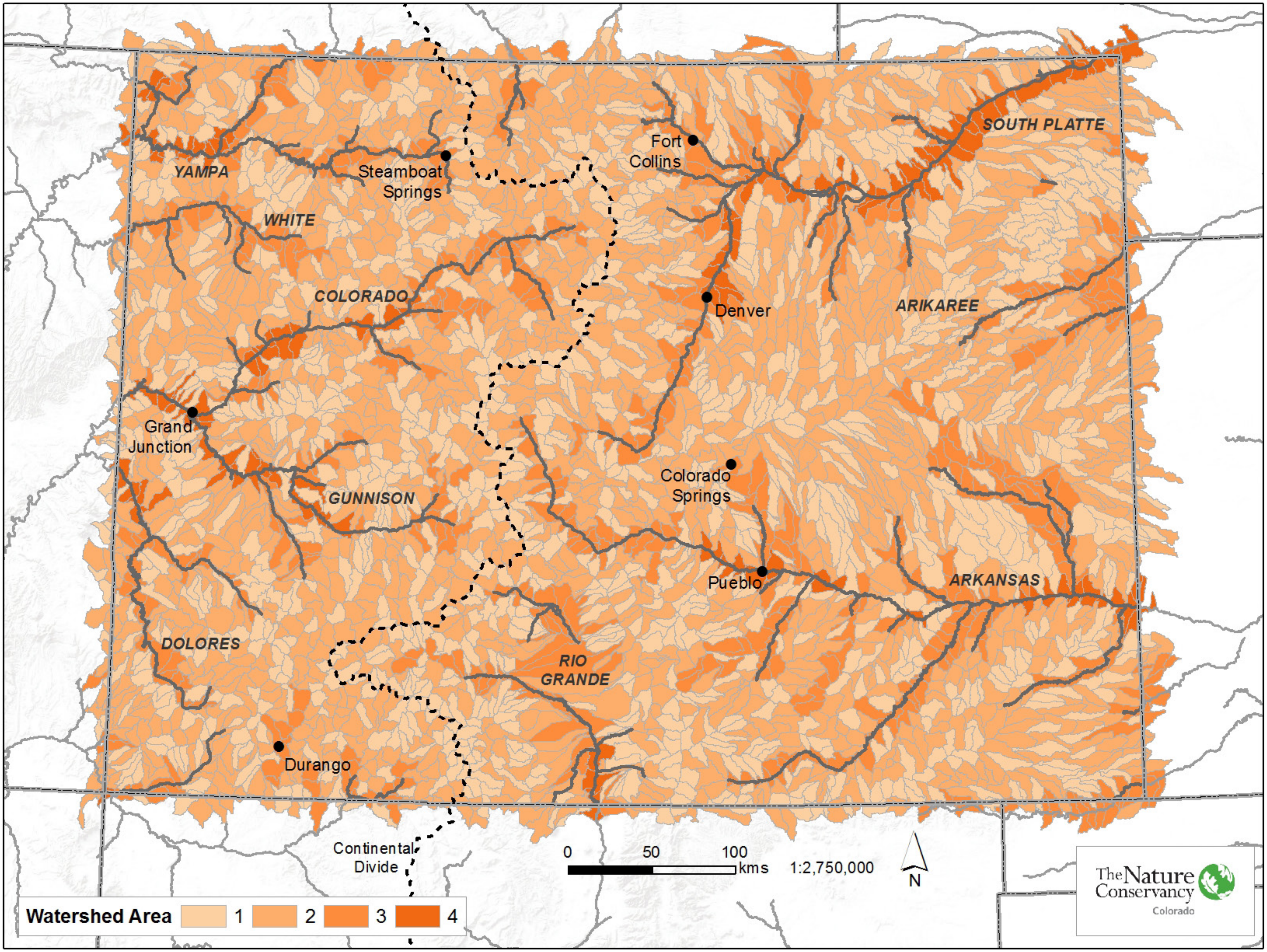
***Table 7.*** Scoring for Watershed Area

| Watershed Area ($km^2$) | Healthy Rivers Index |
|---|---|
| <100 | 1 |
| 100 < 1,000 | 2 |
| 1,000 < 10,000 | 3 |
| > 10,000 | 4 |

### Interpreting the Results

Like network complexity, watershed area patterns (Map 6) depict which subwatersheds are the largest in size and thereby able to support greater network complexity, larger intact floodplains, and movement of materials and energy. Not surprisingly, larger river systems were associated with larger watershed areas.

Gunnison River © *Mark Skalny*




***Map 6.*** Healthy River Scores for Watershed Area in HUC 12 subwatersheds. 1 = small watersheds, 4 = larger watersheds

## Linear Connectivity

Linear connectivity is a measure of the total length of uninterrupted stream or river miles in a subwatershed. Connectivity within a watershed is essential to support freshwater ecosystem processes and natural assemblages of organisms. It enables water flow, sediment, and nutrient regimes to function naturally, individuals to move throughout the network to find the best feeding and spawning conditions, and, in times of stress, it enables individuals to relocate where conditions are more suitable for survival (Anderson et al, 2013; Pringle, 2001). There has been considerable impact on the connectivity of river systems in Colorado and throughout the western United States due to dams and diversions, leading to a substantial decrease in the length of connected stream networks.

We assessed linear connectivity using NHDPlus V2 and the Global Reservoir and Dam Database (GRanD) to define upstream and downstream networks. Included in this variable were all reservoirs with a storage capacity of more than 0.1 $km^3$ and smaller reservoirs if data was available. We did not include smaller diversion structures, which also can act as barriers to fish passage in this analysis. Instead, we focused on larger, more permanent infrastructure that would require significant shifts in policy to remove or change.

### Scoring the Subwatersheds

Linear Connectivity was ranked based on quartiles. The underlying rationale is higher linear connectivity in a subwatershed leads to great resiliency due to increased habitat availability and complexity. Table 8 depicts linear connectivity thresholds and associated scores.

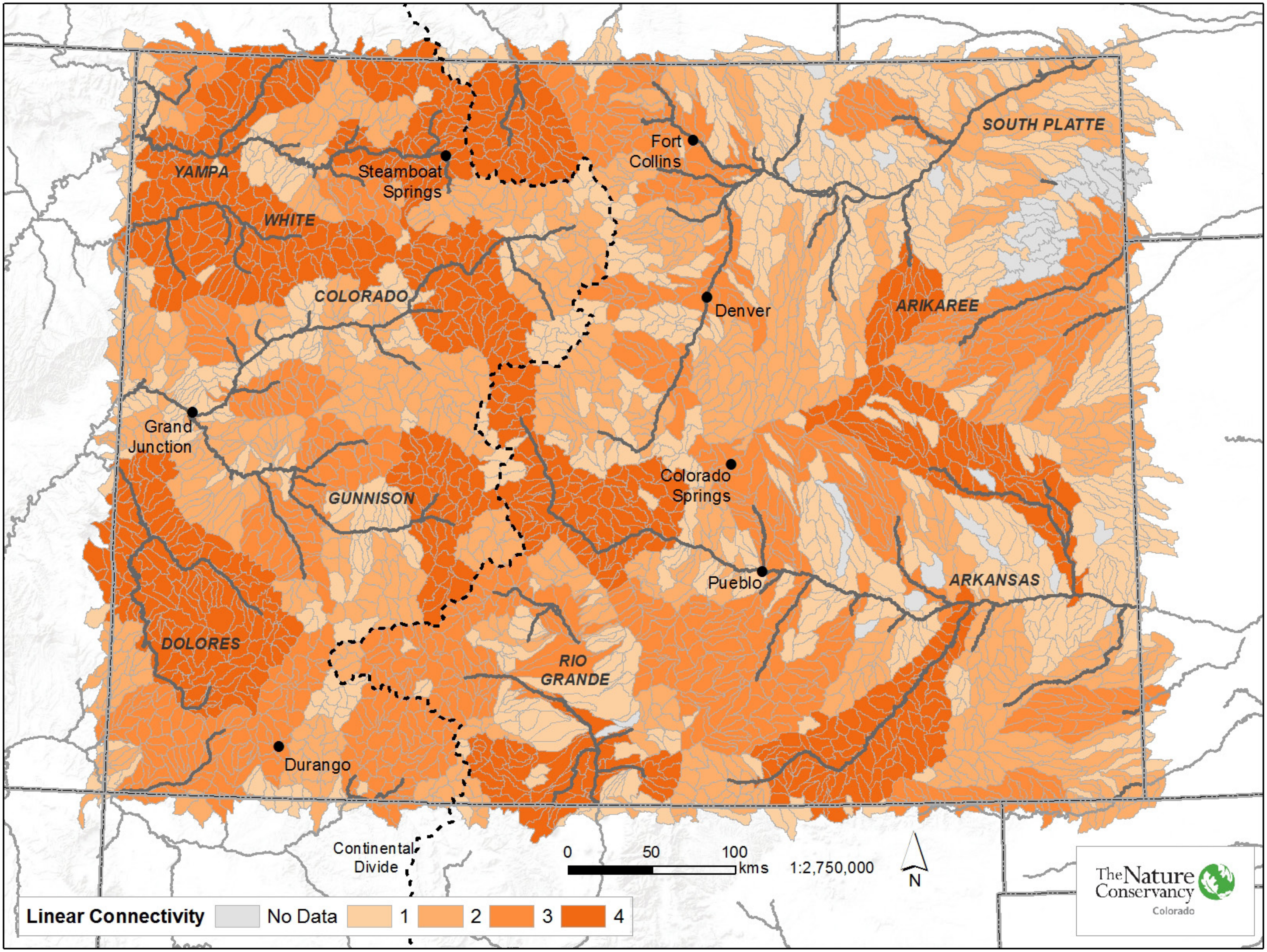
***Table 8.*** Scoring for Linear Connectivity

| Linear Connectivity | Healthy Rivers Index |
|---|---|
| <149,775 | 1 |
| 149,775 < 630,488 | 2 |
| 630,488 < 1,508,361 | 3 |
| > 1,508,361 | 4 |

### Interpreting the Results

The patterns in linear connectivity highlight the capacity of watersheds—and their rivers and streams—to move materials, transfer energy, and carry out ecosystem functions. Map 7 depicts the subwatersheds with varying degrees of connectivity. The watersheds with the lowest scores indicate that connectivity is highly impacted by large infrastructure, which impedes fish migration and impacts population dynamics and can serve as a proxy for significantly altered flows.

Browns Canyon on the Arkansas River © *Bob Wick/BLM*




***Map 7.*** Healthy River Scores for Linear Connectivity in HUC 12 subwatersheds. 1 = low connectivity, 4 = high connectivity

## Elevation

Elevation classes in a watershed provide an alternative to directly measuring water temperature and gradient in the field. The variety of elevation within a subwatershed serves as an indicator for the diversity of stream types and habitats available for aquatic and riparian species. We generated three elevation classes based on fish ecology and research that are important freshwater habitat characteristics in Colorado (Polvi et al, 2011):

- 0 - 1400 meters: Prairie and warmwater species
- 1400 - 2200 meters: Transition zone for warm water and cold water species. Cold water fishes (i.e., trout) are not found below 1400 meters while warm water fishes are not found above 2200 meters.
- 2200+ meters: Cold water and higher elevation species.

ArcMap was used to classify these three elevation classes and to identify rivers and streams within a subwatershed found in the above elevation classes.

### Scoring the Subwatersheds

We adjusted the boundaries of quartiles to define the elevation classes divided into three classes. The underlying rationale is that watersheds with more elevation classes present offer greater habitat diversity and therefore are more resilient to changing climate and hydrologic regimes. Table 9 depicts the elevation class thresholds and associated scores.

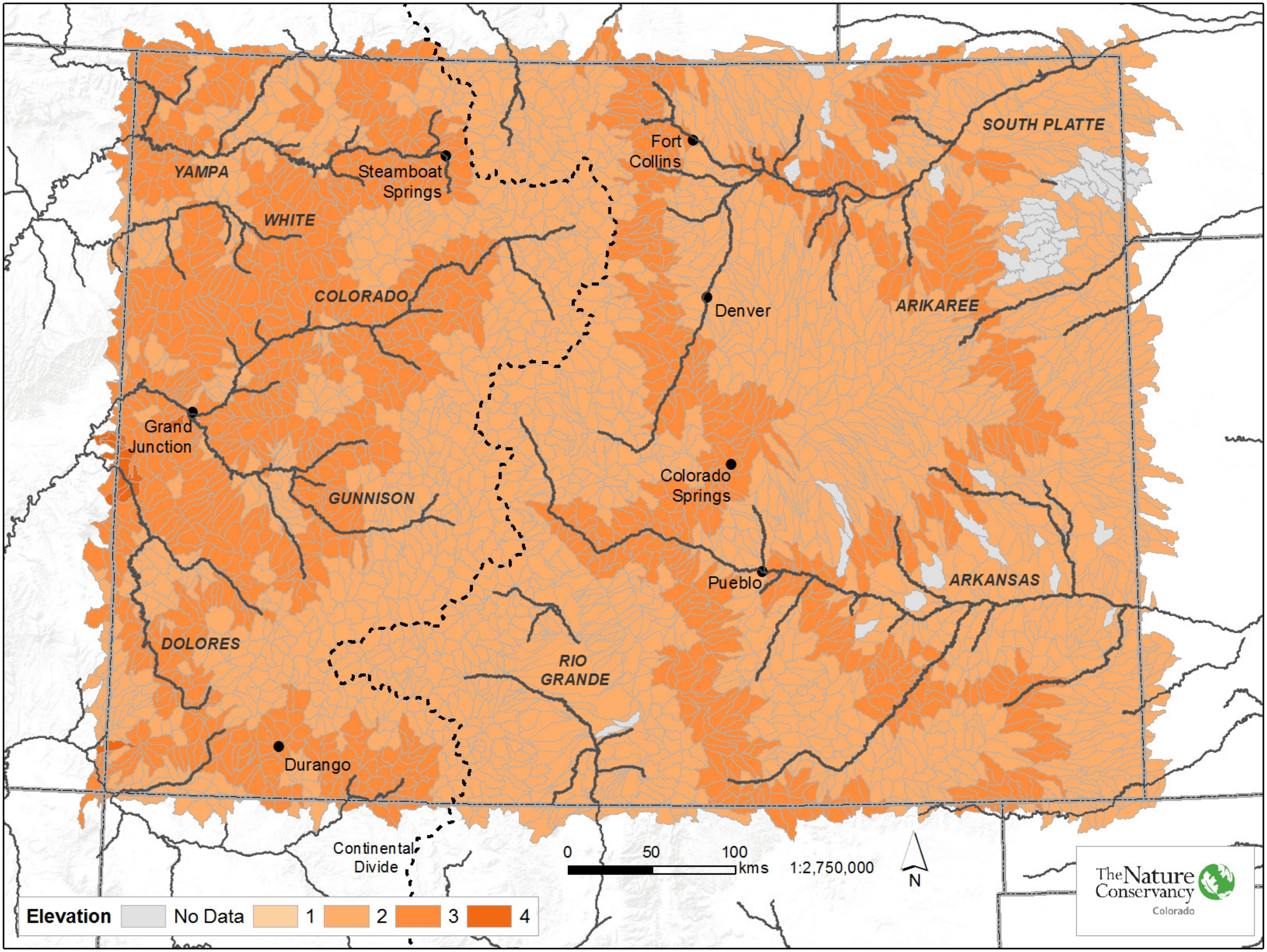
***Table 9.*** Scoring for Elevation

| # of elevation classes | Healthy Rivers Index |
|---|---|
| N/A | N/A |
| 1 | 2 |
| 2 | 3 |
| 3 | 4 |

### Interpreting the Results

The elevation class patterns reflect the widely varied topographic conditions and elevational differences across the state. Fewer elevation classes were found in subwatersheds in the eastern plains, while the subwatersheds in the central and western portions of Colorado had greater richness in elevation classes. Subwatersheds with greater richness in elevation classes offer a greater range of aquatic habitat types which provides an additional indication of ecosystem resilience and habitat complexity.

South Platte River in Weld County © *Eli Nixon,* San Miguel River © *Russ Schnitzer*




***Map 8.*** Healthy River Scores for Elevation Classes in HUC 12 subwatersheds. 1 = low # of elevation classes, 4 = higher # of elevation classes

## Gradient

Gradient, the slope or steepness of a stream reach, is considered an important component of a landscape's geophysical setting that drives patterns of diversity over evolutionary timescale (Anderson et al., 2013). In watersheds, variation in gradient has been identified as essential in shaping patterns of freshwater biodiversity (Higgins et al., 2005). Watersheds with high variation in gradient indicate diversity of available habitat, flow conditions, and microclimates that species can utilize in response to changing environmental conditions. Using NHDPlus V2, we calculated the number of gradient classes in each subwatershed. We used slope classes from Polvi et al., 2011: <0.01, 0.01-0.04, 0.04-0.1, >0.1 m/m, which depict a range including relatively flat prairie streams to steep, mountainous headwaters.

### Scoring the Subwatersheds

The underlying rationale is that the more gradient classes present in a subwatershed offer greater habitat diversity and refugia, and therefore are more resilient to climate change pressures. Table 10 depicts the gradient class thresholds and associated scores.

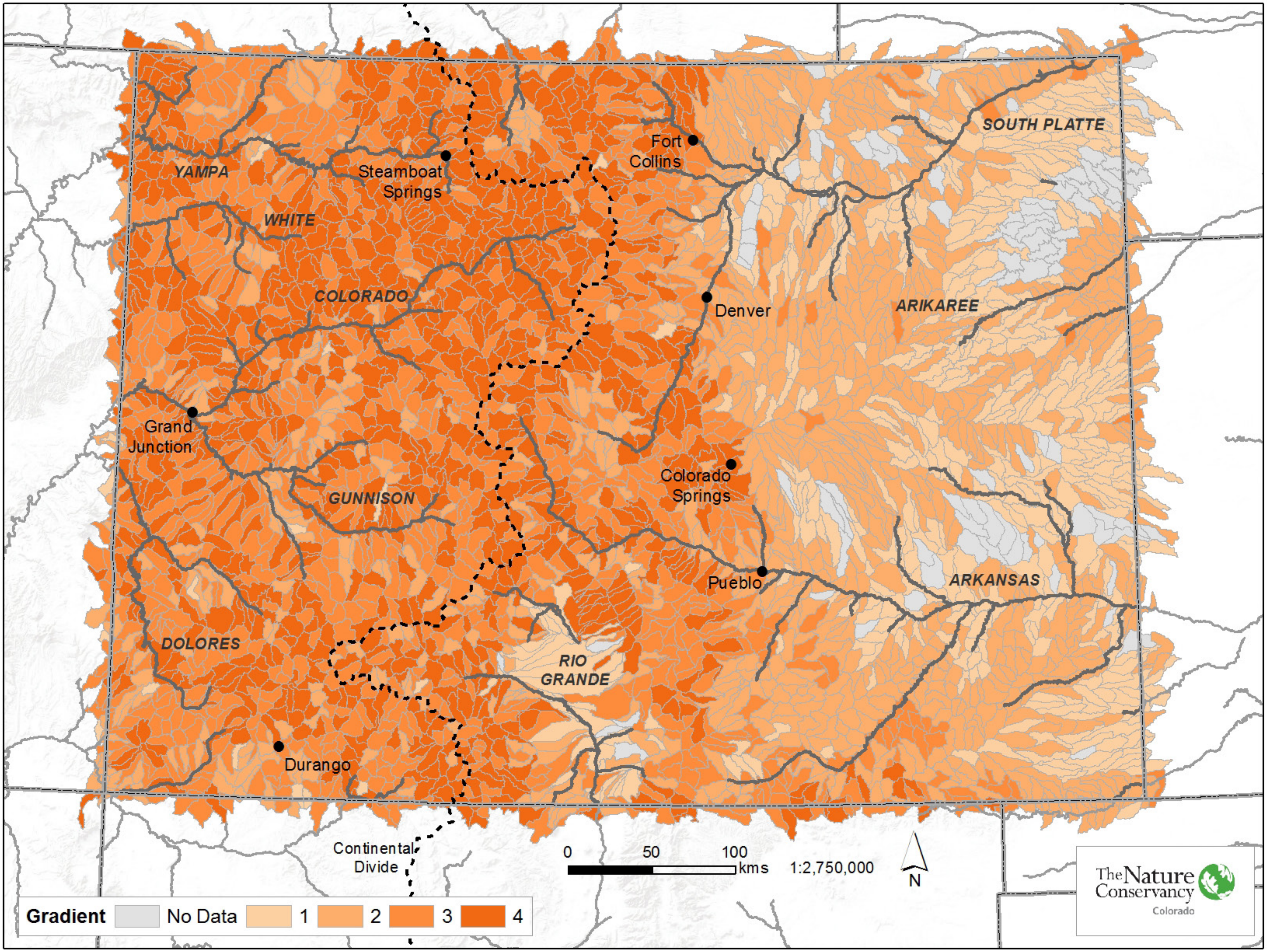
***Table 10.*** Scoring for Gradient

| Gradient classes | Healthy Rivers Index |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |

### Interpreting the Results

Effectively protecting river flows and conserving freshwater biodiversity require preserving physical conditions like stream gradient, which drive patterns of diversity (Palmer et al. 2009, Rieman & Isaak 2010). Map 9 illustrates the range of geodiversity across the state. Subwatersheds with high variation in these properties capture the variety of available microclimates, habitats, and flow velocity conditions that species can exploit during rearrangement in response to environmental changes.

Dolores River © *Mark Skalny,* Rafting on the Colorado River © *Erika Nortemann/TNC*



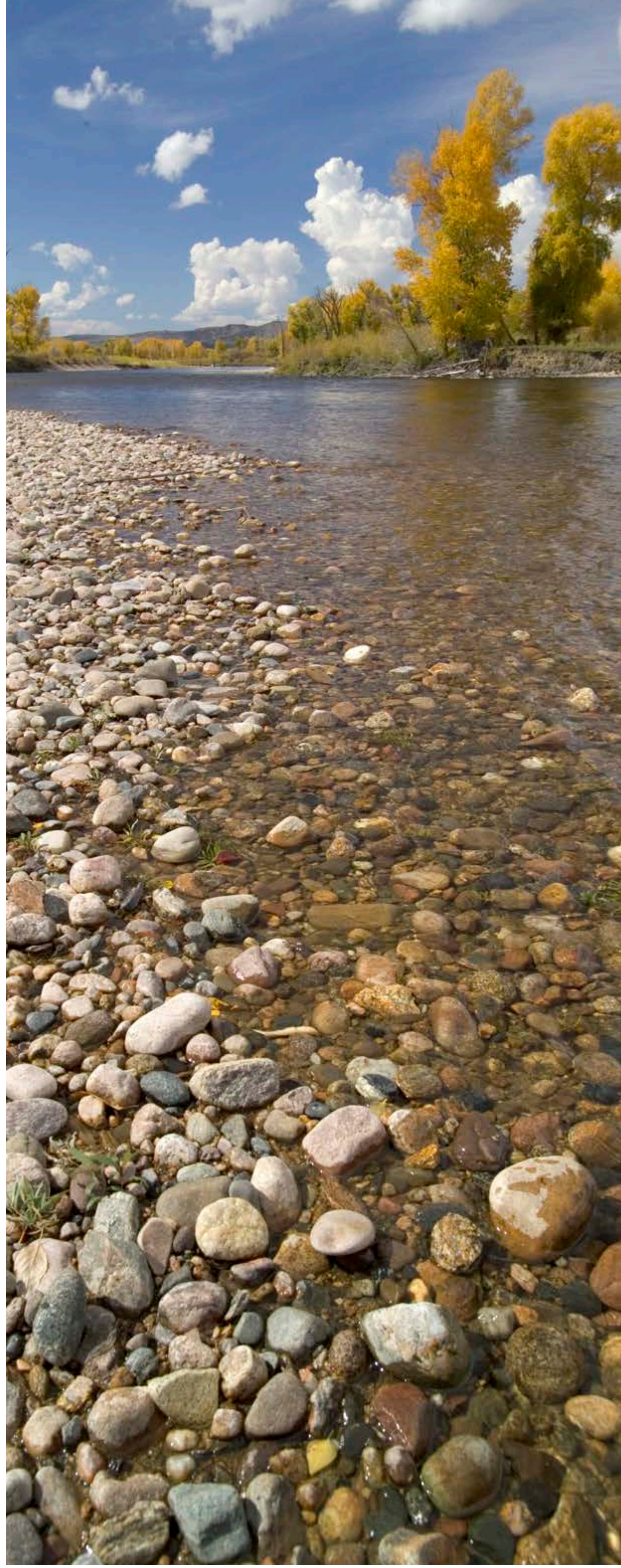

***Map 9.*** Healthy River Scores for Gradient in HUC 12 subwatersheds. 1 = low # of gradient classes; 4 = higher # of gradient classes

## Air Temperature

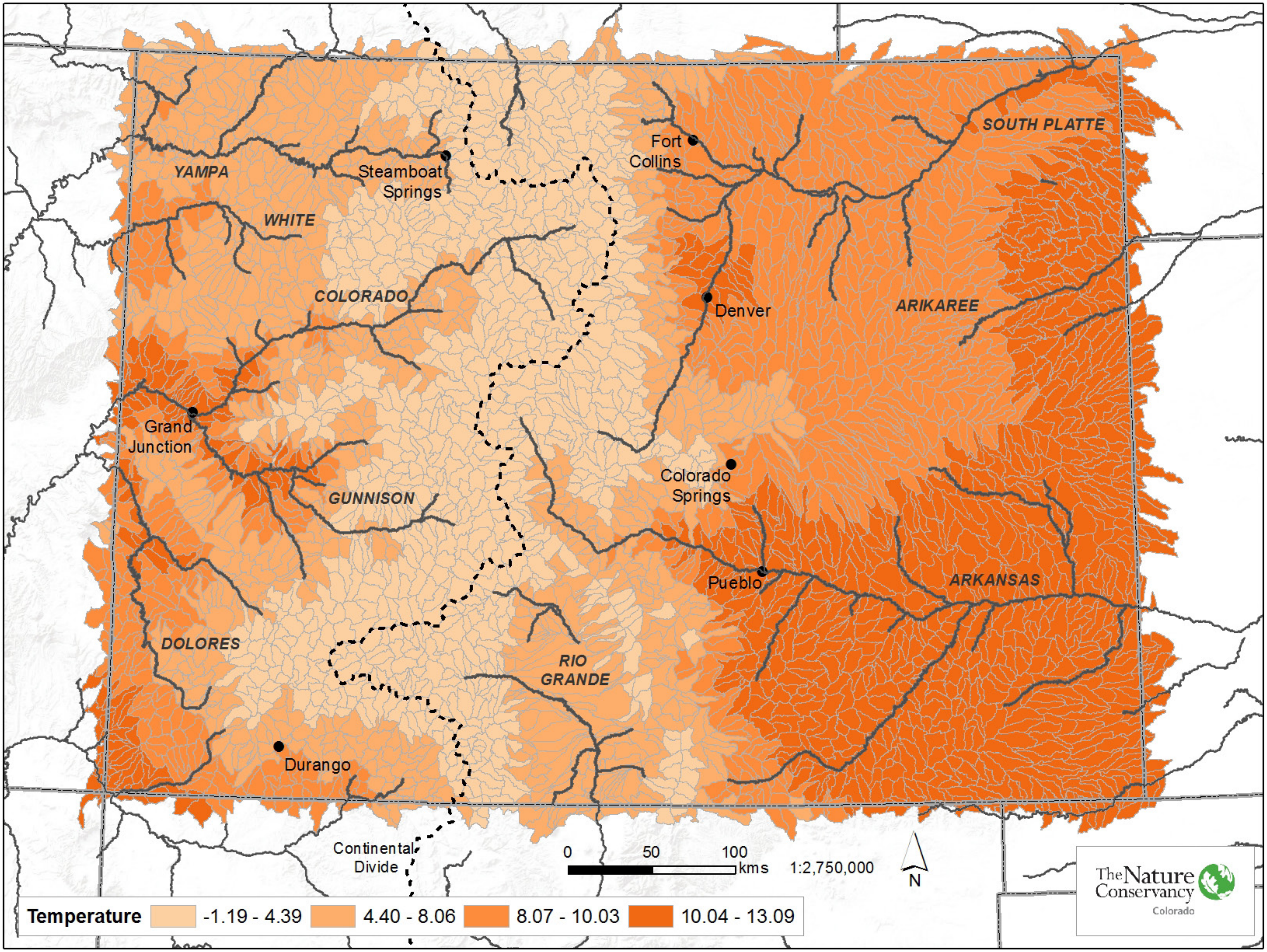
Understanding water resource responses to temperature, particularly considering ongoing droughts and climate change, is critical for water resources planning and management. Snow-fed rivers, a major water supply in the western United States (U.S.), are largely influenced by winter precipitation, but increasingly warmer temperatures are expected to play a role in water year runoff (Woodhouse et al, 2016). Linking air temperature directly to changes in streamflow is difficult, but recent studies have shown that variability in air temperature can lead to reduced runoff volumes in stream and river ecosystems (Christensen and Lettenmaier, 2006; Hoerling and Eischeid, 2007; Vano et al., 2012). Temperatures can also impact the efficiency of runoff relative to precipitation, resulting in marked declines in streamflow (Woodhouse et al, 2016). Temperature patterns can also be a strong driver behind increased frequency of drying in more intermittent, groundwater dependent rivers and streams (Reynolds et al. 2015).

Using the 30-year (1981-2010) temperature normals created by PRISM (parameter-elevation regressions on independent slopes model: http://www.prism.oregonstate.edu), we generated the average 30-year temperature in Celsius to show spatial variation in air temperature across the state of Colorado at the subwatershed level. PRISM generates climate variables at an eight-kilometer resolution for the contiguous U.S. based on climate station records and topographic variables and climate mapping knowledge framework (Daly et al., 2002).

We chose to include air temperature patterns as a variable in Physical Settings because it illustrates the climatic variability across a broad range of ecosystems in Colorado. However, air temperature will not be included in the final summary index because the variation in temperature is what drives the community types—ranging from grasslands to montane forests to semi-desert shrublands—and there is no direct approach to weight this variation that would be meaningful for measuring resiliency.



Yampa River © *Mark Godfrey*




***Map 10.*** Air Temperature patterns (30-year average) across HUC 12 subwatersheds. **Note: variable was not included in the final Healthy River Index calculation.*

## Precipitation

Variability in precipitation is a critical driver of runoff and flow dynamics, even more so than temperature variability, particularly in western river basins (Gleick, 1987; Woodhouse et al., 2016). Changes in the timing and location of precipitation can strain freshwater ecosystems and potentially impact the life cycles and survival of many riparian and aquatic species. More recently, water balance modeling of hydrology with observed climate inputs confirmed this, indicating that virtually all annual runoff variability for the periods from 1900 and 1950 can be attributed to variations in precipitation, for all regions in the U.S., including regions that have warmed (McCabe and Wolock, 2011).

We used PRISM's 30-year precipitation normal to calculate the average precipitation in each subwatershed in Colorado. The combination of temperature and precipitation offers insight into natural moisture patterns and potential water scarcity pressures in Colorado's landscape.

### Scoring the Subwatersheds

Precipitation was ranked based on quartiles. The underlying rationale is higher precipitation in a subwatershed supports flowing rivers and streams and thereby means increased ecosystem resiliency. Table 11 depicts the precipitation thresholds and associated scores.

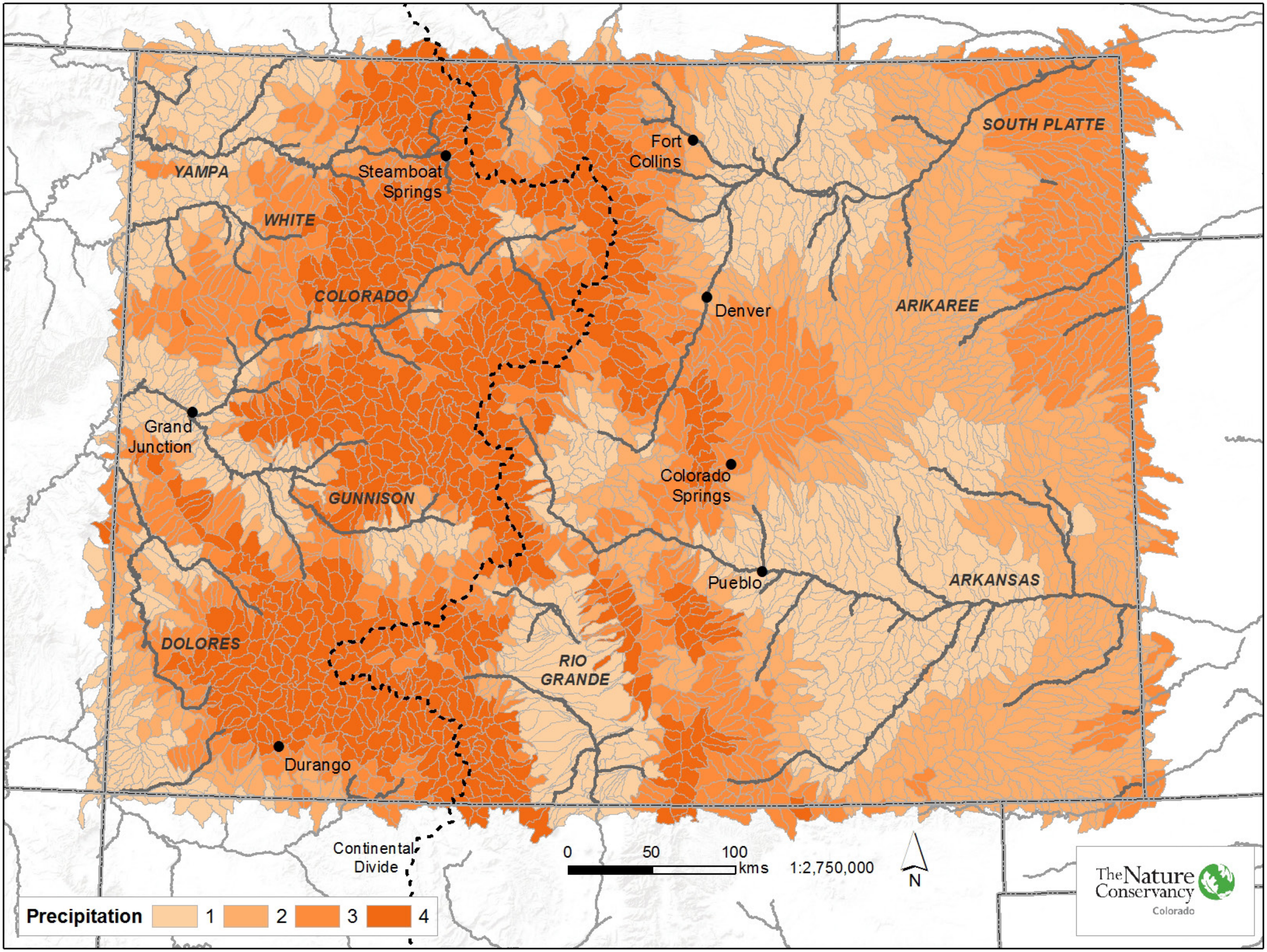
***Table 11.*** Scoring for Precipitation

| Precipitation (mm) | Healthy Rivers Index |
|---|---|
| < 380 | 1 |
| 380 < 437 | 2 |
| 438 < 564 | 3 |
| > 564 | 4 |

### Interpreting the Results

The flow regime of a river is a natural byproduct of the sequence of flow pulses conveyed to the stream network from the contributing catchment after rainfall (Botter et al., 2013). The flow regime is often recognized as the distribution of daily flows, which offers information on the mean water availability, the extent of discharge fluctuations, and the frequency of high/low flows. The variation in precipitation offers insight into the water budget for each subwatershed, ultimately shaping the form and function of riverine ecosystems and constraining anthropogenic uses, such as energy production and irrigation.

San Miguel River canyon © *Kim Baker*




***Map 11.*** Healthy River Scores for Precipitation in HUC 12 subwatersheds. 1 = low precipitation, 4 = high precipitation

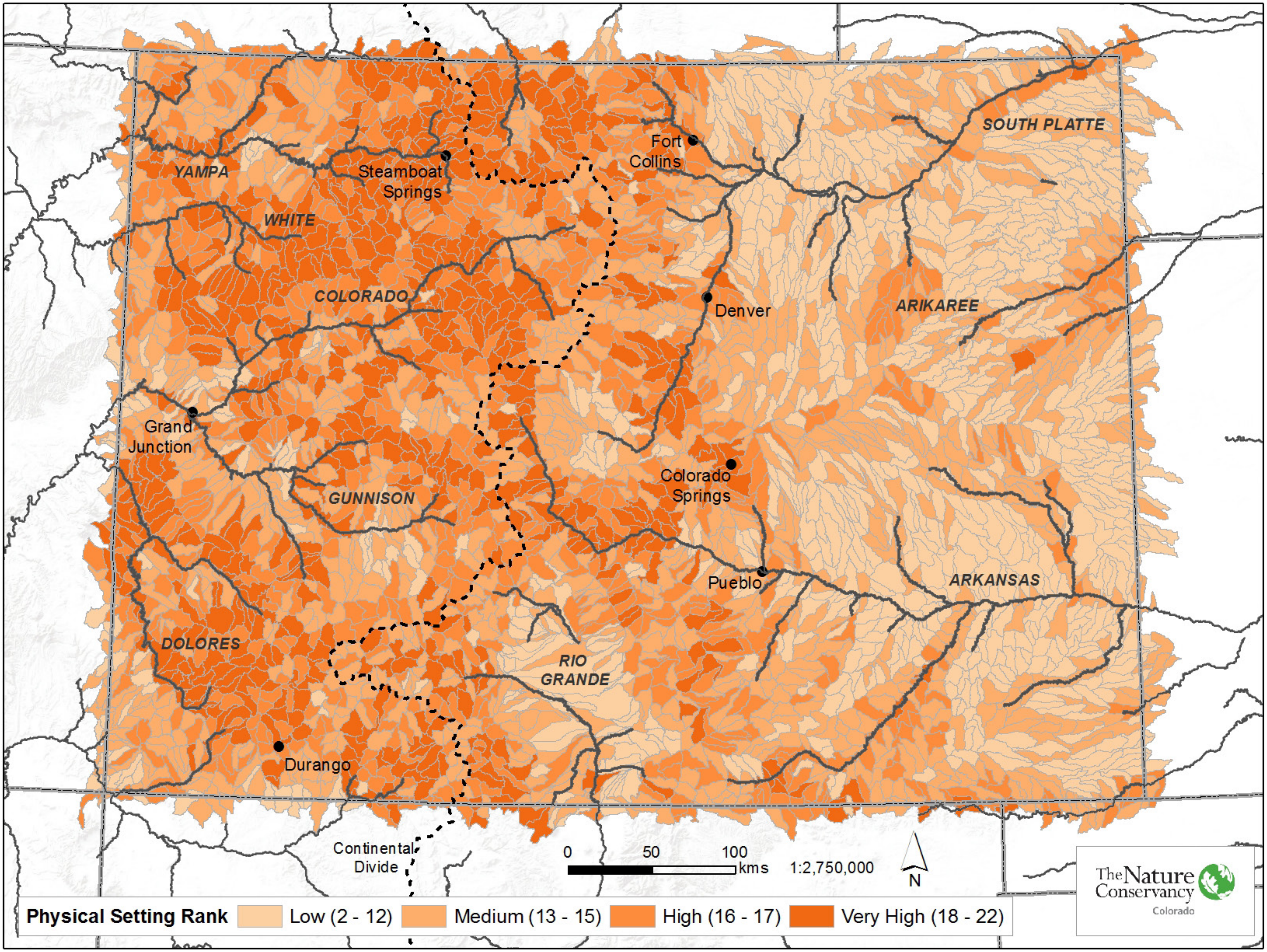
## Summary Index for Physical Setting Variables

The combined summary index for the Physical Setting variables highlights the existing physical conditions and constraints for each subwatershed. Scores were based on quartiles, dividing the dataset into four equal-size groups. The subwatersheds with the highest resilience scores have high network complexity and linear connectivity, contain more elevation and gradient classes, and receive ample precipitation. These patterns indicate there are great habitat features, or complexity, available in these watersheds, which offers greater refugia. In the case of these physical settings, resilient stream systems are those that will support a full spectrum of biodiversity and maintain their functional integrity even as species compositions and hydrologic properties change in response to shifts in conditions.

***Table 12.*** Scoring for Physical Setting Variables

| Physical Settings Variables Score | Healthy Rivers Index |
|---|---|
| 2-12 | Low |
| 13-15 | Medium |
| 16-17 | High |
| 18-22 | Very High |

San Miguel River © *Lauryn Wachs/TNC,* Confluence Park in Denver © *Kent Kanouse,* Yampa River © *Taylor Hawes/TNC*




***Map 12.*** Summary scores for combined Physical Setting variables*
"Very High" = most resilient "Low" = least resilient

**Temperature not included*

## CATEGORY 3: HABITAT CONDITIONS VARIABLES

The Habitat Conditions variables offer insight into how water management systems and other development influence freshwater ecosystem structure and function. Historic water management has diverted flows from rivers and pumped groundwater to meet agricultural, municipal, and industrial needs. If not needed for immediate use, the diverted water is stored for future use, often during periods of low flow. In Colorado, hydrologic conditions have been altered through in-basin diversions, transbasin diversions, storage in reservoirs, and land use, especially agriculture. Altered flows that result from these patterns of water development and management have consequences for both aquatic and floodplain ecological integrity, often quantified as the degree to which a river can sustain the complex structure of native animals and plants that live in or near it.

The suite of variables under Habitat Conditions captures land cover and use, instream infrastructure and management practices, and direct alteration to the natural flow regime. The eight variables include: Floodplain Riparian Cover, Agricultural Land Use, Urban Land Use (Impervious Surface), Instream Fish Barriers, Reservoir Storage Index, Index of Local Depletions, Total Water Use, and Degree of Flow Alteration. The last three variables in this list were designed to measure and track how water is used consumptively. Taken together, these variables can serve as an estimate of how much water is used relative to the mean annual flow under natural conditions and provides an indication of depletions within a watershed.

Dolores River © *Mark Skalny*

## Floodplain Riparian Cover

Riparian zones in Colorado are inextricably linked to streamflow. Riparian vegetation composition, structure and abundance are governed to a large degree by river flow regime and flow-mediated fluvial processes (Merritt et al., 2010). Flood flows maintain the active channel area, the surface and vegetation disturbance that comes with floods periodically resets the successional process of riparian communities, and water provided to riparian areas during floods helps to maintain vegetation that is not able to persist in surrounding dry landscapes. River regulation typically reduces flood disturbance and sediment supply, permitting invasion by nonnative species (e.g. tamarisk) or allowing successional processes to reach an artificial equilibrium. In many cases, the result is replacement with a different riparian community (Johnson, 1994). Flow regulation also enables agricultural and urban development of the riparian zone by suppressing larger and more frequent flood events.

We assessed riparian land use by calculating the proportion of the floodplain that has natural riparian cover using FEMA floodplain polygons for Colorado, digital elevation models, 2011 National Land Cover Database (NLCD) vegetation data, USGS Landscape Fire and Resource Management Planning Tools Project (Landfire) existing vegetation types, and National Wetlands Inventory (NWI) data. Using these data, we generated floodplains using slope to indicate changes in topography. Next, we used the FEMA floodplain polygons to determine average slope of floodplains in Colorado and used a mean (+/-1 SD) to identify a threshold slope distance and delineate floodplains throughout the state. We then subtracted open water from the floodplain to create the final terrestrial floodplain area.

To calculate the proportion of riparian cover within the floodplain zone, we generated an aggregated layer of riparian vegetation from values determined to be riparian vegetation cover from the NLCD, Landfire, and NWI. The total area of riparian land cover in the floodplain was divided by the area of floodplain in the subwatershed to give the proportion of riparian cover in the floodplain.

### Scoring the Subwatersheds

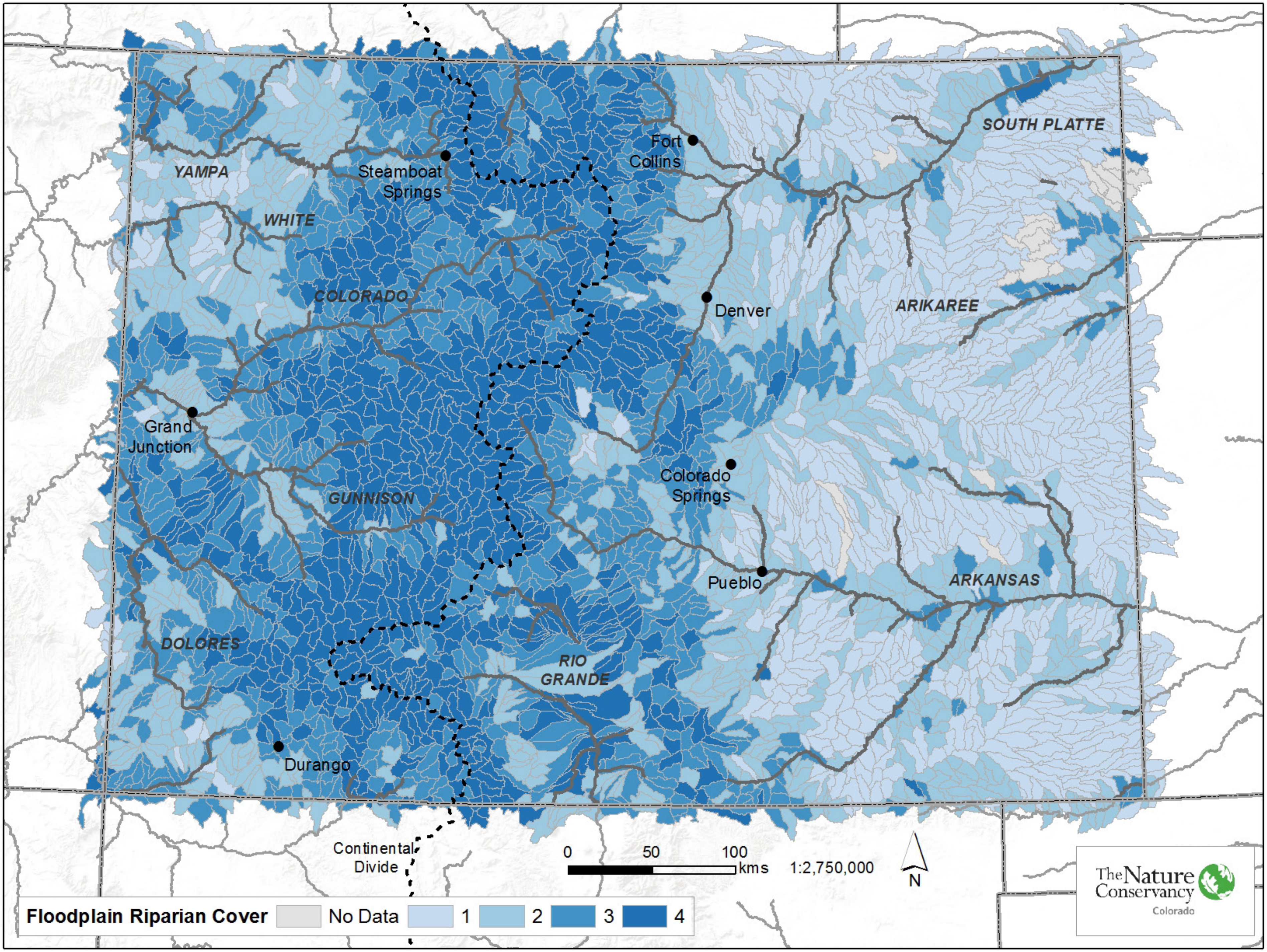
Floodplain riparian cover was ranked based on quartiles. The underlying rationale is that subwatersheds with higher riparian cover in the floodplain translate to higher resiliency due to habitat availability and ecosystem services. Table 13 depicts the floodplain riparian cover thresholds and associated scores.

***Table 13.*** Scoring for Floodplain Riparian Cover

| Floodplain Riparian Cover (%) | Healthy Rivers Index |
|---|---|
| <5.8 | 1 |
| 5.8<21.28 | 2 |
| 21.28 <41.06 | 3 |
| >41.06 | 4 |

### Interpreting the Results

Map 13 shows the patterns across subwatersheds of floodplain development, or lack thereof, throughout the state. It is important to note that this variable is simply a measure of the amount of natural floodplain cover, but does not take into consideration the ratio of floodplain area to watershed size. The subwatersheds in eastern Colorado have the lowest natural riparian cover, likely related to the degree of agricultural development in those floodplains.




***Map 13.*** Healthy River Scores for Floodplain Riparian Cover in HUC 12 subwatersheds. 1 = low riparian cover; 4 = high riparian cover

## Agricultural Land Use

Land uses in the watershed, and particularly those adjacent to riparian corridors can significantly influence river function and degrade both aquatic and riparian habitat. Grazing and crop agriculture have the potential to degrade riparian and aquatic habitat conditions, and diminish water quality by increasing nutrients, salinity, and sediment inputs. More specifically, irrigated agriculture in Colorado, and especially the irrigated acreage devoted to pasture, alfalfa, and other forage crops, can be especially consumptive. However, employing innovative irrigation techniques more strategically and in more places—techniques that many farmers are already using—is helping to ensure agriculture continues in the face of rising demand and climate change's projected impact on supply.

To capture the extent of developed agricultural lands in a watershed, we calculated the proportion of each subwatershed that was classified as agriculture or irrigated agricultural lands, using NHDPlus V2 data, NLCD, and CDSS. We created a map of agricultural land cover from NLCD landcover classified as hay/pasture and from CDSS irrigated lands at 30 m resolution. We divided the calculated agricultural lands (NLCD + irrigated agricultural lands) by the total land area of the watershed to determine percent of watershed covered by agriculture.

### Scoring the Subwatersheds

The amount of agricultural cover in watershed is informed by quartiles, but was ultimately ranked based on literature and previous evidence (Allan, 2004). The ranking scores are reversed—lower Healthy River index scores indicate high agricultural cover. The underlying rationale is that subwatersheds with high agricultural cover are less resilient because of greater impacts to freshwater ecosystem (and flows) quantity and quality. Table 14 depicts the agricultural cover thresholds and associated scores.

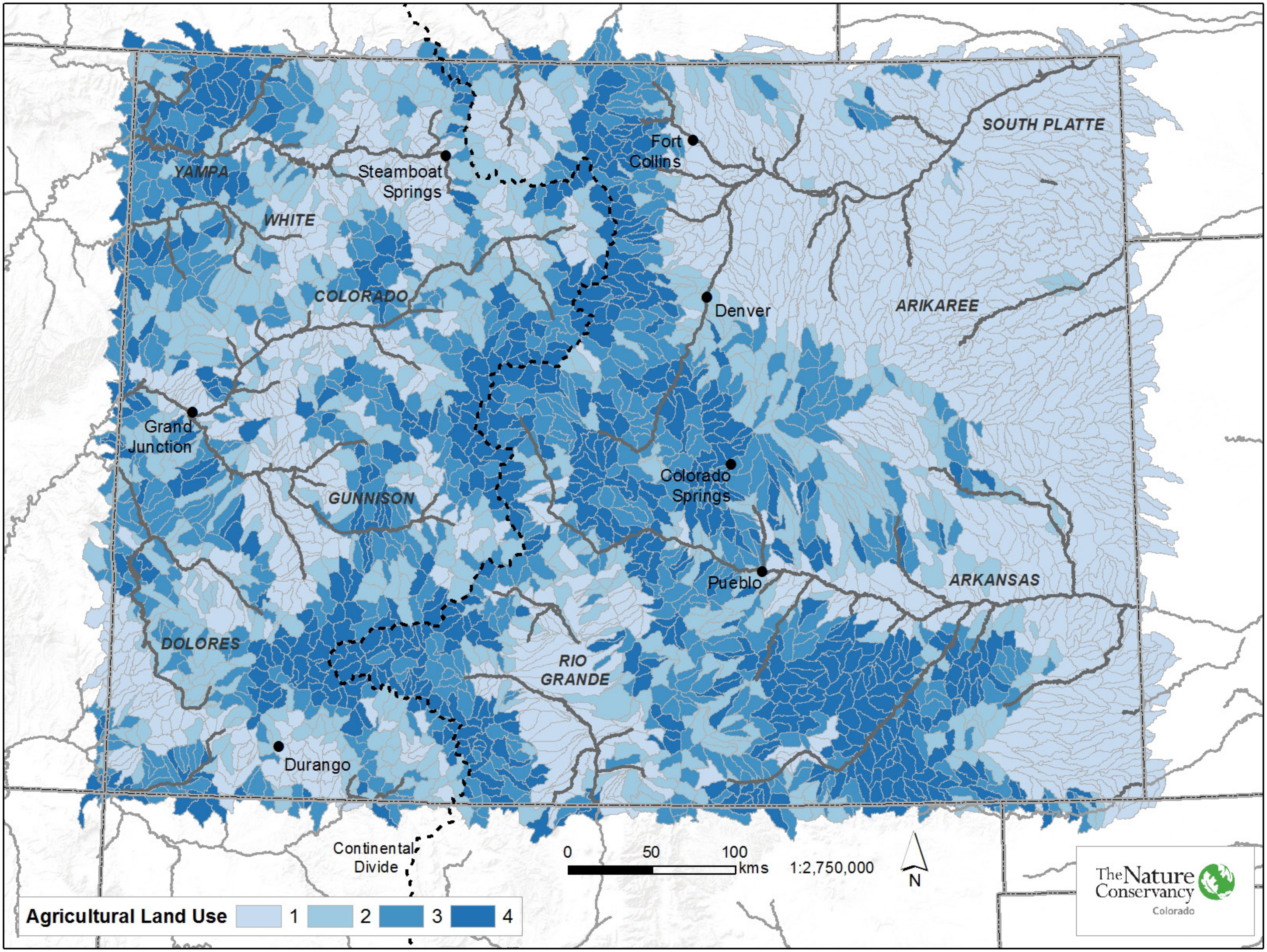
***Table 14.*** Scoring for Agricultural Land Use

| Agricultural Cover (%) | Healthy Rivers Index |
|---|---|
| > 5.0 | 1 |
| 1.0 < 5.0 | 2 |
| 0.05 < 1.0 | 3 |
| < 0.05 | 4 |

### Interpreting the Results

Map 14 depicts the range in variability of intensity of agricultural land cover across Colorado. Subwatersheds with higher agricultural land cover tend to be in lower elevation regions, and are particularly prominent in the eastern portion of the state. These regions also potentially have more impacted floodplain and aquatic habitat from agricultural lands.

Colorado River and the Grand Valley © *Ken Geiger/TNC*




***Map 14.*** Healthy River Scores for Agricultural Land Use in HUC 12 subwatersheds. 1 = high agriculture, 4 = low agriculture

## Urban Land Cover (Impervious Surface)

Urban land cover can significantly alter the natural watershed hydrography by fundamentally altering runoff patterns and lag times during precipitation events due to a significant increase in impervious surfaces. Impervious surface and urban infrastructure diminish infiltration in a watershed thereby increasing surface runoff into waterways, impacting water quality, erosion, and channel morphology. Increased impervious surface area (e.g., increased surface runoff, warmer temperatures, and lower dissolved oxygen levels) has been identified as the cause of reductions in fish species diversity, riparian and wetland habitat, species richness, and biotic integrity (Helms et al., 2009).

To calculate the total amount of urban land cover in every subwatershed, we used impervious surface data from the 2011NLCD to calculate the area of impervious surface for each subwatershed. We divided the calculated impervious surface area by the watershed size to determine percent covered by impervious surface.

### Scoring the Subwatersheds

The amount of urban land cover (percent impervious surface) in watershed is informed by quartiles and ranked based on literature (Allan, 2004; USGS, 2015). The ranking scores are reversed—lower Healthy River index scores indicate high impervious surface cover in a subwatershed. The underlying rationale is that subwatersheds with high urban land cover (impervious surface) have greater impacts to floodplain habitats, the hydrograph, and water quality. Table 15 depicts the urban land cover thresholds and associated scores.

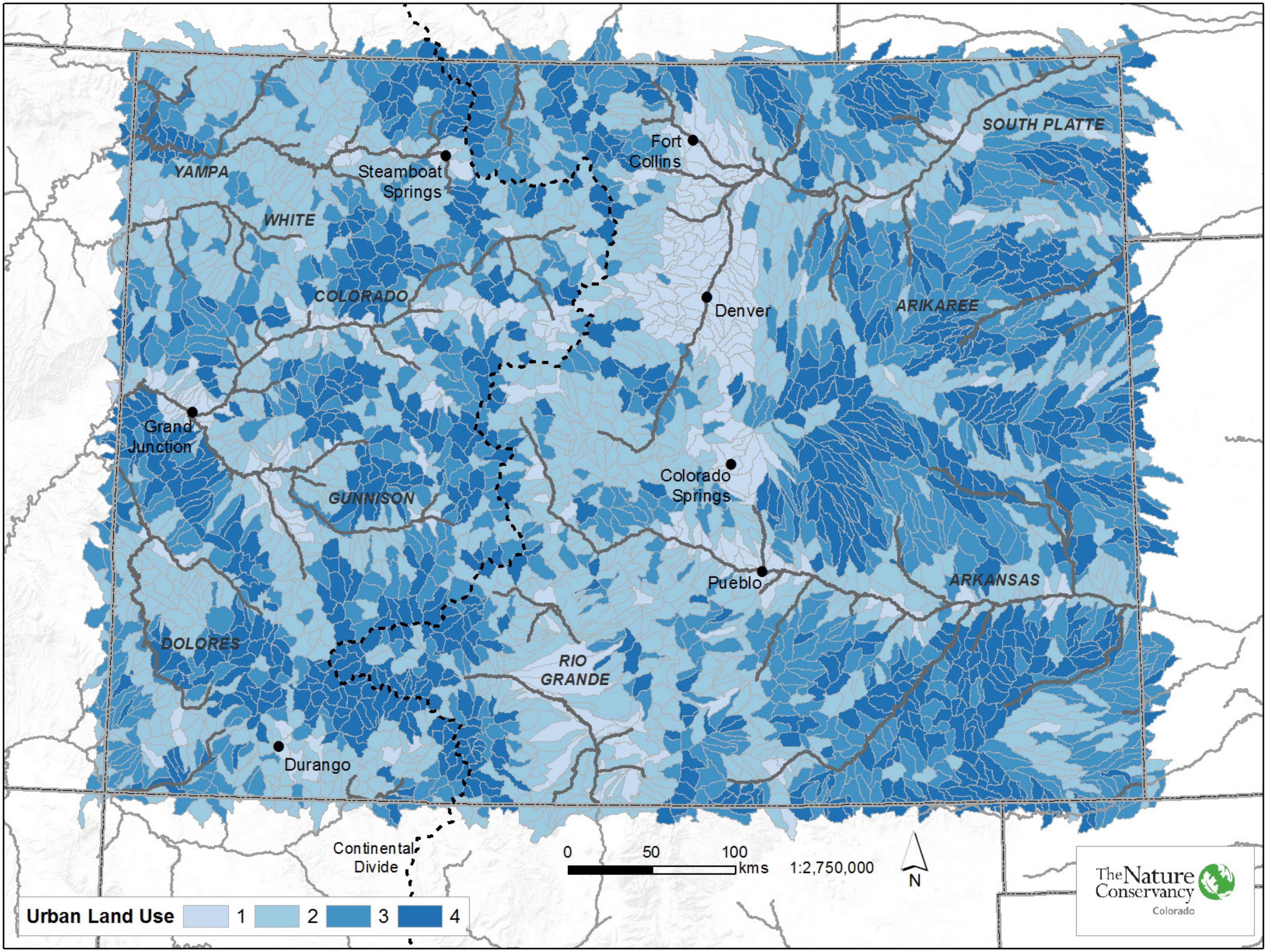
***Table 15.*** Scoring for Urban Land Cover

| Impervious Surface (%) | Healthy Rivers Index |
|---|---|
| >0.1 | 1 |
| 0.02 < 0.1 | 2 |
| 0.01 < 0.02 | 3 |
| < 0.01 | 4 |

### Interpreting the Results

Urban land uses, measured as the percent of impervious surface in a subwatershed, are highest along the Front Range. The patterns in Map 15 provide some insights into altered flow patterns and impacts to water quality based on developed land area in the subwatershed. In Colorado, larger river systems consistently are more impacted. These lower scoring subwatersheds should be carefully evaluated for conservation outcomes as there may be additional constraints due to competing risk management goals (i.e., flood management). However, there are also opportunities to explore infrastructure improvements, including using nature-based solutions to improve freshwater ecosystem structure and function.

South Platte River in Denver © *Kent Kanouse*




***Map 15.*** Healthy River Scores for Urban Land Cover (Impervious Surface) in HUC 12 subwatersheds. 1 = high impervious surface, 4 = low impervious surface

## Instream Fish Barriers (Diversion Structures)

Connectivity of freshwater habitats is vital for the long-term viability of fish populations. Habitat requirements often change seasonally, with many species moving from feeding habitat to spawning reaches, or seeking out refuge habitat from elevated temperatures, receding flow or ice. For example, the Colorado pikeminnow *(Ptychocheilus lucius)* migrates from resident habitat to spawning grounds that are as much as 120 miles away (Tyus, 1984). Several fishes of the Great Plains have buoyant eggs that are carried downstream by the river, and these species are susceptible to barriers that prevent the return migration of hatched juveniles (Fausch, 1997). Brassy minnow *(Hybognathus hankinsoni)* can persist through drought in isolated pools but successful reproduction depends on access to seasonal flowing habitats (Scheurer, 2003). Headwater streams that provide a cool refuge for trout from summer heat may freeze solid in winter and if a dam or weir obstructs temporal movement between refuges, few fish will survive (Fausch, 2002).

Research has shown that fish will eventually recover from localized extinction events, whether they are natural or a consequence of human activity, provided access is maintained from other surviving populations (Fausch, 2002). Small habitat areas isolated by instream barriers are more susceptible to disturbance, with localized events sufficient to eliminate the fish population. Dams, weirs, and agricultural infrastructure can restrict both upstream and downstream movement. The instream fish barrier variable provides a measure of the ability of an aquatic species (more specifically, a fish) to move within a stream or river systems. Unlike the Linear Connectivity, which is focused on the impediment posed by larger, more permanent instream infrastructure, such as dams, the Instream Fish Barrier variable is focused on smaller points of diversion and agricultural infrastructure. This variable captures diversion density, by calculating the number of diversions per kilometer of stream within a watershed. The output from this measure is the average length of stream in a subwatershed before a diversion point, or potential barrier, is encountered. To calculate this variable, we used the NHD Plus V2 hydrography data and the CDSS structures dataset representing diversions. Within ArcMap, we simply determined the total number of existing structures and total stream and river length for each subwatershed and then divided the number of structures by length of streams and rivers.

### Scoring the Subwatersheds

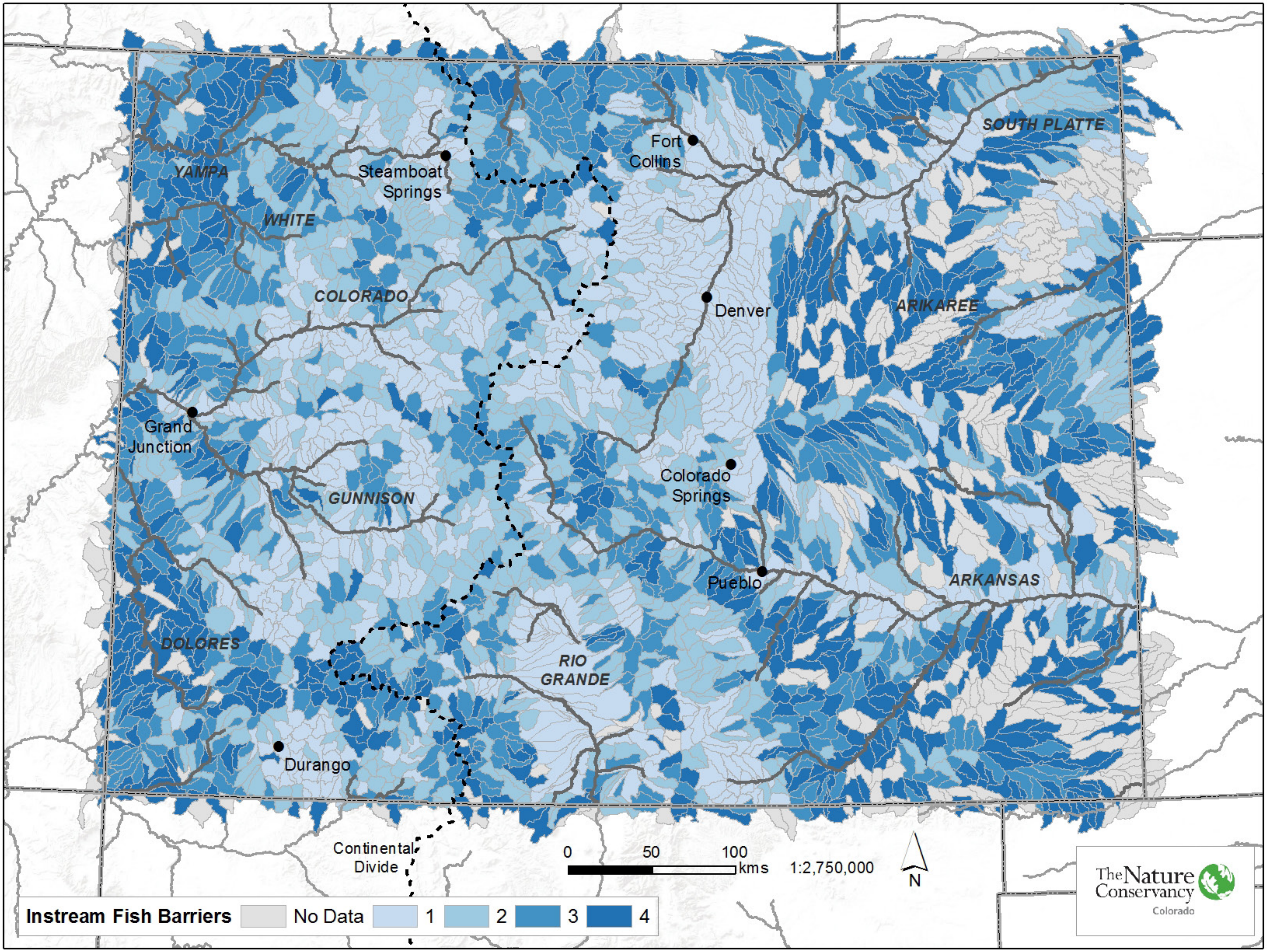
The density of diversion structures represents management and barriers to fish passages in waterways, and can also serve as significant barriers to fish passage and maintenance of healthy populations. We ranked instream fish barriers based on quartiles. With these variables, densities and ranks are inversely related to one another—lower Healthy Rivers Index scores indicate high density of fish barriers. Table 16 depicts the thresholds and associated scores for diversion structures.

***Table 16.*** Scoring for Instream Fish Barriers

| Diversion structures (#/km of stream) | Healthy Rivers Index |
|---|---|
| >1.2 | 1 |
| 0.49 < 1.2 | 2 |
| 0.185 < 0.49 | 3 |
| < 0.185 | 4 |

### Interpreting the Results

The densities of diversion structures can represent disconnection to fish population movement. Map 16 shows that higher elevation watersheds had the lowest densities of diversion structures and the highest densities were in subwatersheds adjacent to larger river systems. The subwatersheds with lower resilience scores offer the opportunity to examine existing infrastructure for potential opportunities to improve fish passage.




***Map 16.*** Healthy River Scores for Instream Fish Barriers in HUC 12 subwatersheds. 1 = high density of barriers/diversion structures, 4 = low density of barriers/diversion structures

## Reservoir Storage Index

Dams and their associated reservoir have a pronounced effect on the magnitude and timing of maximum and minimum flows, and can also fundamentally alter the amount of water available in a watershed through storage. For example, the mean annual flow in the Green River below Flaming Gorge Dam has only changed 5%, yet there has been a reduction in peak flows of 64% and an increase in magnitude of baseflows after dam completion (Bestgen et al., 2007b). Reductions in flood flows and the presence of dams can cause changes in sediment transport in a river so that there is either too much or too little silt, sand, and gravel. If high flows do not occur with sufficient magnitude or frequency, sediment accumulates, and among the problems generated is that fine sediment like silt and sand can clog interstices in gravel where trout spawn. Water management can also affect temperature as water released through dams often comes from the bottom of the reservoir where temperatures are commonly much colder than native species require. Re-timing of flows through reservoir storage creates a more stable flow regime that can also increase non-native species movement and reproduction (Marchetti, 2004).

Generally speaking, the greater the volume of available storage, the more flows can be altered. The ability to modify the natural flow regime (magnitude, variability, and timing of flows) is a function of the water residence time (aka storage). Colorado's rivers and streams, and the biota in them, have evolved under the influence of floods from both snowmelt and, less frequently, large summer thunderstorms. These flood dynamics are essential for maintaining healthy aquatic and riparian habitats (Merritt and Poff, 2010).

To understand water storage and flow alteration patterns across Colorado, we calculated the ratio of reservoir storage volume to mean annual flow using data from NHDPlus V2, Colorado Decision Support System (CDSS), and dams from the Global Water System Project GRanD database. We found 2124 lakes or reservoirs in the study area with associated volumes: 2104 water bodies having actively monitored volumes in data organized by the CDSS and 20 water bodies having estimated capacities from the global GRAND database (Lehner et al., 2011; http://sedac.ciesin.columbia.edu/data/set/grand-v1-reservoirs-rev01). For waterbodies from the CDSS database, we averaged annual volumes across 1981-2014 to calculate an average measure of reservoir storage in each waterbody in acre-feet (ac-ft). For waterbodies outside Colorado but within the upstream watersheds, we relied on volume estimates from the Grand Dams database.

We calculated the upstream accumulated reservoir volume for each sub-watershed and divided the sum by the maximum NHDPlus V2 Enhanced Runoff Method (EROM) natural flow value in ac-ft. For sub watersheds without estimated EROM natural flows, no reservoir storage index is reported.

Pueblo dam on the Arkansas River © *Steve Doria,* Horsetooth Reservoir on the Cache la Poudre River © *Cassandra Turner*

## Scoring the Subwatersheds

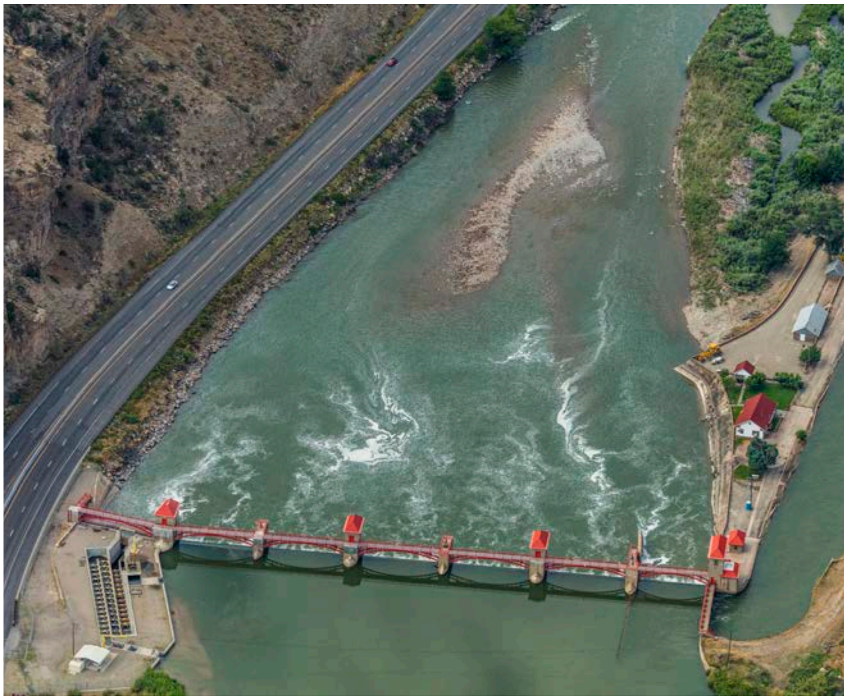
Reservoir storage index provides an indicator of how the timing of flow can be altered within a subwatershed. Reservoir storage index was ranked based on literature (Poff, 2002; Wilding and Poff, 2008) and indicates the capacity of flows to be modified within a subwatershed. Once again, reservoir storage volumes and ranks are inversely related to one another. Lower Healthy Rivers Index scores indicate high reservoir storage capacity and therefore higher capacity to alter natural flow regimes. Table 17 shows the reservoir storage thresholds and associated scores.

***Table 17.*** Scoring for Reservoir Storage Index

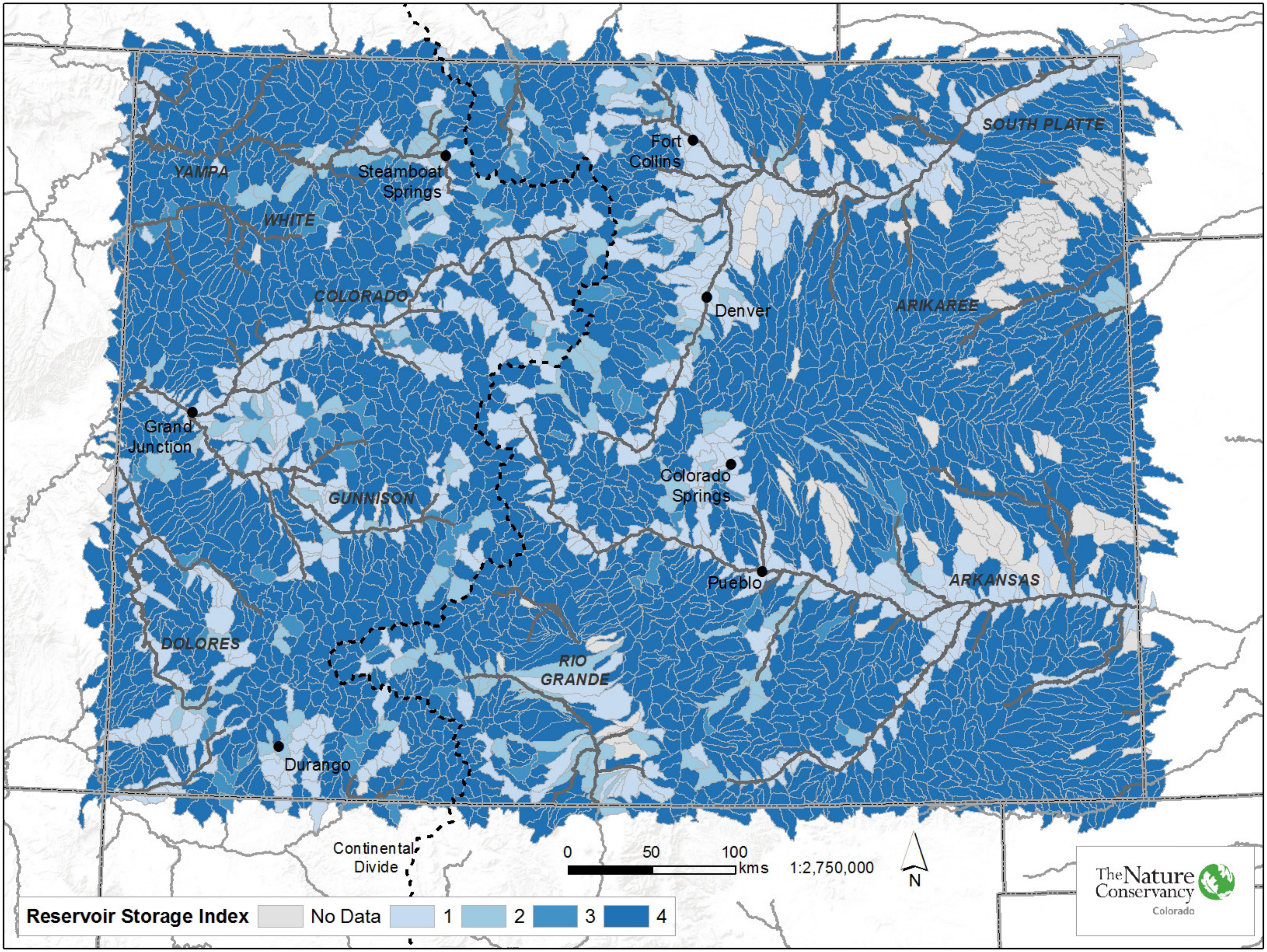
| Reservoir Storage | Healthy Rivers Index |
|---|---|
| >.75 | 1 |
| 0.25 < 0.75 | 2 |
| 0.1 < 0.25 | 3 |
| < 0.1 | 4 |

## Interpreting the Results

The patterns in Map 17 show the variability in storage capacity across the state, which can serve as strong indicators of altered flow regimes. This variable emphasizes the physical impacts of reservoir infrastructure on freshwater ecosystem structure and function. However, when interpreting these results for project implementation or potential management outcomes, reservoir reoperation may be an intervention that can increase opportunities for water transactions that restore base flows or even provide environmental flows.



The Grand Valley diversion dam on the Colorado River © *Ken Geiger/TNC*




***Map 17.*** Healthy River Scores for Reservoir Storage Index in HUC 12 subwatersheds. 1 = high storage, 4 = low storage

## Index of Local Depletions

The Index of Local Depletions variable captures all diversion volumes within a subwatershed. This variable is designed to account for patterns associated with local water withdrawals in a subwatershed, including any transmountain diversions. The patterns captured by the Local Depletions variables describes the portion of available water that is diverted, or pulled, from rivers and streams within a subwatershed to meet local demands. It does not account for return flows, but does capture the pressures on the waterways. To measure local depletions, we calculated the average diverted volume of water between 1981-2014 using CDSS data and the shapefiles of diversion structures. We summed the average diversions and divided by the EROM natural flow to create an index of local depletions.

### Scoring the Subwatersheds

The Index of Local Depletions was ranked based quartiles with slightly adjusted boundaries and provides an indicator of water demands that pull water from rivers and streams within a subwatershed. The ranking scores are reversed to indicate the demand pressures on a system; lower Healthy Rivers Index scores indicate high depletions in a subwatershed. Table 18 depicts local depletion thresholds and associated scores.

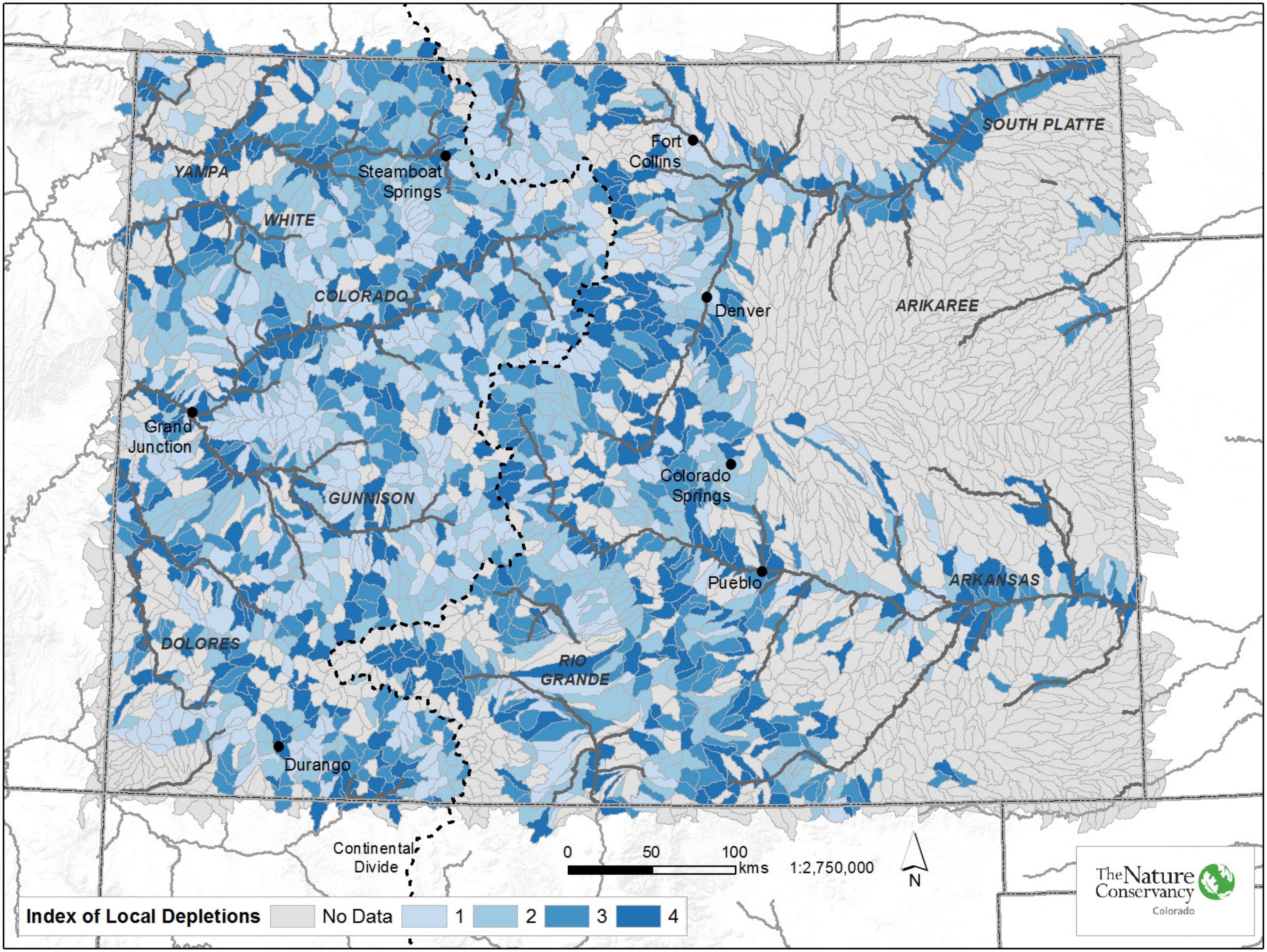
***Table 18.*** Scoring for Local Depletions

| Local Depletions | Healthy Rivers Index |
|---|---|
| >1.2 | 1 |
| 0.49<1.2 | 2 |
| 0.185<0.49 | 3 |
| <0.185 | 4 |

### Interpreting the Results

Map 18 shows patterns of all diversion volumes, including transmountain diversions, in a subwatershed. These patterns account for the local demands on water, capturing the pressures in a subwatershed, or what is being pulled from the waterways. It is important to note that this variable does not account for return flows; it is simply a measure of total withdrawals from rivers and streams in a watershed. These results can be used to help identify watersheds where there might be opportunities to reduce depletion volumes for instream flows.

South Platte River © *900hp*




***Map 18.*** Healthy River Scores for Local Depletions in HUC 12 subwatersheds. 1 = high depletions, 4 = low depletions

## Total Water Use

The Total Water Use variable accounts for where and how demand occurs within a subwatershed. This variable is designed to account for both surface and groundwater demands by combining agricultural water use and municipal water use in each subwatershed. Total Water Use more precisely depicts the total footprint of land use demands associated with water use in a subwatershed.

To generate total water use metrics, we used a combination of the 2011 NLCD cover types (http://www.mrlc.gov/), CDSS irrigated lands, and USGS Water Use in the United States databases (http://water.usgs.gov/watuse/). To calculate the total footprint, we reclassified the appropriate land cover types into binary grids. For agriculture lands, we used both NLCD pasture, hay, and crops and CDSS irrigated lands to create the most comprehensive layer of agriculture. For municipal lands, we used NLCD low, medium and high intensity development. We then summed the areas of associated land cover by county and calculated the water use for agriculture and municipal per 30 m pixel of associated land cover in each county and generated a grid of these values at 30 m resolution. For agriculture, we used UGSG water use for irrigated crops – total freshwater. For municipal, we included public supply, domestic, industrial, mining, and thermo (total freshwater) from the USGS water use. For each subwatershed, we then summed water use for agriculture and municipal.

### Scoring the Subwatersheds

Total Water Use was ranked based on quartiles and provides an indicator of the intensity of water demands locally within a subwatershed. The ranking scores are reversed—lower Healthy Rivers Index scores indicate high intensity of municipal and agricultural water demands. Table 19 shows the thresholds and associated scores for Total Water Use.

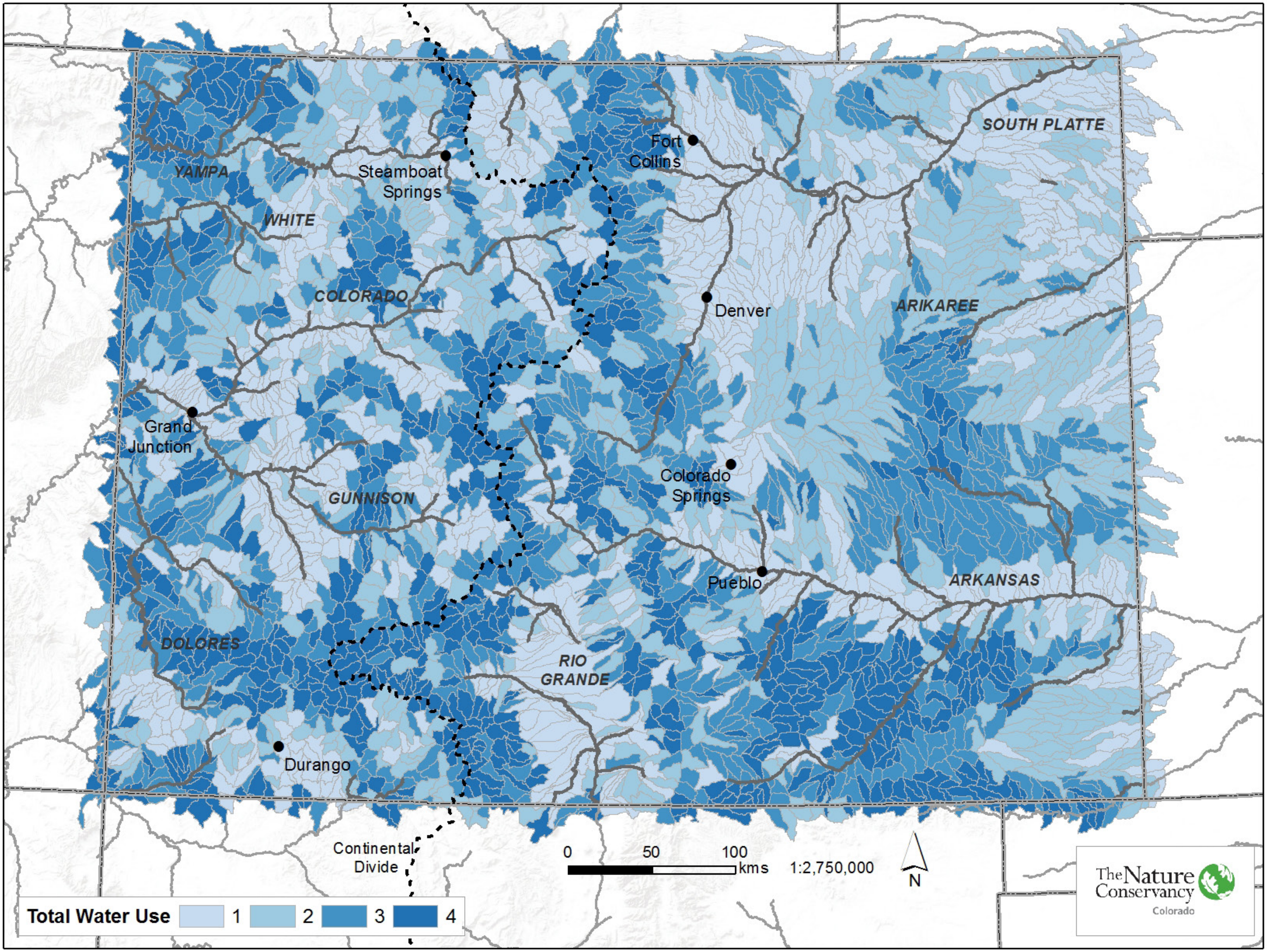
***Table 19.*** Scoring for Total Water Use

| Total Water Use | Healthy Rivers Rank |
|---|---|
| >1.2 | 1 |
| 0.49<1.2 | 2 |
| 0.185<0.49 | 3 |
| <0.185 | 4 |

### Interpreting the Results

Total Water Use patterns in Map 19 provide an opportunity to better understand how land uses (i.e. agriculture and municipal) and water demands intersect at the subwatershed level. This variable represents the "footprint" of land area to which water demands are tied. Like local depletions, these results can be used to help identify watersheds in which there might be opportunities to change or reduce consumption patterns.

Yampa River © *Alan W. Eckert*




***Map 19.*** Healthy River Scores for Total Water Use in HUC 12 subwatersheds. 1 = high water use, 4 = low water use

## Degree of Flow Alteration (Departure from Natural Flow)

The Degree of Flow Alteration variable describes the water demand patterns, including consumptive use and return flows in a subwatershed. This variable provides an indication of the degree of flow modification in subwatershed and shows the interconnected, and downstream, impacts of water consumption patterns. Our model captures the difference between water that is diverted and water that returns to the system, whether local or transbasin.

The calculation for Degree of Natural Flow Alteration is (agricultural lands [NLCD agricultural land cover and CDSS irrigated lands] x average crop water use) + (# of households [census data] x average municipal and industrial consumptive demand [average consumption derived from SWSI 2010]) + (transbasin export & imports)/mean annual natural flow

*Agricultural consumptive use:*

To calculate consumptive use for agriculture, we generated a layer using irrigated lands databases from CDSS and NLCD to better capture both surface and groundwater dependent agriculture. For agricultural consumptive use, we used the statewide assessment of current agricultural demand by basin to average the water supply limited consumptive use per acre of agriculture (1.35 FT) (SWSI, 2010). The accumulated area of agriculture was multiplied by the average agricultural consumptive use to generate the accumulated agriculture consumptive use for each subwatershed.

*M&I consumptive use:*

To calculate municipal and industrial consumptive use, we used 2010 census block data (census.gov) and projected the information to NAD1983-Albers. We then intersected the statewide subwatersheds with the census blocks to translate the census block data to the appropriate scale of analysis. We calculated the percentage of the population living in that watershed. If a census block was split between two subwatersheds, then the population was split between those watersheds. The final step was to sum the populations.

We obtained municipal and industrial consumptive use rates from the CWCB's 2010 publication: State of Colorado 2050 Municipal & Industrial Water Use Projections. The authors used rate of use as system wide gallons per capita per day (gpcd), which was collected from local water providers and aggregated to the county level on a weighted basis (CDM Smith, 2010). To calculate consumptive use per subwatershed based on population densities we took the 2008 statewide water demand of 974,500 and divided by the 2010 Colorado state population from the census data to get an average value (0.19 acre-feet per year per capita). We then took the acre-feet per year per capita and multiplied by the local and upstream populations of each subwatershed to depict depletions caused by M&I demands.

Irrigation ditch in Larimer County © *AJ Schroetlin,* Rafting on the Colorado River © *Erika Nortemann/TNC,* South Platte River © *Stachelbeer*

*Trans-Mountain Diversions*

To account for transmountain diversions (TMDs) in Colorado, we obtained data on structures and flow volumes from the State Engineer's Office and CDSS. We matched diversion structures with associated flowlines in ArcMap and digitized direct lines from the structure to the receiving subwatershed. Next, we added or subtracted the diverted water for the appropriate subwatersheds. Through this process, we could model and track the major water diversion in Colorado. When several subwatersheds contributed to a diversion (e.g. a collection system) the total water diverted was equally split among all contributing subwatersheds.

*Mean annual natural flows*

To determine the maximum estimated natural flow of each subwatershed, we calculated the maximum flow in each subwatershed. To calculate mean annual natural flows, we used the reference gage regression values in the EROM data. All flow estimates were in cubic feet per second (cfs) and converted to acre-feet per year. We validated the maximum natural flow as the pour point with a flow accumulation model created from a DEM.

### Scoring the Subwatersheds

The Degree of Flow Alteration was ranked based on literature and identified thresholds from ecological limits of hydrologic alteration (ELOHA) framework and flow-ecology relationships (Wilding and Poff, 2008; Poff and Zimmerman, 2009; Poff et al, 2009; Richter et al., 2009, Richter et al., 2011). This variable indicates the degree of water management and movement of water into and out of a subwatershed. The ranking scores are reversed—lower Healthy Rivers Index scores indicate a high degree of flow alteration, or departure from natural flow patterns. Table 20 depicts the thresholds and associated scores for the degree of flow alteration variable.

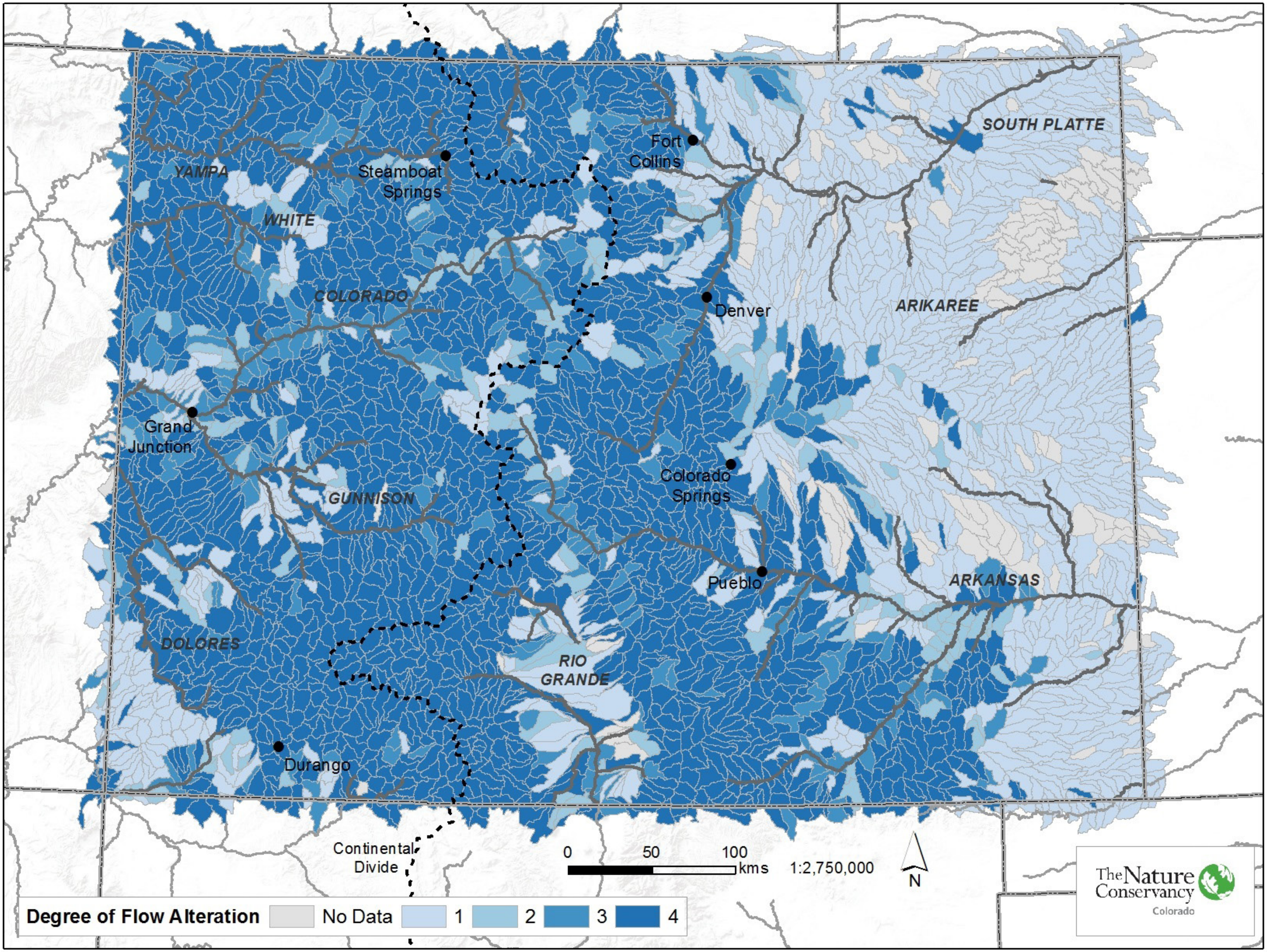
***Table 20.*** Scoring for Flow Alteration

| Flow Alteration | Healthy Rivers Index |
|---|---|
| >0.4 | 1 |
| 0.3<0.4 | 2 |
| 0.2<0.3 | 3 |
| <.2 | 4 |

### Interpreting the Results

Map 20 depicts the water patterns within a subwatershed, including return flows, and serves as an indicator of the degree of modification to the flow regimes from natural (either from additional storage capacity or water budget depletions). These patterns show the interconnected, downstream impacts of water management and consumption on a statewide level. These patterns offer insights into places to explore potential opportunities to reduce demands, change management practices, improve agricultural efficiencies, and other types of interventions to restore flow and improve freshwater habitat conditions.

Irrigation canal in Palisade, CO © *Lauryn Wachs*



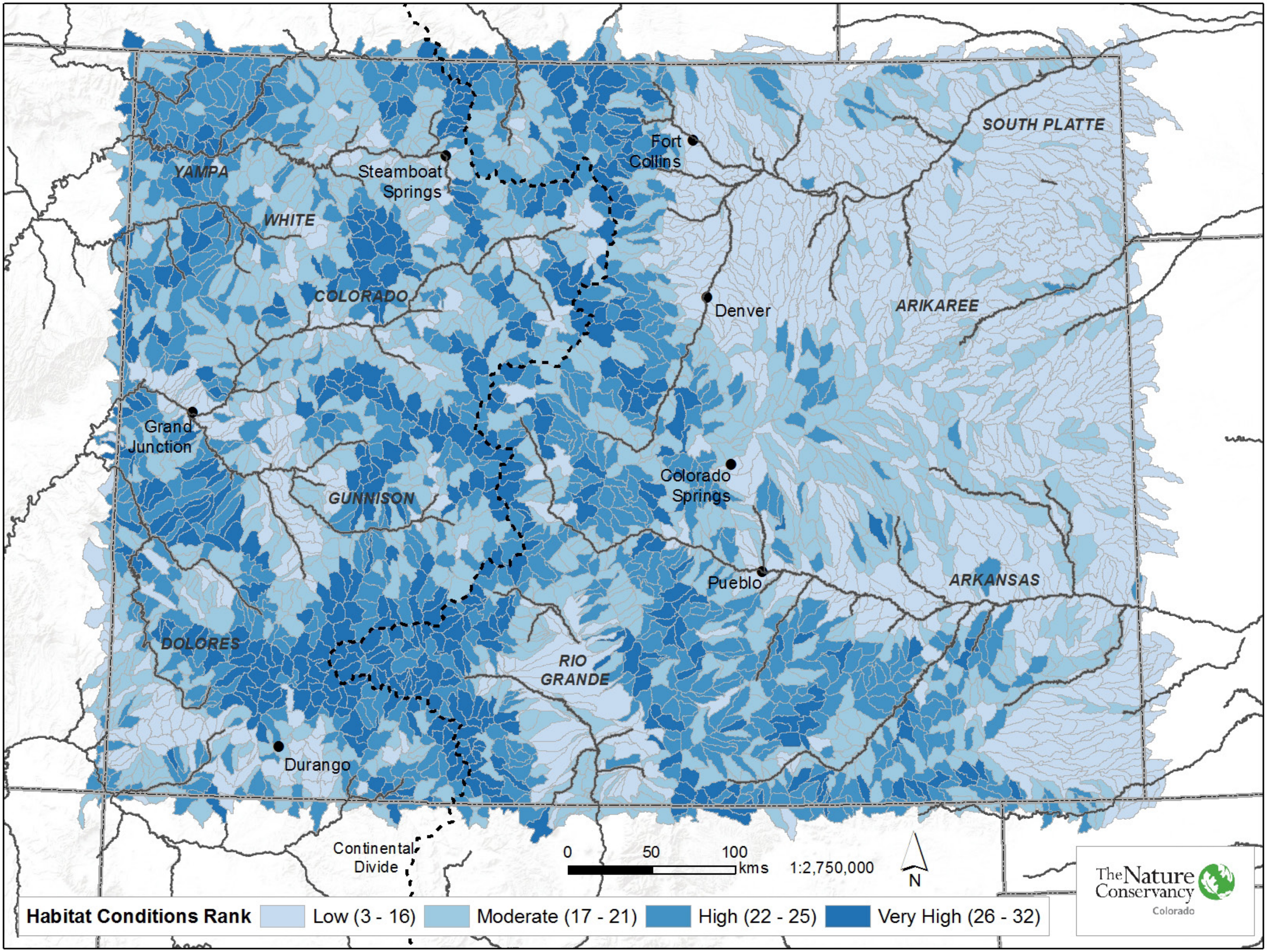

***Map 20.*** Healthy River Scores for Flow Alteration in HUC 12 subwatersheds. 1 = high flow alteration, 4 = low flow alteration

## Summary Index for Habitat Conditions Variables

The patterns for the individual Habitat Conditions variables (Maps 13-20) and the summary index for these variables (Map 21) are some of the most important to explore because these variables indicate human-induced changes to freshwater ecosystems. The resilience scores for these variables offer the most insight into opportunities to change management practices to improve flow and habitat conditions. Scores were based on quartiles, dividing the dataset into four equal-size groups. The subwatersheds with the highest scores have the least altered flow regimes and are also the least impacted by urban and agricultural land use pressures.

***Table 21.*** Scoring for Habitat Conditions Variables

| Habitat Conditions Variables Score | Healthy Rivers Index |
|---|---|
| 3-16 | Low |
| 17-21 | Medium |
| 22-25 | High |
| 26-32 | Very High |




***Map 21.*** Summary scores for Habitat Conditions variables; "Very High" = most resilient "Low" = least resilient

# CATEGORY 4. RISKS AND THREATS VARIABLES

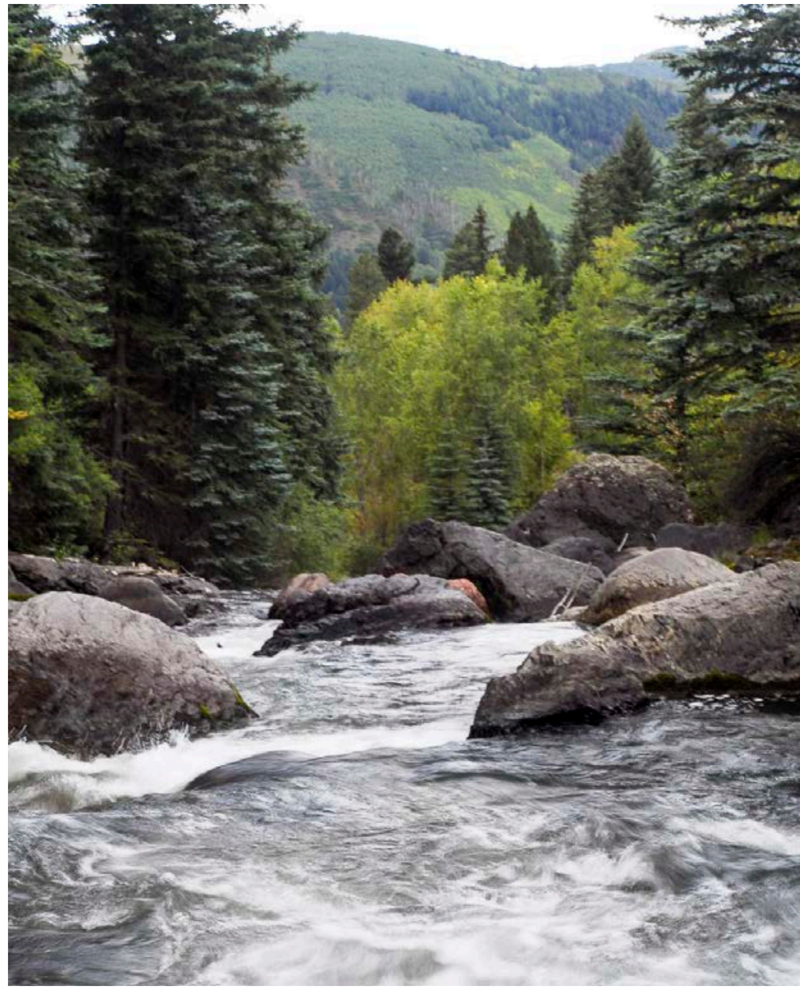
In addition to the physical constraints and management challenges facing freshwater ecosystems already outlined, there are also pervasive risks and threats that impact freshwater habitat quality and water supplies. These challenges, ranging from providing adequate amounts of clean water and controlling polluted runoff and groundwater to managing the risks of floods and droughts and maintaining aging water infrastructure —all while maintaining healthy aquatic and riparian ecosystems, are projected to intensify across local, regional, and global scales.

These types of risks and threats are rarely incorporated into conservation planning due to the difficulties in quantifying the threats. There is currently no widely accepted method to quantify these types of risks and threats, and determining how to measure threats to upstream catchments using disturbance metrics can be time consuming and subjective. For our analysis, we have included two variables as risks and threats to Colorado's rivers and streams and could be quantified relatively objectively: non-native species and drought.

## Nonnative Aquatic and Riparian Species

Nonnative aquatic and riparian species can have a significant impact on the ecological integrity of freshwater ecosystems, particularly when invasive. Invasive species can lead to the degradation of freshwater habitat and outcompete or prey on native species. Aquatic invasive species are one of the largest threats to freshwater biota in Colorado. In a study of 12 western states, Schade and Bonar (2005) found that of 400,000 stream miles sampled, Colorado had the highest ratio of nonnative fish; two out of every three fish sampled was non-native. Additionally, many introduced fish species can hybridize with native fishes, threatening the genetic integrity of the native fishes. Colorado has four endangered fish species: Colorado pikeminnow, humpback chub, razorback sucker, and bonytail chub. These listed fish are particularly impacted by three non-native fish species: northern pike, channel catfish, and smallmouth bass, which compete for similar resources and are also predators. In addition to the endangered fishes, three native species of concern in Colorado (flannelmouth sucker, bluehead sucker, roundtail chub) hybridize with the non-native white sucker and longnose sucker. While some genetically pure populations still exist, the hybridizations are of increasing concern.

Under altered flow conditions, introduced species may be more adapted to compete for resources. For example,



Colorado Pikeminnow © *Joe Ferreira,* San Miguel River © *Russ Schnitzer,* Humpback chub © *George Andrejko/AZ Fish & Game Dept.*

the New Zealand mudsnail impacts fish populations by destroying their forage, while rusty crayfish eat fish eggs and small fish. Other introduced species such as quagga and zebra mussels reproduce rapidly and are considered a "nuisance species" because they can clog infrastructure. Invasive aquatic plants impact freshwater systems as well. Aquatic plants like water hyacinth can grow rapidly, covering water surfaces and blocking sunlight.

The alteration of riparian, groundwater and river flow regimes have facilitated the expansion of non-native plants such as tamarisk (salt cedar), giant reed, and Russian olive throughout the western and southwestern United States (Sher et al., 2000; Stromberg, 1998). Dams that are large enough to reduce annual flooding can precipitate the colonization of banks by tamarisk and Russian olive, which can lead to fundamental shifts in community composition and geomorphic conditions. Stabilization of banks by root systems and sediment accumulation can lead to channel narrowing and deepening. The combined effect of damming and tamarisk invasion can therefore eliminate backwater areas that are critical rearing habitat for many endangered fish (Pease et al., 2006). Tamarisk has a relatively high tolerance for fire, drought, and salinity, and has been found at elevations up to 6500 feet (2000 m). Tamarisk can also form dense stands that can exclude native riparian plants such as cottonwood and willow.

To capture the extent of non-native aquatic and riparian species across Colorado, we accounted for presence/absence in the subwatershed. We used several data sources from Colorado Parks and Wildlife Aquatic and Nuisance Species (ANS), USGS, and the Early Detection and Distribution Mapping System (EDDMS; https://www.eddmaps.org/). The non-native fish species and ANS from CPW were already captured at the subwatershed scale. Point presence records of EDDMaPS species were joined to subwatersheds in ArcMap. The stats program R was used to summarize the number of non-native species occurring in each subwatershed using CPW fish and ANS data as well as EDDMaPS data.

### Scoring the Subwatersheds

Non-native aquatic and riparian species were ranked based on quartiles. This variable provides a measure of the presence of non-native freshwater species in a subwatershed. The ranking scores are reversed—lower Healthy Rivers Index scores indicate lower habitat quality and higher competition and/or predation pressures to native species. Table 22 depicts the non-native aquatic and riparian cover thresholds and associated scores.

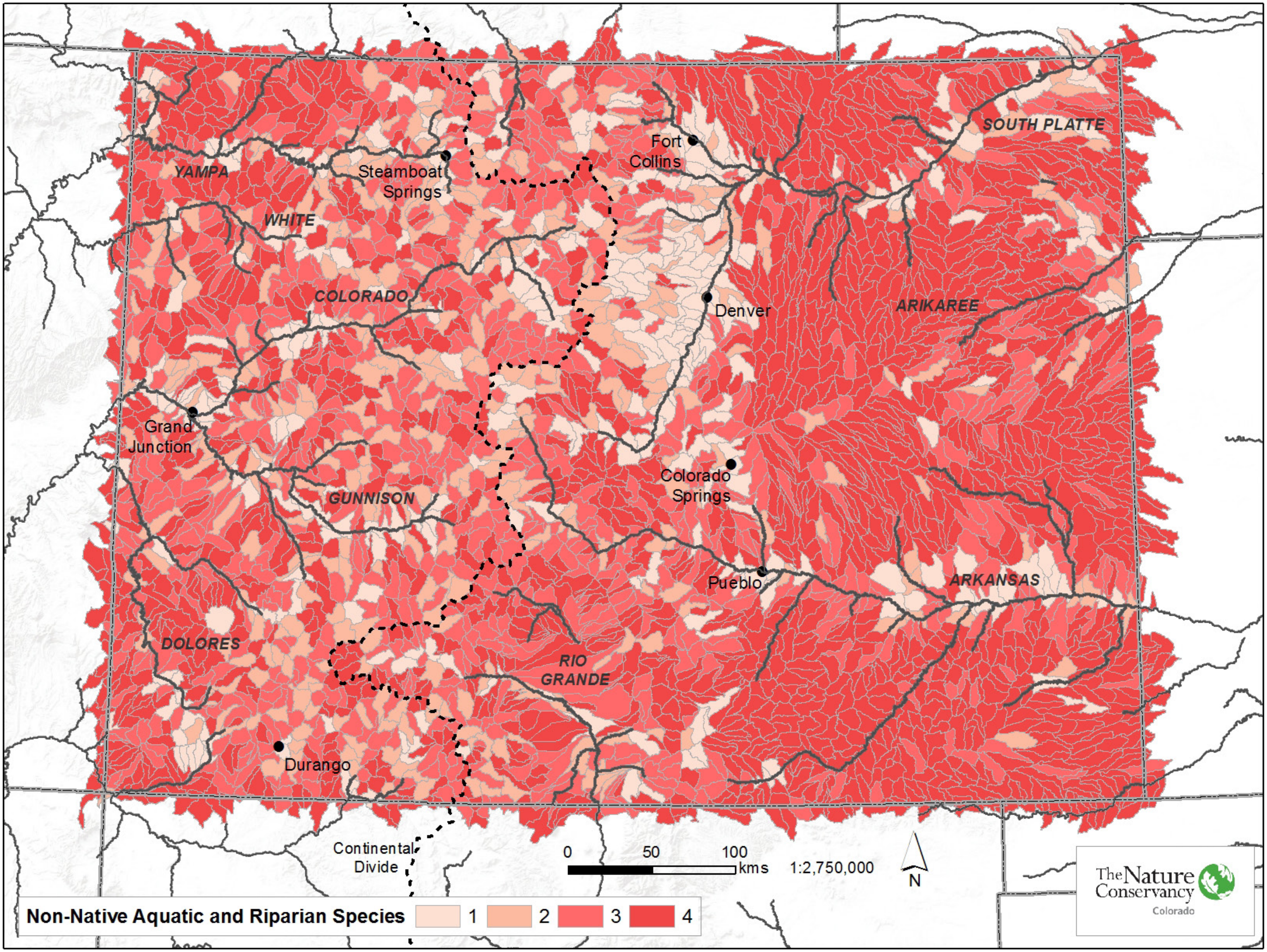
***Table 22.*** Scoring for non-native aquatic & riparian species

| Non-native aquatic and riparian species (#) | Healthy Rivers Index |
|---|---|
| >5 | 1 |
| 3-4 | 2 |
| 1-2 | 3 |
| 0 | 4 |

### Interpreting the Results

Quantifying the presence of non-native species offers opportunities to examine patterns driving changes in community assembly, which can have fundamental consequences for the biogeography of both native and non-native species. For example, non-native fishes often out-compete native fishes under more stable, human-altered flow regimes. The patterns of non-native species highlighted in Map 22 offer insights into subwatersheds where interventions, such as reservoir reoperations or improve agricultural infrastructure, can make significant differences in flow patterns and the biotic communities reliant upon them.

Tamarisk removal along the Dolores River © *Dolores River Restoration Partnership*




***Map 22.*** Healthy River Scores for Non-native Aquatic and Riparian Species in HUC 12 subwatersheds. 1 = high non-natives, 4 = low non-natives

## Drought (PDSI)

Annual precipitation in Colorado averages only 17 inches statewide, with much of the State receiving only 12–16 inches. With Colorado's semiarid and variable climate, there will always be a concern for water availability within the state. Historical analysis of precipitation and other drought indices show that drought is a frequent occurrence in Colorado, and climate continues to affect Colorado's use and distribution of water. Climate models project Colorado will warm by 1.4°C (2.5°F) by 2025 and 2.2°C (4°F) by 2050, relative to the 1950-99 baseline (Ray et al, 2008). Short duration drought as defined by the three-month Standardized Precipitation Index (SPI) occur somewhere in Colorado in nearly nine out of every ten years. However, severe, widespread multiyear droughts are much less common.

Since 1893, Colorado has experienced six droughts that are widely considered "severe." These droughts affected most of the state, involved record-breaking dry spells, and/or lasted for multiple years. Data have shown that variations in precipitation are the main driver of drought in Colorado and low Lake Powell inflows, including the drought of 2000-07. As Colorado's climate continues to warm, drought impacts may be exacerbated and are projected to include smaller snowpacks, earlier snowmelt, flood-control releases, extreme flood events, more evaporation and dryness, less groundwater, more droughts, more wildfires and water quality challenges.

Drought indicators are any single observation or combinations of observations that contribute to identifying the onset and/or continuation of a drought. Drought indicators can include measures of streamflow, precipitation, reservoir storage, the Palmer Drought Severity Index, which is a function of precipitation, temperature, and the available water content of the soil, and other similar measures. The effectiveness of drought indicators depends on the region and the resources. Often, the degree of infrastructure development in a region may define the most appropriate indicators.

Palmer Drought Severity Index (PDSI) provides the monthly value (index) that is generated indicating the severity of a wet or dry spell. This index is based on the principles of a balance between moisture supply and demand. The index generally ranges from -6 to +6, with negative values denoting dry spells and positive values indicating wet spells. There are a few values in the magnitude of +7 or -7. PDSI values 0 to -.5 = normal; -0.5 to -1.0 = incipient drought; -1.0 to -2.0 = mild drought; -2.0 to -3.0 = moderate drought; -3.0 to -4.0 = severe drought; and greater than - 4.0 = extreme drought. For our calculations, we spatially tied the PDSI values to subwatersheds and calculated values between 2000 and 2015, using a threshold of greater than or equal to 3 as an indicator of drought. We then ran zonal statistics of the mean summer drought (April – September) from 2000–2015. From this model, we could sum the numbers of years of drought for each subwatershed, using moderate to severe conditions (> -3) as our threshold.

Lake Powell © *NASA Earth Observatory*

### Scoring the Subwatersheds

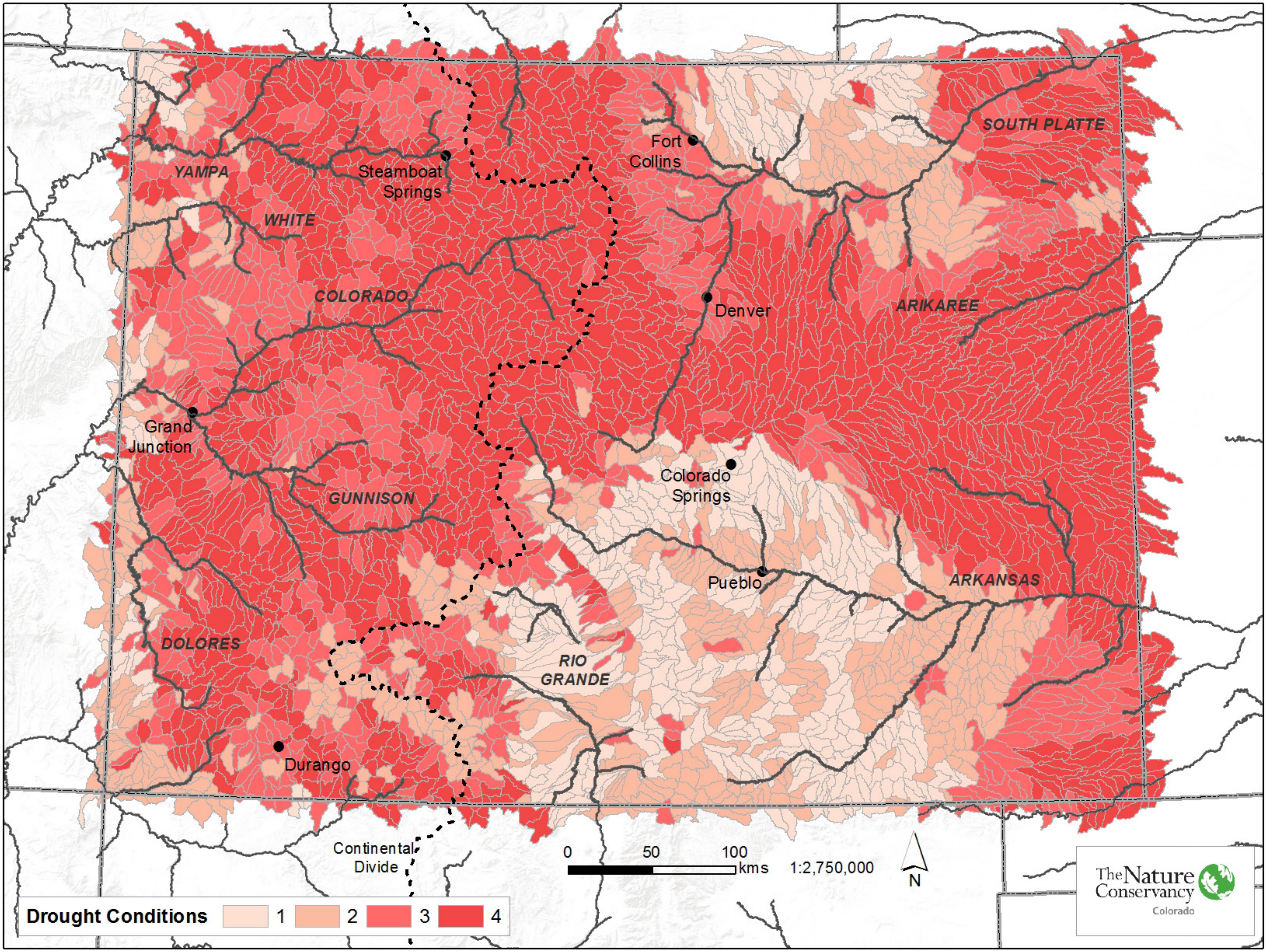
PDSI were ranked based on quartiles and informed by the PDSI ranking system. The ranking scores are reversed —lower Healthy Rivers Index scores indicate higher drought magnitudes and greater pressures on freshwater ecosystem health. Table 23 depicts PDSI thresholds and associated scores.

***Table 23.*** Scoring for Drought (PDSI)

| PDSI | Healthy Rivers Index |
|---|---|
| >4 | 1 |
| 4 | 2 |
| 3 | 3 |
| <2 | 4 |

### Interpreting the Results

Map 23 shows the subwatersheds that have been most susceptible to drought pressures in recent years, which often include lower elevation subwatersheds, particularly along the South Platte and Arkansas Rivers. These subwatersheds may be locations to explore identifying drought triggers that can inform management practices. A drought trigger is the specific value of a drought indicator that activates a management response. For example, a drought trigger could be a reservoir decreasing below 50% of its storage capacity. In a drought contingency plan, trigger levels can be varied to alter the sensitivity of the response and the effectiveness of the plan. Defining drought triggers can be difficult. Trigger levels change over time;` an appropriate trigger level for a particular system may change dramatically if that system has an increase in available infrastructure or if water demands change dramatically. Urban water triggers are often quite different from agriculture drought triggers, as the urban infrastructure can often mitigate the impacts of short-term droughts.




***Map 23.*** Healthy River Scores for Drought in HUC 12 subwatersheds. 1 = high historic recent drought, 4 = low historic recent drought

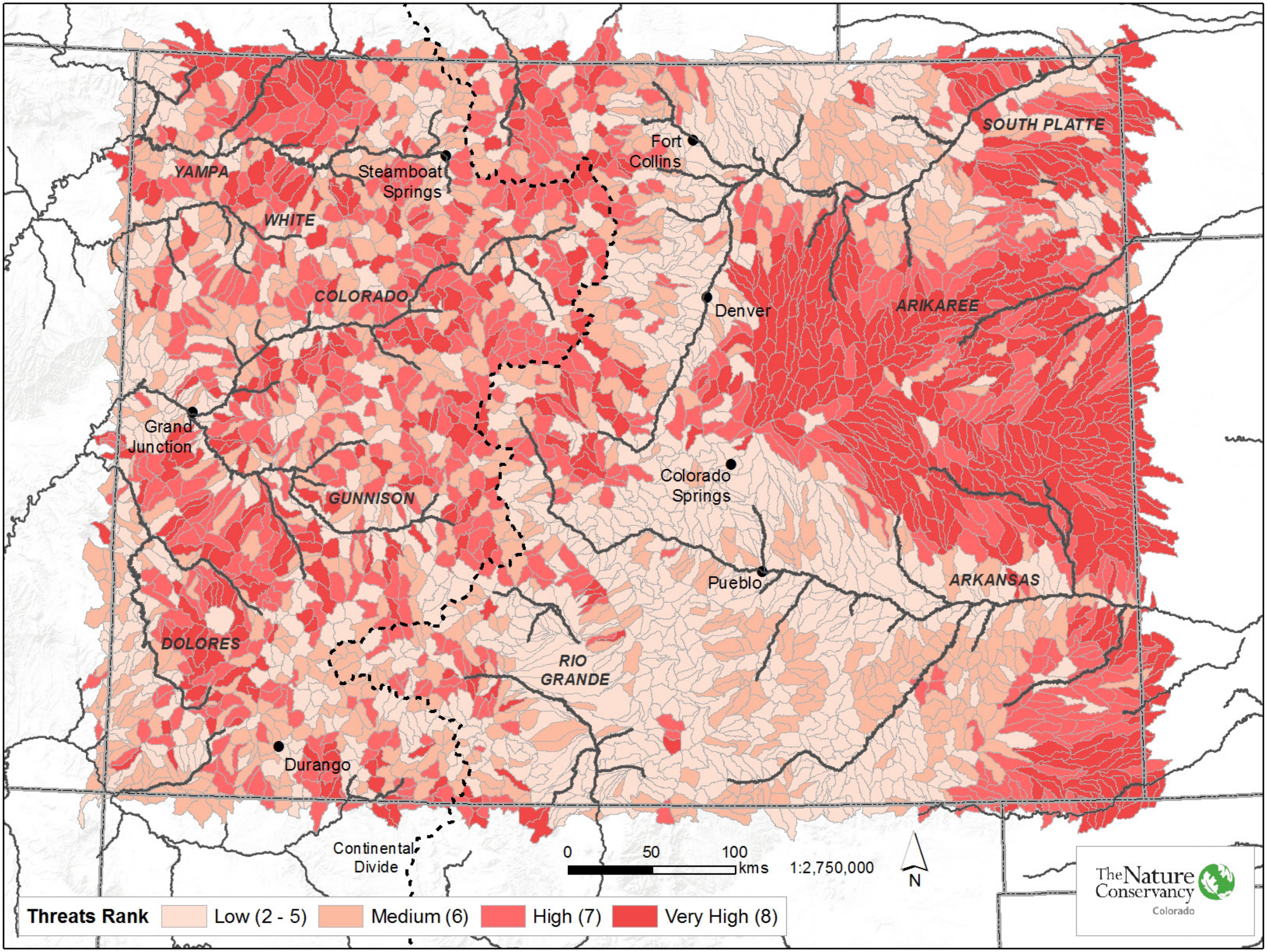
## Summary Index for Risks and Threats Variables

Patterns for the two Risk and Threats variables combined in a single map highlight subwatersheds that are significantly under pressure from these two perturbations.  Scores were based on quartiles, dividing the data into four equal-size groups. Subwatersheds with very high and high scores are not significantly impacted by drought or non-native species.The groundwater dependent subwatersheds in the northeastern portion of Colorado are Watersheds with higher concentrations of risk and threats need to be carefully evaluated to determine how much of a constraint those risks or threats pose.

***Table 24.*** Scoring for Risks and Threats Variables

| Risks and Threats Variables Score | Healthy Rivers Index |
|---|---|
| 2-5 | Low |
| 6 | Medium |
| 7 | High |
| 8 | Very High |

Colorado River © *Ken Geiger/TNC*




***Map 24.*** Summary scores for Risks and Threats variables. "Very High" = most resilient "Low" = least resilient

## CATEGORY 5. PROTECTION VARIABLES

The Protection variables are designed to capture significant management activities and programs that help protect or preserve river flows and associated habitat in Colorado. Three variables included in this category: Instream Flow Protections (ISFs), Critical Habitat, and Voluntary Flow Agreements. To account for these variables in the summary index, we calculated presence/absence of the protections in each subwatershed.

### Instream Flow Protections (ISFs)

Recognizing the need to mitigate the impacts of water supply infrastructure and management practices, the CWCB has taken the responsibility for the appropriation, acquisition, protection and monitoring of instream flow (ISF) and natural lake level water rights to preserve and improve the natural environment to a reasonable degree. The Water Acquisition Program is a voluntary program that allows owners of the water rights to donate, sell, lease, or loan existing decreed water rights to the CWCB on a permanent or temporary basis.

ISFs are nonconsumptive, in-channel, or in-lake uses of water made exclusively by the CWCB for minimum flows between specific points on a stream or levels in natural lakes. Since 1973, the CWCB has appropriated instream flow water rights on more than 1,500 stream segments covering more than 8,500 miles of stream and 477 natural lakes. The CWCB has also completed more than 20 voluntary water acquisition transactions which help to protect:

- Coldwater and warm water fisheries (various streams and lakes)
- Waterfowl habitat (e.g., Gageby Creek)
- Unique glacial ponds and habitat for neotenic salamanders (e.g., Mexican Cut Ponds and Galena Lake)
- Riparian vegetation, unique hydrologic and geologic features (e.g., Hanging Lake and Deadhorse Creek)
- Critical habitat for threatened or endangered native fish (e.g., Yampa and Colorado Rivers)

To generate this variable, we captured ISF reaches and natural lake levels data from CDSS and the CWCB instream flow program completed transactions database. We then intersected the ISF reaches and natural lakes data with subwatersheds to determine presence/absence for each subwatershed.

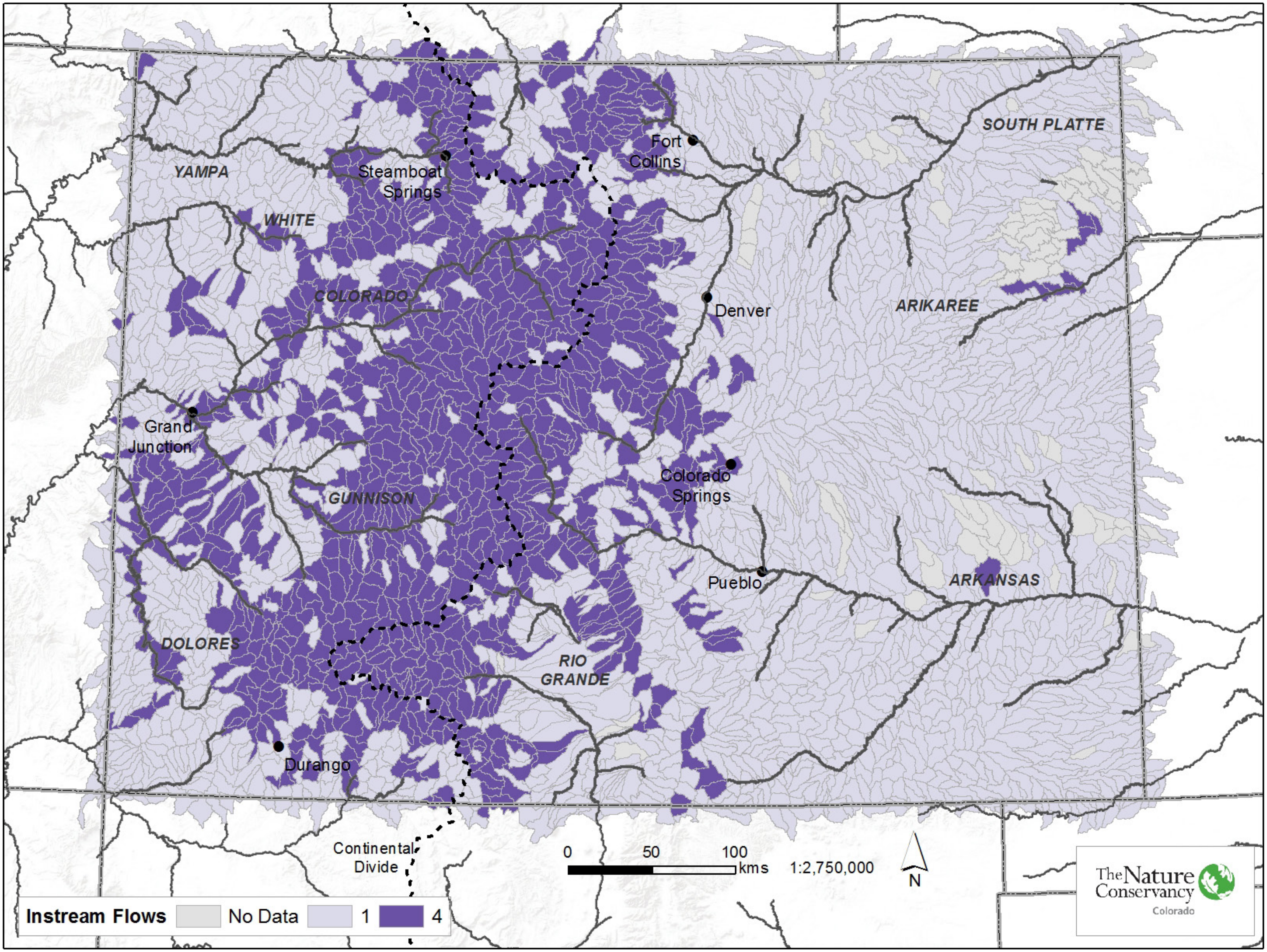
#### Scoring the Subwatersheds

ISFs were simply assigned a rank of 0 if there were no presence of protection in a subwatershed and a rank of 4 if protections were present. The underlying rationale is that presence of ISFs means that minimum baseflows are being maintained and flow gaps are minimized.

#### Interpreting the Results

The patterns in this map show that ISFs are heavily concentrated in the mountains and lower sections of larger rivers often do not have instream flow protections in place. If there are no protections on these larger rivers, then other mechanism to protect and manage flows need to be in place. This can also be true for somewhat smaller, heavily engineered systems like the Cache La Poudre River. Additionally, the presence of ISFs is not necessarily a strong indicator that the flows are protected, particularly because most ISFs are junior water rights in the system of prior appropriation. For example, the Dolores River minimum flows are not achieved much of the time and the Arikaree River is impacted by groundwater pumping that significantly impacts its baseflows.

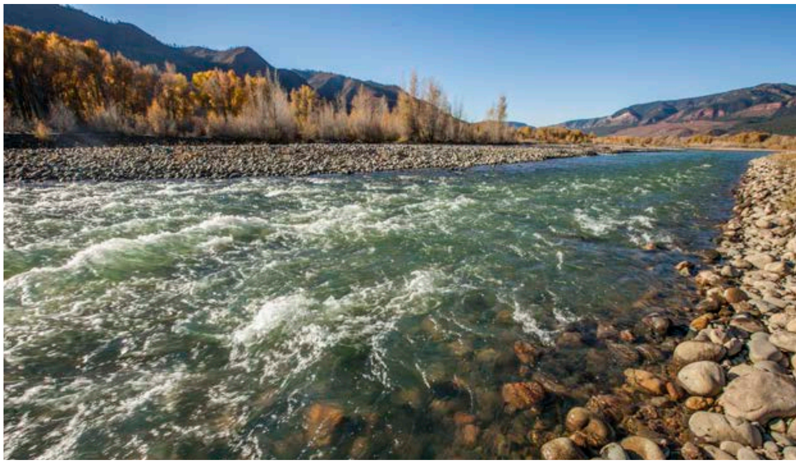
Pond at Mexican Cut © *Lisa Runkel/TNC*




***Map 25.*** Healthy River Scores for Instream Flow Protections (ISFs) in HUC 12 subwatersheds.

## Critical Habitat Designations

Critical habitat is a term used in the Endangered Species Act (ESA) that refers to specific geographic areas that contain habitat features essential for the conservation of a threatened or endangered species. Designating critical habitat is a tool to identify areas that are important to the recovery of a listed species. It is also a tool used to notify Federal agencies of areas that must be given special consideration when they are planning, implementing, or funding activities. Federal agencies are required to consult with the Service on actions they carry out, authorize, fund, or permit, that may affect critical habitat. A critical habitat designation has no effect when a Federal agency is not involved. For example, a landowner undertaking a project on private land that involves no Federal funding or permit has no additional responsibilities if his property falls within critical habitat boundaries.



Along with critical habitat designations, the Recovery Program run by U.S. Fish and Wildlife Service (USFWS) uses a range of conservation tools to ensure that endangered and threatened species are able to survive and thrive. Recovery plans provide a road map with detailed site-specific management actions for private, federal, and state cooperation in conserving listed species and their ecosystems. However, a recovery plan is a non-regulatory document that provides guidance on how best to help listed species achieve recovery (USFWS, 2011). In Colorado, the Upper Colorado River Recovery Program focuses on four endangered fish in the Yampa/White, Colorado and Gunnison River Basins: bonytail chub (*Gila elegans),* humpback chub *(Gila cypha),* razorback sucker *(Xyrauchen texanus),* and Colorado pikeminnow *(Ptychocheilus lucius)*. Recovery strategies include conducting research, improving river habitat, providing adequate stream flows, managing non-native fish, and raising endangered fish in hatcheries for stocking. The San Juan River Recovery Program focuses on the San Juan River Basin and two endangered fish: razorback sucker and Colorado pikeminnow. This program focuses on developing an operating plan for the Navajo Reservoir to allow for environmental flow releases that will support the life cycles and reproductive needs of these endangered fishes.

To generate this variable, we captured presence of final and potential critical habitat for federally-listed species within subwatersheds. We used the subwatershed boundaries from NHD Plus V2 and final critical habitat data for southwestern willow flycatcher, razorback sucker, humpback chub, bonytail chub, and Colorado pikeminnow and proposed critical habitat for the yellow-billed cuckoo from USFWS Environmental Conservation Online System. To capture the coverage in Colorado, we intersected the proposed and final critical habitats for the six species listed above with subwatershed boundaries.

### Scoring the Subwatersheds

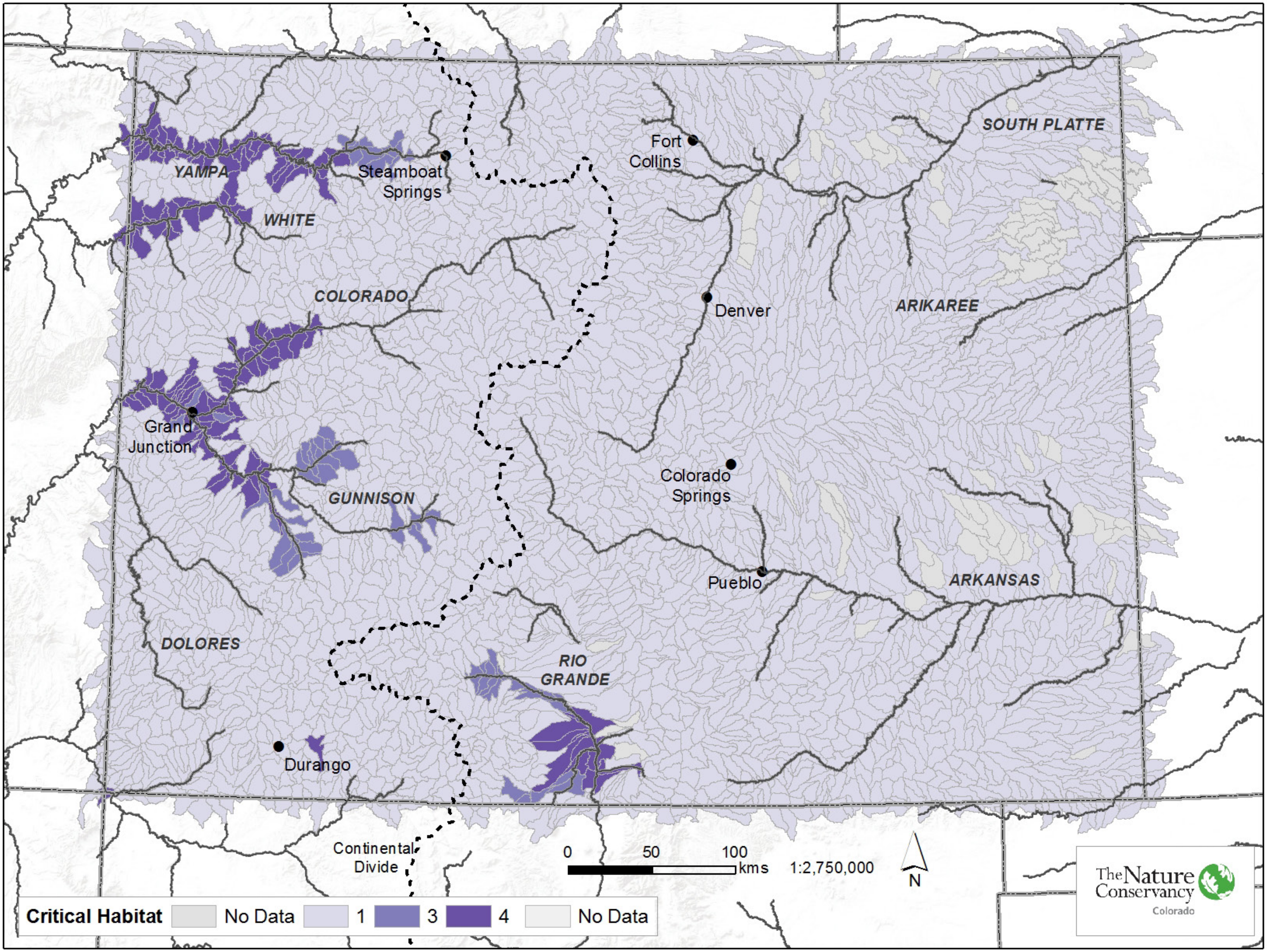
Critical habitat was ranked based on presence/absence, however we chose to give potential critical habitat a score of "3" and final critical habitat designations a score of "4" as final designations offer more defined regulatory processes.

### Interpreting the Results

Most of the critical habitat protections are located on larger rivers on Colorado's west slope, many of which are important tributaries to the Colorado River. The Rio Grande also has some important protections that are driven by aquatic and terrestrial species. These patterns flag specific subwatersheds that contain features essential for the conservation of a threatened or endangered species and that may require special management and protection.



Las Animas River © *Erika Nortemann/TNC,* Razorback suckers added to the San Juan River basin ©*Erika Nortemann/TNC,* Colorado Pikeminnow © *Ben Kiefer/UWDR*




***Map 26.*** Healthy River Scores for Critical Habitat in HUC 12 subwatersheds.

## Other Protections - Voluntary Flow Agreements

In addition to the ISF program and critical habitat designations, there are other voluntary program and measures that have been successful in providing protection for freshwater habitat conditions and flows in Colorado and with adjacent states. A voluntary flow management program is a unique arrangement between state and federal agencies, nonprofits, water management organizations, and commercial rafting organizations. It is fundamental that these agreements are voluntary: the parties are under minimal obligation to participate, but remain involved because the agreement is successful year after year.

There are several examples of voluntary flow agreements and other management activities that were included in our analysis. For example, the Upper Arkansas River voluntary flow management program, which was first established in 1990, is a partnership among Colorado Parks and Wildlife, Southeastern Colorado Water Conservancy District, Pueblo Board of Water Works, Trout Unlimited, the Arkansas River Outfitters Association, and the Bureau of Reclamation (BOR). This cooperative program provides water management guidelines that provide for whitewater flows in the Arkansas River for recreation users in the summer months, while also protecting and enhancing the fishery by establishing minimum flow guidelines throughout the rest of the year.

Another example of multiple interests collaborating is the enlargement of Elkhead Reservoir. Elkhead Reservoir was originally owned by the city of Craig and constructed to provide energy to the Craig Station Power Plant and to support recreational sport fishing and boating. Multiple stakeholders gathered together to plan an extensive $31 million multi-purpose expansion project that would enhance endangered fish and water flow management. As part of the project, the city of Craig, the Colorado River Water Conservation District (CRWCD), and Colorado Parks and Wildlife formed a joint management agreement for the reservoir. The multi-purpose project allocated 5,000 acre-feet of storage for endangered fish management, which provided the Yampa Basin with water to enhance environmental flows.

Like the other protection variables, we used spatial data and information from CWCB to capture presence of voluntary flow agreements within subwatersheds.

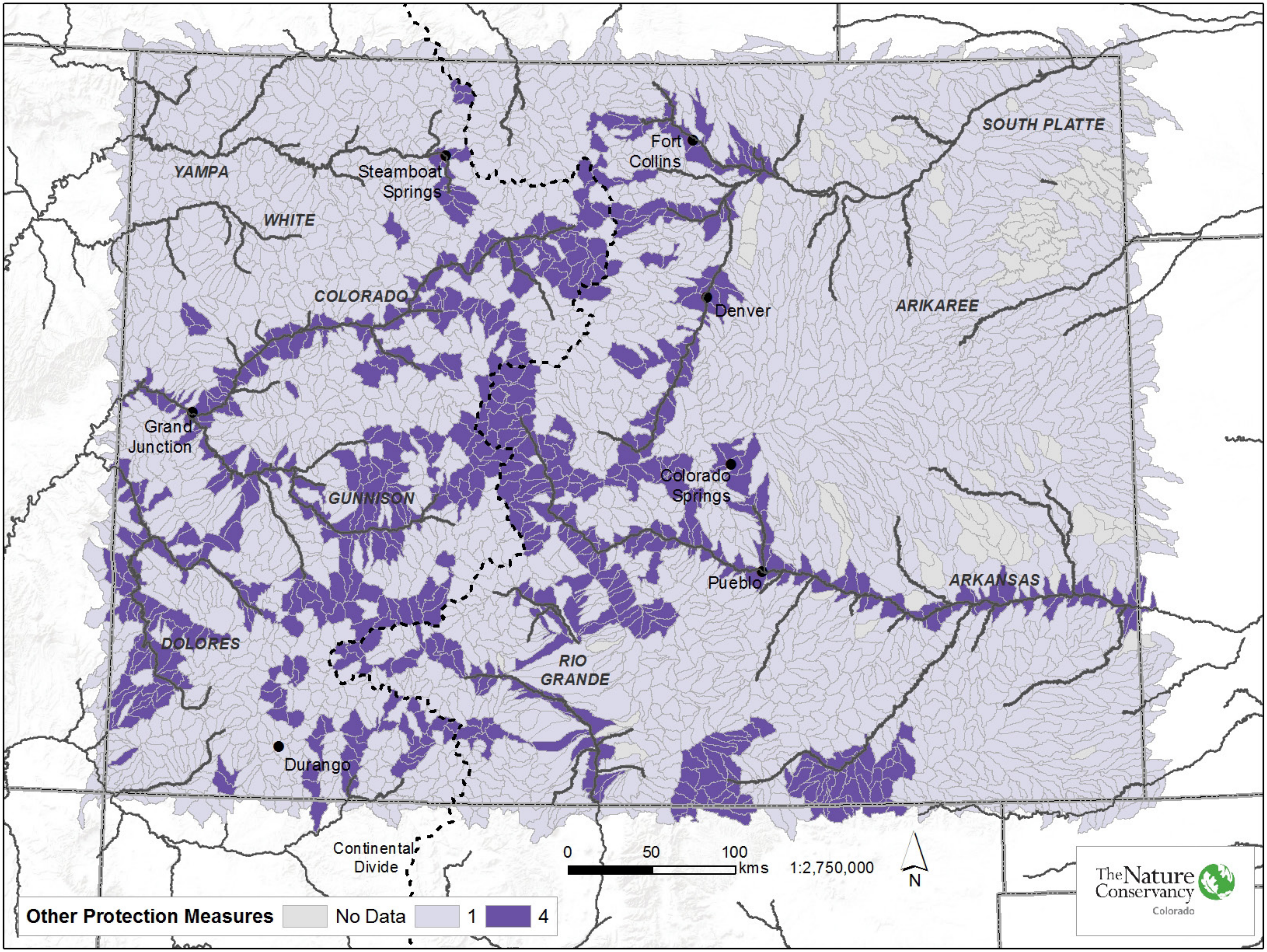
### Scoring the Subwatersheds

Other protections, including voluntary flow agreements and collaborative efforts, were assigned a rank of 0 if there was no project in a subwatersheds and a rank of 4 if agreements were present. The underlying rationale is that presence of these types of agreements indicates that baseflows are being maintained for environmental and recreational activities, and therefore flow gaps are minimized.

### Interpreting the Results

The patterns in Map 26 highlight subwatersheds where cooperative, or alterative, flow management practices are already occurring and may represent a good opportunity to pursue additional flow protection mechanisms.

Rafting on the Arkansas River © *Zaskoda,* Twin Lakes © *Grant Matthews*




***Map 27.*** Healthy River Scores for Other Protections - Voluntary Flow Agreements, Collaborative Efforts in HUC 12 subwatersheds

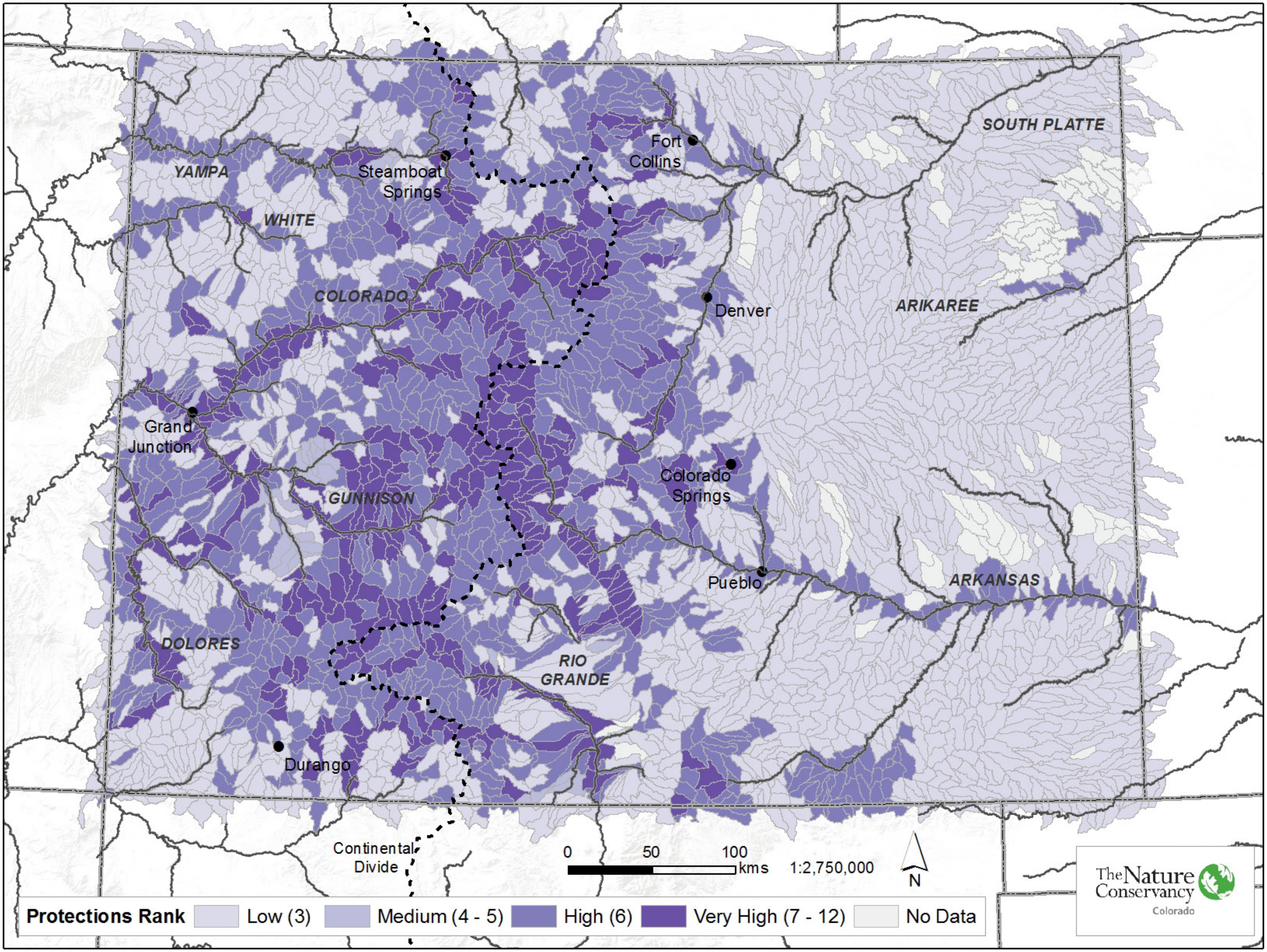
### Summary Index for Protections Variables

The three Protections variables highlight subwatersheds with existing mechanisms or programs in place that help protect baseflows and, in some cases, offer opportunities for the natural flow variability to be mimicked or protected. Scores were based on quartiles, dividing the data into four equal-size groups. Many of the protections exist on western slope rivers and in critical headwaters systems.

***Table 25.*** Scoring for Protection Variables

| Protections Variables Score | Healthy Rivers Index |
|---|---|
| 3 | Low |
| 4-5 | Medium |
| 6 | High |
| 7-12 | Very High |

Conejos River © *Betsy Neely/TNC,* San Miguel River © *Todd Warnke,* Arikaree River flooding © *Unknown*




***Map 28.*** Summary scores for Protections variables; "Very High" = most resilient "Low" = least resilient

# 5. Final Summary – The Healthy Rivers Index

The Healthy Rivers index offers a metric indicating the overall resilience of freshwater ecosystems for each subwatershed, based on summing 21 variables across the five categories. Air temperature was not included in the final scoring. Therefore, the maximum resilience score that a subwatershed could receive was 84 (21 variables x 4 rank scores). High scores reflect the subwatersheds with the most resilient river and stream systems - those that will support biodiversity and maintain their functional integrity even as their structure and function change in response to human alteration and climate conditions.

Yampa River © *Kate Shorrock/TNC*

### Scoring the Subwatersheds

To generate the comprehensive Healthy Rivers Index, the variables were summed to provide a total relative resilience score at the subwatershed level. Thresholds were established using quartiles. Subwatersheds with scores equal to or below 41 were labeled as having a "low," or highly impacted, resilience score; between 42 and 49 were "medium," or moderately impacted; between 50 and 55 had "high" resilience scores and low impacts; and the most resilient subwatersheds had scores greater than or equal to 56. Table 26 highlights the thresholds and associated relative rankings for resilience and overall river health for the Healthy Rivers Index.

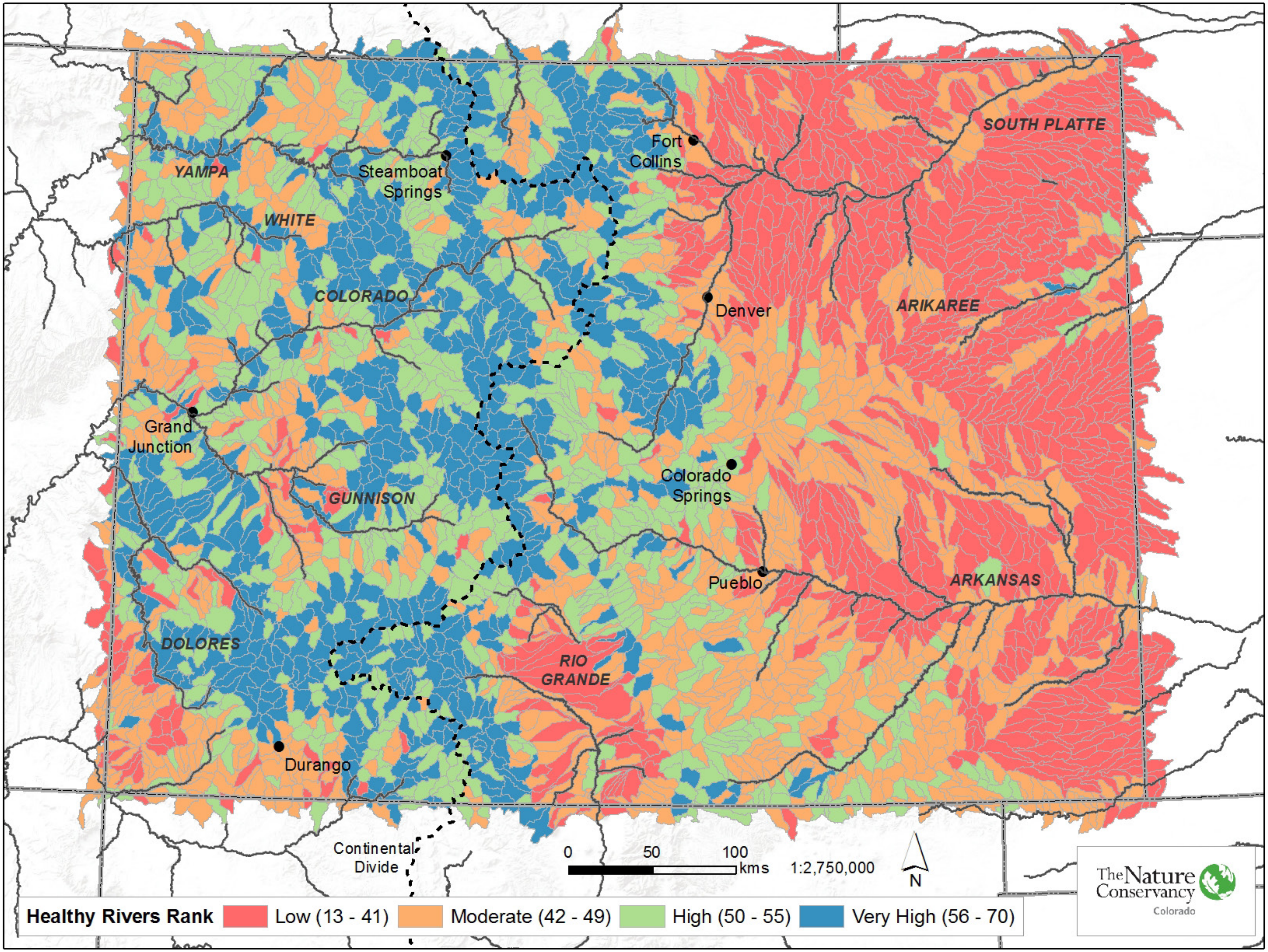
***Table 26.*** Scoring thresholds for Healthy Rivers Index

| Final resilience score | Healthy Rivers Index |
|---|---|
| < 40 | Low |
| 41 - 47 | Medium |
| 48 - 53 | High |
| > 54 | Very High |

### Interpreting the Results

Map 28 represents the overall patterns of resilience by subwatershed across Colorado. This summary measure serves as an indicator of overall resilience, and ecological integrity, of freshwater ecosystems at a statewide level. This approach offers a foundation to classify freshwater ecosystems and accounts for alterations to flow conditions that impact the physical, chemical, and biological conditions of a river or stream. These patterns illustrate the long-term ecosystem function and resilience of subwatersheds across Colorado. These results can guide prioritization and decision making for stream flow protection and habitat restoration for conservation outcomes.


Kayaking on the Las Animas River © *Erika Nortemann/TNC*




***Map 29.*** Healthy Rivers Resiliency Index for Colorado; < 40 = low resilience score > 54 = highest resilience score

# 6. Conservation and Management Implications

Challenges related to water will become increasingly difficult over the coming decades across local, regional, and global scales. The hydrologic limits of water supply systems, conflicts over shared water resources, and drought-induced water shortages are increasingly prominent concerns in water management and decision making. In semi-arid states like Colorado, there is a growing sense that securing water to a full range of diverse users – including the natural environment, especially during periods of drought – is critical to human health and well-being. Conservation will continue to play a critical role in stretching existing supplies, but cannot meet all the requirements alone; there is a pressing need to fundamentally reevaluate water management practices to better incorporate flow regime, and ecosystem services, into water resources management and policy.

This analysis offers new information for making decisions about how to prioritize freshwater conservation for enduring outcomes. The underlying assumption of this work is that freshwater networks with relatively higher resilience scores will adapt to a changing climate while continuing to sustain diversity and function. In other words, we do not expect rivers and streams to remain the same. Species composition will shift with continued water management decisions and changes in climate, but in the more resilient systems, ecosystem function and processes will continue. Thus, a subwatershed with a higher resilience score reflects a more structurally intact physical setting that can sustain a diversity of species and natural communities, maintains basic relationships among ecological features and key ecological processes, and allows for adaptive change in composition and structure (Anderson et al. 2012).

We evaluated variables that drive the adaptive capacity of stream networks and could be modeled at a scale that reflects flow and management conditions in the modern landscape. The variables we included are known to strongly influence the biological and physical conditions in rivers and streams by facilitating the recovery of a system after a disturbance and creating habitat diversity (Palmer et al., 2009; Wenger et al., 2008). For example, longer networks provide greater diversity and multiple occurrences of habitat types. They also share the functional flow of nutrients, sediment, and

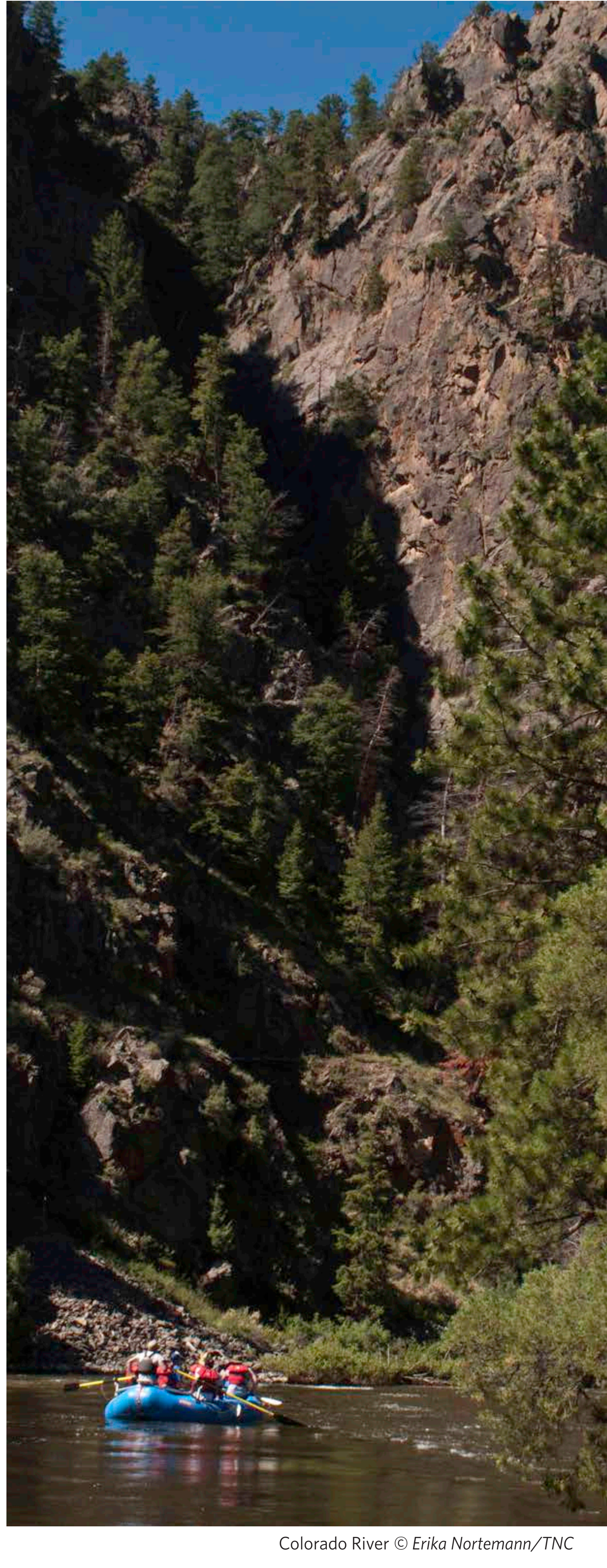
Gunnison River © *Mark Skalny*

other longitudinal processes, which increases their capacity to recover from disturbances across multiple scales (Walker et al., 2006). Gradient diversity leads to variation in substrates, riffle/pool structure, micro-temperature refugia, and other related habitat structure which different species and aquatic communities can exploit (Allan, 1995).

While the physical setting variables emphasized habitat options in a subwatershed, the habitat conditions, risks and threats, and protections variables focused on different aspects of resilience, exploring the relative 'intactness' of hydrological and ecological processes influenced by water management practices and infrastructure. For example, the alteration of the natural flow regime from reservoirs and diversion structures has been shown to influence biota, change seasonal flow patterns, and impact processes such as nutrient transport and sediment movement. Shifts in land use, such as impervious surface, has been correlated with ecological stream degradation through changes in habitat complexity and water quality (Cuffney et al., 2010; Violin et al., 2011). These variables provide more specific insight into human-induced patterns and impacts to river and streams from a long history of water management practices.

This work offers a critical step toward protecting healthy rivers and streams in Colorado by serving as a tool to help water resources managers identify rivers and streams with the capacity to adapt to these changes, while maintaining similar biodiversity characteristics and functional processes under novel conditions. The patterns highlight opportunities for protection and restoration of subwatersheds based on their relative resilience scores. The outcomes are biased toward reaches with a greater body of natural heritage inventory and higher levels of potential biodiversity. However, because this analysis highlights resilience and adaptive capacity as key outcomes, the emphasis is on measures of ecosystem function and complexity rather than just a consideration of rare species presence for the identification of highly functioning systems. Thus, this assessment identifies subwatersheds that offer a wide diversity of options and microhabitats and indicate greater resilience for ecological outcomes. The systems that have the highest relative resilience scores are more likely to maintain ecosystem function and support biodiversity despite human alteration to flow and habitat conditions.

Previous freshwater conservation planning efforts have largely focused on the current condition or the distributions of a target species. By focusing on the



Colorado River © *Erika Nortemann/TNC*

relative resilience of freshwater ecosystems, this analysis offers insight into long-term adaptability of subwatersheds to human-induced stressor and shifting climate conditions. While the Healthy Rivers Index provides a comprehensive, state-level analysis and scoring, we emphasize that local knowledge is essential for informing prioritization and decision making.  The Healthy Rivers Assessment can help guide the strategic allocation of limited conservation resources and help direct conservation efforts towards stream networks that are likely to remain complex, adaptable, and diverse systems in the face of environmental changes. By employing and encouraging a long-term ecosystem function-based perspective on river and stream ecosystems, these results can help water managers, state and local agencies, conservation organizations, and other stakeholders determine where conservation actions are most likely to be effective investments for restoring and preserving river flows and stream health. Analyses such as this provide a decision basis to allocate resources today to yield benefits well into the future for the protection and restoration of rivers and streams.

Dolores River © *Lauryn Wachs/TNC with aerial support from Lighthawk*

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# Appendix A – Freshwater and Flow Indicator Species

## CPW DATA

*An asterisk (*) highlights flow indicator species*

| Common Name | Scientific Name |
|---|---|
| Arkansas Darter* | *Etheostoma cragini* |
| Black Bullhead | *Ameiurus melas* |
| Bluehead Sucker | *Catostomus discobolus* |
| Bigmouth Shiner | *Notropis dorsalis* |
| Brassy Minnow* | *Hybognathus hankinsoni* |
| Brook Stickleback | *Culaea inconstans* |
| Bullsnake | *Pituophis catenifer sayi* |
| Blue-Flannelmouth Sucker hybrid | *Catostomus discobolus x latipinnis* |
| Bonytail Chub* | *Gila elegans* |
| Colorado River Cutthroat Trout* | *Oncorhynchus clarkii pleuriticus* |
| Channel Catfish | *Ictalurus punctatus* |
| Colorado Pikeminnow* | *Ptychocheilus lucius* |
| Creek Chub | *Semotilus atromaculatus* |
| Common Shiner* | *Notropis cornutus* |
| Flathead Chub* | *Platygobio gracilis* |
| Flannelmouth Sucker* | *Catostomus latipinnis* |
| Fathead Minnow | *Pimephales promelas* |
| Greenback Cutthroat Trout* | *Oncorhynchus clarkii stomias* |
| Gizzard Shad | *Dorosoma cepedianum* |
| Great Basin Spadefood | *Spea intermontana* |
| Humpback Chub* | *Gila cypha* |
| Iowa Darter* | *Etheostoma exile* |
| Johnny Darter | *Etheostoma nigrum* |
| Lake Chub* | *Couesius plumbeus* |
| Leopard Frog | *Rana blairi* |
| Longnose Sucker | *Catostomus catostomus* |
| Longnose Dace | *Rhinichthys cataractae* |
| Longnose Snake | *Rhinocheilus lecontei* |
| Longnose-Flannelmouth Hybrid | *Catostomus catostomus x latipinnis* |
| Mountain Sucker* | *Catostomus platyrhynchus* |
| Mottled Sculpin | *Cottus bairdii* |
| Mountain Whitefish | *Prosopium williamsoni* |
| Northern Leopard Frog | *Rana pipiens* |
| Northern Redbelly Dace* | *Phoxinus eos* |
| Northern Water Snake | *Nerodia sipedon sipedon* |
| New England Mudsnail | *Potamopyrgus antipodarum* |
| Orangethroat Darter | *Etheostoma spectabile* |

| Common Name | Scientific Name |
|---|---|
| Orangespotted Sunfish | *Lepomis humilis* |
| Paiute Sculpin | *Cottus beldingii* |
| Painted Turtle | *Chrysemys picta* |
| Plains Garter Snake | *Thamnophis radix* |
| Northern Plains Killifish | *Fundulus kansae* |
| Plains Leopard Frog | *Rana blairi* |
| Plains Minnow* | *Hybognathus placitus* |
| Pikes Peak Cutthroat Trout | *Oncorhynchus clarkii stomias* |
| Plains Topminnow | *Fundulus sciadicus* |
| Razorback Sucker* | *Xyrauchen texanus* |
| Rusty Crayfish | *Orconectes rusticus* |
| Rio Grande Chub* | *Gila pandora* |
| River Carpsucker | *Carpiodes carpio* |
| Red Shiner | *Cyprinella lutrensis* |
| Slider - Red Eared Turtle | *Trachemys scripta elegans* |
| Rio Grande Cutthroat* | *Oncorhynchus clarkii virginalis* |
| Rio Grande Sucker* | *Catostomus plebeius* |
| Roundtail Chub | *Gila robusta* |
| Razorback-Flannelmouth Sucker hybrid | *Xyrauchen texanus x c. latipinnis* |
| Sand Shiner | *Notropis stramineus* |
| Striped Chorus Frog | *Pseudacris triseriata* |
| Suckermouth Minnow* | *Phenacobius mirabilis* |
| Green Sunfish | *Lepomis cyanellus* |
| Snapping Turtle | *Chelydra serpentina* |
| Speckled Dace | *Rhinichthys osculus* |
| Southern Redbelly Dace* | *Phoxinus erythrogaster* |
| Spiny Softshell Turtle | *Trionyx spiniferus* |
| Stonecat* | *Noturus flavus* |
| Central Stoneroller | *Campostoma anomalum* |
| Tiger Salamander | *Ambystoma tigrinum* |
| White Sucker | *Catostomus commersonii* |
| Woodhouse Toad | *Bufo woodhousii woodhousii* |
| White x Mountain Sucker | *Catastomus commersoni x platyrhynchus* |

## CNHP DATA

| Common Name | Scientific Name |
|---|---|
| Boreal Toad | *Anaxyrus boreas pop. 1* |
| Green Toad | *Anaxyrus debilis* |
| Canyon Treefrog | *Hyla arenicolor* |
| Couch's Spadefoot | *Scaphiopus couchii* |
| Great Basin Spadefoot | *Spea intermontana* |
| Plains Leopard Frog | *Lithobates blairi* |
| Northern Leopard Frog | *Lithobates pipiens* |
| Wood Frog | *Lithobates sylvatica* |
| American White Pelican | *Pelecanus erythrorhynchos* |
| Snowy Egret | *Egretta thula* |
| White-faced Ibis | *Plegadis chihi* |
| Bald Eagle | *Haliaeetus leucocephalus* |
| Greater Sandhill Crane | *Grus canadensis tabida* |
| Western Snowy Plover | *Charadrius alexandrinus nivosus* |
| Piping Plover | *Charadrius melodus* |
| Black-necked Stilt | *Himantopus mexicanus* |
| Willet | *Catoptrophorus semipalmatus* |
| Long-billed Curlew | *Numenius americanus* |
| Wilson's Phalarope | *Phalaropus tricolor* |
| Forster's Tern | *Sterna forsteri* |
| Least Tern | *Sterna antillarum* |
| Short-eared Owl | *Asio flammeus* |
| Black Swift | *Cypseloides niger* |
| Lewis's Woodpecker | *Melanerpes lewis* |
| Southwestern Willow Flycatcher | *Empidonax traillii extimus* |
| Ovenbird | *Seiurus aurocapilla* |
| Colorado River Cutthroat Trout* | *Oncorhynchus clarkii pleuriticus* |
| Greenback Cutthroat Trout* | *Oncorhynchus clarkii stomias* |
| Rio Grande Cutthroat Trout* | *Oncorhynchus clarkii virginalis* |
| Mountain Whitefish | *Prosopium williamsoni* |
| Lake Chub* | *Couesius plumbeus* |
| Humpback Chub* | *Gila cypha* |
| Rio Grande Chub* | *Gila pandora* |
| Roundtail Chub* | *Gila robusta* |
| Brassy Minnow* | *Hybognathus hankinsoni* |
| Suckermouth Minnow* | *Phenacobius mirabilis* |
| Northern Redbelly Dace* | *Phoxinus eos* |
| Southern Redbelly Dace* | *Phoxinus erythrogaster* |
| Colorado Pikeminnow* | *Ptychocheilus lucius* |
| Common Shiner* | *Notropis cornutus* |

| Common Name | Scientific Name |
|---|---|
| Flathead Chub* | *Platygobio gracilis* |
| Rio Grande Sucker* | *Catostomus plebeius* |
| Razorback Sucker* | *Xyrauchen texanus* |
| Stonecat* | *Noturus flavus* |
| Arkansas Darter* | *Etheostoma cragini* |
| Fringed Myotis | *Myotis thysanodes* |
| Meadow Jumping Mouse Subsp | *Zapus hudsonius preblei* |
| Meadow Jumping Mouse Subsp | *Zapus hudsonius luteus* |
| Yellow Mud Turtle | *Kinosternon flavescens* |
| Common Kingsnake | *Lampropeltis getula* |
| Sullivantia Hanging Gardens | *Sullivantia hapemanii - (Aquilegia barnebyi) Herbaceous Vegetation* |
| Iron Fen | *(Picea engelmannii) / Betula nana / Carex aquatilis - Sphagnum angustifolium Woodland* |
| Mixed Montane Forests | *Abies concolor - Pseudotsuga menziesii / Acer glabrum Forest* |
| Mixed Montane Forests | *Abies concolor / Mahonia repens Forest* |
| Montane Riparian Forests | *Abies concolor - Picea pungens - Populus angustifolia / Acer glabrum Forest* |
| Montane Riparian Forests | *Abies lasiocarpa / Alnus incana Forest* |
| Montane Riparian Forests | *Abies lasiocarpa - Picea engelmannii / Calamagrostis canadensis Forest* |
| Subalpine Forests | *Abies lasiocarpa / Carex geyeri Forest* |
| Montane Riparian Forest | *Abies lasiocarpa / Salix drummondiana Forest* |
| Coniferous Wetland Forests | *Abies lasiocarpa / Ribes (montigenum, lacustre, inerme) Forest* |
| Engelmann Spruce/White Marsh Marigold | *Picea engelmannii - (Abies lasiocarpa) / Caltha leptosepala Forest* |
| Montane Riparian Forest | *Picea pungens / Cornus sericea Woodland* |
| Montane Riparian Forest | *Picea pungens / Equisetum arvense Woodland* |
| Montane Riparian Forests | *Populus tremuloides / Acer glabrum Forest* |
| Montane Riparian Woodland | *Populus tremuloides / Cornus sericea Forest* |
| Montane Riparian Forests | *Populus tremuloides / Corylus cornuta Forest* |
| Montane Riparian Forests | *Populus tremuloides / Lonicera involucrata Forest* |
| Aspen Wetland Forests | *Populus tremuloides / Pteridium aquilinum Forest* |
| Aspen Wetland Forests | *Populus tremuloides / Veratrum californicum Forest* |
| Montane Riparian Deciduous Forest | *Acer negundo / Cornus sericea Forest* |
| Narrowleaf Cottonwood Riparian Forests | *Acer negundo - Populus angustifolia / Cornus sericea Forest* |
| Montane Riparian Deciduous Forest | *Acer negundo / Prunus virginiana Forest* |
| Montane Riparian Forest | *Populus angustifolia / Betula occidentalis Woodland* |
| Narrowleaf Cottonwood/Common Chokecherry | *Populus angustifolia / Prunus virginiana Woodland* |
| Narrowleaf Cottonwood/Skunkbrush | *Populus angustifolia / Rhus trilobata Woodland* |
| Narrowleaf Cottonwood Riparian Forests | *Populus angustifolia / Salix exigua Woodland* |
| Narrowleaf Cottonwood Riparian Forests | *Populus angustifolia / Salix ligulifolia - Shepherdia argentea Woodland* |
| Plains Cottonwood Riparian Woodland | *Populus deltoides - (Salix amygdaloides) / Salix (exigua, interior) Woodland* |

| Common Name | Scientific Name |
| --- | --- |
| Plains Cottonwood Riparian Woodland | *Populus deltoides / Symphoricarpos occidentalis Woodland* |
| Riparian Woodland | *Juniperus scopulorum / Cornus sericea Woodland* |
| Montane Riparian Forests | *Picea pungens / Alnus incana Woodland* |
| Lower Montane Riparian Forests | *Pseudotsuga menziesii / Cornus sericea Woodland* |
| Montane Riparian Forests | *Populus angustifolia - Picea pungens / Alnus incana Woodland* |
| Boxelder/River Birch | *Acer negundo / Betula occidentalis Woodland* |
| Plains Cottonwood Riparian Forests | *Populus deltoides / Distichlis spicata Woodland* |
| Fremont's Cottonwood Riparian Forests | *Populus deltoides ssp. wislizeni / Rhus trilobata Woodland* |
| Peachleaf Willow Alliance | *Salix amygdaloides Woodland* |
| Mixed Mountain Shrublands | *Amelanchier utahensis / Pseudoroegneria spicata Shrubland* |
| Montane Riparian Shrubland | *Dasiphora fruticosa ssp. floribunda / Deschampsia caespitosa Shrubland* |
| Foothills Riparian Shrubland | *Prunus virginiana - (Prunus americana) Shrubland* |
| Foothills Riparian Shrubland | *Shepherdia argentea Shrubland* |
| Alpine Willow Scrub | *Salix brachycarpa / Mesic Forbs Shrubland* |
| Thinleaf Alder-Red-osier Dogwood Riparian Shrubland | *Alnus incana / Cornus sericea Shrubland* |
| Montane Riparian Shrublands | *Alnus incana / Equisetum arvense Shrubland* |
| Thinleaf Alder/Mesic Forb Riparian Shrubland | *Alnus incana / Mesic Forbs Shrubland* |
| Montane Riparian Shrubland | *Alnus incana / Mesic Graminoids Shrubland* |
| Montane Riparian Forests | *Populus tremuloides / Alnus incana Forest* |
| Lower Montane Riparian Shrublands | *Betula occidentalis / Cornus sericea Shrubland* |
| Foothills Riparian Shrubland | *Betula occidentalis / Maianthemum stellatum Shrubland* |
| Foothills Riparian Shrubland | *Cornus sericea Shrubland* |
| Foothills Riparian Shrubland | *Forestiera pubescens Shrubland* |
| Montane Willow Carrs | *Salix bebbiana Shrubland* |
| Booth Willow/Canadian Reed Grass | *Salix boothii / Calamagrostis canadensis Shrubland* |
| Booth's Willow/Beaked Sedge | *Salix boothii / Carex utriculata Shrubland* |
| Booth's Willow/Mesic Forb | *Salix boothii / Mesic Forbs Shrubland* |
| Riparian Willow Carr | *Salix boothii / Mesic Graminoids Shrubland* |
| Drummonds Willow/Mesic Forb | *Salix drummondiana / Mesic Forbs Shrubland* |
| Coyote Willow/Bare Ground | *Salix exigua / Barren Shrubland* |
| Coyote Willow/Mesic Graminoid | *Salix exigua / Mesic Graminoids Shrubland* |
| Montane Riparian Willow Carr | *Salix geyeriana / Calamagrostis canadensis Shrubland* |
| Montane Willow Carr | *Salix geyeriana / Carex aquatilis Shrubland* |
| Geyer's Willow/Beaked Sedge | *Salix geyeriana / Carex utriculata Shrubland* |
| Geyer's Willow/Mesic Graminoid | *Salix geyeriana / Mesic Graminoids Shrubland* |
| Montane Riparian Shrubland | *Salix lucida ssp. caudata Shrubland [Provisional]* |
| Montane Willow Carr | *Salix ligulifolia Shrubland* |
| Montane Willow Carr | *Salix monticola / Calamagrostis canadensis Shrubland* |
| Geyer's Willow-Rocky Mountain Willow/Mesic Forb | *Salix geyeriana - Salix monticola / Mesic Forbs Shrubland* |

| Common Name | Scientific Name |
| --- | --- |
| Subalpine Riparian Willow Carr | *Salix planifolia / Calamagrostis canadensis Shrubland* |
| Subalpine Riparian Willow Carr | *Salix planifolia / Carex aquatilis Shrubland* |
| Subalpine Riparian Willow Carr | *Salix planifolia / Carex scopulorum Shrubland* |
| Subalpine Riparian Willow Carr | *Salix planifolia / Deschampsia caespitosa Shrubland* |
| Subalpine Riparian Willow Carr | *Salix wolfii / Carex aquatilis Shrubland* |
| Subalpine Riparian Willow Carr | *Salix wolfii / Carex utriculata Shrubland* |
| Subalpine Riparian Willow Carr | *Salix wolfii / Mesic Forbs Shrubland* |
| Subalpine Riparian/Wetland Carr | *Salix brachycarpa / Carex aquatilis Shrubland* |
| Montane Willow Carrs | *Salix geyeriana - Salix monticola / Calamagrostis canadensis Shrubland* |
| Saline Bottomland Shrublands | *Sarcobatus vermiculatus / Bouteloua gracilis Shrubland* |
| Saline Bottomland Shrublands | *Sarcobatus vermiculatus / Distichlis spicata Shrubland* |
| Saline Bottomland Shrublands | *Sarcobatus vermiculatus / Sporobolus airoides Sparse Vegetation* |
| Saline Bottomland Shrublands | *Sarcobatus vermiculatus / Suaeda moquinii Shrubland* |
| Plains Cottonwood Riparian Forests | *Populus deltoides / Panicum virgatum - Schizachyrium scoparium Woodland* |
| Western Slope Marsh | *Phragmites australis Western North America Temperate Semi-natural Herbaceous Vegetation* |
| Prairie Slough Grass | *Spartina pectinata Western Herbaceous Vegetation* |
| Montane Wet Meadows | *Calamagrostis canadensis Western Herbaceous Vegetation* |
| Beaked Sedge Montane Wet Meadows | *Carex utriculata Herbaceous Vegetation* |
| Montane Emergent Wetland | *Glyceria borealis Herbaceous Vegetation* |
| Bulrush | *Schoenoplectus pungens Herbaceous Vegetation* |
| Western Slope Salt Meadows | *Spartina gracilis Herbaceous Vegetation* |
| Mesic Alpine Meadow | *Deschampsia caespitosa Herbaceous Vegetation* |
| Great Plains Salt Meadows | *Sporobolus airoides Southern Plains Herbaceous Vegetation* |
| Wet Meadow | *Carex saxatilis Herbaceous Vegetation* |
| Salt Meadows | *Distichlis spicata Herbaceous Vegetation* |
| Great Plains Salt Meadows | *Muhlenbergia asperifolia Herbaceous Vegetation* |
| Montane Wetland | *Carex microptera Herbaceous Vegetation* |
| Western Slope Salt Meadows | *Puccinellia nuttalliana Herbaceous Vegetation* |
| Montane Wet Meadows | *Carex aquatilis Herbaceous Vegetation* |
| Montane Wet Meadows | *Carex aquatilis - Carex utriculata Herbaceous Vegetation* |
| Buxbaum's Sedge Wet Meadow | *Carex buxbaumii Herbaceous Vegetation* |
| Montane Riparian Meadow | *Carex foenea Herbaceous Vegetation* |
| Montane Wet Meadows | *Carex pellita Herbaceous Vegetation* |
| Montane Wetland | *Carex lasiocarpa Herbaceous Vegetation* |
| Montane Wetland | *Carex limosa Herbaceous Vegetation* |
| Wet Meadows | *Carex nebrascensis Herbaceous Vegetation* |
| Alpine Wetlands | *Carex scopulorum - Caltha leptosepala Herbaceous Vegetation* |
| Wet Meadow | *Carex simulata Herbaceous Vegetation* |
| Emergent Wetland | *Eleocharis palustris Herbaceous Vegetation* |

| Common Name | Scientific Name |
|---|---|
| Alpine Wetlands | *Eleocharis quinqueflora Herbaceous Vegetation* |
| Western Slope Wet Meadows | *Juncus balticus Herbaceous Vegetation* |
| Emergent Wetland (Marsh) | *Schoenoplectus maritimus Herbaceous Vegetation* |
| Alpine Wetlands | *Carex vernacula Herbaceous Vegetation* |
| Alpine Wetlands | *Carex illota Herbaceous Vegetation* |
| Mesic Alpine Meadows | *Deschampsia caespitosa - Geum rossii Herbaceous Vegetation* |
| Alpine Wetlands | *Ligusticum tenuifolium - Trollius laxus ssp. albiflorus Herbaceous Vegetation* |
| Mesic Alpine Meadows | *Sibbaldia procumbens - Polygonum bistortoides Herbaceous Vegetation* |
| Montane Wet Meadows | *Caltha leptosepala Herbaceous Vegetation* |
| Montane Floating/submergent Palustrine Wetlands | *Sparganium angustifolium Herbaceous Vegetation* |
| Wet Shrubland | *Suaeda moquinii Shrubland* |
| Western Slope Salt Meadows | *Triglochin maritima Herbaceous Vegetation* |
| Western Slope Salt Meadows | *Salicornia rubra Herbaceous Vegetation* |
| Western Slope Floating/Submerged Palustrine Wetlands | *Myriophyllum sibiricum Herbaceous Vegetation* |
| Western Slope Floating/Submergent Palustrine Wetlands | *Nuphar lutea ssp. polysepala Herbaceous Vegetation* |
| Montane Wet Meadows | *Polygonum amphibium Permanently Flooded Herbaceous Vegetation [Placeholder]* |
| Narrow-leaf Cattail Marsh | *Typha (latifolia, angustifolia) Western Herbaceous Vegetation* |
| Plains Cottonwood Riparian Woodland | *Populus deltoides - (Salix nigra) / Spartina pectinata - Carex spp. Woodland* |
| Great Plains Marsh | *Schoenoplectus acutus - Typha latifolia - (Schoenoplectus tabernaemontani) Sandhills Herbaceous Vegetation* |
| Subalpine Riparian Willow Carr | *Salix wolfii /Calamagrostis canadensis Shrubland* |
| Woolly Sedge Wet Meadow | *Carex pellita - Calamagrostis stricta Herbaceous Vegetation* |
| Montane Willow Carr | *Salix drummondiana / Carex utriculata Shrubland* |
| Montane Riparian Woodland | *Picea pungens / Betula occidentalis Woodland* |
| Ponderosa Pine/Thin Leaf Alder | *Pinus ponderosa / Alnus incana Woodland* |
| Montane Riparian Forest | *Pseudotsuga menziesii / Betula occidentalis Woodland* |
| Montane Riparian Forest | *Populus angustifolia - Juniperus scopulorum Woodland* |
| Montane Riparian Forest | *Populus angustifolia - Pseudotsuga menziesii Woodland* |
| Montane Riparian Forest | *Populus angustifolia / Alnus incana Woodland* |
| Cottonwood Sand Dune Forest | *Populus angustifolia Sand Dune Forest* |
| Narrowleaf Cottonwood Riparian Forests | *Populus angustifolia / Crataegus rivularis Woodland* |
| Narrowleaf Cottonwood/Mixed Willows Montane Riparian Forest | *Populus angustifolia / Salix (monticola, drummondiana, lucida) Woodland* |
| Narrowleaf Cottonwood/Mixed Willows Montane Riparian Forest | *Populus angustifolia / Salix drummondiana - Acer glabrum Woodland* |
| Foothills Riparian Woodland | *Populus angustifolia / Salix irrorata Woodland* |

| Common Name | Scientific Name |
|---|---|
| Narrowleaf Cottonwood/Snowberry Montane Riparian Forest | *Populus angustifolia / Symphoricarpos albus Woodland* |
| Plains Cottonwood Riparian Woodland | *Populus deltoides / Carex pellita Woodland* |
| Cottonwood Riparian Forest | *Populus tremuloides / Betula occidentalis Forest* |
| Thinleaf Alder-Mixed Willow Species | *Alnus incana - Salix (monticola, lucida, ligulifolia) Shrubland* |
| Montane Riparian Shrubland | *Alnus incana - Salix drummondiana Shrubland* |
| Subalpine Riparian Shrubland | *Betula nana / Mesic Forbs - Mesic Graminoids Shrubland* |
| Lower Montane Riparian Shrublands | *Betula occidentalis / Mesic Graminoids Shrubland* |
| Strapleaf Willow-Coyote Willow | *Salix exigua - Salix ligulifolia Shrubland* |
| Montane Riparian Willow Carr | *Salix monticola / Carex aquatilis Shrubland* |
| Montane Riparian Willow Carr | *Salix monticola / Carex utriculata Shrubland* |
| Montane Riparian Willow Carr | *Salix monticola / Mesic Forbs Shrubland* |
| Montane Riparian Willow Carr | *Salix monticola / Mesic Graminoids Shrubland* |
| Clustered Sedge Wetland | *Carex praegracilis Herbaceous Vegetation* |
| Montane Wetland | *Carex vesicaria Herbaceous Vegetation* |
| Alpine Wetlands | *Cardamine cordifolia - Mertensia ciliata Herbaceous Vegetation* |
| Montane Riparian Forests | *Abies lasiocarpa / Mertensia ciliata Forest* |
| Cottonwood Riparian Forest | *Populus angustifolia / Cornus sericea Woodland* |
| Subalpine Riparian Willow Carr | *Salix planifolia / Caltha leptosepala Shrubland* |
| Montane Willow Carr | *Salix geyeriana / Mesic Forbs Shrubland* |
| Lower Montane Willow Carrs | *Salix drummondiana / Calamagrostis canadensis Shrubland* |
| Montane Riparian Forests | *Picea engelmannii / Cornus sericea Woodland* |
| Fremonts Cottonwood Riparian Forests | *Populus deltoides ssp. wislizeni / Salix exigua Woodland* |
| Hanging Gardens | *Aquilegia micrantha - Mimulus eastwoodiae Herbaceous Vegetation* |
| West Slope Riparian Woodland | *Fraxinus anomala / Quercus gambelii Woodland* |
| Scouring Rush | *Equisetum hyemale Herbaceous Vegetation* |
| Foothills Riparian Shrubland | *Crataegus rivularis Shrubland* |
| Planeleaf Willow/Mesic Forbs | *Salix planifolia / Mesic Forbs Shrubland [Provisional]* |
| Dwarf Birch/sphagnum Shrubland | *Betula nana / Sphagnum spp. Shrubland* |
| Extreme Rich Fens | *Kobresia myosuroides - Thalictrum alpinum Herbaceous Vegetation* |
| Extreme Rich Fen | *Kobresia simpliciuscula - Trichophorum pumilum Saturated Herbaceous Vegetation* |
| Quaking Aspen / Drummond's Willow Riparian Forest | *Populus tremuloides / Salix drummondiana Forest* |
| Skunkbrush Riparian Shrubland | *Rhus trilobata Shrubland* |
| Beaked Sedge Perched Wetland | *Carex utriculata Perched Wetland Herbaceous Vegetation* |
| Montane Floating/Submergent Wetland | *Potamogeton natans Herbaceous Vegetation* |
| Sea Milkwort | *Glaux maritima Herbaceous Vegetation [Provisional]* |
| Common Bladderwort Aquatic Vegetation | *Utricularia macrorhiza Herbaceous Vegetation [Provisional]* |
| Common Mare's-tail Aquatic Vegetation | *Hippuris vulgaris Herbaceous Vegetation* |
| Foothills/Plains Floating/Submergent Palustrine Wetlands | *Sparganium eurycarpum Herbaceous Vegetation* |

| Common Name | Scientific Name |
| --- | --- |
| Emergent Wetland | *Eleocharis rostellata Herbaceous Vegetation* |
| Rio Grande Cottonwood / Disturbed Understory Woodland | *Populus deltoides ssp. wislizeni / Disturbed Understory Woodland* |
| Cottonwood / Switchgrass Floodplain Woodland | *Populus deltoides / Pascopyrum smithii - Panicum virgatum Woodland* |
| Coniferous Wetland Forests | *Picea engelmannii / Equisetum arvense Forest* |
| Diamondleaf Willow / Beaked Sedge | *Salix planifolia / Carex utriculata Shrubland* |
| Box-elder / Narrowleaf Willow Riparian Woodland | *Acer negundo / Salix exigua Woodland* |
| Plains Cottonwood / Alkali Sacaton | *Populus deltoides / Sporobolus airoides Forest* |
| Spring Wetland | *Catabrosa aquatica - Mimulus ssp. Spring Wetland* |
| Montane Riparian Woodland | *Populus balsamifera Woodland* |
| Montane Riparian Forest | *Populus acuminata Forest* |
| Foothills Riparian Forest | *Picea pungens / Alnus incana - Corylus cornuta Woodland* |
| Alpine Willow Scrub | *Salix brachycarpa / Deschampsia caespitosa - Geum rossii Shrubland* |
| Montane Riparian Deciduous Forest | *Acer negundo / Equisetum hyemale Forest* |
| Two-spotted Skipper | *Euphyes bimacula* |
| Hops Feeding Azure | *Celastrina humulus* |
| Regal Fritillary | *Speyeria idalia* |
| Great Basin Silverspot Butterfly | *Speyeria nokomis nokomis* |
| Sandhill Fritillary | *Boloria selene sabulocollis* |
| Smoky Eyed Brown Butterfly | *Satyrodes eurydice fumosa* |
| Theano Alpine | *Erebia pawlowskii* |
| Saffron-bordered Meadowfly | *Sympetrum costiferum* |
| Desert Forktail | *Ischnura barberi* |
| A Stonefly | *Mesocapnia frisoni* |
| A Stonefly | *Pictetiella expansa* |
| Susan's purse-making caddisfly | *Ochrotrichia susanae* |
| Giant Floater | *Anodonta grandis* |
| Rocky Mountain Capshell | *Acroloxus coloradensis* |
| Baltic Bog Moss | *Sphagnum balticum* |
| Girgensohn Bog Moss | *Sphagnum girgensohnii* |
| Flatleaf Bog Moss | *Sphagnum platyphyllum* |
| Fine Bog Moss | *Sphagnum angustifolium* |
| Nodule Cracked Lichen | *Acarospora nodulosa var. nodulosa* |
| Plains Ragweed | *Ambrosia linearis* |
| Kachina Daisy | *Erigeron kachinensis* |
| Philadelphia Fleabane | *Erigeron philadelphicus* |
| Gay-feather | *Liatris ligulistylis* |
| Few-flowered Ragwort | *Packera pauciflora* |
| Salt-lick Mustard | *Thellungiella salsuginea* |
| Weber's Draba | *Draba weberi* |

| Common Name | Scientific Name |
|---|---|
| Mosquito Range mustard | *Eutrema penlandii* |
| Water Awlwort | *Subularia aquatica* |
| Slender Spiderflower | *Peritoma multicaulis* |
| Roundleaf Sundew | *Drosera rotundifolia* |
| Longstem Water-wort | *Elatine triandra* |
| American Groundnut | *Apios americana* |
| Bodin Milkvetch | *Astragalus bodinii* |
| King's Clover | *Trifolium kingii* |
| Marsh Felwort | *Lomatogonium rotatum* |
| American Currant | *Ribes americanum* |
| Lavender Hyssop | *Agastache foeniculum* |
| Lesser Bladderwort | *Utricularia minor* |
| Colorado butterfly plant | *Oenothera coloradensis ssp. coloradensis* |
| Tufted Loosestrife | *Naumburgia thyrsiflora* |
| Greenland Primrose | *Primula egaliksensis* |
| Nagoon Berry | *Cylactis arctica ssp. acaulis* |
| Hoary or Silver Willow | *Salix candida* |
| Low Blueberry Willow | *Salix myrtillifolia* |
| Autumn Willow | *Salix serissima* |
| Kotzebue's grass-of-parnassus | *Parnassia kotzebuei* |
| Leafy Saxifrage | *Spatularia foliolosa* |
| Hanging Garden sullivantia | *Sullivantia hapemanii var. purpusii* |
| Marsh-meadow Indian-paintbrush | *Castilleja lineata* |
| Budding Monkeyflower | *Mimulus gemmiparus* |
| Sweet Flag | *Acorus calamus* |
| Lesser Panicled Sedge | *Carex diandra* |
| Lunell's Heavy-fruited Sedge | *Carex gravida var. lunelliana* |
| Slender Sedge | *Carex lasiocarpa* |
| Bristle-stalk Sedge | *Carex leptalea* |
| Mud Sedge | *Carex limosa* |
| Livid Sedge | *Carex livida* |
| A sedge | *Carex oreocharis* |
| Peck sedge | *Carex peckii* |
| Retrorse sedge | *Carex retrorsa* |
| Rocky Mountain sedge | *Carex saximontana* |
| Canadian single-spike sedge | *Carex scirpoidea* |
| Sprengel's sedge | *Carex sprengelii* |
| Small-winged sedge | *Carex stenoptila* |
| Torrey sedge | *Carex torreyi* |
| Green Sedge | *Carex viridula* |
| Altai cottongrass | *Eriophorum altaicum var. neogaeum Eriophorum chamissonis* |

| Common Name | Scientific Name |
|---|---|
| Slender Cottongrass | *Eriophorum gracile* |
| Simple Kobresia | *Kobresia simpliciuscula* |
| Little Bulrush | *Trichophorum pumilum* |
| Blue-eyed Grass | *Sisyrinchium demissum* |
| Pale blue-eyed Grass | *Sisyrinchium pallidum* |
| Small-headed Rush | *Juncus brachycephalus* |
| Vasey Bulrush | *Juncus vaseyi* |
| Colorado Wood-rush | *Luzula subcapitata* |
| Wild chives | *Allium schoenoprasum var. sibiricum* |
| Yellow Stargrass | *Hypoxis hirsuta* |
| Giant Helleborine | *Epipactis gigantea* |
| Northern Twayblade | *Listera borealis* |
| Broad-leaved Twayblade | *Listera convallarioides* |
| White Adder's-mouth | *Malaxis monophyllos ssp. brachypoda* |
| Alcove Bog Orchid | *Limnorchis zothecina* |
| Ute Ladies' Tresses | *Spiranthes diluvialis* |
| Snow Grass | *Phippsia algida* |
| Parish's Alkali Grass | *Puccinellia parishii* |
| Porter Feathergrass | *Ptilagrostis porteri* |
| Broadfruit Bur-Reed | *Sparganium eurycarpum* |
| Variegated Scouringrush | *Hippochaete variegata* |
| Spiny-spored Quillwort | *Isoetes setacea ssp. muricata* |