City of Steamboat Springs

Yampa River Health Assessment & Streamflow Management Plan

Yampa River Health Assessment Report

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lōtic hydrological

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Overview

Purpose and Scope

The Yampa River Health Assessment is a platform for identifying and evaluating the management alternatives available to the City of Steamboat Springs and local stakeholders for addressing important river health issues in the 2017-2018 Yampa River Streamflow Management Plan. There are many factors affecting river condition and the ability to provide the vast array of functions local residents appreciate and depend upon. The complex interactions that exist between the many components of river systems make a comprehensive and integrative approach to assessment necessary. Focused management objectives, such as identifying target flows to meet water quality standards for temperature, must be understood in the broader context of overall river and riparian health to be effective and sustainable. Management actions that address specific river health issues involve trade-offs between different aspects of river function that become clear in a robust characterization of whole-system condition and behavior.

Stream Health Assessment Framework

Over the summer and fall of 2017, an interdisciplinary team of scientists incorporated information from existing reports, available data, field surveys, and scientific models into a holistic assessment of river function. The assessment considers the core drivers of Yampa River health, represented by 11 variables (flow regime, sediment regime, water quality, landscape, floodplain connectivity, riparian condition, organic material, morphology, stability, physical structure, and trophic structure) in an organizational framework adapted from FACStream 1.0. The FACStream framework organizes information in a way that makes it easy to interpret at all levels of technical expertise in reach-by-reach report cards with color-coded visualizations and concise explanations of findings. A simple grading system is used to express varying degrees of impairment and the ability of a reach to perform characteristic functions (Table 1). This format encourages stakeholder involvement and enables meaningful dialogue regarding management decisions.

Appendix B describes the methods and guidelines for scoring the 11 variables. It explains what each grade category means.

Table 1. Functional condition grading criteria in the stream health assessment.

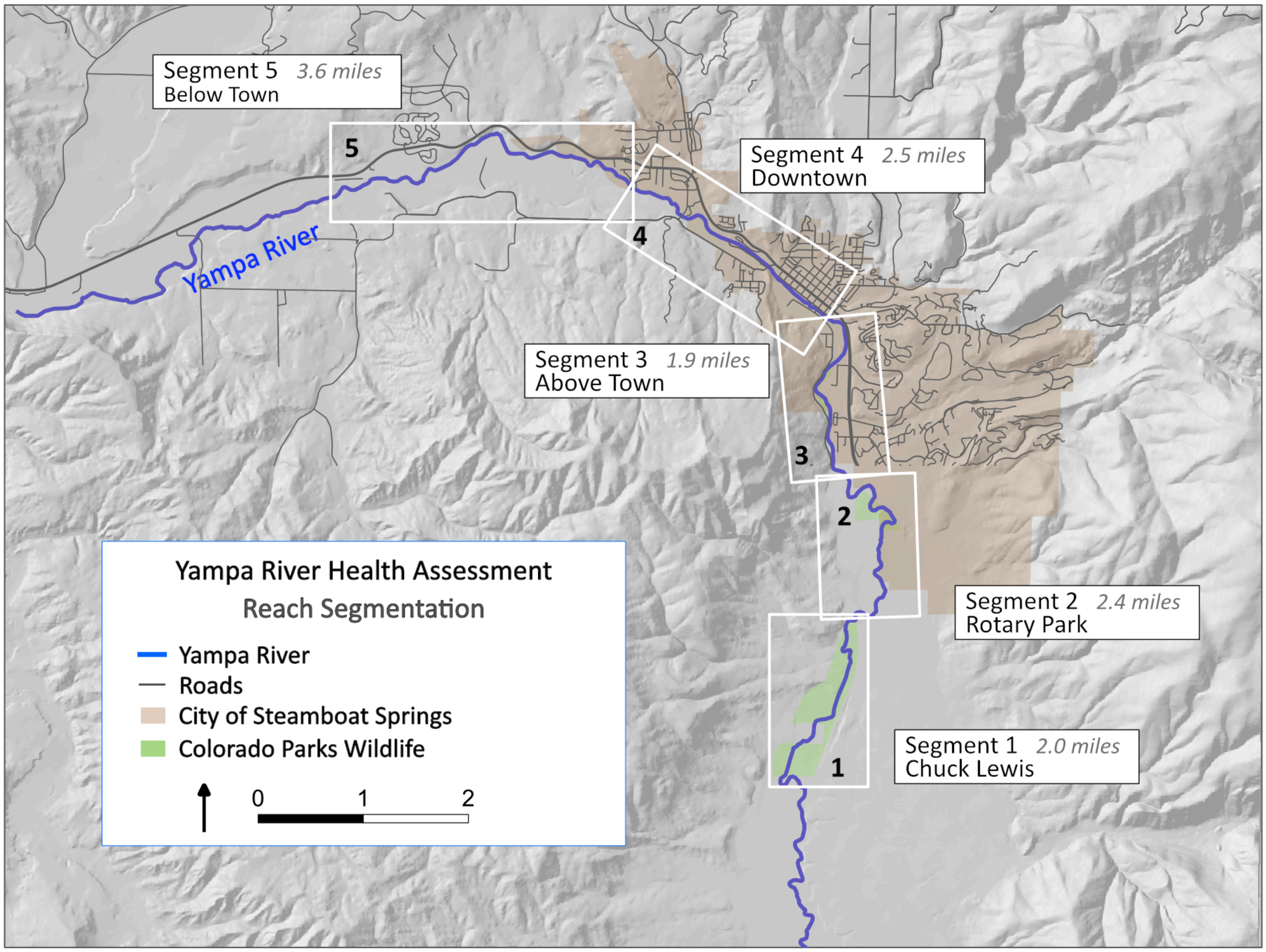
	A	Reference standard
	B	Highly functional
	C	Functional
	D	Functionally impaired
	F	Nonfunctional

Identifying stressors—the causes of impairment—is a critical first step to understanding which aspects of river health local stakeholders can feasibly and practically address. This assessment evaluates river health impairment, by reach, and the degree of departure from a natural state. It is based on the assumption that ecological condition and function is optimal in the reference or unaltered state, and that functional degradation brings about a corresponding reduction in the ecosystem goods and services that the river naturally provides. It is an ecological and holistic approach that does not factor in social preferences or special interests.

Yampa River Segments Studied

This study area includes about 12.5 miles of the Upper Yampa River from the confluence of Oak Creek on the Chuck Lewis State Wildlife Area (SWA), through the city of Steamboat Springs, downstream to the City's wastewater treatment plant. It is divided into 5 segments described below (Figure 1), and each segment is further divided into 19 assessment reaches.

Figure 1. Five river segments assessed on the Yampa River near Steamboat Springs.



1. **Chuck Lewis SWA Segment** (~10,600 feet long, 5 assessment reaches). This segment is an unconfined, low-gradient river with valley slope about 0.21%. The Yampa River historically meandered and spread across a half-mile-wide native valley bottom in a sinuous and branching pattern, but is now largely confined to a single straighter channel bounded by artificial levees[1], roads, railroad, and/or high banks. Most of the valley bottom and riparian area was converted for use as hay meadow and pastureland in the 1800s. Ranching is still a dominant land use today, though some of the river reaches and floodplain were converted again for use in aggregate mining during the late 1900s. Most of the mined areas have been restored as ponds, parks, and natural areas.

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[1] In this report, a **levee** is considered any artificial embankment that prevents overflow of a river onto its floodplain. The term is not used to imply a structure designed and constructed to contain or control the flow of water during a flood.

2. **Rotary Park Segment** (~12,800 feet long, 3 assessment reaches). Like the Chuck Lewis SWA, the Rotary Park segment historically had a half-mile-wide valley bottom and very low 0.23% gradient. The river's naturally unconfined branching and sinuous pattern is now a much straighter single-thread channel, but it is not as channelized or confined as the Chuck Lewis SWA. Most of the riparian zone was cleared in the 1800s, and agriculture is still an important land use on this segment, though a large portion is now managed as open space natural area. Urban development has been encroaching on the upper portions of the segment since the mid-1900s. River and floodplain form on the upper reaches were heavily impacted by aggregate mining in the late 1900s, especially near the confluence of Walton Creek. The City of Steamboat Springs constructed an infiltration gallery in the alluvial aquiver on this segment to augment drinking water supplies.
3. **Above Town Segment** (~10,000 feet long, 3 assessment reaches). The valley becomes markedly steeper on this segment, and floodplain width also begins to decrease. Valley slope is about 0.41% and mean natural bottom width is about 1,000 feet. The contributions of Walton Creek and Fish Creek considerably increase streamflows on this segment, especially during runoff. Urban development is the dominant land use, though significant portions of the riparian zone are preserved as parks or open space. For most of its length, this segment is bounded on one side or the other by railroad, road, trail, and/or flood-control levee structures.
4. **Through Town Segment** (~13,000 feet long, 4 assessment reaches). The segment of the Yampa River that flows through downtown Steamboat Springs is even steeper and more geologically confined than upstream segments. Channel slopes average about 0.56% and mean bottom width is about 500 feet. This river segment is straight, channelized, and confined on both sides for most of its length, but valley and floodplain widths begin to increase near the western end of town. The core area of Steamboat Springs is sited mostly on high uplands, terraces, and alluvial fans above the valley floor, although much of the riverside development is on artificial fill covering the historic floodplain. The rodeo grounds and parks on the west side of the river are constructed directly on the historical floodplain. The river is highly manipulated in this segment to accommodate streamside commercial development and transportation corridors. Numerous engineered in-stream structures were constructed over the last 20-30 years to improve trout habitat and recreational opportunities for whitewater enthusiasts. Spring Creek and Soda Creek enter the Yampa River in this segment and increase Yampa River streamflows during runoff. The tributaries provide only modest contributions of flow during other times of the year.
5. **Below Town Segment** (~19,000 feet long, 4 assessment reaches). Below town, the valley width increases to approximately 2,000 feet, and mean channel gradient falls to about 0.44%. The river’s access to the large floodplain to the south of the river

channel is cut off by the railroad line and other landfills. Agricultural land uses dominate near-channel areas, and most of the valley bottom is productive and highly valued hay meadow and pastureland. Some reaches on this segment retain a natural braided river pattern while others have been straightened and channelized.

Assessment Findings

Findings are organized into the following sections:

- A report card for each of the five river segments includes the score for each health assessment variable and the estimated contribution of various stressors to impairment of each variable.
- Summaries of the findings related to each river health variable.
- Summaries of the major off-site and on-site stressors overall and for each river segment.

Health Assessment Report Cards by River Segment

Chuck Lewis SWA Segment Report Card

Upper Yampa River, Chuck Lewis SWA Segment

River Health Assessment

Reach Condition: A | B | C | D | F

Stressor Contribution: None | Low | Moderate | High | Extreme

1.1	1.2	1.3	1.4	1.5			Unknown source(s)	Surface water diversions	Dam/reservoir operations	Watershed scale land use activities	Hillslope and channel erosion	Irrigation return flows/ urban runoff	Urbanization	Riparian land cover conversion	Aggregate mining	Roads/bridges	Levees/ channelization	Bank/channel armoring	Channel structures (dams/wiers)	Woody material recruitment/removal	Exotic plant species/weeds	Exotic aquatic species
2040 ft	1270	2320 ft	2930 ft	2010 ft																		
					B+	**Flow Regime**																
					B	**Sediment Regime**																
					C-	**Water Quality**																
					B	**Landscape**																
					D+	**Floodplain Connectivity**																
					B-	**Riparian Condition**																
					B-	**Organic Material**																
					C-	**Morphology**																
					C-	**Stability**																
					C	**Physical Structure**																
					C	**Trophic Structure**																
					C	**River Health**																

Rotary Park Segment Report Card

Upper Yampa River, Rotary Park Segment

River Health Assessment

A	B	C	D	F

Reach Condition

None	Low	Moderate	High	Extreme

Stressor Contribution

2.1	2.2	2.3
6100 ft	1580	5160 ft

Causes of Impairment (Estimated Contribution of Stressors)

Grade	Indicator	Unknown source(s)	Surface water diversions	Dam/reservoir operations	Watershed scale land use activities	Hillslope and channel erosion	Irrigation return flows/ urban runoff	Urbanization	Riparian land cover conversion	Aggregate mining	Roads/bridges	Levees/ channelization	Bank/channel armoring	Channel structures (dams/wiers)	Woody material recruitment/removal	Exotic plant species/weeds	Exotic aquatic species
B+	Flow Regime																
B	Sediment Regime																
C-	Water Quality																
C+	Landscape																
B-	Floodplain Connectivity																
B-	Riparian Condition																
B	Organic Material																
B-	Morphology																
B-	Stability																
B-	Physical Structure																
B-	Trophic Structure																
B-	River Health																

Above Town Segment Report Card

Upper Yampa River, Above Town Segment

River Health Assessment

Reach Condition: A | B | C | D | F

Stressor Contribution: None | Low | Moderate | High | Extreme

Causes of Impairment (Estimated Contribution of Stressors)

3.1	3.2	3.3	Grade	Variable	Unknown source(s)	Surface water diversions	Dam/reservoir operations	Watershed scale land use activities	Hillslope and channel erosion	Irrigation return flows/ urban runoff	Urbanization	Riparian land cover conversion	Aggregate mining	Roads/bridges	Levees/ channelization	Bank/channel armoring	Channel structures (dams/wiers)	Woody material recruitment/removal	Exotic plant species/weeds	Exotic aquatic species
3380 ft	4270 ft	2380 ft																		
			A	Flow Regime																
			B	Sediment Regime																
			C-	Water Quality																
			C	Landscape																
			D	Floodplain Connectivity																
			C	Riparian Condition																
			B	Organic Material																
			B-	Morphology																
			D+	Stability																
			C+	Physical Structure																
			B-	Trophic Structure																
			C+	River Health																

Through Town Segment Report Card

Upper Yampa River, Through Town Segment

River Health Assessment

A	B	C	D	F

Reach Condition

None	Low	Moderate	High	Extreme

Stressor Contribution

Causes of Impairment (Estimated Contribution of Stressors)

4.1	4.2	4.3	4.4	Grade	Indicator	Unknown source(s)	Surface water diversions	Dam/reservoir operations	Watershed scale land use activities	Hillslope and channel erosion	Irrigation return flows/ urban runoff	Urbanization	Riparian land cover conversion	Aggregate mining	Roads/bridges	Levees/ channelization	Bank/channel armoring	Channel structures (dams/wiers)	Woody material recruitment/removal	Exotic plant species/weeds	Exotic aquatic species
3980 ft	3670 ft	2260 ft	3090 ft																		
				A	Flow Regime																
				B	Sediment Regime																
				C-	Water Quality																
				D	Landscape																
				D	Floodplain Connectivity																
				D	Riparian Condition																
				C	Organic Material																
				D+	Morphology																
				D+	Stability																
				C	Physical Structure																
				C	Trophic Structure																
				C	River Health																

Below Town Segment Report Card

Upper Yampa River, Below Town Segment

River Health Assessment

A	B	C	D	F	Reach Condition					
None	Low	Moderate	High	Extreme	Stressor Contribution					

5.1	5.2	5.3	5.4	Grade	Attribute
3910 ft	5900 ft	3480 ft	5750 ft		
				A	Flow Regime
				B	Sediment Regime
				C-	Water Quality
				B-	Landscape
				C+	Floodplain Connectivi
				B-	Riparian Condition
				B-	Organic Material
				C+	Morphology
				C+	Stability
				B-	Physical Structure
				B-	Trophic Structure
				B-	River Health

Causes of Impairment (Estimated Contribution of Stressors)

Attribute	Unknown source	Surface water diversi	Dam/reservoir operat	Watershed scale land activitie	Hillslope and channel erc	Irrigation return flows/ ur runol	Urbanizatic	Riparian land cover conve	Aggregate mini	Roads/bridg	Levees/ channelizat	Bank/channel armoi	Channel structures (dams/v	Woody materi recruitment/remc	Exotic plant species/we	Exotic aquatic spec
Flow Regime																
Sediment Regime																
Water Quality																
Landscape																
Floodplain Connectivi																
Riparian Condition																
Organic Material																
Morphology																
Stability																
Physical Structure																
Trophic Structure																
River Health																

Results Summary for each Health Variable

Flow Regime

Compared to most other Colorado Rivers with similar land use, the Yampa River near Steamboat Springs is in very good condition. A prime reason for this is that the river has a very natural flow regime. Few diversions, no trans-basin diversions, and just a couple small reservoirs with mostly natural release schedules gives rise to flow regime scores in the A to upper B range, indicating highly functional to reference standard condition. This may be the most important finding of this study, as flow regime is a foundational aspect of river health that affects all other factors and functions. Total volume of water flowing through these reaches is essentially unchanged. Peak flow and rate of change variables score from A to B. Base flow is rated A- due to slight changes caused by summer releases. Base flows are slightly higher than they would naturally be if it were not for reservoir storage and managed releases.

Sediment Regime

Sediment regime is also in good condition, scoring B throughout the study area. The potential impacts of the reservoirs on sediment continuity evident on the upper reaches diminish quickly as catchment area from undammed tributaries increases below Walton Creek and Fish Creek. These effects are balanced by increasing influence of urban development and channel alteration on the lower segments. Surely the river experienced epochs of severely altered sediment regime in the recent past while aggregate mines operated on the river, but there is so indication of severe alteration to the natural sediment regime today.

Water Quality

Past reports and watershed plans agree that water quality on this section of the Yampa is very good. There is some indication of nutrient loading on the upper reaches, which may explain the exceptionally high algae and macrophyte density in the river on the Chuck Lewis SWA and Rotary Park segments. Increased nutrient levels on the Chuck Lewis SWA (C+) may be related to agricultural runoff and/or eutrophication in Catamount Reservoir, but these effects appear to be minimal, and conditions improve on reaches downstream. Nutrient levels are within state water quality standards, and studies that looked at macroinvertebrate communities did not identify shifts in composition that would indicate significant nutrient impairment. Other chemical condition scores are in the B to B+ range indicating high level of function. All the segments score D for the water temperature—a subvariable of the water quality variable. This section of river is listed on the state 303(d) list of impaired rivers due to regular exceedance of temperature standards. In drought, late summer and early fall daily maximum and weekly average water temperatures reach levels unfavorable to rainbow trout, brown trout, and mountain whitefish. Elevated late summer water temperatures in average years additionally create conditions that are conducive to propagation of whirling disease favorable to Northern Pike. As a result, Colorado Parks and Wildlife stocks whirling-disease-resistant rainbow trout at the Chuck Lewis SWA and employs aggressive Northern Pike removal strategies between Chuck Lewis SWA and the confluence of Walton Creek.

Landscape Connectivity

Habitat connectivity and riparian buffer capacity are described by the landscape connectivity variable, which ranges from B to D across the assessment area. The Chuck Lewis SWA, Rotary Park, and Below-Town segments score B to C+, with mild to moderate impacts on terrestrial habitat connectivity and buffer capacity related to riparian land conversion, neighboring wetland loss, and urban development. Aquatic habitat connectivity is good on these reaches, with only minor impediments to migration and fish passage caused by diversion structures. Landscape connectivity impacts are most severe in the segment through town, where terrestrial habitat connectivity and buffer capacity are both rated D, indicating functional impairment. Colorado Parks and Wildlife indicates that some artificial weirs constructed on the reach through town limit aquatic habitat connectivity, especially for young fish during runoff conditions. Reductions in connectivity are likely most impactful to the behavior of wide-ranging fish like mountain whitefish.

Floodplain Connectivity

Floodplain connectivity is severely impaired on the Check Lewis SWA, Above Town, and Through Town segments due to channelization and levees. On Chuck Lewis, the altered channel forms, berms on streambanks, and remnant waste piles left over from aggregate mining operations limit river access the entire extent of the historic floodplain. On the segments above and through town, hydraulic models indicate and direct observation confirms, that normal peak runoff flows tend to be contained within the channel. Extensive overbanking—expected during most years for the channel types that occur above and below town—occurs only during large runoff events (e.g. 1-in-10-year flood). The lateral extent of the 10-year floodplain is also constrained in many areas by constructed features on the floodplain such as the railroad line, roads, and trails. The numerous bridges also present a direct impact to floodplain function, as high flows are constricted through artificially narrow spans.

Poor floodplain connectivity directly impacts other important river functions. It is a direct impact on riparian condition as adjacent riparian areas are drier than normal causing widespread decrease in wetland area. Frequent flooding is also critical for establishing cottonwoods and other native riparian vegetation, as well as recharging the alluvial aquifer. Lack of floodplain activation also has geomorphic impacts, primarily by increasing channel capacity and stream power that causes erosion and damage during large floods. Floodplain connectivity is less impaired on the Rotary Park and Below Town segments that score B- and C+, respectively.

Riparian Condition

Despite the direct impacts of land conversion and indirect effects of diminished floodplain connectivity, riparian condition is still good on the Chuck Lewis SWA, Rotary Park, and Below Town segments where B- grades indicate highly functional condition. Relatively good riparian vegetation structure on areas with disconnected floodplain may be supported by a high groundwater table maintained by groundwater-surface water interactions, hillslope inputs, or irrigation return flows. Areas that were historically cleared for agricultural use also tend to have moderately good vegetation due to effective land management and low intensity use. Riparian condition above and through town is typical of urban areas where most of the riparian zone has been developed. These reaches score C and D, respectively. The effects of urbanization are moderated, to some degree, by a fairly continuous strip of streamside native trees and occasional parks and natural areas.

Organic Material

Wood and detritus supply to the river is primarily limited by riparian condition since riparian vegetation is the most important source of these materials. As a result, organic material scores are similar to riparian condition scores. Channelization and armoring are also important since lateral migration is necessary for entraining trees and large wood. Wood supply can also be impacted by active debris removal to facilitate urban drainage. For these reasons, the wood supply scores are especially low through town (C, compared to B or B- on other segments). Detritus can be transported a long way from fetch areas through the river corridor, so these scores are relatively consistent (B to B-) through the study area.

Morphology

Stream morphology is significantly altered on the Chuck Lewis SWA due to artificial entrenchment, channelization, consolidation of flows to a single channel, and mechanical straightening and armoring. Were it not for these historical impacts, the native branching and highly sinuous meandering stream type evidenced by mid-twentieth century aerial photographs may very well still exist. A score of C- in this reach indicates significant impairment. The Rotary Park segment exists in a similar setting and process domain, and had a similar native stream morphology. Scores improve to B- in this segment reflecting less channelization, fewer streamside berms, less bank armoring and structures, and better floodplain connectivity.

The segments above and through town are more geologically confined, and the native river type was less branching and less sinuous than the reaches upstream. Nevertheless, urban development and the necessary channelization, floodplain filling, and bank armoring that goes with it have hemmed in the river creating an artificially straightened pattern and high degree of entrenchment. These segments score C and D+. Below Town, the valley becomes unconfined, similar to the reaches above town. Morphological condition and degree of impairment in this area are very similar to the Rotary Park segment.

Stability

The Yampa scores relatively well for resistance and dynamic equilibrium throughout the study area (B to C+) with little evidence of excessive erosion, aggradation, or degradation. One exception is on the lowest reach below town, downstream form the water treatment plant, where excess deposition is causing one short section of the river to aggrade and migrate laterally. The biggest impacts to stability are related to resilience. Many sections of the river rely on artificial stabilization measures, and if these become overwhelmed there is little capacity for rapid natural recovery. A significant portion of the natural channel migration zone is developed above town and through town, causing functional impairment. These segments scored D- and D for resilience. The better score of D+ on the Chuck Lewis SWA segment is due to less development in the channel migration zone. The Rotary Park and Below Town segments have development in the channel migration zone, better floodplain connectivity, and healthier riparian vegetation, resulting in scores of C to B-.

Physical Structure

River form on most of the segments is altered, and the geomorphic processes of scour, deposition, vegetation, and wood accumulation that would naturally create and maintain macrohabitat diversity are depressed as a result, especially on the Chuck Lewis SWA, and segments above and through town. The relatively homogenous physical structure on these segments has been treated intensively with the installation of more than 200 artificial in-stream features meant to increase structural complexity. These have some effect, and macrohabitat scores range from C- to C. Natural processes are more intact on the Rotary Park and Below Town segments where scores are C+ and B- and there are far fewer artificial structures. Microhabitat structure scores range from C+ to B. Embeddedness, armoring, and algal cover are issues on from Chuck Lewis SWA through Rotary Park, but the causes are unknown.

Biotic Structure

Aquatic food webs are most impacted in the areas above town where invasive Northern Pike are most prevalent. These aggressive piscivores occupy an apex predator niche and reduce the number of adult fish and overall biomass of native species like mountain whitefish. Native food webs are further altered by continued stocking of sportfish like rainbow trout and brown trout. The bottom of the food web appears less impacted, and macroinvertebrate community assessments generally score well. Primary production may be elevated in some reaches above town, supported by nutrient enrichment. Algal blooms are indicative of eutrophication, however they do not appear significant enough to disrupt other parts of the tropic structure.

Stressor Identification

Stressors are human activities (historical or present-day) that impact river health and contribute to impairment.

Table 2: River health stressors on the Upper Yampa River.

	Category	Explanation
	Unknown stressor(s)	The dominant source of the impairment is unknown.
Off-site: Watershed & surrounding area	Surface water diversion	Flow diversions to support agricultural and municipal needs
	Dams/reservoir operation	Peak flow reduction and baseflow augmentation caused by normal reservoir operations
	Watershed land use	Development and land use in the watershed and surrounding area
	Hillslope and channel erosion	Sediment supply from eroding hillslopes, channels (and/or artificially low supply from stabilized channels)
	Irrigation return flows/ urban runoff	Return flows to the river with altered timing, physical and chemical properties
On-site: River & riparian zone	Riparian land cover conversion	Riparian land altered to support rural or agricultural uses
	Urbanization	Riparian land converted for commercial/industrial, infrastructure, transportation, or residential use
	Aggregate mining	In-channel or floodplain aggregate mining and large-scale excavation, gravel pits/ponds
	Roads/bridges	Roads, railroad, trails and bridges in riparian and channel area
	Levees/channelization	Levees, high banks, and/or channelized river segments
	Bank/channel armoring	River segments stabilized with engineered structures, armored banks (e.g. rip-rap)
	Channel structures	Diversion structures, dams, weirs, vanes, spurs
	Woody material recruitment/removal	Channel/floodplain debris removal or diminished wood recruitment
	Exotic plant species/weeds	Exotic plants present in riparian area
	Exotic aquatic species	Exotic aquatic biota (any taxa) present in the river

Off-Site Stressors

Off-site stressors occur in the contributing watershed or area surrounding the reach. Surface water diversion affects all the reaches in the study area, as agricultural land uses dominate the Yampa river watershed above Steamboat Springs. Diversion and consumptive use of water results in some decrease to the total volume of water that flows annually through each reach. Diversions also alter the timing, magnitude, and rate of change of streamflows.

These characteristics of the flow regime are also impacted by managed releases of water from the Stagecoach, Catamount and Fish Creek Reservoirs. Reservoirs dampen and attenuate peak flows, increase baseflows, and reduce the transport of sediment from the watershed to downstream reaches (Figure 2). Unique thermal stratification and nutrient dynamics present in small and large reservoirs alike additionally alter the physicochemical properties of water released from the outlet works.

Figure 2: In-line dam and reservoir on the Yampa River at Lake Catamount.

Alteration of reach scale hydrological regime behavior and water quality are also related to irrigation return flows and storm-water runoff. Runoff from urban areas often entrains pollutants associated with residential, commercial, industrial activities. Sheet flow over impervious surfaces may also experience elevated thermal loading, which can impact temperature patterns in receiving waters. Return flows from agricultural activities may include elevated nutrient concentrations that increase aquatic vegetation cover. While return flows may negatively impact ecological conditions, return flows making their way back to the river as slow-moving groundwater may support wetland and riparian vegetation on floodplains (Figure 3).

Figure 3. The driving factor behind elevated aquatic vegetation cover on the Chuck Lewis SWA and Rotary Park segments is unknown, but it could indicate nutrient enrichment from agricultural runoff or reservoir eutrophication

Most of the Upper Yampa watershed is undeveloped forestland. Road density is low and there are few major disturbances that affect either hillslope or channel erosion processes. Development in areas adjacent to riparian areas do have significantly decrease buffer capacity, and terrestrial habitat connectivity is decreased where roads, bridges, and other development acts as migration barriers, especially in the segments above and through town (Figure 4).

Figure 4. Railroad lines, roads, and other development may act as migration and dispersal barriers, limiting the movement of terrestrial organisms into and out of riparian areas.

On-Site Stressors

On-site stressors occur in the riparian area or stream on the reach itself. The conversion of riparian land for agricultural or rural uses is an important historical stressor on the Chuck Lewis SWA, Rotary Park, and Below Town segments. On Chuck Lewis and Rotary Park, the riparian areas were naturally wide, wet shrublands that were cleared in the 1800s to create valuable and productive hay meadow and pastureland (Figure 5). Many of these areas are still working ranchlands managed for grazing and hay production (Figure 6), while others have been converted to other uses. Similar land use changes occurred below town where the natural riparian condition was likely dominated by cottonwood forest (Figure 7). These pastoral land uses not only affected riparian vegetation condition, but also the supply of organic material, river and floodplain morphology, stability, physical structure, and trophic structure.

Figure 5. Shrub cover, like that lining the stream banks on this reach of the Rotary Park segment, historically spread across the width of the valley bottom. On some reaches, as much as 80% of the riparian areas were cleared for agricultural land use.

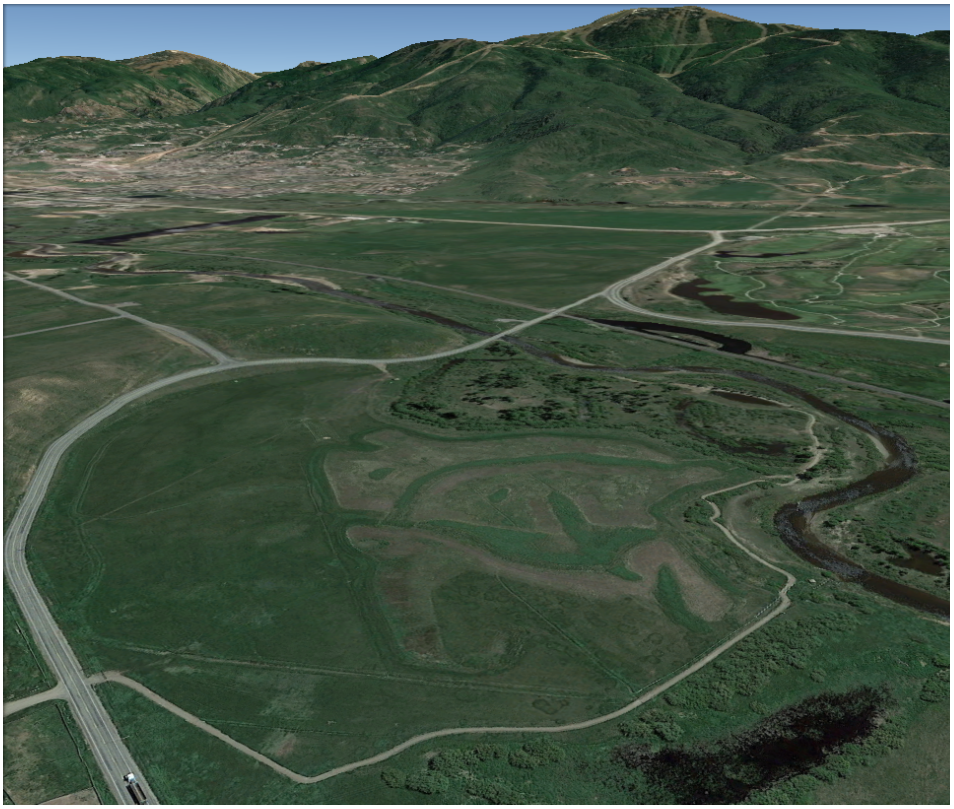

Figure 6. Agricultural land use on the Chuck Lewis SWA segment.

Figure 7. A section of riparian area below town with mature cottonwood forest.

Urbanization resulted in conversion of portions of the riparian area above and through town to commercial or industrial uses, infrastructure, transportation corridors, and residential areas. Conversion of riparian areas into buildings and paved areas make up a significant portion of historic floodplain through town. Less intensive development-induced changes occurred following development of streamside parks and the rodeo grounds (Figure 8).

Figure 8. Most of the historical riparian area in the segments above and through town have been developed for land uses that vary in intensity from buildings and paved surfaces to parks.

Roads, railroad lines, and bridges affect river health primarily by limiting floodplain access. Road and railroad fill act like dams and levees that prevent flood flows from spreading laterally or constrict them through narrow bridge openings. There are only a few bridges crossing the river on the Chuck Lewis, Rotary Park, and Below Town segments, but the segments Above and Through Town have dozens. The railroad line that runs through the study area was constructed as a linear mound of fill that often runs through the middle of the floodplain—limiting water access to one side or the other (Figure 9). Roads and trails that are similarly constructed on fill have similar impacts.

Figure 9. Floodplain and riparian area cut off by railroad line.

Aggregate mining was a severely invasive floodplain land use practice that occurred on reaches in the Chuck Lewis, Rotary Park, and Below Town segments. Most of these operations occurred in the 1970s, 80s, and 90s (Figure 10). Gravel was mined directly from the stream and floodplain and the river was routed through entrenched channels bounded by levees. Floodplain areas were subsequently reclaimed for development or repurposed as ponds, parks, or depressional wetlands. Many of the channelized river form and levees remain intact. Some river sections appear to persist in an over-widened state, indicating that reclamation in all historical mining area may not have occurred (Figure 11). The long-term impacts of aggregate mining on localized sediment dynamics are unknown, but channel planform became progressively less complex over the last half of the twentieth century. This reduced complexity coincided with geomorphic indicators consistent with reduced lateral migration of channels across the floodplain areas.

Figure 10. Aggregate mining was an invasive land use on the Chuck Lewis SWA segment in the 1970s through 1990s. Mined lands were reclaimed as gravel pit ponds and depressional wetland, but the channelized river form and floodplain levees remain.

Figure 11. A reach of the Yampa River on Chuck Lewis SWA where the river was excavated for aggregate mining.

Much of the Yampa River through the study area is channelized and/or bounded by levees or artificially high banks. Any artificially high area that limits floodplain access is considered a levee in this assessment, regardless of its intended purpose. Areas adjacent to channelized segments or separated from the river by levees tend to be unnaturally dry, at least for part of the season. In many cases, riparian areas that were seasonally saturated by overbank flows are now wet only during occasional years during unusually high runoff peaks. Channelization, either by direct manipulation of the river or from channel evolution following destabilization, is also one of the major causes of decreased sinuosity and river length, lack of channel branching, and decreased physical structural diversity.

Around 200 artificial in-stream structures**,** such as weirs, vanes, spurs, and boulder clusters have been installed on the study reach over the past 20-30 years (Figures 12-16). Most of these structures were intended to create physical habitat features for sport fish and increase structural diversity. Some structures serve other purposes, such as maintaining the efficiency of surface water diversions, stabilizing or protecting eroding streambanks, or promoting recreational boating. Armored banks are also common on all segments, and are especially prevalent above and through town.

Figure 12. Diversion structure on Chuck Lewis SWA.

Figure 13. Fish habitat structures on Chuck Lewis

Figure 14. Diversion structure Below Town

Figure 15. Recreation and bank stabilization structures Above Town

Figure 16. Recreational boating structures Through Town

Biological stressors include exotic riparian vegetation and aquatic species. Weeds do not appear to be a serious vegetation issue on any of the segments, but invasive and exotic aquatic species are a concern throughout. While most of the fish biomass is nonnative trout, these fish likely fill niches that were previously held by natives. Northern pike and perhaps large adult trout, on the other hand, may represent a class of apex predators not present in the native aquatic food web. Northern pike predation reduces reproductive success and total biomass of mountain whitefish and introduced sport fish alike.

Unknown Stressors

While the exceedances of water temperature standards on all reaches in the study area are documented, identifying a credible cause for this level of impairment is difficult. The upper watershed is in excellent condition with few stressors that would cause unnatural warming. The putative sources of thermal pollution are decreased groundwater exchange caused by poor floodplain connectivity and increased radiation warming due to degradation or removal of riparian vegetation and geomorphic alteration of the river between Catamount Reservoir and Rotary Park. But this section may be too short to account for all of the observed impairment, especially considering that the section still has some shading, and morphology that is shortened, steepened, and probably deeper and narrower than it would have been naturally.

Another potential source of temperature impairment is warming due to releases from Catamount Reservoir. While data does not exist to quantify the degree of warming from this relatively shallow reservoir, it is likely somewhat offset from documented cooling of late summer and fall releases of water from Stagecoach Reservoir. Further detailed investigations of the temperature regime and thermal loading sources throughout the study area may be warranted.

The temperature issue, thus, remains unsolved. It is unclear whether the Yampa is truly temperature impaired or whether the periods of relatively warm temperatures that are commonly experienced on the river are natural, perhaps a result of warm groundwater discharge or other natural processes. If a relatively warm temperature regime is natural, then the native biotic community and natural biogeochemical processes will have been adapted to that regime, and any efforts to cool it artificially may introduce stress to the systems. From a practical perspective, however, the degree of to which the Yampa River temperature regime is natural or not may be of less concern. State temperature standards are based on thermal tolerances and preferences of trout (and more recently also of mountain whitefish). If the community strongly values a sustainable year-long trout fishery and frequent occupation of the reach by mountain whitefish, it may be important to manage water temperature to meet existing water quality standards, regardless of whether the causes of warming are natural or artificial.

Table 3: Summary of health issues and likely causes for the five stream segments.

Segment	Priority Health Issues	Likely Causes
Chuck Lewis SWA	1. Floodplain Connectivity 2. Morphology 3. Stability (equilibrium and resilience) 4. Physical Structure 5. Water quality (temperature) 6. Trophic Structure	1. Channelization and levees, direct impacts from aggregate mining 2. Direct impacts from aggregate mining, avulsions and channel evolution following riparian degradation and destabilization 3. Encroachment on channel migration zone, levees and artificially high banks, riparian degradation, channel enlargement, direct impacts from aggregate mining 4. Channelization, armored and artificially high banks, in-stream structures, channel enlargement and evolution 5. Causes largely unknown 6. Habitat issues related to #1-5, exotic species.
Rotary Park	1. Water quality (temperature)	1. Causes unknown
Above Town	1. Floodplain Connectivity 2. Stability (resilience) 3. Water Quality (temperature) 4. Riparian Vegetation	1. Channelization and levees, floodplain encroachment, bridges 2. Development, road, railroad encroachment on channel migration zone 3. Causes largely unknown 4. Riparian development and land conversion, levees and high banks
Through Town	1. Floodplain Connectivity 2. Riparian Condition 3. Landscape connectivity 4. Morphology 5. Stability (resilience) 6. Water quality (temperature) 7. Physical Structure 8. Trophic Structure	1. Channelization and levees, floodplain encroachment, bridges 2. Riparian development 3. In-stream structures, development, roads and bridges 4. Channelization and levees, channel armoring, in-stream structures 5. Development, road, and railroad encroachment on channel migration zone 6. Causes largely unknown 7. Channelization, armored and artificially high banks, in-stream structures, channel enlargement and evolution 8. Habitat issues related caused by #1-5, exotic species.
Below Town	1. Water quality (temperature)	1. Causes largely unknown

Appendix A: 2017 Yampa Health Assessment Master Database

The master database is an excel document that can be found here: Yampa Health Assessment Master Database.

Appendix B: Methods and Data Sources for Each Variable

Watershed Attributes

Flow Regime

Water is supplied to a reach from its contributing watershed in a characteristic pattern, or flow regime, represented by a hydrograph, and flow regime is a primary determinant of the structure and function of streams and rivers. Land and water uses in the watershed may affect the total net volume of water supplied to the reach, or impact the pattern of the hydrograph by impacting peak flows, low flows, and rates of change. The **Total Volume** subvariable rates the net annual change in water volume caused by depletions and/or augmentation as a percentage of natural. **Peak Flow** rates impairment to the magnitude, timing, and duration of high-flow events. Grading criteria are based on changes to the pattern of peaks in the hydrograph and deviation of annual net peak flow discharge compared to geomorphically relevant thresholds. The **Base Flow** subvariable rates impairment to the magnitude, timing, and duration of low-flow events. Grading criteria are based on changes to the pattern of dips, or low flow periods, in the hydrograph and deviation of annual net base flow discharge compared to biologically relevant thresholds. **Rate of Change** considers impacts to the rate at which discharge varies over time, with grading criteria based on the degree to which changing flows stress native plants and animals. The **Flow Regime** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Flow\ Regime = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines

Scoring Guidelines for $V_{hyd}1$: Flow Regime - Total Volume			
A	⩾ 90	Negligible	Net change from augmentations and depletions less than 5% of the total annual volume.
B	⩾ 80	Mild	Net change from augmentations and depletions between 5% and 15% of the total annual volume.
C	⩾ 70	Significant	Net change from augmentations and depletions between 15% and 30% of the total annual volume.
D	⩾ 60	Severe	Net change from augmentations and depletions between 30% and 50% of the total annual volume.
F	⩾ 50	Profound	Net change from augmentations and depletions more than 50% of the total annual volume.

Scoring Guidelines for $V_{hyd}2$: Flow Regime - Peak Flows			
A	⩾ 90	Negligible	Magnitude and duration of annual discharge peaks closely resembles natural hydrograph. Departure from natural peak flow magnitude less than 10%.
B	⩾ 80	Mild	Hydrograph has a natural seasonal pattern but peaks are attenuated, elevated, extended, or shortened. Departure from natural peak flow magnitude 10-20%.
C	⩾ 70	Significant	Hydrograph has a natural seasonal pattern but peaks are attenuated, elevated, extended, or shortened. Departure from natural peak flow magnitude 20-33%.
D	⩾ 60	Severe	Disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude 33-50%.
F	⩾ 50	Profound	Disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude greater than 50%.

Scoring Guidelines for Flow Regime - Base Flows			
A	⩾ 90	Negligible	Magnitude and duration of base flows closely resembles the natural hydrograph. Departure from natural seasonal minimum discharge less than
B	⩾ 80	Mild	Hydrograph has a natural seasonal low-flow pattern. Seasonal minimum discharge diminished 10-20% or increased by 10-50%.
C	⩾ 70	Significant	Periods of biologically critical low flows occur occasionally. Seasonal minimum discharge diminished 20-33% or increased by more than 50%.
D	⩾ 60	Severe	Periods of biologically critical low flows are frequent. Seasonal minimum discharge diminished 33-50%.
F	⩾ 50	Profound	Frequent and extended periods of biologically critical low flows and/or periods of no flow occur. Seasonal minimum discharge diminished by more than 50%.

Scoring Guidelines for Flow Regime – Rate of Change			
A	≥ 90	Negligible	Flow rates of change closely resemble natural hydrograph. Departure in rise and/or fall rates less than 10%
B	≥ 80	Mild	No rapid artificial flow changes. Departure in rise and/or fall rates 10-20%.
C	≥ 70	Significant	Occasional rapid artificial flow changes. Departure in rise and/or fall rates 20-33%.
D	≥ 60	Severe	Frequent rapid artificial flow changes. Departure in rise and/or fall rates 33-50%.
F	≥ 50	Profound	Artificially uniform hydrograph or hydrographs in which rapid daily fluctuations are common. Departure in rise and/or fall rates greater than 50%

Data Sources

Relevant Reports

- CDSS Yampa River Basin Information--AECOM *(water rights info)*
- Management Plan for Endangered Fishes in the Yampa River Basin--USFS
- Yampa Basin Watershed Plan (2008 Plan) -- Harza, Montgomery Watson
- Yampa River Management Plan (2003)
- Water-Quality Assessment and Macroinvertebrate Data for the Upper Yampa River Watershed, Colorado, 1975-2009--USGS
- Watershed Scale Response to Climate Change--Yampa River Basin (USGS)
- RICD Filing and Assessment
- Upper Yampa River Watershed Plan (2016)

Additional Surveys, Studies, and Models

Hydrological simulation modelling tools made available from the Upper Yampa Water Conservancy District were used to simulate natural and existing daily streamflows on all study reaches. Measures of hydrological regime behavior (i.e. Indicators of Hydrological Alternation statistics) provided the basis for assessing the degree of hydrological alteration present on the Yampa River near Steamboat Springs.

Analysis of historical stream gauge data were evaluated to ascertain whether reservoirs constructed in the upper watershed during the late 20th century may be responsible for statistically significant changes in hydrological regime.

Sediment Regime

Rivers tend to be naturally adapted to the characteristic flow and sediment regime of their watersheds. Like changes to flow regime, an altered sediment regime may cause a cascade of impacts to stream form and function. The **Sediment Regime** variable reflects the net combined impact to amount and timing of sediment supply to a reach from all sources. The sources of sediment to the reach are land erosion in the contributing watershed and channel erosion on reaches upstream and tributary to it. The **Land Sources** subvariable rates impairment to the amount of sediment produced via land erosion in the contributing watershed with grading criteria based on the extent of land use and unnatural bare ground in the watershed. **Channel Sources** rates impairment to the amount of sediment produced by human-induced channel erosion and incision on main stem and tributary reaches upstream of the reach. While some portion of sediment enters directly from valley side slopes, most of it is discharged to the reach as bedload and suspended sediment by the stream. **Continuity** rates impairment to the natural transport of sediment from its sources in the contributing watershed to the reach. Grading criteria are based on the number and size of unnatural impediments to sediment transport and on the proportion of the watershed from which sediment transport is blocked. The **Sediment Regime** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Sediment\ Regime = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for $V_{sed}1$: Sediment Regime - Land Sources			
A	⩾ 90	Negligible	The amount and timing of sediment production from land erosion is relatively unaffected by human land use.
B	⩾ 80	Mild	Stressors are present and rates of surface erosion and mass erosion events minimally impacted. Examples include watersheds with low road or development density or grazing practices that do not deplete vegetation cover.
C	⩾ 70	Significant	Land uses in the watershed are causing significant changes to the amount of land erosion. Examples include overgrazed slopes with increased bare ground, high density of unimproved roads, or evidence of past human-caused mass erosion.
D	⩾ 60	Severe	Greatly increased land erosion caused by human activity or land use is evident. Examples include widespread overgrazed or clear-cut slopes, erosion associated with roads adjacent to the stream, or evidence of recent human-caused mass erosion.

Scoring Guidelines for $V_{sed}1$: Sediment Regime - Land Sources			
F	⩾ 50	Profound	Land uses in the watershed are causing an overwhelming amount of sediment from land erosion. Examples include widespread loss of ground cover on adjacent slopes with rill or gully formation or very large or frequent human-caused mass erosion.

Scoring Guidelines for $V_{sed}2$: Sediment Regime - Channel Sources			
A	⩾ 90	Negligible	Main stem and tributaries in the contributing drainage network have natural rates of erosion. Total net sediment supply from channel erosion is increased by less than 10% over natural rate.
B	⩾ 80	Mild	Some main stem and tributary reaches have areas of accelerated channel erosion. Total net sediment supply from channel erosion is increased by 10-20% or is artificially low.
C	⩾ 70	Significant	Accelerated channel erosion is common in the watershed, or there are localized reaches with major instability, incision, and/or gully formation. Total net sediment supply from channel erosion is increased by 20-33%.
D	⩾ 60	Severe	Anthropogenic channel erosion is a major source of sediment to the reach. Total net sediment supply from channel erosion is increased by 33-50%.
F	⩾ 50	Profound	Anthropogenic channel erosion is an overwhelming source of sediment to the reach. Total net sediment supply from channel erosion is increased by more than 50%.

Scoring Guidelines for $V_{sed}3$: Sediment Regime - Continuity			
A	⩾ 90	Negligible	Impediments to sediment continuity block sediment from less than 10% of the contributing watershed.
B	⩾ 80	Mild	Impediments to sediment continuity block 10-25% of sediment supply from of the contributing watershed, or small impediments
C	⩾ 70	Significant	Impediments to sediment continuity block 25-50% of sediment supply from of the contributing watershed.
D	⩾ 60	Severe	Impediments to sediment continuity block more than 50% of sediment supply from of the contributing watershed.
F	⩾ 50	Profound	Impediments to sediment continuity trap almost all incoming sediment, supplying the reach with clear water discharge.

Data sources

Relevant Reports

- Upper Yampa River Basin Implementation Plan (2006)-RCCD
- 2014 Upper Yampa River State of the Watershed Report-UYRWC
- Yampa River 2007 Benthic Invertebrate and Water Quality Sampling-GEI Consultants
- USGS Study on Catamount Reservoir
- Upper Yampa Muddy Creek study
- USFS Road assessment (Liz Schnackenberg)
- USFS Bark beetle analysis/analysis
- Upper Yampa River Watershed Plan (2016)

Additional Surveys, Studies, and Models

- Remote watershed survey using current and historical aerial photography
- Field visits to significant watershed sites, tributary streams
- Field surveys, observations during runoff and base flow, indicators of excess or depleted
- Streambed sampling to assess bed composition, embeddedness, armoring

Water Quality

Physicochemical properties are largely inherited to a reach from its contributing watershed, and water quality is determined by a combination of upstream land and water uses and biogeochemical processing. Water quality parameters are typically the most quantified and monitored aspects of stream health, and regulatory standards play a role in scoring all the water quality subvariables. But from the perspective of holistic stream health, the departure from natural conditions is more important than tight adherence to standards. The **Temperature** subvariable rates impairment to water temperature regime, especially as it impacts native biota. **Nutrients** deals with nutrient levels (especially nitrogen, potassium, and phosphorus) as well as dissolved and particulate organic material. Dissolved oxygen is closely tied to both temperature regime and nutrient levels. The **Chemical Conditions** subvariable accounts for all other potential biologically-limiting water quality parameters, especially inorganic compounds and metals. The **Water Quality** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Water\ Quality = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines

Scoring Guidelines for Water Quality - Temperature			
A	⩾ 90	Negligible	Temperature regime is natural and appropriate for a well-functioning river in its process domain.
B	⩾ 80	Mild	Temperature regime is within the range of natural variability, natural aquatic biota are minimally impaired and regulatory standards not exceeded.
C	⩾ 70	Significant	Temperature regime is altered to a degree that could significantly affect natural aquatic biota and/or regulatory standards are occasionally exceeded. 303d M&E reaches.
D	⩾ 60	Severe	Temperature regime is altered to a degree that is known to affect natural aquatic biota and/or regulatory standards are frequently exceeded. 303d listed reaches.
F	⩾ 50	Profound	The temperature regime is fundamentally altered. Natural biota are severely impaired and/or regulatory standards are chronically exceeded.

Scoring Guidelines for Water Quality - Nutrients			
A	⩾ 90	Negligible	Nutrient levels are natural and appropriate for a well-functioning river in its process domain.
B	⩾ 80	Mild	Nutrient levels are within the range of natural variability, natural aquatic biota are minimally impaired and regulatory standards not exceeded.
C	⩾ 70	Significant	Nutrient levels are altered to a degree that they significantly affect natural aquatic biota and/or regulatory standards are occasionally exceeded. 303d M&E reaches.
D	⩾ 60	Severe	Nutrient levels are altered to a degree that is known to affect natural aquatic biota and/or regulatory standards are frequently exceeded. 303d listed reaches.
F	⩾ 50	Profound	The physicochemical environment is fundamentally altered. Natural biota are severely impaired and/or regulatory standards are chronically exceeded.

Scoring Guidelines for Water Quality – Chemical Conditions			
A	⩾ 90	Negligible	Chemical conditions are natural and appropriate for a well-functioning river in its process domain.
B	⩾ 80	Mild	Chemical conditions are within the range of natural variability, natural aquatic biota are minimally impaired and regulatory standards not exceeded.
C	⩾ 70	Significant	Chemical conditions are altered to a degree that could potentially limit natural aquatic biota and/or regulatory standards are occasionally exceeded. 303d M&E reaches.
D	⩾ 60	Severe	Chemical conditions are altered to a degree that is known to be lethal or limiting to natural aquatic biota and/or regulatory standards are frequently exceeded. 303d listed reaches.
F	⩾ 50	Profound	The chemical environment is fundamentally altered. Natural biota are severely impaired and/or regulatory standards are chronically exceeded.

Data Sources

Relevant Reports

- Yampa Basin Watershed Plan (208 Plan) -Harza, Montgomery Watson
- Yampa River 208 Plan -Montgomery Watson Harza
- Water-Quality Assessment and Macroinvertebrate Data for the Upper Yampa River Watershed, Colorado, 1975-2009-USGS
- Yampa River 2007 Benthic Invertebrate and Water Quality Sampling-GEI Consultants
- Upper Yampa River Basin Implementation Plan (2006)-RCCD
- 2014 Upper Yampa River State of the Watershed Report-UYRWC
- Yampa River Management Plan (2003)
- Catamount Reservoir historical documents and EIS
- Upper Yampa River Watershed Plan (2016)
- Yampa Basin Watershed Plan (208 Plan) -Harza, Montgomery Watson

Additional Surveys, Studies, and Models

- Calculation of water temperature exceedances (maximum weekly average temperature, daily maximum) using CPW and City of Steamboat Springs temperature data
- Statistical evaluation of water quality data stored accessible through the Water Quality Portal (https://www.waterqualitydata.us)

- Field observations of water quality indicators (e.g. algal blooms)
- Regulation #93: Colorado's section 303(d) list of impaired waters and monitoring and evaluation list

Landscape

The interaction and connectivity of a reach with its landscape and surrounding area is an important component of stream health. The **Buffer Capacity** subvariable rates the degree to which surrounding land area supports healthy stream and riparian function by buffering potential stressors in the contributing area. Grading criteria area based on the types and extent of land use within a buffer area extending 200 meters out from the riparian zone. **Terrestrial Connectivity** rates impairment to the migration and dispersal of terrestrial organisms into and out of the reach based on the loss of habitat and dispersal/migration barriers within a habitat connectivity envelope extending 500 meters out from the riparian zone. **Aquatic Connectivity** rates impairment to the migration and dispersal of aquatic organisms between the reach and adjacent segments of the stream and its tributaries. Grading criteria are based on the severity and proximity of migration barriers.

Scoring Guidelines

Scoring Guidelines for Landscape – Buffer Capacity			
A	⩾ 90	Negligible	No appreciable land use change in the buffer area (BA).
B	⩾ 80	Mild	Land use in the BA has minor impacts to its ability to buffer surrounding stressors. High-intensity land uses or development with impervious surfaces, bare soil, and structures covers less than 10% of the buffer area.
C	⩾ 70	Significant	Land use in the BA is responsible for a marked shift in land cover, diminishing its ability to buffer surrounding stressors. High-intensity land use or development with impervious surfaces, bare soil, and structures covers 10 – 40%.
D	⩾ 60	Severe	Artificial land cover types dominate most of the BA and/or high-intensity land use or development with impervious surfaces, bare soil, and structures covers 40 – 75%. Buffer capacity is diminished but not totally extinguished.
F	⩾ 50	Profound	High-intensity land use or development with impervious surfaces, bare soil, and structures covers more than 75% of the BA. The surrounding area has no capacity to buffer outside stressors and the BA itself is a major source of ecological stress.

Scoring Guidelines for Landscape – Terrestrial Connectivity			
A	⩾ 90	Negligible	Less than 10% habitat loss within the surrounding 500-meter habitat connectivity envelope (HCE) and no significant barriers to migration or dispersal of terrestrial organisms.
B	⩾ 80	Mild	10-25% of habitat in the HCE is lost or isolated from the reach by impermeable barriers and/or permeable barriers affect a greater portion of surrounding habitat.
C	⩾ 70	Significant	25-50% of habitat in the HCE is lost or isolated from the reach by impermeable barriers and/or permeable barriers affect a greater portion of surrounding habitat.
D	⩾ 60	Severe	50-75% of habitat in the HCE is lost or isolated from the reach by impermeable barriers and/or permeable barriers affect a greater portion of surrounding habitat.
F	⩾ 50	Profound	More than 75% of habitat in the HCE is lost or isolated from the reach by impermeable barriers and/or permeable barriers affect a greater portion of surrounding habitat.

Scoring Guidelines for Landscape – Aquatic Connectivity			
A	⩾ 90	Negligible	There are no significant barriers that prevent migration or dispersal of aquatic organisms within the entire ecoregion and upstream to headwaters.
B	⩾ 80	Mild	Impermeable migration/dispersal barriers are within 10 miles and/or there are minor migration/dispersal impediments on the reach or adjacent reaches.
C	⩾ 70	Significant	Impermeable migration/dispersal barriers exist within 5 miles and/or there are multiple migration/dispersal impediments on the reach or adjacent reaches.
D	⩾ 60	Severe	Impermeable migration/dispersal barriers exist within 2 miles and/or migration/dispersal is severely impeded on the reach or adjacent reaches.
F	⩾ 50	Profound	The reach is effectively isolated. Impermeable migration/dispersal barriers exist within 1 miles and/or migration/dispersal is completely impeded on the reach or adjacent reaches.

Data Sources

Relevant Reports

- Aquatic Wildlife Management Plan-CDW
- Management Plan for Endangered Fishes in the Yampa River Basin-USFS
- Yampa River Structural Master Plan (2008)-Ecological Resource Consultants
- Yampa River Management Plan (2003)
- Yampa River 2007 Benthic Invertebrate and Water Quality Sampling-GEI Consultants
- Upper Yampa River Watershed Plan (2016)

Additional Surveys, Studies, and Models

- Remote survey to assess surrounding land use and percent development and impervious surfaces within Buffer Area
- Remote survey to identify migration/dispersal barriers, degree of aquatic habitat loss, and percent development within Habitat Connectivity Envelope
- Field verification of significant terrestrial barriers
- Mapped all existing in
- Remote survey, and mapping distance to relevant aquatic migration/dispersal barriers
- Field evaluation of structural passage barriers
- Interview with regional aquatic biologist about aquatic connectivity issues

Riparian Attributes

Floodplain Connectivity

Floodplain connectivity describes the degree to which water accesses and hydrates the land. The amount and timing of flow interacts with channel and floodplain morphology to create a characteristic pattern of land saturation or inundation. This variable rates the degree to which the aerial extent of effective floodplain is decreased due to either hydrologic impacts, channel impacts (e.g. enlargement, entrenchment, channelization), or land uses in the floodplain area (e.g. levees, drainage ditches, development, floodplain fill) that impede water access and aerial distribution. Scoring guidelines are based on the comparison of present day floodplain extent to historic natural conditions in three tiers. The **High-frequency Floodplain** subvariable rates impairment to the floodplain area regularly saturated or inundated during average annual high flow events with return interval of 1-2 years. **Medium-frequency Floodplain** considers the active floodplain during events with 5-10-year return interval, and **Low-frequency Floodplain** with extreme floods that occur once every 50 to 100 years, on average. The **Floodplain Connectivity** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Floodplain\ Connectivity = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines

Scoring Guidelines for Floodplain Connectivity – High-frequency Floodplain			
A	⩾ 90	Negligible	Natural pattern of floodplain activation during average annual flow regime. Area of land saturated or inundated at flows with return interval 1-2 years is natural and decreased less than 10%. (> 90% intact).
B	⩾ 80	Mild	Area of land saturated or inundated at flows with return interval 1-2 years is decreased 10 - 25% (75 - 90% intact).
C	⩾ 70	Significant	Area of land saturated or inundated at flows with return interval 1-2 years is decreased 25 – 50% (50 - 75% intact).
D	⩾ 60	Severe	Area of land saturated or inundated at flows with return interval 1-2 years is decreased 50 - 70%. (30 - 50% intact).
F	⩾ 50	Profound	Area of land saturated or inundated at flows with return interval 1-2 years is decreased 70%. (< 30% intact).

Scoring Guidelines for Floodplain Connectivity – Medium-frequency Floodplain			
A	⩾ 90	Negligible	Natural pattern of floodplain activation during high flow events. Area of land saturated or inundated at flows with return interval 5-10 years is natural and decreased less than 10%. (> 90% intact).
B	⩾ 80	Mild	Area of land saturated or inundated at flows with return interval 5-10 years is decreased 10 - 25% (75 - 90% intact).
C	⩾ 70	Significant	Area of land saturated or inundated at flows with return interval 5-10 years is decreased 25 – 50% (50 - 75% intact).
D	⩾ 60	Severe	Area of land saturated or inundated at flows with return interval 5-10 years is decreased 50 - 70%. (30 - 50% intact).

Scoring Guidelines for Floodplain Connectivity – Medium-frequency Floodplain			
F	⩾ 50	Profound	Area of land saturated or inundated at flows with return interval 5-10 years is decreased 70%. (< 30% intact).

Data Sources

Relevant Reports

- Yampa River Structural Master Plan (2008)-Ecological Resource Consultants
- 2014 Upper Yampa River State of the Watershed Report-UYRWC
- Upper Yampa River Watershed Plan (2016)
- Chuck Lewis Habitat Improvement projects
- Feasibility of Yampa River Walton Creek Confluence Reconstruction–Stantec (2015)

Additional Surveys, Studies, and Models

- HEC-RAS inundation modeling using existing survey and DEM data to calculate 2-year, 10-year, and 100-year inundation extents
- Topographic estimation to map extent of saturation/inundation on 2-year, 10-year, and 100-year flow return interval
- Mapped identifiable levees, artificially high banks, and other structural features that limit flood extent
- Mapped estimated historical (natural) floodplain extent
- Field identification of flood indicators
- Riparian vegetation mapping
- Field observation of all reaches during runoff

Riparian Condition

Riparian areas are complex assemblages of plant species with characteristic structure, diversity, and processes that interact directly with the river. The **Riparian Condition** variable describes the degree to which riparian areas support river health and critical functions such as habitat for fish and wildlife, bank stabilization, flood energy dissipation, biogeochemical cycling, and water temperature regulation. The variable rates the degree to which the supporting aspects of riparian vegetation structure, connectivity, and ecological processes are impaired by human impacts such as land conversion and land management.

Scoring Guidelines

Scoring Guidelines for Riparian Condition			
A	≥ 90	Negligible	Native riparian conditions that are natural and appropriate for a well-functioning river in its process domain. Vegetation diversity is self-sustaining with intact hydrology and topography that supports a preponderance of native flora and fauna, without spread of aggressive or noxious species. Habitat is characteristically patchy, with strong interspersion of patches and good vertical structure. Full support of river health.
B	≥ 80	Mild	Riparian habitat resembles native conditions with detectable changes, connectivity to the river, and characteristic topography. Vegetation is self-sustaining, requiring little maintenance to preserve characteristic structure diversity. Native species predominate with only minor invasion by aggressive species. Noxious species do not threaten functioning. Habitat maintains a high degree of patchiness and interspersion, with little homogenization or loss of vertical structure. Minor reduction in the support of hiver health attributes.
C	≥ 70	Significant	Hydrologic alteration, disconnection from the river, decreased plant diversity, loss of structural complexity, and/or homogenization of vertical structure, patchiness and interspersion and are evident, but the riparian area is vegetated. Small populations of noxious species may occur, and a significant proportion of the species are exotic or aggressive natives. Examples include floodplain hayfields. Riparian land use contributes to the degradation of one or more river health attributes.
D	≥ 60	Severe	Hydrologic alteration, disconnection from the river, decreased plant diversity, loss of structural complexity, and/or homogenization of vertical structure, patchiness and interspersion and are severe. Riparian habitat may be isolated from the river and noxious weeds, aggressive species, or exotics are prevalent or dominant. Bare ground or impervious surfaces make up a significant portion of land cover. Vegetation tends to be unnatural, landscaped, or manicured. Examples include residential lawns, sports fields and golf courses. Riparian land use contributes to river dysfunction.
F	≥ 50	Profound	Riparian area is developed or wholly converted with predominantly bare ground, impervious surfaces or otherwise lacking in vegetation as a result of land use and management actions. Riparian habitat function is essentially extinguished and land use contributes substantially to river dysfunction

Organic Material

Organic material is the bodies and fragments of dead organisms, especially plants, that enter a stream. **Wood** is the coarsest organic material, functioning primarily as a structural component affecting stream morphology, stability, and physical structure. It occurs as individual pieces, such as logs, branches, and downed trees, or bunched together in wood jams or beaver dams. **Detritus** is smaller vegetative fragments such as leaves, needles, twigs, and grass, plus animal bodies and feces. Detritus is often the primary energy source for a stream reach, but it also functions in forming microhabitat and substrate structure. These two subvariables rate the degree of alteration to the supply and accumulation of organic materials. The **Organic Material** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Organic\ Material = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines

Scoring Guidelines for Organic Material - Wood			
A	⩾ 90	Negligible	Wood supply is natural and appropriate for a well-functioning river in its process domain. Mean annual LWD volume is decreased less than 10%.
B	⩾ 80	Mild	Wood volume is decreased 10 - 25%, or the river has unnaturally high input of wood from unnatural sources.
C	⩾ 70	Significant	Wood volume is decreased 25 - 50%, or the river is occasionally clogged with debris from unnatural sources.
D	⩾ 60	Severe	Wood volume is decreased 50 - 80%, or the river is chronically clogged with debris from unnatural sources.
F	⩾ 50	Profound	Wood volume is decreased by more than 80%.

Scoring Guidelines for Organic Material - Detritus			
A	⩾ 90	Negligible	Detritus supply is natural and appropriate for a well-functioning river in its process domain. Mean annual detritus mass is decreased less than 10%.
B	⩾ 80	Mild	Mean annual detritus mass is decreased 10 - 25%, or the river has unnaturally high input of detritus from unnatural sources.
C	⩾ 70	Significant	Mean annual detritus mass is decreased 25 - 50%, or the river has extremely high input of detritus from unnatural sources.
D	⩾ 60	Severe	Mean annual detritus mass is decreased 50 - 80%.
F	⩾ 50	Profound	Mean annual detritus mass is decreased more than 80%.

Data Sources

Relevant Reports

- Preliminary Classification of the Riparian Vegetation of the Yampa-Kittel and Lederer
- 2014 Upper Yampa River State of the Watershed Report-UYRWC
- Yampa River Management Plan (2003)
- Yampa River 2007 Benthic Invertebrate and Water Quality Sampling-GEI Consultants
- Wetland assessments on City of Steamboat Conservation Easements
- Watershed Flow Evaluation Tool
- Upper Yampa River Watershed Plan (2016)

Additional Surveys, Studies, and Models

- Remote assessment and mapping of riparian vegetation condition
- Qualitative assessment of in-stream and floodplain coarse woody material
- Qualitative evaluation of percent cover deciduous vegetation

Stream Attributes

Morphology

Streams exhibit characteristic patterns of morphology by process domain as a result of geomorphic processes such as dynamic equilibrium between hydrology and sediment, adaptations to natural disturbance, and response to biotic agents such as vegetation, beavers, and other animals. Morphology is also altered directly by humans. The **Planform** subvariable rates impairment to the aerial shape of a river reach, including patterns of branching, sinuosity, and curvature. Grading criteria area based on the extent of artificial impacts such floodplain encroachment, channelization, straightening, and bank armoring. **Dimension** deals with impairment to the cross-sectional shape and size, especially the degree of entrenchment, channel capacity, and width-depth ratio. The **Profile** subvariable rates impairment to the longitudinal shape (gradient or slope) of a river reach based on the degree of alteration to river bed profile and water surface slope. The **Morphology** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Stream\ Morphology = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines

Scoring Guidelines for Morphology - Planform			
A	≥ 90	Negligible	Planform is natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Localized impacts to sinuosity, branching, or meander patterns. Ratio of channel length to valley length departure less than 10%.
C	≥ 70	Significant	Reach-scale impacts to sinuosity, branching, or meander patterns and/or ratio of channel length to valley length departure 10-25%.
D	≥ 60	Severe	Widespread impacts sinuosity, branching, or meander patterns and/or ratio of channel length to valley length departure 25-50%.
F	≥ 50	Profound	Severely altered sinuosity, branching, or meander patterns and/or ratio of channel length to valley length departure greater than 50%.

Scoring Guidelines for Morphology - Dimension			
A	≥ 90	Negligible	Dimension is natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Localized impacts to entrenchment, channel capacity, or width/depth. Departure less than 10%.
C	≥ 70	Significant	Reach-scale impacts to entrenchment, channel capacity, or width/depth. Departure 10-25%.
D	≥ 60	Severe	Widespread impacts to entrenchment, channel capacity, or width/depth. Departure 25-50%.
F	≥ 50	Profound	Severely altered entrenchment, channel capacity, or width/depth. Departure greater than 50%.

Scoring Guidelines for Morphology - Profile			
A	⩾ 90	Negligible	Water surface slope and bed profile variation are natural and appropriate for a well-functioning river in its process domain.
B	⩾ 80	Mild	Localized bed profile or water surface slope impacts at low flows and/or bankfull slope departure up to 10%. Examples: reaches with small grade control structures, minimal planform changes.
C	⩾ 70	Significant	Localized bed profile or water surface slope impacts at low to moderate flows and/or bankfull slope departure 10-25%. Examples: reaches with large grade control structures, moderate planform changes.
D	⩾ 60	Severe	Widespread bed profile or water surface slope impacts at all flows and/or bankfull slope departure 25-50%. Examples: reaches with numerous large grade control structures, major planform changes.
F	⩾ 50	Profound	Severe changes to water surface slope at all flows and/or bankfull slope departure greater than 50%.

Data Sources

Relevant Reports

- Yampa River Structural Master Plan (2008)-Ecological Resource Consultants
- Yampa River Management Plan (2003)
- Upper Yampa River Watershed Plan (2016)
- Feasibility of Yampa River Walton Creek Confluence Reconstruction–Stantec (2015)
- NRCS assessment of riparian areas/weed mapping
- NRCS Proper Functioning Condition report

Additional Surveys, Studies, and Models

- Overlain historical and current aerial imagery, analysis of stability trends, channel evolution, land use, and direct impacts
- Remote measurement of valley confinement, slope, and planform parameters
- Field observation and rapid measures of dimension and profile
- Field observation at high and low flow to identify indicators of channel capacity enlargement, entrenchment, homogenization
- Channel classification and application of stream evolution model

Stability

Resistance, equilibrium, and resilience are considered together to rate the probability that the stream will maintain functional geomorphic and vegetation structure over time. **Resistance** rates impairment to the strength of streambed, banks, and floodplain compared to natural forces of scour and erosion. **Equilibrium** considers the dynamic balance between sediment supply and transport capacity represented by Lane's Balance. **Resilience** rates the ability of the system to recover after a large disturbance such as a large flood, wildfire, or mass erosion event based on its ability to move and adjust and the potential for riparian vegetation communities to recover. The **Stability** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Stability = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines

Scoring Guidelines for $V_{stab}2$: Stability - Resistance			
A	⩾ 90	Negligible	Bank and bed strength is natural and appropriate for a well-functioning river in its process domain.
B	⩾ 80	Mild	Bank and/or bed strength mildly compromised and susceptible to erosion in extreme flow events. E.g., moderately altered vegetation root strength or depth.
C	⩾ 70	Significant	Bank and/or bed strength compromised and susceptible to erosion in normal flow events; or meandering reaches that have localized areas of artificially armored channel or hard points.
D	⩾ 60	Severe	Decreased bank or bed strength is directly responsible for responsible for high levels of lateral instability; or meandering reaches that are artificially hardened or armored channel.
F	⩾ 50	Profound	Decreased bed or bank strength giving rise to widespread extreme lateral instability, or initiation of channel incision.

Scoring Guidelines for Stability - Equilibrium			
A	⩾ 90	Negligible	Pattern and rate of erosion, deposition, and migration are natural and appropriate for a well-functioning river in its process domain.
B	⩾ 80	Mild	Reach-scale pattern and rate of erosion, deposition, and migration are within the natural range for the river type and process domain, but localized impacts are present.
C	⩾ 70	Significant	Reach-scale impacts to the pattern and rate of erosion, deposition, and migration; reaches with excess deposition, scour, bank erosion, accelerated migration, pool filling, unnatural bars, over-widening, enlargement, or mild incision.
D	⩾ 60	Severe	Severe reach-scale impacts to the pattern and rate of erosion, deposition, and migration; reaches with widespread bank erosion, avulsions, complete pool filling, reach-wide aggradation, recent head cuts, or artificially hardened channels in unconfined alluvial valleys.
F	⩾ 50	Profound	Rapidly aggrading or degrading reaches where instability is actively expanding to adjacent reaches.

Scoring Guidelines for Stability - Resilience			
A	⩾ 90	Negligible	The reach is fully resilient and capable of rapid recovery. There are no significant stressors that obstruct the physical movement or adjustment of the river within its historical migration zone, and no impediments to native plant source, dispersal, and establishment of critical components.
B	⩾ 80	Mild	The reach is resilient to moderate events, but may be slow to recover its functional potential from major disturbance. It retains most of its historical channel migration zone, few obstructions to movement and adjustment, and mostly native riparian vegetation.
C	⩾ 70	Significant	The reach can likely recover its functional potential after moderate disturbance but may not recover from major disturbance without direct intervention. It has significantly diminished channel migration zone, obstructions to physical movement and adjustment, and/or vegetation that is limited due to a lack of local source material, dispersal barriers, impediments to establishment, or exotics.
D	⩾ 60	Severe	The reach is unlikely to recover its functional potential after moderate disturbance without direct intervention. The reach has a severely limited channel migration zone and stability depends on artificial stabilization or structures. Natural recolonization and recovery of the riparian zone is improbable due to a lack of local source material, dispersal barriers,

Scoring Guidelines for Stability - Resilience			
			impediments to establishment, or exotics.
F	⩾ 50	Profound	The reach depends entirely on artificial stabilization, engineered structures, or routine maintenance to maintain stability and functional condition. It has no capacity to recover naturally if these fail. Channel migration zone and the potential for natural vegetation recovery are nonexistent.

Data Sources

Relevant Reports

- Yampa River Structural Master Plan (2008)-Ecological Resource Consultants
- Yampa River 2007 Benthic Invertebrate and Water Quality Sampling-GEI Consultants
- NRCS Proper Functioning Condition report

Additional Surveys, Studies, and Models

- Overlain historical and current aerial imagery, analysis of stability trends, channel evolution, land use, and direct impacts
- Mapped estimated historical (natural) channel migration zone, degree of encroachment, percent existing CMZ; identified impeding structures within CMZ
- Mapped and assessed all artificial structures, bank armor, revetment, and constructed banks and channel
- Remote assessment and mapping of riparian vegetation condition
- Field observation of lateral and vertical instability indicators during high and low flow
- Sediment transport modeling
- Feasibility of Yampa River Walton Creek Confluence Reconstruction–Stantec (2015)

Physical Structure

Heterogeneity in the physical structure of a stream is the result of complex interactions between hydraulics and geomorphology via the processes of erosion, scour, and deposition that shape the form of bed, banks, and substrate. Biological drivers such as riparian vegetation, wood, beavers, aquatic vegetation and algae may also have a profound effect. The **Macrohabitat** subvariable, which is relevant as physical habitat for fish and larger animals, rates impairment to the distribution of and diversity of water depth, velocity, and physical cover, the shape of bed and bank features, and other large physical structure provided by wood, rock, vegetation, and debris dams and jams. **Microhabitat** rates impairment to the physical habitat relevant to aquatic organisms the size of macroinvertebrates or fish larvae, particularly the availability of interstitial space within the river bed substrate, degree of embeddedness, armoring, proportion of fine sediment, aquatic vegetation or algae cover, and patches of organic materials or detritus accumulation such as leaf packs and wood. The **Physical Structure** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Physical\ Structure = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines

Scoring Guidelines for Physical Structure - Macrohabitat			
A	⩾ 90	Negligible	Macro-scale structural heterogeneity is natural and appropriate for a well-functioning river in its process domain. All velocity-depth combinations and structural components are present in characteristic distribution.
B	⩾ 80	Mild	Most typical velocity-depth combinations are present, but distribution of features is slightly skewed due to dispersed stressors or minimal direct impacts.
C	⩾ 70	Significant	Some typical velocity-depth combinations or characteristic structural elements are absent or limited. Examples include reaches with altered pool spacing, skewed riffle-pool ratio, or lack of bank structure. Reaches with artificial structure or revetted banks.
D	⩾ 60	Severe	Some typical velocity-depth combinations or characteristic structural elements are absent making the reach uncharacteristically homogenous. Examples include reaches with graded or heavily revetted banks, or features that are frequently limited by inundation or low flow.
F	⩾ 50	Profound	Homogenous form with uniform velocity-depth pattern and lack of physical structure. Examples include reaches with severely homogenized physical characteristics such as unnatural plain-bed morphology.

Scoring Guidelines for Physical Structure - Microhabitat			
A	⩾ 90	Negligible	Micro-scale structural heterogeneity is natural and appropriate for a well-functioning river in its process domain. Bed conditions similar to reference with all habitat types reflected in appropriate proportions.
B	⩾ 80	Mild	All aspects of micro-scale structural diversity are present but distribution of features is slightly skewed due to dispersed stressors or minimal direct impacts. Examples include reaches with fine sediment deposition, slightly decreased interstitial space (mild embeddedness).
C	⩾ 70	Significant	Some aspects of micro-scale structural diversity are lacking or limited. Examples include reaches with altered bed material distribution, moderate embeddedness, patches of armoring, or increased cover of persistent algae/aquatic vegetation, or decreased detritus/organic accumulation patches.
D	⩾ 60	Severe	Some aspects of micro-scale structural diversity are lacking or severely limited, making the reach uncharacteristically homogenous. Examples include reaches with severe embeddedness, widespread armoring, persistent algae/aquatic vegetation in riffles, or lack of any detritus/organic accumulation patches.
F	⩾ 50	Profound	Completely static or homogenous armored micro-scale physical structure. Examples include gravel or cobble-bed streams that are aggrading with fine material or choked with algae, alluvial streams unnaturally scoured to bedrock, or grouted/ hardened artificial streambeds.

Data Sources

Relevant Reports

- Yampa River Structural Master Plan (2008)-Ecological Resource Consultants
- 2014 Upper Yampa River State of the Watershed Report-UYRWC
- Yampa/White/Green BIP (2015)
- Yampa River Management Plan (2003)

Additional Surveys, Studies, and Models

- Remote assessment of macrohabitat structure based on observable features such as riffle/pool distribution, sloughs, backwater
- Qualitative assessment of in-stream and floodplain coarse woody material
- Rapid field evaluation of macrohabitat structure and diversity

- Mapped and assessed all artificial structures, bank armor, revetment, and constructed banks and channel
- Streambed sampling to assess bed composition, embeddedness, armoring
- Interview with regional aquatic biologist
- Upper Yampa River Watershed Plan (2016)
- Yampa River 2007 Benthic Invertebrate and Water Quality Sampling-GEI Consultants
- Feasibility of Yampa River Walton Creek Confluence Reconstruction–Stantec (2015)

Trophic Structure

Biotic structure is the biological component of the natural infrastructure of a stream, and the main subject of stream ecology. Biota is an essential element of functional condition due to the essential biochemical processing performed through a characteristic trophic structure. It is a core feature of reach health and an important factor to consider when rating the ability of a reach to perform other functions. The **Trophic Structure** variable is not broken down into subvariables, so all of the trophic levels and taxonomic groups must be considered together.

Scoring Guidelines

Scoring Guidelines for Trophic Structure			
A	≥ 90	Negligible	Community structure is natural and appropriate for a well-functioning river in its process domain. It is representative of the native, undisturbed condition.
B	≥ 80	Mild	Community structure consists of mostly native species. Distribution, age structure, or overall biomass of species may be slightly altered, but all functional guilds are appropriately represented and filled by native species.
C	≥ 70	Significant	Community structure is altered. Exotic species may be common, diversity lacking, and/or species distributions skewed, but niches typical of natural niches. Important functional guilds are appropriately represented even when composed of nonnative species.
D	≥ 60	Severe	Community structure is severely altered and may include a preponderance of exotic species, major loss of diversity, or lacking keystone species. One or more important functional guilds is unfilled or poorly represented.
F	≥ 50	Profound	Community structure is fundamentally altered. Examples include communities dominated by exotic species and communities with multiple important functional guilds that are vacant or severely diminished.

Data Sources

Relevant Reports

- Aquatic Wildlife Management Plan-CDW
- Management Plan for Endangered Fishes in the Yampa River Basin-USFS
- Water-Quality Assessment and Macroinvertebrate Data for the Upper Yampa River Watershed, Colorado, 1975-2009-USGS
- Yampa River 2007 Benthic Invertebrate and Water Quality Sampling-GEI Consultants
- Yampa River Management Plan (2003)
- Ranking Predatory Threats by Nonnative Fishes in the Yampa River, via Bioenergetics Modeling-Johnson et. al.
- Yampa River 2007 Benthic Invertebrate and Water Quality Sampling-GEI Consultants
- Upper Yampa River Watershed Plan (2016)

Additional Surveys, Studies, and Models

- Interview with regional aquatic biologist
- Rapid qualitative assessment of benthic macroinvertebrates during field visits

Overall River Health Grade

An overall River Health grade was calculated for each reach as a weighted average of its variable scores. The percent contribution of each variable is given in the table below. Segment grades were calculated as an average of their composite reach scores weighted by reach length (stream feet).

Variable	%
Flow Regime	15
Sediment Regime	5
Water Quality	10
Landscape	5
Floodplain Connectivity	10
Riparian Condition	15
Organic Material	5
Morphology	10
Stability	10
Physical Structure	10
Trophic Structure	5