South Arkansas River Stream Health Assessment

County Road 107 to confluence

December 18, 2020
Central Colorado Conservancy, Salida
Trout Unlimited, Collegiate Peaks Chapter
EcoMetrics, Buena Vista
Round River Design, Salida
Supported by: Gillilan and Associates, Buena Vista

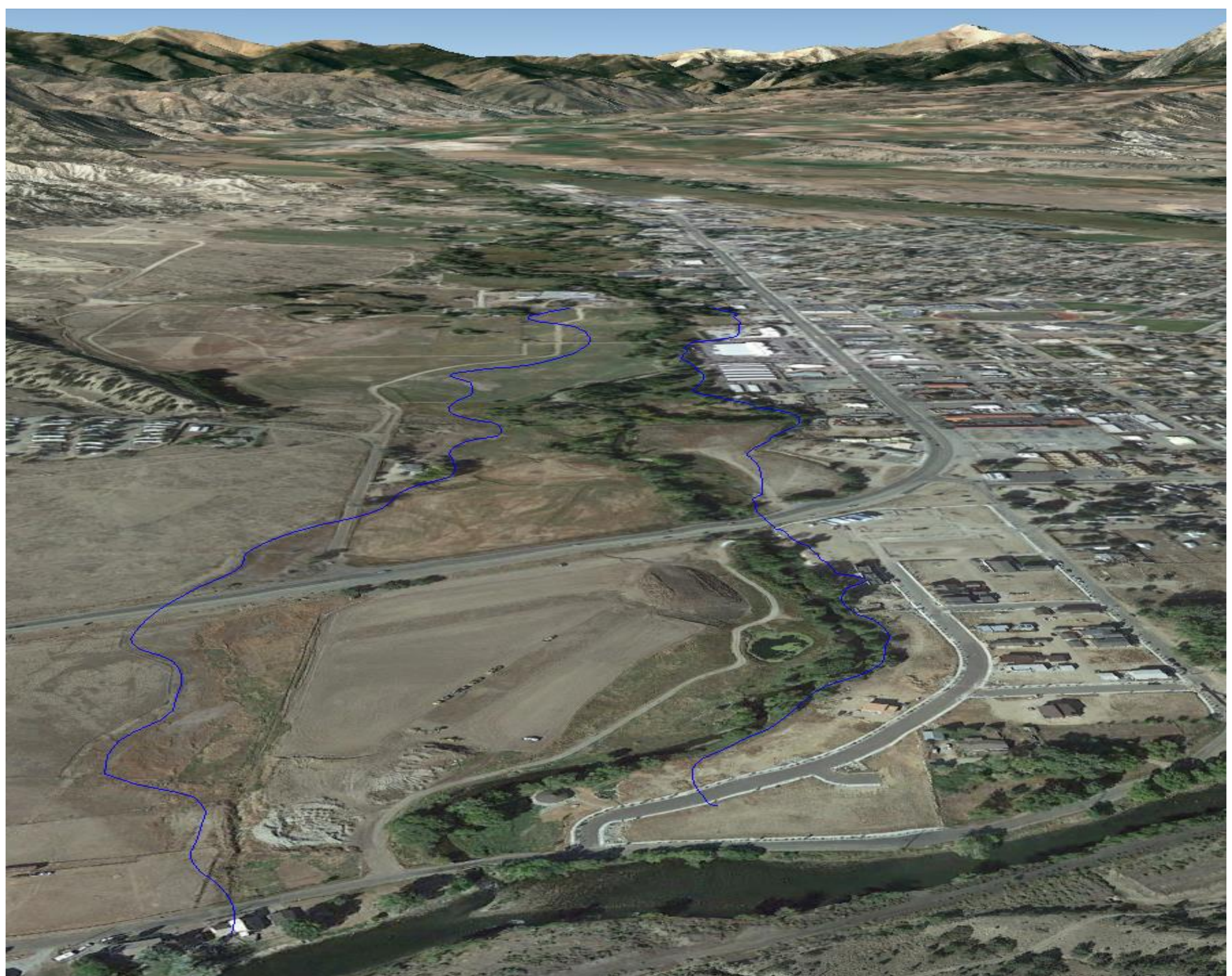
Purpose and scope

This study is a holistic riverscape health assessment of a 1.9 km reach of the South Arkansas River from County Road 107 to the confluence with the Arkansas River east of Salida. The purpose is threefold:

(1) to demonstrate the use of a holistic riverscape health assessment in stream management planning,

(2) to identify potential opportunities to restore or conserve stream health and function, and

(3) to provide a rational basis for restoration and/or conservation plans.



Executive summary

This study is a holistic stream health assessment of the South Arkansas River. It builds upon prior work by the South Arkansas Watershed Coalition to identify conservation and restoration potential on the 1.9 km reach through Salida from County Road 107 downstream to the confluence with the Arkansas. This reach is highly modified for past and current land and water uses. Flow regime is significantly diminished due to upstream water diversions. The stream is channelized and often deeply entrenched. Most of stream corridor was converted for ranching and agriculture in the 1800s which is also when the major roads, and rail lines were built across it. Nowadays, the 150-year-old valley-bottom ranching uses are giving way to urbanization. Most of the riverscape has become incrementally constrained by infrastructure and development, leaving less room for ecosystem function. In its static and greatly simplified state, with a shrunken corridor, narrowed floodplain, and diminished flows, riverscape health and resilience are waning. Composite stream health scores on the reach range from C (significantly impaired) to D+ (severely impaired).

Opportunities to improve stream health and resilience depend upon the ability to reverse or mitigate these impacts, the causes of impairment, to restore natural ecosystem processes and give back some space where these processes can operate. The best prospect for meaningful improvement is on the segment of the old Vandeveer Ranch owned by the City of Salida plus the adjacent private properties up- and downstream. Land use on this section of the stream corridor has moved on from historical industrial-scale ranching, the stream is much less entrenched and beginning to recover naturally, and most of the direct causes of impairment can be practically and feasibly mitigated. Past levees and cross-valley road fills can be removed to reverse the impacts of channelization, entrenchment, and floodplain disconnect; and with improved hydrology native riparian vegetation and wetland can be reestablished. Simple treatments can be applied to promote natural fluvial processes such as sediment capture, scour, structural complexity, and riparian forest regeneration. In short, this segment provides a rare opportunity where natural stream ecosystem processes may occur over a broader portion of the historical riverscape without threatening infrastructure or infringing on property owner's needs. Conservation and process-based restoration of the riverscape aligns well with landowner values of increased natural habitat, floodplain function, open space, recreation, and environmental education. On other segments where stream functions are constrained by land use, development, or infrastructure, marginal stream health gains or limited enhancement benefits might be possible using costly engineering-based or artificial approaches.

Contents

Introduction and background

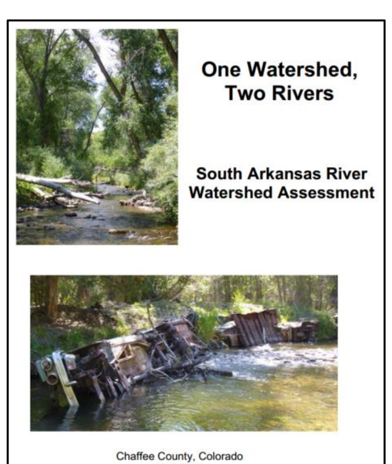
The South Arkansas River, or Little River, is a tremendous resource for residents of Chaffee County. From its origins high in the Sawatch Range, the South Arkansas flows along and through public lands, ranchlands, residential, and commercial neighborhoods. Along the way it provides drinking water to the City of Salida, irrigation water to local ranches, critical habitat for fish and wildlife, and recreational opportunities for residents and visitors. Streams and wetlands comprise only 2% of our land cover in Chaffee County, they benefit more than 75% of our wildlife species. Healthy riverscapes, the green ribbons that fill stream corridors, are living filters that attenuate floods, enhance water quality, recharge groundwater, provide open space, aesthetic values, and a chance for all generations to experience and learn about nature.

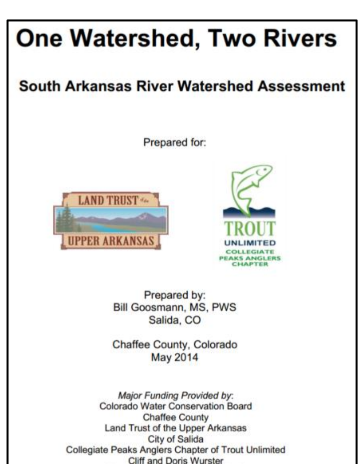
Central Colorado Conservancy and the Collegiate Peaks Chapter of Trout Unlimited have teamed up to study opportunities along the South Arkansas River to improve stream health while supporting landowners along the river with their management goals. In 2014 we completed the first ever river health assessment of the South Arkansas, which gave us a great foundation for understanding of this river system and its many functions. While many of the findings of that study remain true today, a lot has also changed in our watershed. We have seen a dramatic shift in forest health, increasing risk of wildfire, and growing development pressure along the stream corridor. There has also been a paradigm shift in river science and understanding of stream processes that illuminated the importance of biotic elements such as vegetation, wood, and beavers as critical drivers of stream change. Healthy streams are no longer viewed as a static channels that optimize water conveyance, but as complex and dynamic ecosystems that operate over broad riverscapes. When they are able to function naturally and to adapt and adjust over time, streams like the South Arkansas create their own habitat while providing resilience to flood, drought, and the runoff from wildfires.

In 2020 we began to explore conservation and restoration opportunities along the reach from County Road 107 downstream to the confluence with the Arkansas River. We secured grants from Colorado Water Conservation Board's Watershed Restoration Program and Trout Unlimited's Embrace a Stream program to develop conservation and restoration concepts aimed at preserving or improving health and resilience of the Little River. This report is the culmination of a holistic riverscape health assessment that identifies several conservation and restoration prospects which appear to be quickly vanishing along this increasingly urbanized stream. We look forward to working with the City of Salida and other interested landowners along this reach to explore strategies to protect and restore riverscape health and resilience so that the many services the South Arkansas River provides our community can be enjoyed for generations.

CENTRAL COLORADO CONSERVANCY
Protecting the Lands and Waters that Sustain Us

TROUT UNLIMITED COLLEGIATE PEAKS CHAPTER





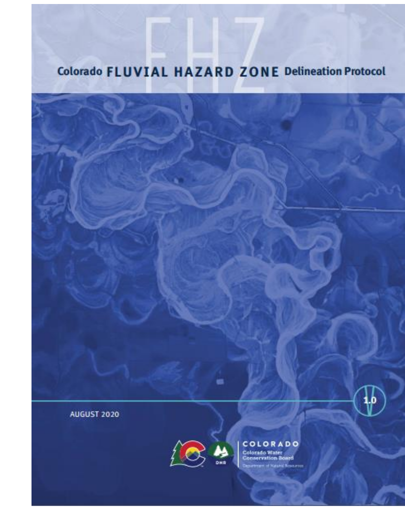
← The 2014 South Arkansas River Watershed Assessment

An assessment of the South Arkansas River Watershed was made for the South Arkansas Watershed Coalition (SAWC), a combined effort of the Central Colorado Conservancy (then known as the land Trust of the Upper Arkansas) and Collegiate Peaks Chapter of Trout Unlimited by Bill Goosmann. A report from this study, submitted in May 2014, provides a wealth of useful information and a foundation for our assessment of stream and riverscape heath. We refer to this report frequently in this document as the "2014 SAWC Report".

Resilience to natural hazards and stream health go hand in hand →

Stream health assessment and fluvial hazard mapping are complimentary studies that provide useful information to decision-makers in stream management planning efforts. Many of the stressors that impair streams are caused by actions taken to engineer riverscapes to protect people and property from natural and predictable fluvial processes. Anticipating these hazards when planning land use, development, conservation and restoration is a good way to protect stream health and valuable ecosystem services while simultaneously reducing risk. This is the path to building healthy resilient communities.

For more information about FHZ mapping in Colorado, see https://www.coloradofhz.com.



A holistic, evidence-based, empirical approach to stream health assessment

Holistic stream health assessment requires a multidisciplinary approach. After carefully delineating the riverscape, hydrological, geomorphological, chemical, and biological evaluations are synthesized into a holistic view of system health to identify the degree and causes of impairment. Factors are rated for degree of impairment using an academic grading scale (A-F) based on predefined criteria that indicate degree of departure from natural pre-disturbance reference condition. Like all assessments (ecological or otherwise) the ratings are informed opinions based on the best available empirical evidence. Grades may be challenged or refined at any time as more evidence or better interpretation becomes available.

Direct evidence of impairment may come from existing studies, monitoring data, field and remote observations, and/or detailed surveys. Judgments must be corroborated by the documentation of stressors—the anthropogenic impacts that cause impairment. Knowing the causes of riverscape health impairment, as well as the degree of impairment, is important in deciding if, where, and how efforts to improve stream health through conservation or restoration might be feasible.

Glossary

Geography and process

Stream – a course through which water naturally flows through a landscape. Geographically, the stream ecosystem is synonymous with riverscape which is mapped as a corridor (*i.e.,* active stream corridor) and measured in with length and width

Riverscape – the corridor through which water naturally flows, including and channels, swales, backwater, ponds, floodplain, riparian, wetland, and hyporheic zones. It is the area in which a stream ecosystem occupies, recently occupied, or could reasonably occupy in the contemporary climatic regime, and is therefore aligned geographically with the active stream corridor, riparian zone, and valley-bottom.

Channel – one component of the riverscape where surface water flows between well-defined banks

Riparian zone – the area within which riparian vegetation would naturally persist; geographically synonymous with the ASC, valley-bottom, and extent of the riverscape

Valley-bottom – the relatively flat bottom of an active alluvial valley; geographically synonymous with the ASC, riparian zone, and extent of the riverscape

Wetland – areas that are seasonally or perennially saturated, with characteristic soil and hydric vegetation. Some but not all riparian areas are wetland.

Stream evolution – the geomorphological and ecological progression of change in a riverscape, described as stages in predictive models (see Cluer and Thorne, 2014, for example)

Channelization – consolidation of flows into a channel as a result of anthropogenic impacts, either intentional or as an indirect result of riverscape changes

Entrenchment – the degree to which a channel is hydrologically and ecologically disconnected from the rest of the riverscape.

Incision – a cause of entrenchment due to downward erosion of a stream; degradation

Aggradation – raised elevation due to the accumulation of sediment in a channel or other part of the riverscape

Reference reach – a relatively unimpaired riverscape in exhibiting natural processes and sustainable performance of functions. Reference reaches must be from similar geological hydrological, and ecological context to the reach being assessed

Stream health factors

Flow regime – the pattern of water supply to a stream reach, defined by the amount and timing of flows.

Materials supply – the pattern of sediment, wood, and detritus supply to a stream reach, defined by the amount and timing of inputs

Water Quality – physicochemical properties of water on a stream reach

Landscape support – connectivity between the riverscape and surrounding landscape, particularly related to the exchange of materials, energy, and biota

Riverscape hydrology – the spatial and temporal pattern of water distribution across a riverscape

Riverscape dynamics – spatial and temporal patterns of fluvial geomorphic activity in the riverscape

Riparian vegetation – spatial and temporal patterns of vegetation extent, diversity, regeneration, and succession in the riparian zone

Physical heterogeneity – topographical, bathometric, and structural diversity in the riverscape at vegetation, macro- and micro-spatial scales

Aquatic biota – community and trophic structure of aquatic and semi-aquatic organisms, especially with respect to the impact of biota on ecosystem function

Careful and consistent use of language is the key to effective communication.

System health, function, and services

Stream health – Physical and biological integrity of a stream ecosystem (*i.e.,* riverscape) defined as its

- ability to perform vital functions (natural processes)
- ability to recover from stress (resilience)
- ability to perform valued roles (ecosystem services)

Stream health is an inherent property of the stream ecosystem, inversely proportional to the degree of human disturbance.

Impairment – loss of function in one or more stream health factors or disruption of natural functions due to anthropogenic impacts; decreased stream health.

Stressor – anthropogenic disruption of natural stream ecosystem processes; the cause of impairment.

Stream (ecosystem) functions – the natural hydrological, geomorphological, physicochemical, and biological processes carried out in a stream ecosystem (riverscape). Functionality is a factor of stream health.

Stream (ecosystem) services – riverscape functions that are valued by society; services rendered by stream ecosystems that benefit people. Some examples are water supply and delivery, flood attenuation, water quality maintenance, habitat for valued fish and wildlife, recreational opportunity.

Conservation – actions taken to prevent stream health impairment due to potential future stressors. It may involve protective easements, management agreements, and/or stewardship.

Restoration – actions taken for the purpose of improving stream health and function. The distinctions between restoration and enhancement, stabilization, or river engineering are often made more explicit with the modifier "process-based" restoration. Societal benefits derive from sustainable riverscape functions and increased ecosystem services.

Enhancement – actions taken for the purpose of maximizing or increasing one or a few select stream functions. Societal benefits are defined by discrete functional objectives.

Stabilization/containment – actions taken for the purpose of containing flows or managing natural fluvial processes to reduce risk to people or property. Societal benefits derive from reduced risk to life and/or property.

Fluvial hazard terms

Fluvial Hazard Zone (FHZ) – the area a stream has occupied in recent history, may occupy, or may physically influence. It includes ASC and FHB plus auxiliary components including Avulsion Hazard Areas (AHZ), Fans (F), Geotechnical Flags (GF), and disconnected portions of the stream corridor

Active stream corridor (ASC) –the land influenced by fluvial processes in the contemporary flow and sediment regime

Fluvial Hazard Buffer (FHB) – erosion-prone land adjacent to the active stream corridor

Avulsion Hazard Zone (AHZ) – the area a stream may occupy and impact due to a wholesale shift in channel position on the valley floor

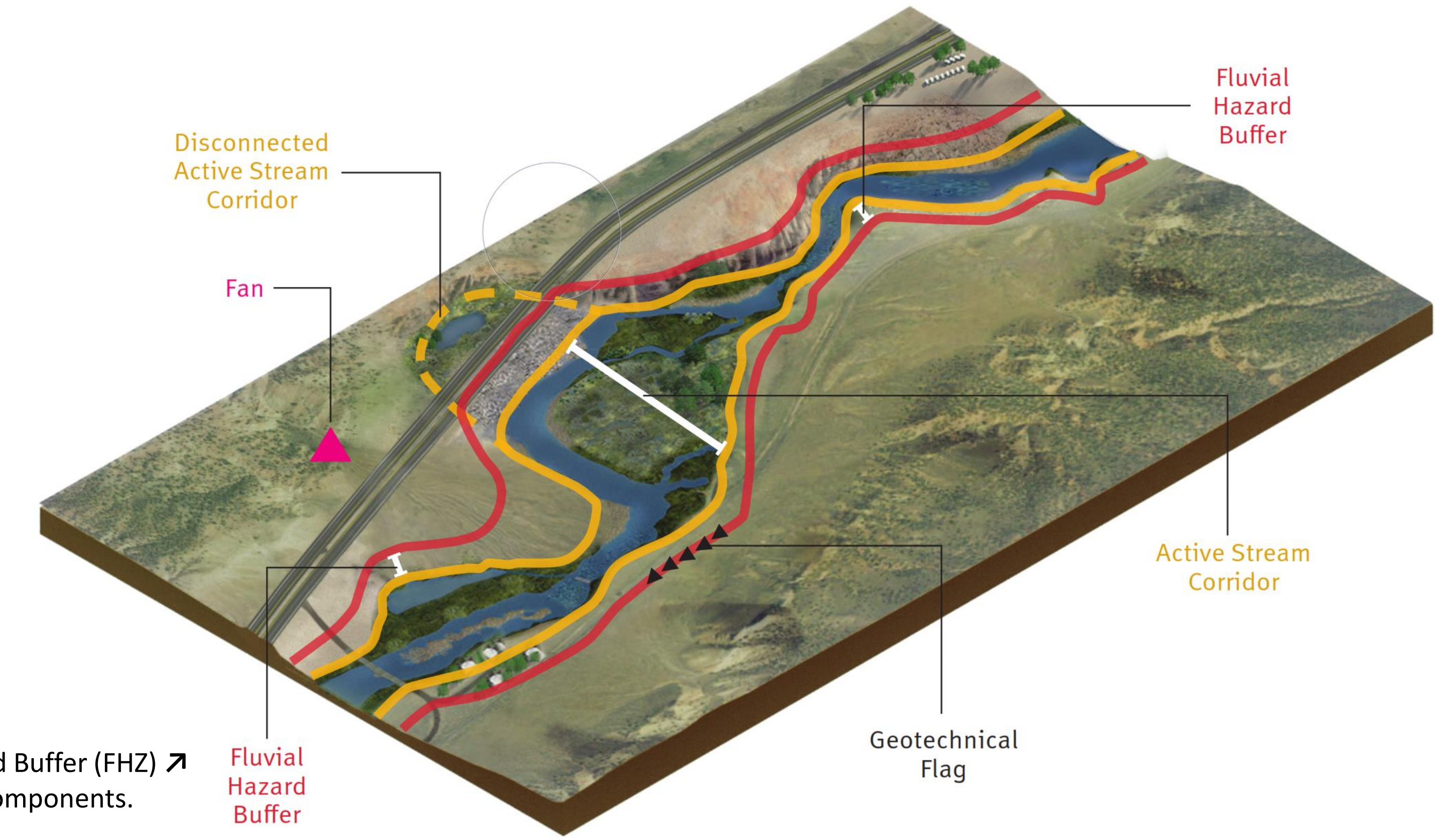
Fluvial processes and fluvial hazards

Fluvial geomorphic processes are natural phenomena in stream corridors such as erosion, sediment transport and deposition, wood recruitment and jamming, and the structural influences of plants and animals. Fluvial geomorphic processes become hazardous when they encounter public infrastructure, houses, businesses, and other investments within and adjacent to the stream corridor. To help communities better understand their existing risks associated with erosion, sediment deposition, and other dynamic river processes, the Colorado Water Conservation Board (CWCB) developed a technical protocol to identify and map the areas where fluvial hazards may exist.

Flood hazard identification and mitigation must recognize that streams are naturally dynamic, prone to move within a corridor, and apt to modify their margins as they transport and deposit water, sediment, and debris inputs from their watersheds. Flood insurance claims and property loss data demonstrate that in Colorado, reliance on traditional flood inundation maps alone does not provide a comprehensive characterization of the hazards imposed by fluvial processes. By taking into account the full suite of dynamic stream processes, CWCB's State of Colorado's Fluvial Hazard Zone Mapping Program represents a significant and necessary step forward in adaptively managing stream corridors, preparing for and mitigating flood impacts, and making informed land use decisions based on awareness of fluvial processes, stream health, and resilience.

FHZ maps provide communities, property owners, and emergency response teams with information on flood- and stream-related hazards beyond those identified by traditional floodplain mapping. They are a tool to help stakeholders visualize and understand the inherent risk on lands that have been and will someday again be shaped by water and sediment moving through the landscape, particularly after large disturbance events like wildfires. As stream corridors are environmentally and economically important areas, Fluvial Hazard Zone maps can also aid in prioritizing lands for environmental, wildlife, or agricultural conservation.

The Fluvial Hazard Zone (FHZ) is the area a stream has occupied in recent history, may occupy, or may physically influence as it stores and transports water, sediment, and debris. FHZs are mapped by fluvial geomorphologists—scientists who study how flowing water shapes and modifies the Earth's surface through erosional and depositional processes. Mapping is completed through the interpretation and synthesis of geomorphic, geologic, hydrologic, and biotic information *(i.e.,* data that describes the physical location, form, flooding intensity, active sediment and debris transport, and ecological conditions of a riverine system).



Example Fluvial Hazard Zone (FHZ) map showing the Active Stream Corridor (ASC), Fluvial Hazard Buffer (FHZ) ↗ and auxiliary Disconnected Active Stream Corridor (DASC), Fan (F), and Geotechnical Flag (GF) components.

***Since 1978, approximately 49% of all National Flood Insurance Program claims in Colorado have come from policies written outside the high-risk area depicted on the FEMA FIRMs. The 2013 Colorado Front Range flood resulted in 52% of flood insurance claims originating outside of regulatory floodplains clearly demonstrating that reliance on flood inundation maps alone does not provide a complete picture of flood hazards*.**

FLUVIAL HAZARD ZONE MAPS (FHZ)

- Identify where a stream may move or may cause damage during a flood (*e.g.,* erode a high bank and undermine a structure or deposit sediment and debris).
- Show susceptibility to flood hazards rather than probability.
- Use a variety of data and methods including high resolution topographic data *(i.e.,* LiDAR), geologic and soils maps, and field verification.
- Assume that stream dimensions change during a flood and that flows are transporting sediment and debris.
- Rely on fluvial geomorphic (stream form and process) expertise to interpret landforms within the floodplain and along a stream.
- Do not affect flood insurance rates, though those with structures within the FHZ are encouraged to purchase flood insurance.
- Regulation, if any, is determined by local communities.
- Non-federally regulated product.

vs.

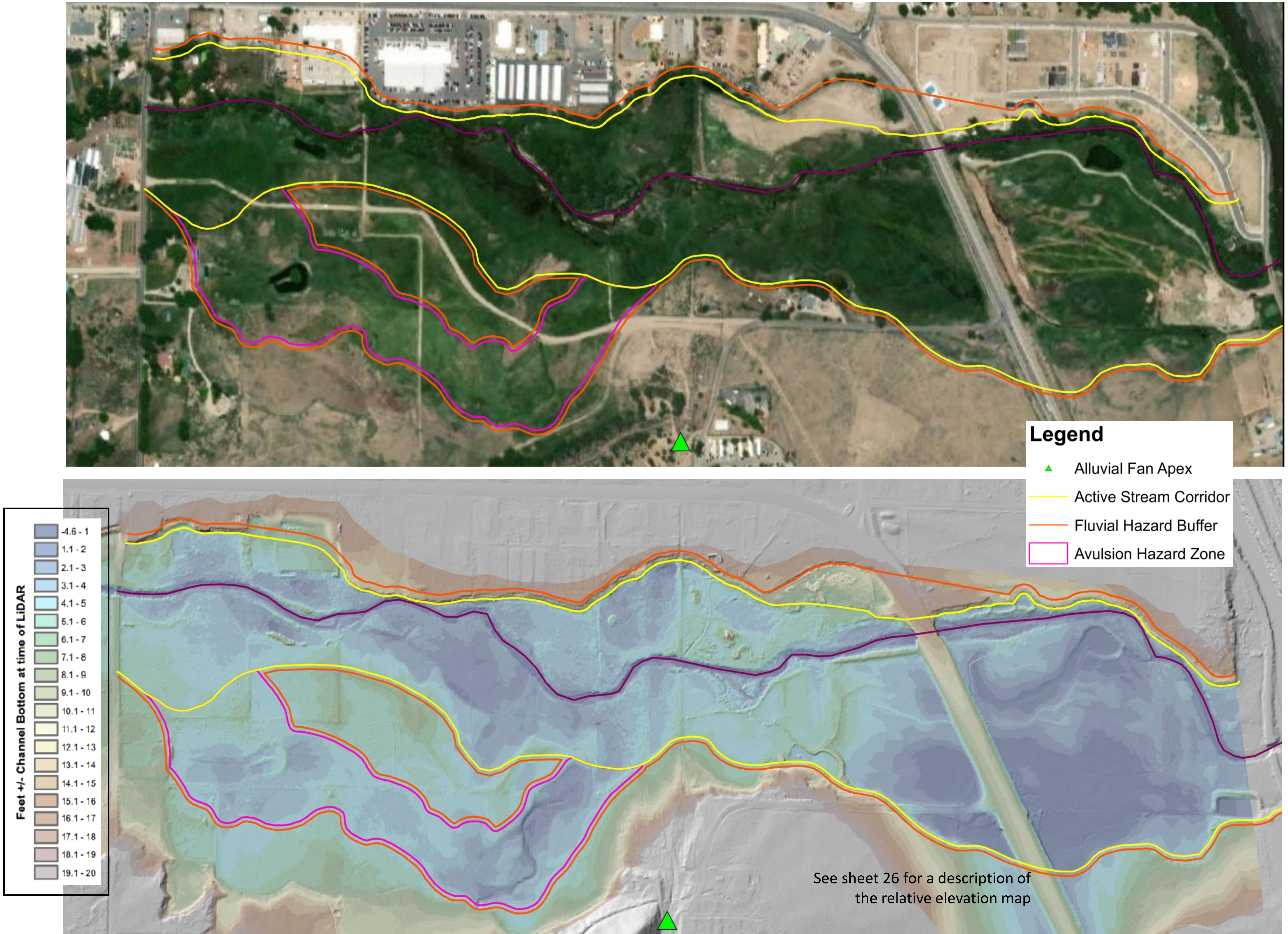
FLOOD INSURANCE RATE MAPS (FIRM)

- Map areas of flood water inundation.
- Correspond to only one estimated peak flow.
- Use a variety of data and methods to map flood surface elevations and extent. This may include historical flood data, rainfall data, topographic data (i.e., LiDAR and field surveys), along with computer models that calculate results for hydraulic equations.
- Rules for map development are set by the federal government via FEMA.
- Assumes a static stream system with no changes to a stream's shape throughout the duration of a flood.
- Developed with methods that typically do not account for the transport of sediment and debris.
- Are typically made by engineers with experience in hydrologic (rainfall and watershed) and hydraulic (stream channel and floodplain) computer modeling.
- Created as part of the National Flood Insurance Program (NFIP) and used to determine where flood insurance is required and what rates apply.
- Federal and State-regulated product (for community participation in the NFIP).

The Active Stream Corridor

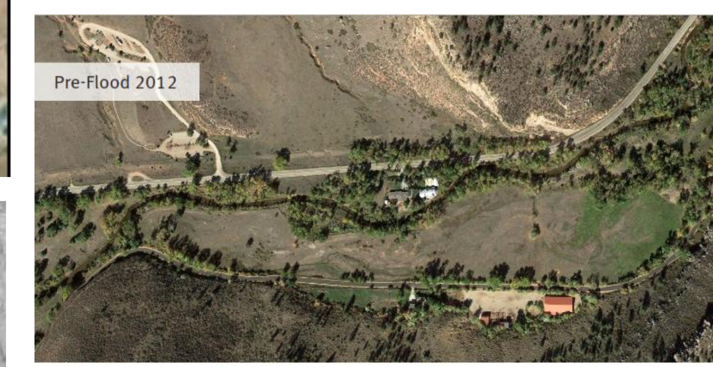
The Active Stream Corridor (ASC) is land that has been or may be shaped by erosion and deposition under a range of conditions in the prevailing flow and sediment regimes *(i.e.,* the contemporary geomorphic floodplain). Dominant processes within this corridor include channel incision, widening, avulsion, lateral and downstream migration, aggradation, and braiding. These processes manifest over a range of time and space.

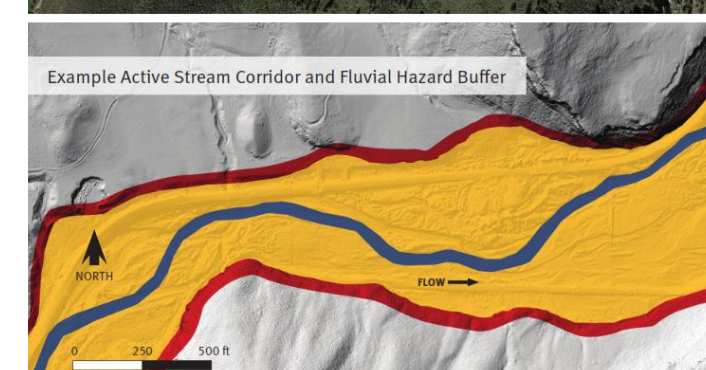
The geographical extent of the riverscape is defined by the boundaries of the ASC.



← Conceptual Fluvial Hazards Map of the South Arkansas Corridor. The Fluvial Hazard Zone consists of two primary components: the ASC (described above) and the Fluvial Hazard Buffer (FHB). The FHB accounts for erosion prone land located beyond the Active Stream Corridor, such as hillslopes and terraces, that may be susceptible to slope failure as a result of toe erosion caused by fluvial scour. It is a buffer applied to the outer boundary of the ASC. Avulsion Hazard Zones (AHZs) mark the area a stream may occupy and impact due to a wholesale shift in channel position on the valley floor as defined in the Colorado FHZ Protocol.

These draft maps were developed for planning purposes only and were delineated with topographic data from a 2011 LiDAR survey.





Inundation Risk

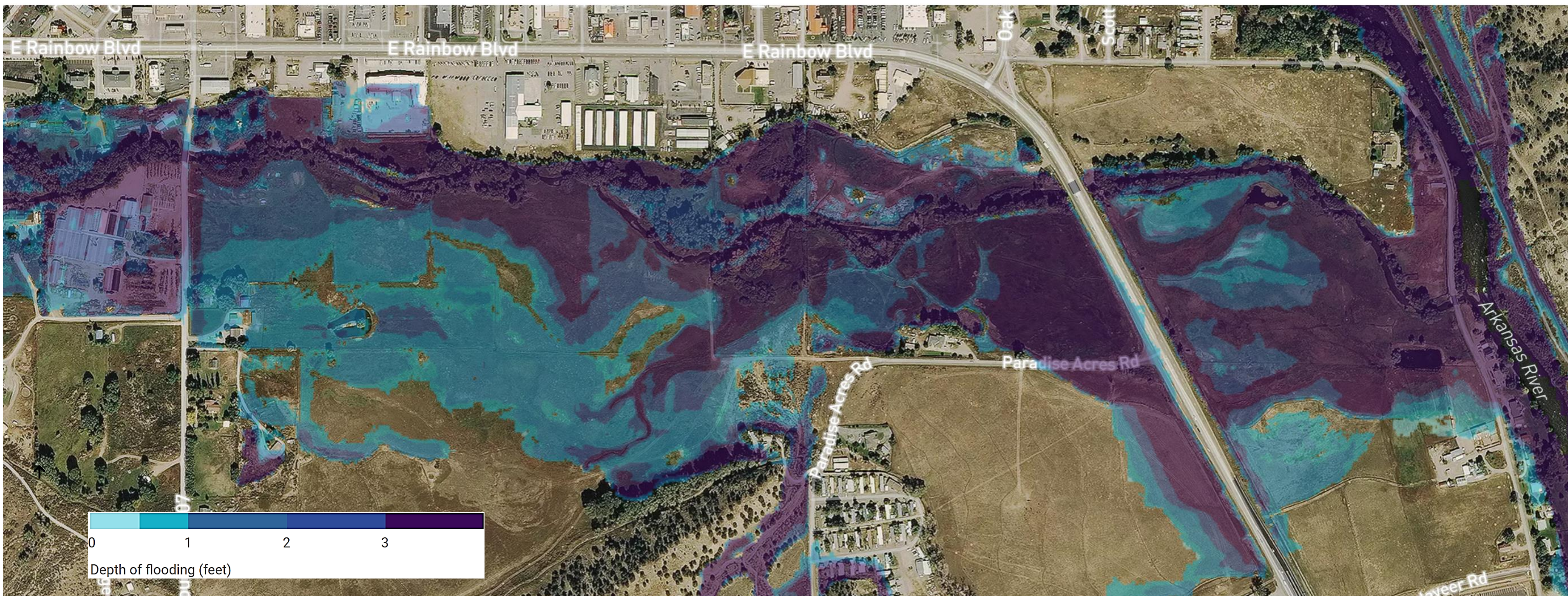
Flooding is the most expensive natural disaster in the United States, costing over $1 trillion in inflation adjusted dollars since 1980. The First Street Foundation Flood Model *(i.e.,* Flood Factor) is a nationwide, probabilistic flood model that shows risk of flooding from rain, rivers, tides, and storm surge. It builds off decades of peer-reviewed research to forecast how flood risks will change over time due to changes in the environment. First Street's data, and other open-source datasets, can serve as important complements to existing sources of flood risk data such as FEMA maps. FEMA maps are designed to set insurance rates and for use by decision-makers, and technical experts—not as communication tools for the general public to understand actual flood risk. This often leaves average Americans navigating the alphabet soup of AE, X, and V zones and having a difficult time understanding how concerned they should be about flood risk. FEMA maps can also create a false sense that flood risk is binary by focusing on whether a property is "inside" or "outside" of a flood zone. Because this designation is binary, it does not provide any indication of risk magnitude for individual properties. This communication challenge is compounded by the fact that FEMA's maps significantly underestimate risk. As discussed in the section on fluvial processes and fluvial hazards (sheet 4), FEMA maps assume stationarity in watershed hydrology, floodplain terrain, and channel dimensions and location. They fail to account for a host of dynamic processes inherent in fluvial systems. They are also often outdated. These shortcomings can lead to substantial consequences for property owners.

The Flood Factor tool and its associated data may be useful in helping individuals and community leaders understand risk and make broad management and planning decisions. Potential uses of this data include:

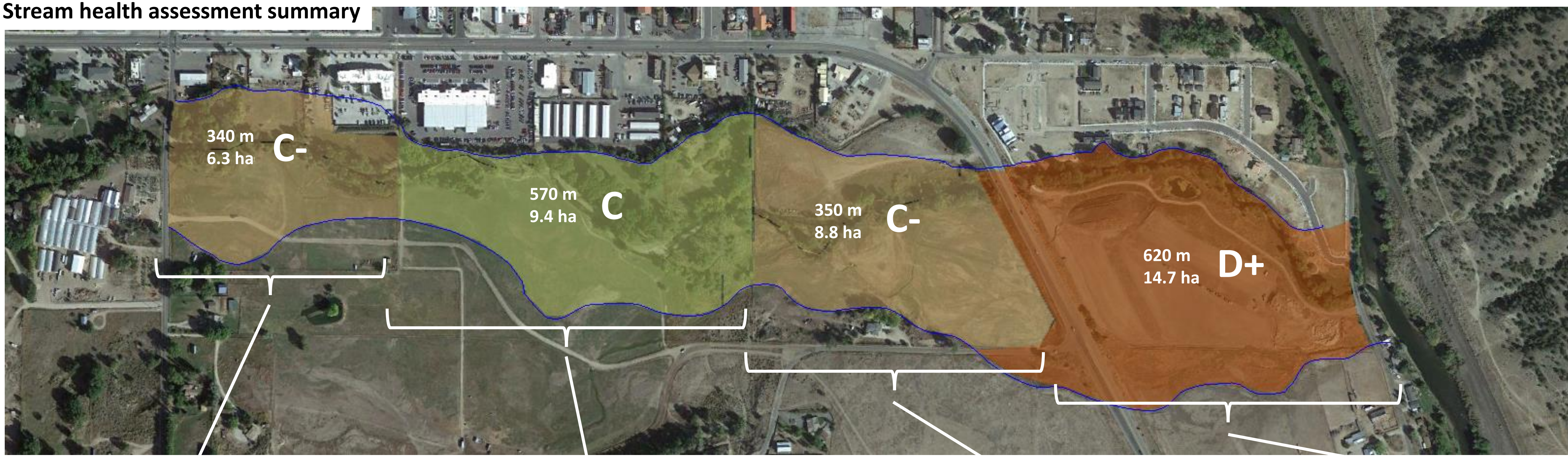
•**Risk Awareness:** This data gives communities a quick and free picture of their flood hazard at both the property and community levels. In order to obtain even screening level data, communities would previously have had to pay for detailed modeling or a flood risk assessment study. While such detailed studies are essential for local planning efforts, they can cost tens of thousands to hundreds of thousands of dollars, a significant financial hurdle for smaller communities or for those with tight budgets.

•**Planning:** This data can help communities understand gaps in FEMA maps, especially in smaller, rural, and inland communities, and prioritize areas in need of future mapping. It can also help identify potential hazard mitigation opportunities by providing an overview of flood risk not captured by FEMA maps. Finally, it can help communities conduct proper emergency response planning and actions, but it does not replace the need for comprehensive planning exercises such as vulnerability assessments or stormwater master planning.

↓ A Flood Factor map of the South Arkansas River corridor shows potential inundation flood risk to an area that correlates with the physical and ecological indicators used to define the ASC.



Stream health assessment summary



Stream Health Report Card: South Arkansas River, SWCC-Wykoff-Smith segment

Driver	Grade	Variable	Grade
Flow regime	C-	Total Volume	C-
		Peak Flow	C
		Base Flow	D+
		Rate of Change	B-
Materials supply	B-	Sediment Supply	B
		Organics (wood, detritus)	C+
Water quality	B	Temperature	B-
		Nutrients, organics	B
		Chemical Conditions, inorganics	B+
Landscape support	C	Land use and buffer	C
		Terrestrial habitat connectivity	C-
		Aquatic habitat connectivity	B+
Riverscape hydrology	D	Frequently saturated area	D+
		Valley bottom/ASC	D-
		Flood-prone area	D
Riverscape dynamics	D	Geomorphic plasticity	D
		Fluvially active zone	D
		Stream evolution	D-
Riparian vegetation	D	Riparian extent	D
		Biodiversity and endemism	C
		Regeneration/succession	D-
Physical heterogeneity	D	Riparian heterogeneity	D+
		Aquatic heterogeneity	D-
		Micro-scale heterogeneity	D+
Aquatic biota	C+	Trophic structure	B-
		Biodiversity and endemism	C+
Riverscape health			**C-**

Stream Health Report Card: South Arkansas River, Vandeveer-Snyder segment

Driver	Grade	Variable	Grade
Flow regime	C-	Total Volume	C-
		Peak Flow	C
		Base Flow	D+
		Rate of Change	B-
Materials supply	B	Sediment Supply	B
		Organics (wood, detritus)	B-
Water quality	B	Temperature	B-
		Nutrients, organics	B
		Chemical Conditions, inorganics	B+
Landscape support	C	Land use and buffer	C
		Terrestrial habitat connectivity	C-
		Aquatic habitat connectivity	B+
Riverscape hydrology	C	Frequently saturated area	C-
		Valley bottom/ASC	B-
		Flood-prone area	C+
Riverscape dynamics	C+	Geomorphic plasticity	B-
		Fluvially active zone	C+
		Stream evolution	C+
Riparian vegetation	C	Riparian extent	C
		Biodiversity and endemism	B-
		Regeneration/succession	C
Physical heterogeneity	C-	Riparian heterogeneity	C
		Aquatic heterogeneity	D+
		Micro-scale heterogeneity	C-
Aquatic biota	C+	Trophic structure	B-
		Biodiversity and endemism	C+
Riverscape health			**C**

Stream Health Report Card: South Arkansas River, Lowry-Treat segment

Driver	Grade	Variable	Grade
Flow regime	C-	Total Volume	C-
		Peak Flow	C
		Base Flow	D+
		Rate of Change	B-
Materials supply	B-	Sediment Supply	B
		Organics (wood, detritus)	C+
Water quality	B	Temperature	B-
		Nutrients, organics	B
		Chemical Conditions, inorganics	B+
Landscape support	C-	Land use and buffer	C-
		Terrestrial habitat connectivity	D+
		Aquatic habitat connectivity	B
Riverscape hydrology	D	Frequently saturated area	D
		Valley bottom/ASC	D+
		Flood-prone area	D
Riverscape dynamics	D	Geomorphic plasticity	C-
		Fluvially active zone	D
		Stream evolution	D+
Riparian vegetation	D+	Riparian extent	D
		Biodiversity and endemism	B-
		Regeneration/succession	C-
Physical heterogeneity	D	Riparian heterogeneity	D+
		Aquatic heterogeneity	D
		Micro-scale heterogeneity	D+
Aquatic biota	C+	Trophic structure	B-
		Biodiversity and endemism	C+
Riverscape health			**C-**

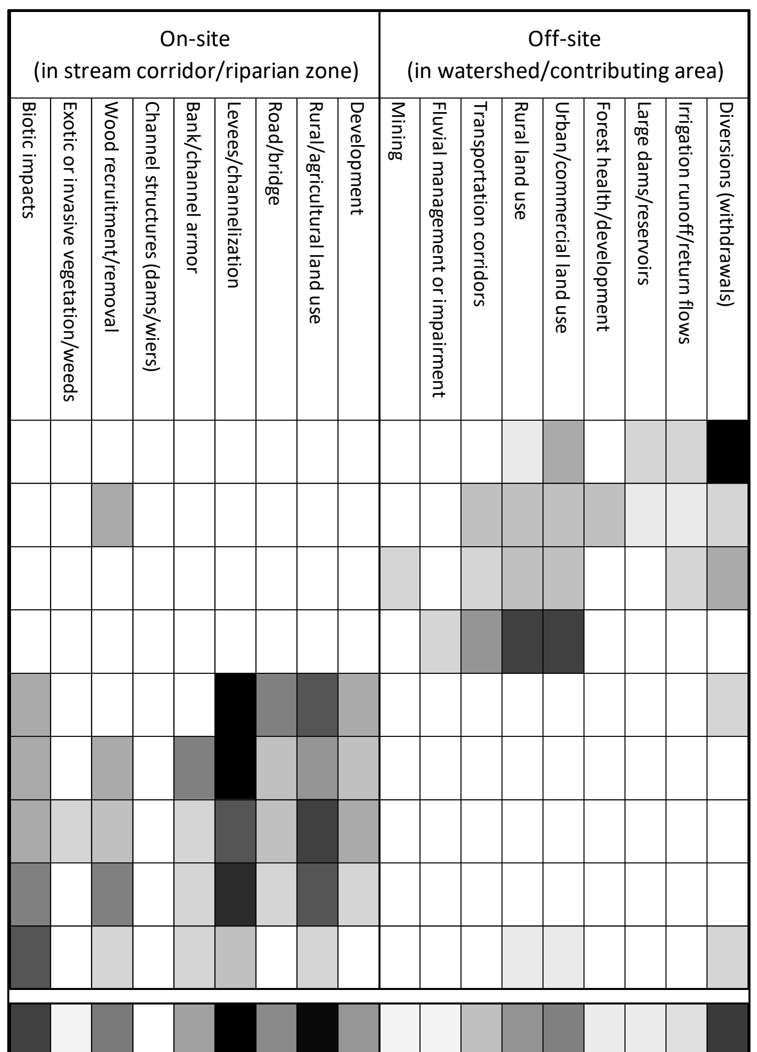
Stream Health Report Card: South Arkansas River, Two Rivers segment

Driver	Grade	Variable	Grade
Flow regime	C-	Total Volume	C-
		Peak Flow	C
		Base Flow	D+
		Rate of Change	B-
Materials supply	B-	Sediment Supply	B
		Organics (wood, detritus)	C+
Water quality	B	Temperature	B-
		Nutrients, organics	B
		Chemical Conditions, inorganics	B+
Landscape support	D+	Land use and buffer	D
		Terrestrial habitat connectivity	D+
		Aquatic habitat connectivity	B-
Riverscape hydrology	D-	Frequently saturated area	D
		Valley bottom/ASC	D-
		Flood-prone area	F+
Riverscape dynamics	D-	Geomorphic plasticity	D-
		Fluvially active zone	D-
		Stream evolution	D-
Riparian vegetation	D	Riparian extent	F+
		Biodiversity and endemism	C
		Regeneration/succession	D+
Physical heterogeneity	D	Riparian heterogeneity	D
		Aquatic heterogeneity	D
		Micro-scale heterogeneity	D+
Aquatic biota	C+	Trophic structure	B-
		Biodiversity and endemism	C+
Riverscape health			**D+**

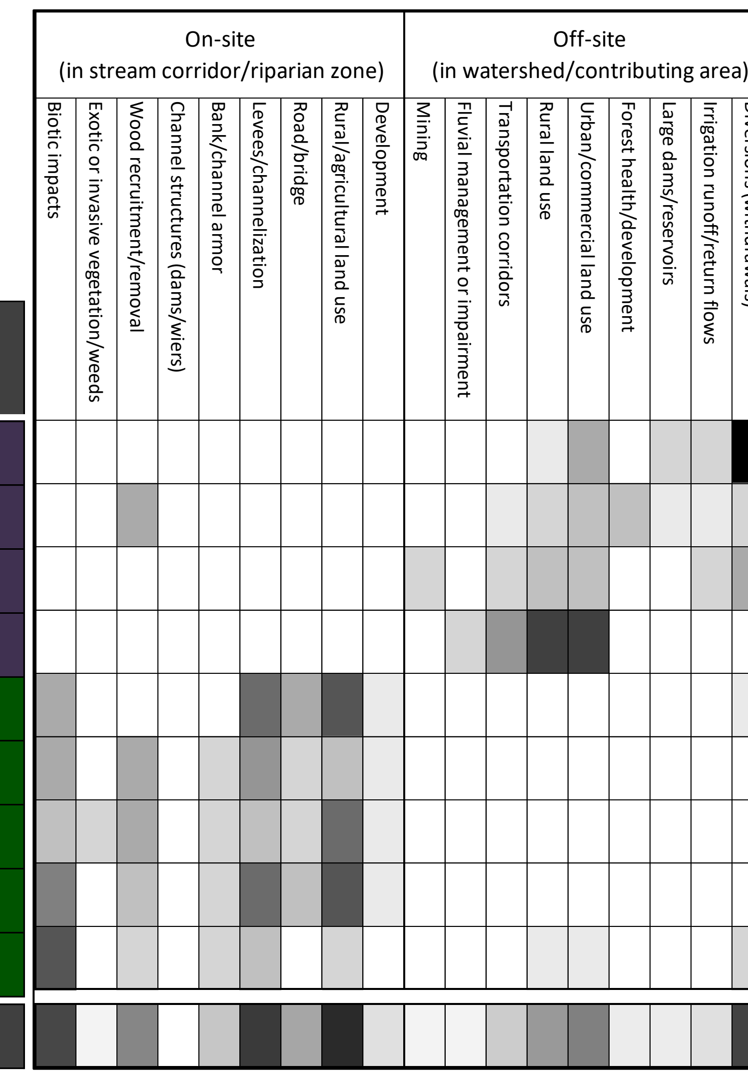
A framework for assessing and communicating riverscape health

The reach is assessed as four segments identified by current land ownership. For each segment, evaluations of 26 variables are expressed as grades (A-F) and bar graphs. These evaluations are used to calculate a summary grade for each of the 9 key drivers of riverscape health, and, ultimately, an overall riverscape health assessment grade for each segment. The variables and drivers shown in purple are watershed-scale (catchment-scale) attributes. Those in green are reach-scale (segment-scale) attributes. Grades reflect a continuum of health condition based on the degree of impairment to natural system processes relative to pre-disturbance reference: A = negligible impairment, B = mild impairment, C = significant impairment, D = severe impairment, and F = profound impairment. Criteria for evaluating the watershed-scale variables may be found on sheet 24. Criteria for the reach-scale variable are on sheet 25.

Stream Health Report Card: South Arkansas River, SWCC-Wykoff-Smith segment	
Flow regime	C-
Materials supply	B-
Water quality	B
Landscape support	C
Riverscape hydrology	D
Riverscape dynamics	D
Riparian vegetation	D
Physical heterogeneity	D
Aquatic biota	C+
Riverscape health	C-

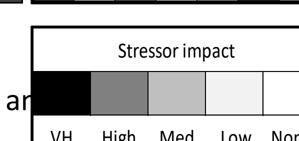


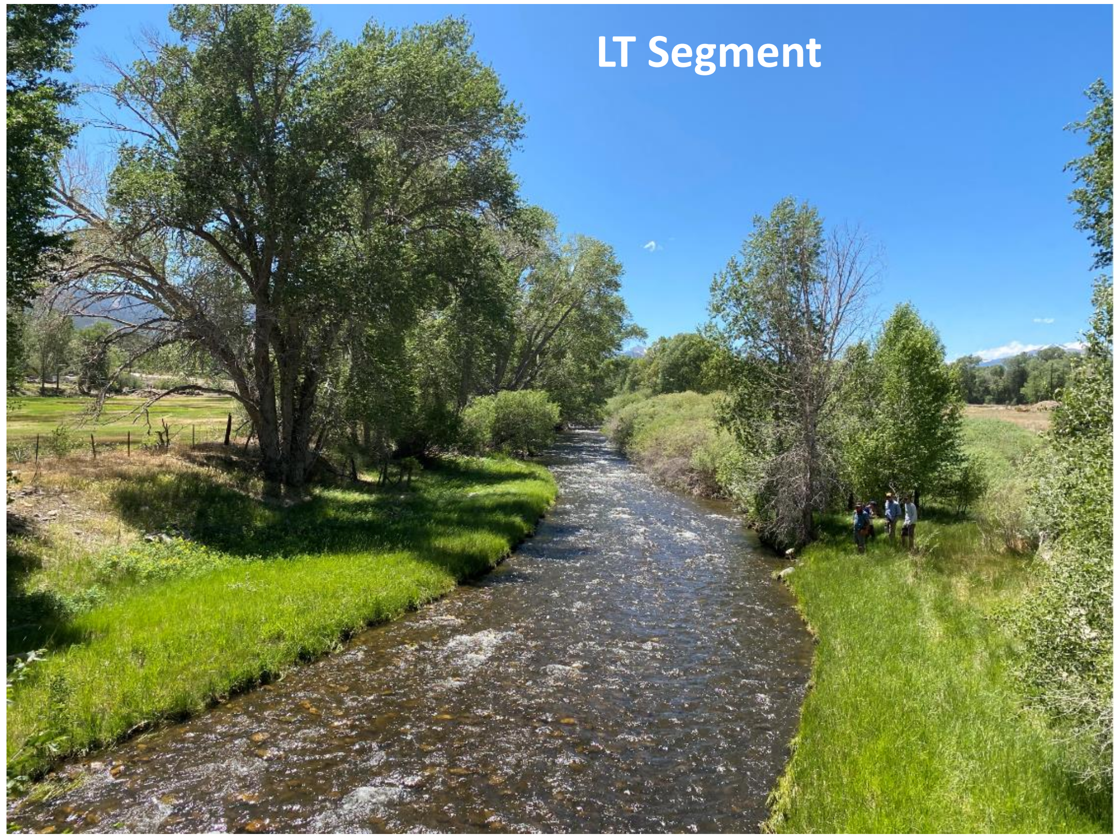
Stream Health Report Card: South Arkansas River, Vandeveer-Snyder segment	
Flow regime	C-
Materials supply	B
Water quality	B
Landscape support	C
Riverscape hydrology	C
Riverscape dynamics	C+
Riparian vegetation	C
Physical heterogeneity	C-
Aquatic biota	C+
Riverscape health	C

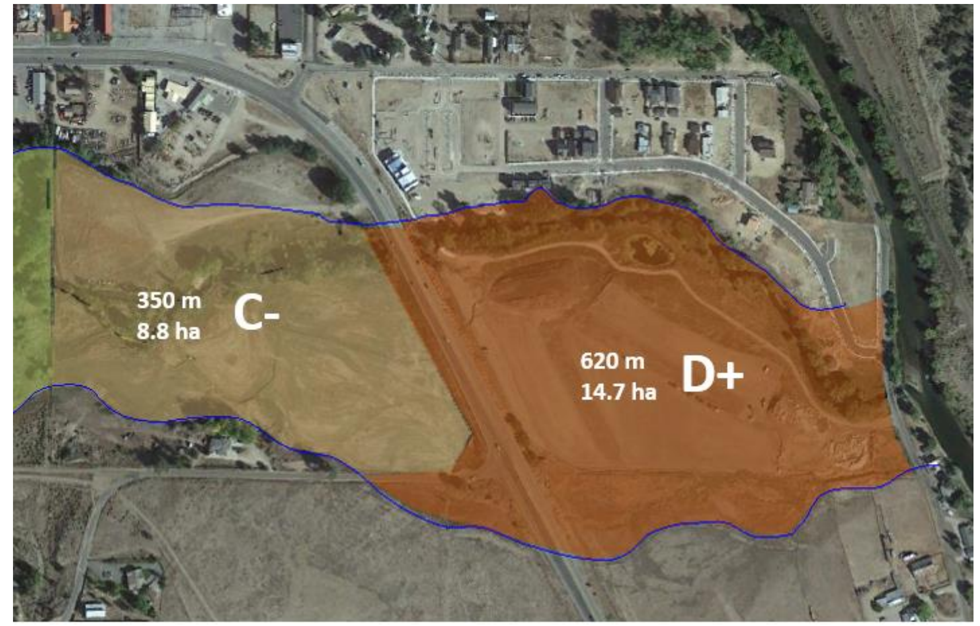


↑ **Stream health report cards** summarize riverscape health for each river segment. Letter grades and bar charts describe the condition and degree of impairment to the 9 key factors. See sheets 14-21 for more detail on the health factors.

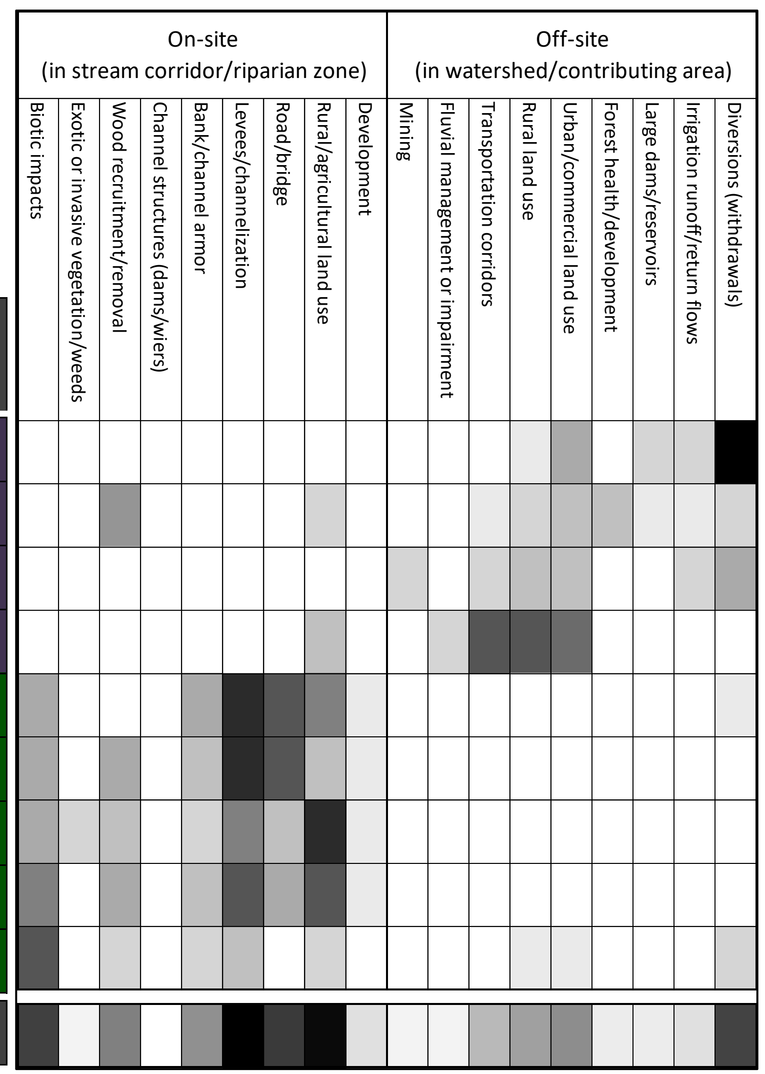
↑ **Stressor matrices** indicate the relative contribution of off-site and on-site stressors to impairment of each riverscape health factor. Note that the stressor categories are overlap ar are often highly interdependent. See sheets 10-13 for more detail on the stressors.



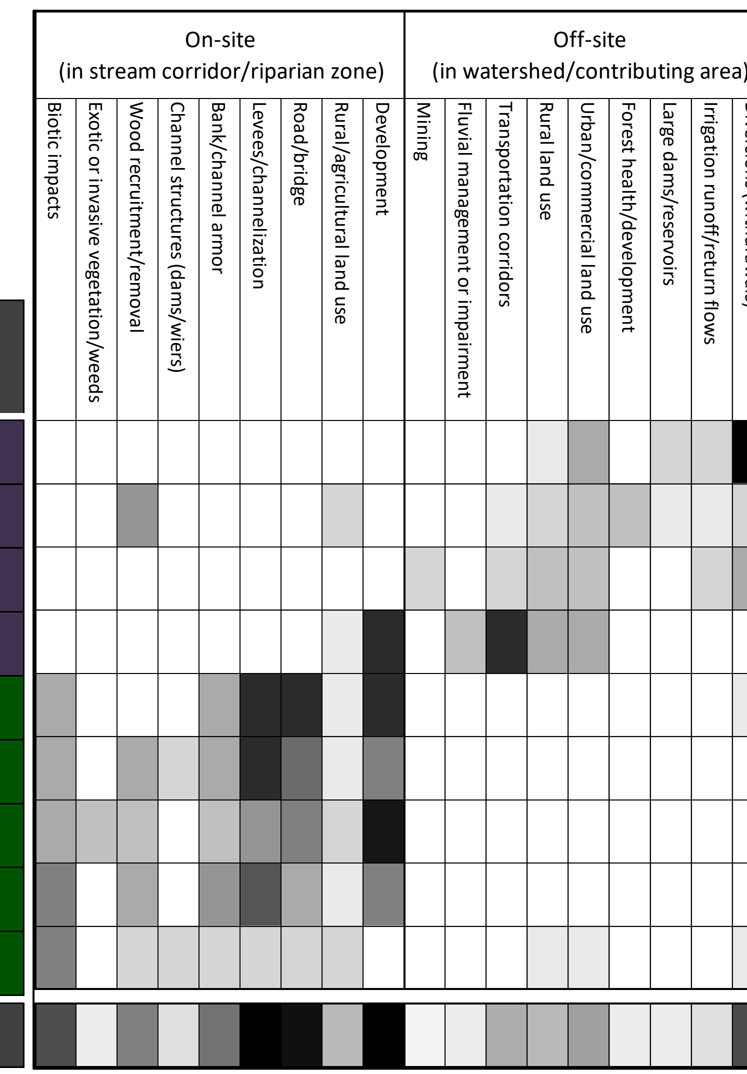


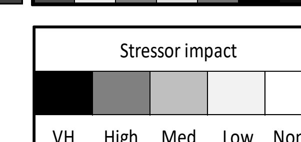


Stream Health Report Card: South Arkansas River, Lowry-Treat segment	
Flow regime	C-
Materials supply	B-
Water quality	B
Landscape support	C-
Riverscape hydrology	D
Riverscape dynamics	D
Riparian vegetation	D+
Physical heterogeneity	D
Aquatic biota	C+
Riverscape health	C-



Stream Health Report Card: South Arkansas River, Two Rivers segment	
Flow regime	C-
Materials supply	B-
Water quality	B
Landscape support	D+
Riverscape hydrology	D-
Riverscape dynamics	D-
Riparian vegetation	D
Physical heterogeneity	D
Aquatic biota	C+
Riverscape health	D+





Off-site stressors

Stressors are the anthropogenic impacts that cause impairment via disruption to natural processes, leading to declines in system health and function. Improving stream health depends on our ability to relieve or mitigate stressors or, in the case of conservation, to prevent the accumulation of more stress by future actions. It is therefore critical to know the causes of impairment if we hope to treat them. On-site stressors have their effects within the stream corridor on the reach and can generally be treated in reach-scale restoration efforts. Off-site stressors (those that act in the contributing watershed or landscape), on the other hand, must be treated at the watershed or landscape scale. Off-site stressors (and the impairment they are responsible for) are generally treated as constraints when evaluating feasibility of reach-scale restoration and conservations actions.

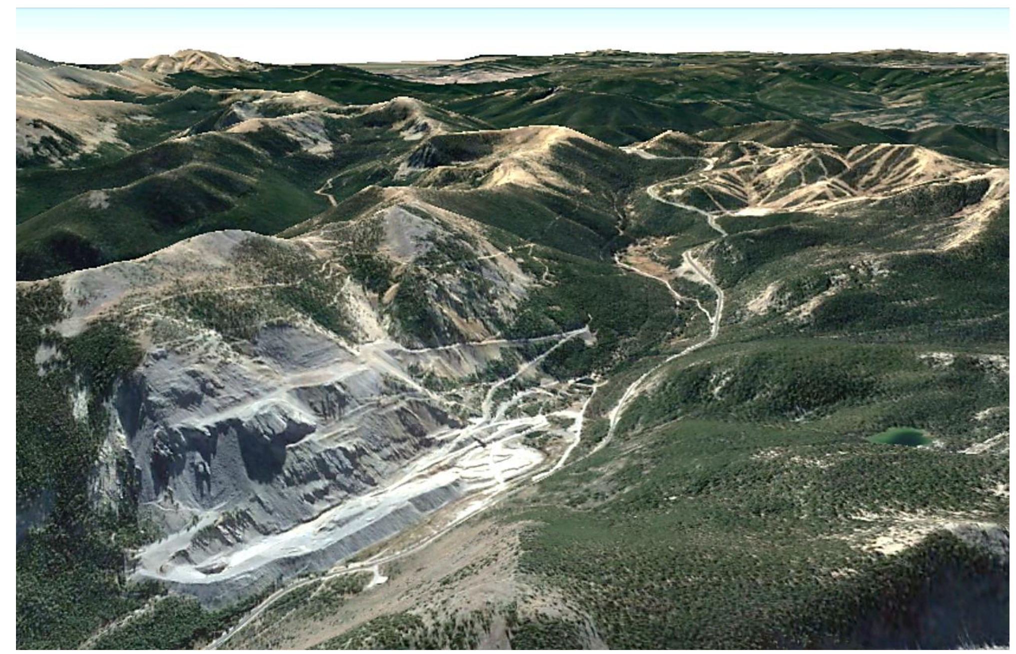
	Stressor	Explanation
Off-site (within watershed/contributing area)	Diversions (withdrawals)	Exported water (withdrawals)
	Irrigation runoff/return flows	Return flows (including water and any pollutants)
	Dams/reservoirs	Large in-line dams and reservoirs (the South Arkansas watershed has only a few small reservoirs)
	Forest health/development	Wildfire burn scars or significant forest health issues in watershed (*e.g.* beetle kill, clear cuts, etc.)
	Urban/commercial land use	Urban and commercial development in watershed or contributing area
	Rural land use	Rural and agricultural development in watershed or contributing area
	Transportation corridors	Highways, roads, railroads, etc. in watershed or contributing area
	Fluvial management or impairment	River management (stabilization, channelization) or impairment (*e.g.* incision, riparian loss)
	Mining	Pollution from active or abandoned mines in watershed (acidity, metals, turbidity, etc.)

Identifying trade-offs and feasibility

The purpose of stressor analysis is to clarify the causes of impairment so planners can focus on impacts that can feasibly be addressed in restoration or conservation. In theory, any stressor could be removed or mitigated to improve riverscape health, but restoration actions to mitigate stressors almost always involve a tradeoff of other values. A cornerstone of good restoration planning is the ability to identify what tradeoffs are necessary to accomplish conservation and restoration goals so decision-makers can evaluate them in cost-benefit analyses.

Water withdrawals and diversions →

Since flow regime on the South Arkansas is impaired by water depletion, one strategy for restoring riverscape health (theoretically) could be to curtail water diversions, but water use can be a very difficult stressor to mitigate. In most cases (as in this diversion for the Harrington Ditch, a source of municipal water for Salida) benefits to riverscape health are outweighed by other uses (*i.e.,* the need for city water. Mitigating the impacts of water diversions would involve a complex collaborative effort on a watershed scale.



← Mining, transportation, and forest development

There are several mines in the watershed, most notably the Monarch Mine on Monarch Pass. While hard rock mines are generally a common source of water pollution in other watersheds, there are no apparent water quality issues from mining on the South Arkansas. Other watershed-scale impacts visible in the photo include surface disturbance related to the mine, forest clearing at Monarch Ski Area, and Highway 50. Combined, these stressors probably have little impact on the health of the reach of the Arkansas below CR 107.

Urban and rural land use →

Urban, residential, and commercial development are increasing land uses in the watershed. Rural development and agriculture are more historical uses, but urbanization and development pressures are on the rise. Stress form surrounding land use may impact flow regime, materials supply, water quality, and landscape support. These constraints limit the potential for improving riverscape health and resilience via reach-scale conservation and restoration efforts.

On-site stressors

On-site stressors are the causes of impairment that can potentially be addressed in reach-scale restoration projects.

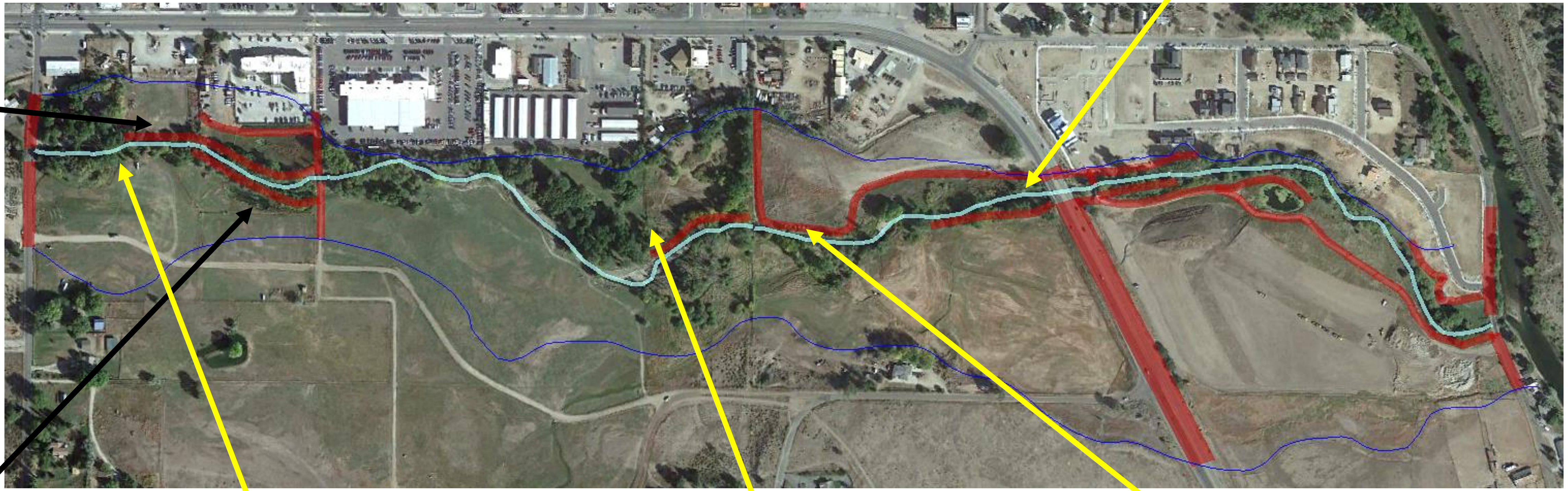
Channelization and levees are ubiquitous on this reach of the South Arkansas, as they are on most low-gradient streams of this size across the U.S. Containing and controlling streams were widespread and necessary practices during the settlement era to put river bottomland into production and to create transportation routes like bridges, trails, roads, highways, and railroads. It was relatively easy to excavate channels, build berms, and drain floodplains, even in the 1800s when the roads and railroads were first built and when this land was part of industrial-scale ranching operations. Channelization, levees, revetment and other engineering practices to control and contain rivers accelerated in the mid-1900s through federal government programs, and these activities are apparent in historical aerial images of the South Arkansas from that time.

Restoring stream health on highly managed riverscapes like the South Arkansas can be difficult. It is not that entrenched rivers cannot be reconnected nor that levees are difficult to remove. It is more a question of whether current land use and social constraints will allow it. Reversing the impacts of river engineering to restore the natural processes that maintain stream health and function—allowing them be natural and wild—means giving up some control. Finding opportunities where these tradeoffs are acceptable is the key to planning successful and sustainable restoration.

	Stressor	Explanation
On-site (within stream corridor/riparian zone)	Development	Land use in stream corridor: urban, commercial/industrial, residential, infrastructure, transportation corridor
	Rural/agricultural land use	Land use in stream corridor: rural, pasture, agriculture, naturalized open space, parks, disturbed open land
	Road/bridge	Roads and bridges in stream corridor
	Levees/channelization	Levees and channelized river segments
	Bank/channel armor	River segments stabilized with engineered structures, armored banks (*e.g.* rip-rap)
	Channel structures (dams/weirs)	Diversion structures, dams, weirs, vanes
	Woody material recruitment/removal	Lack of woody material recruitment (due to stabilization or riparian degradation) or removal of woody material
	Exotic or invasive vegetation/weeds	Exotic or invasive plants
	Biotic impacts	Exotic or species, biotic management, keystone species impacts, beaver extirpation or removal, culling


Channelization upstream of the Highway 50 culverts.

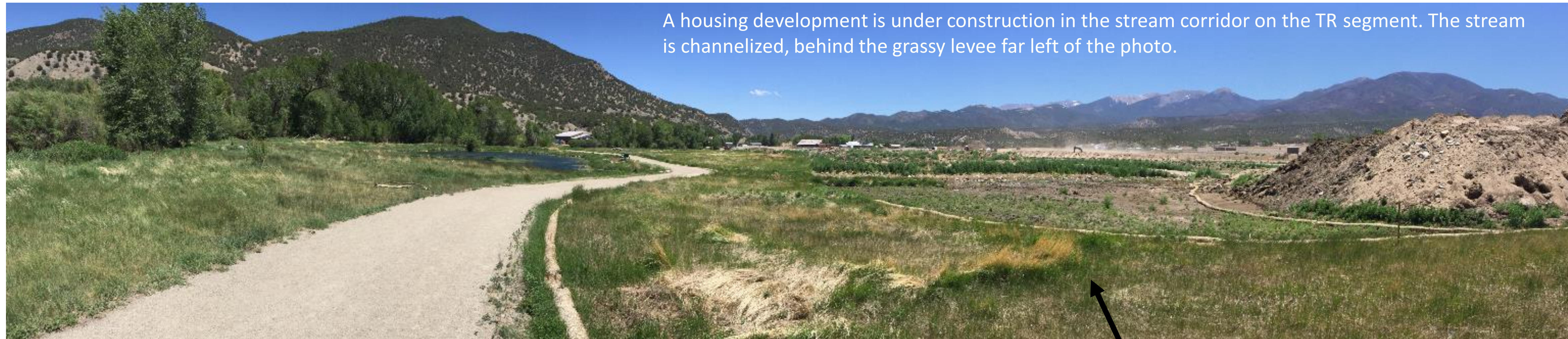

↑ Levees like these (above and below) were constructed during channelization projects in the 1940s or 50s by excavating the channel bed to build berms to create an incised channel with elevated banks—a double-whammy in terms of entrenchment. ↓




↑ Channelization below the CR 107 bridge


↑ A levee built to create a dam for an off-channel pond.


↑ A deeply entrenched channel through ranchland



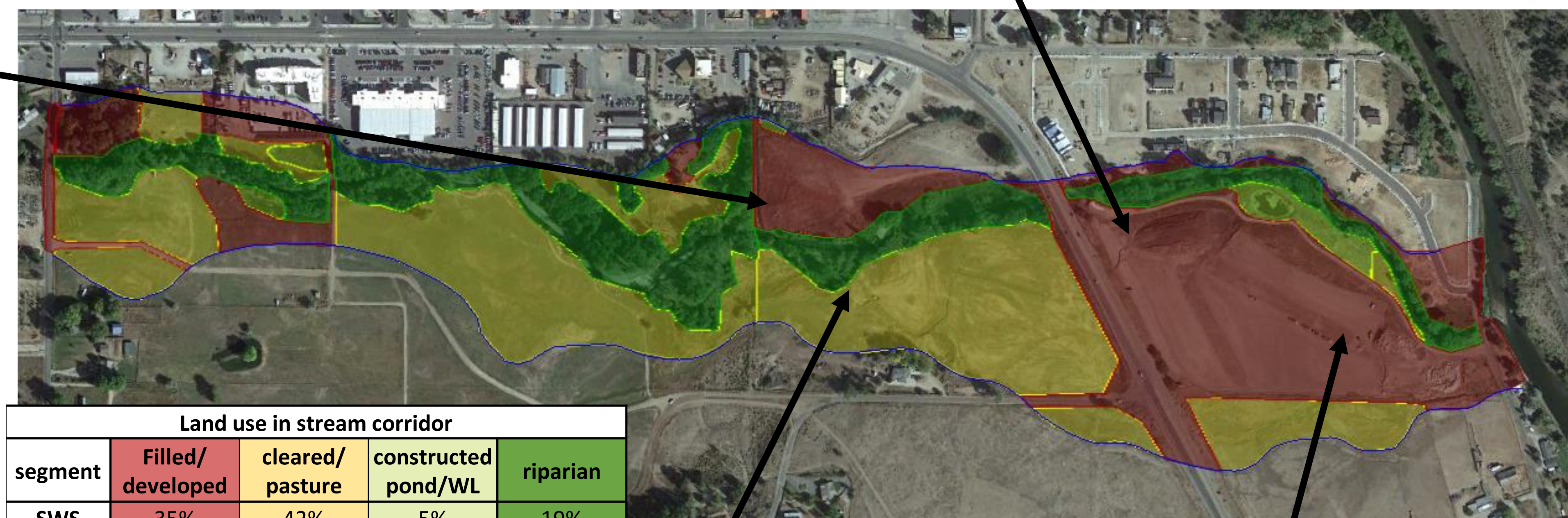
A housing development is under construction in the stream corridor on the TR segment. The stream is channelized, behind the grassy levee far left of the photo.

Land use in the riverscape

Riverscape lands are commonly put to use for valuable purposes. It makes sense. The relatively flat floodplain valley-bottoms are where rich hydrated soil is found in arid environments. They also make great building sites. There has been much to gain in converting riverscape to other land uses, but there is also a tradeoff in stream health and function. Riverscape land use is probably the dominant stressor to stream ecosystems. In addition to the loss of riparian and wetland habitat, putting riverscapes to use almost always means having to control the flow of water and other fluvial processes via channelization, entrenchment, armoring, levees, floodplain fills, and other methods to protected the land from fluvial processes. Because of that, riverscape land use usually involves a suite of additional secondary impacts.

Some land uses are more impactful than others. Land cleared for pasture or agriculture retain some habitat and ecological functions, especially when they are kept wet by irrigation. They also provide some floodplain functions where seasonal inundation or saturation can be tolerated. Areas of the riverscape that have been filled or developed for housing, roads, or other important infrastructure are more impactful. These areas provide little to no aquatic or riparian habitat, and they cannot function as floodplain. Developments within the stream corridor introduce liability in that they must be protected against natural fluvial processes and predictable hazard. To keep them safe, riverine processes (including inundation, erosion, and deposition) must be controlled and confined to a fraction of the historic riverscape extent, which is especially difficult in watersheds subject to drought, wildfire, and floods. Engineering solutions to this dilemma necessarily involve tradeoffs to stream health and natural functions.

A basic mapping exercise shows 38% of the riverscape on this reach of the South Arkansas has either been filled or developed (or is in the process of being developed) for residential or transportation uses. 40% is cleared for pastureland. 2% is engineered ponds or constructed wetland. That leaves 20% for aquatic and riparian habitat.



Land use in stream corridor

segment	Filled/ developed	cleared/ pasture	constructed pond/WL	riparian
SWS	35%	42%	5%	19%
VS	2%	59%	0%	40%
LT	21%	61%	0%	18%
TR	73%	14%	4%	9%
all	**38%**	**40%**	**2%**	**20%**

↑ 73% of the riverscape on the TR segment is being developed. Active riparian habitat occupies 9%.

← The VS segment was a historical cattle ranch, with 59% cleared and used for decades as pasture, grazing, and hay. Most of the old pastureland is now city open space.

Hard points: Bridges, culverts, dams, weirs, vanes, revetment, and diversions serve important functions like protecting infrastructure in the fluvial hazard zone, facilitating transportation, and providing water to ditches. These hard points are also a source of stress to riverine systems that may disrupt natural hydrological, geomorphological, and ecological processes. The 6 bridge/culvert crossings on the reach (white squares on the map below) force a channelized and entrenched stream form. They restrict the natural spread of flows through a riverscape and constrict floodways, cutting off access to floodplains. Weirs (circles) similarly require a static channelized and entrenched form at most discharge levels, but they are les restrictive to floodplain functions during large floods. Banks armored with revetment, vanes, spurs, or other structures (triangles) prevent lateral migration and stream adjustment, forcing a static channel form and liability in big floods. Diversions (blue arrows) are points where water access to ditches must be maintained.

Geographically, the hard points work as a series of constraints. They are static points at which hydrological, geomorphological, and ecological processes must be controlled, to some degree, to keep the structures maintained and functional. This leaves discrete segments in between the structures where natural processes (and potential for process-based restoration) involving woody material transport and accumulation, sediment deposition, scour, channel migration, branching, beaver dams, floodplain activation, hyporheic flow, and riparian vegetation regeneration and succession can be tolerated.

Bridges and culverts (along with the roads and trails they connect) can be migration barriers to both aquatic and terrestrial fauna, as are weirs which create hydraulic jumps and segments of high velocity flow that can be difficult for fish and other organisms to navigate. →

Flow regime	SWS	VS	LT	TR
Total volume	C-	C-	C-	C-
Peak flow	C	C	C	C
Base flow	D+	D+	D+	D+
Rate of change	B-	B-	B-	B-
Flow regime	C-	C-	C-	C-

Flow regime is a primary determinant of the structure and function of riverscape ecosystems. Geomorphological, chemical and biological processes are adapted to the characteristic hydrograph and may become impaired with changes to the natural flow regime. Flows vary greatly through a season on the South Arkansas, with peak flows typically occurring during snowmelt runoff in May to June, low flows in summer, fall, and winter, and short-term peaks during rainstorms. Variation also occurs from season to season with varying climate. The 2014 SAWC study concluded that flow regime impacts are the greatest source of impairment to stream health on the lower South Arkansas.

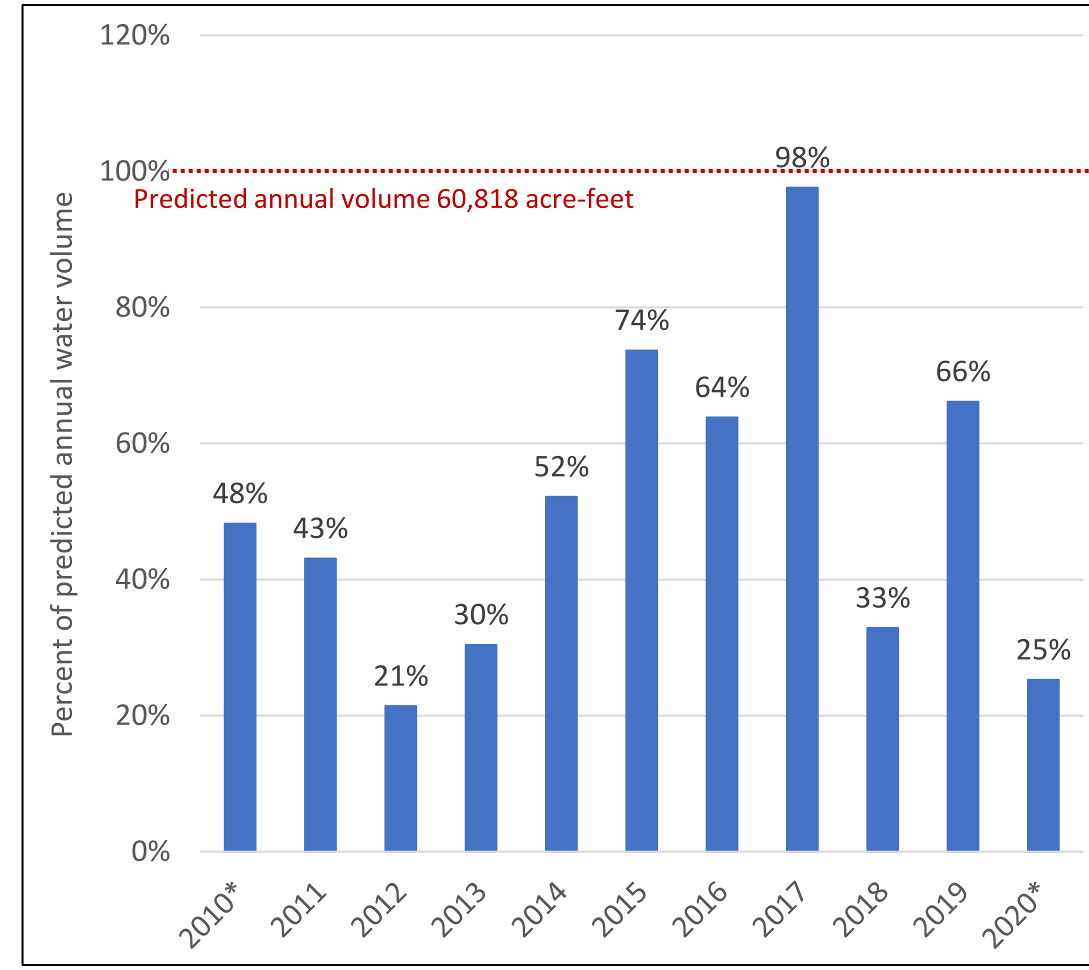
The magnitude, duration, and timing of discharge may be impacted by cumulative land use impacts in the watershed (*e.g.,* forest clearing, impervious surfaces, *etc.*). Increasing forest health issues and climate change may increase the potential for catastrophic wildfire and subsequent large-magnitude floods, but outside of these big events watershed land impacts to flow regime are probably minor compared to direct management of flow regime and depletions for water use. According to records available on the CWCB Colorado Decision Support System (CDSS) website, there are more than 150 water rights in the watershed with a combined discharge that greatly exceeds average annual flow of the stream (it even exceeds normal annual peak flow). A complex system for water calls assures that diversions and releases are timed to reduce effects on stream flow and other water users, and some portion of the water diverted from the stream remains in the corridor. Nevertheless, the magnitude of water use indicates potential for depletions and major impacts to flow regime.

Changes to total volume, peak flow, and base flow regimes may be evaluated by comparing 11 years of actual discharge data from the SOAKTECO stream gage (on the South Arkansas below the Tennassee Ditch) to predicted flows calculated regression equations (Capesius and Stevens 2009) and watershed characteristics (obtained from the latest USGS Colorado StreamStats tool). The results suggest flow magnitude impacts to total volume, peak flows and base flows. Impacts to the rates of flow change were inferred from an evaluation of daily hydrograph records and the proximity off large diversion points.

Total volume →

Measured yearly annual total volume of water passing the SOAKTECO gage expressed as a percentage of annual flow predicted by regression models for the watershed for the time of record. Over 11 years, percent total volume ranged from 21% to 98%. The average was 50%, median 48% which corresponds to severe impairment (>40% departure).

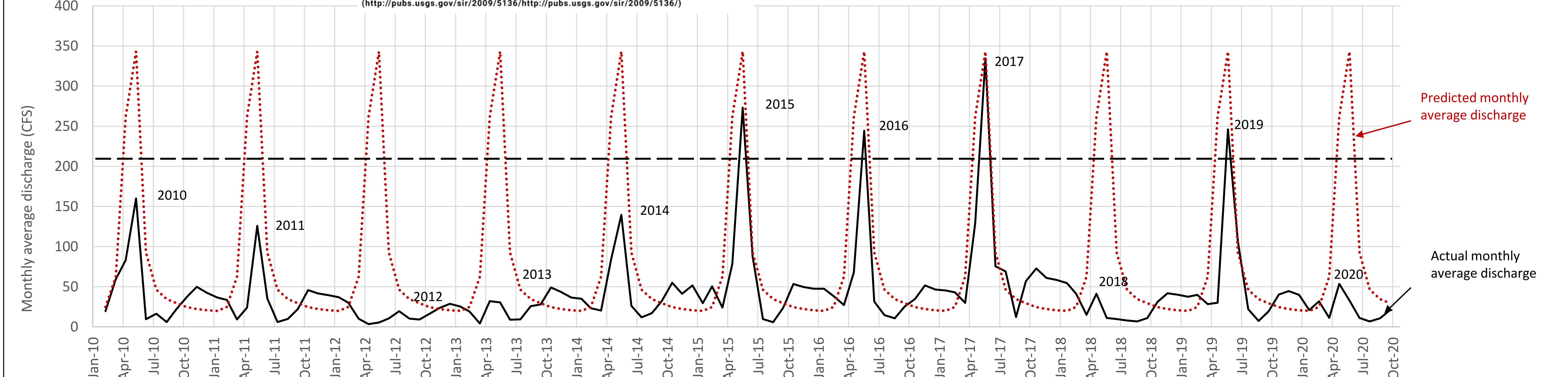
* For 2010, the percent of predicted total volume is based on 10 months (March through December). For 2020, the percent of predicted total volume is based on 10 months (January through October).



↓ Flow magnitude and timing

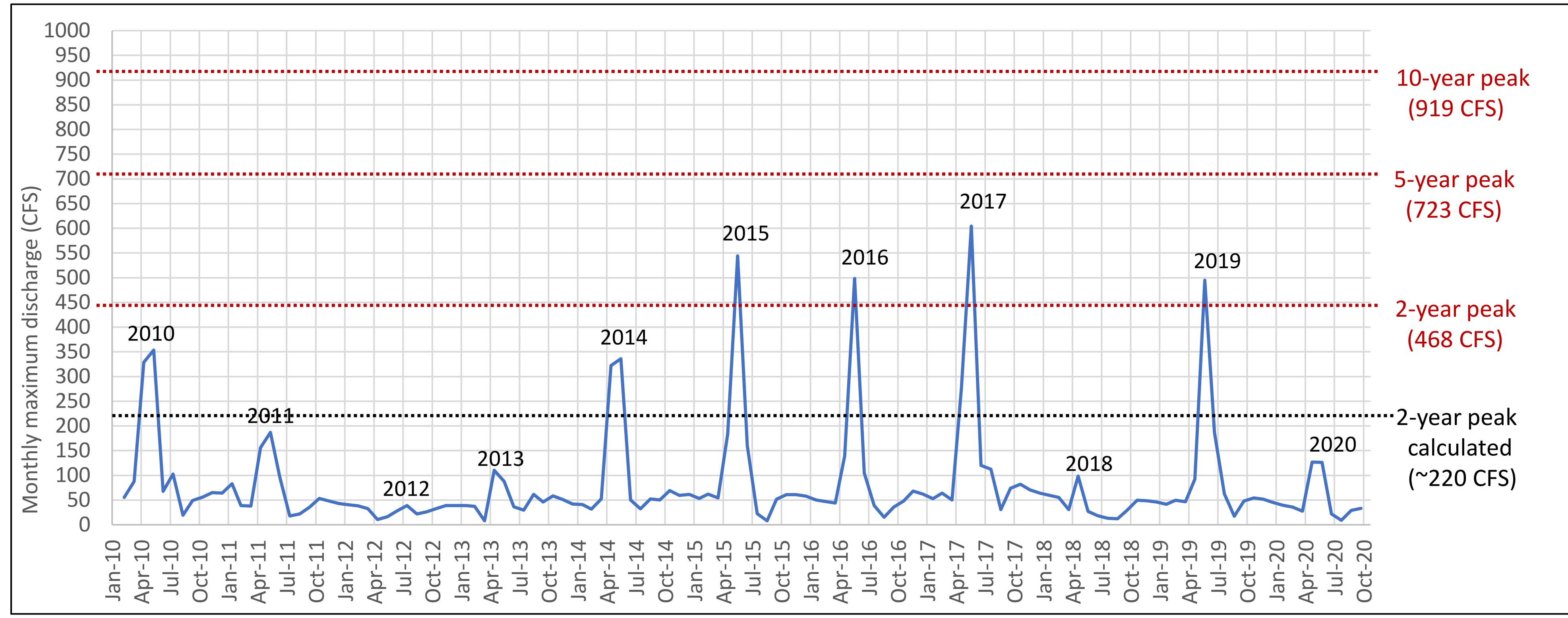
Monthly average discharge at the SAKTECO gage (black line) compared to predicted monthly average (red dashed line) highlights alteration to magnitude and timing of flows.

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)



Flow regime	SWS	VS	LT	TR
Total volume	C-	C-	C-	C-
Peak flow	C	C	C	C
Base flow	D+	D+	D+	D+
Rate of change	B-	B-	B-	B-
Flow regime	C-	C-	C-	C-

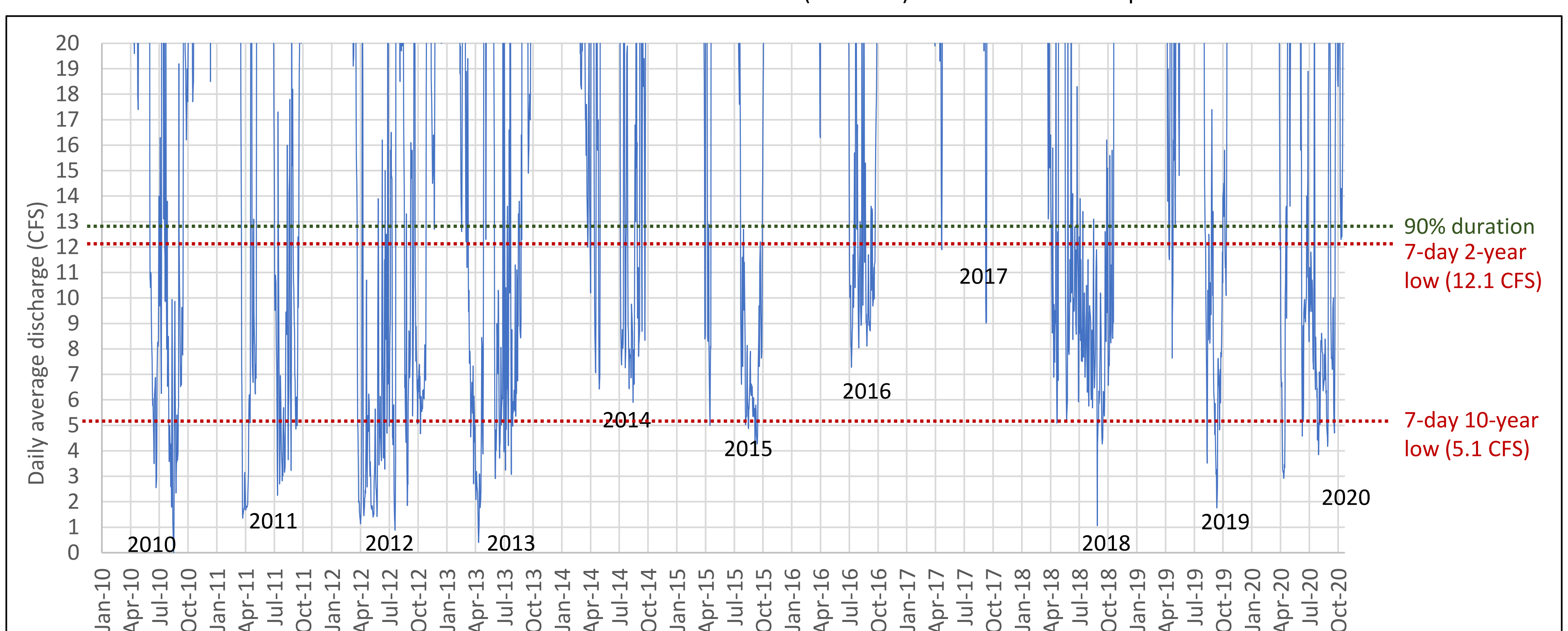
↑ Despite above average snowfall, 2020 runoff peaked at about 140 CFS. Shown here on the receding limb at about 60 CFS on the VS segment on June 8.



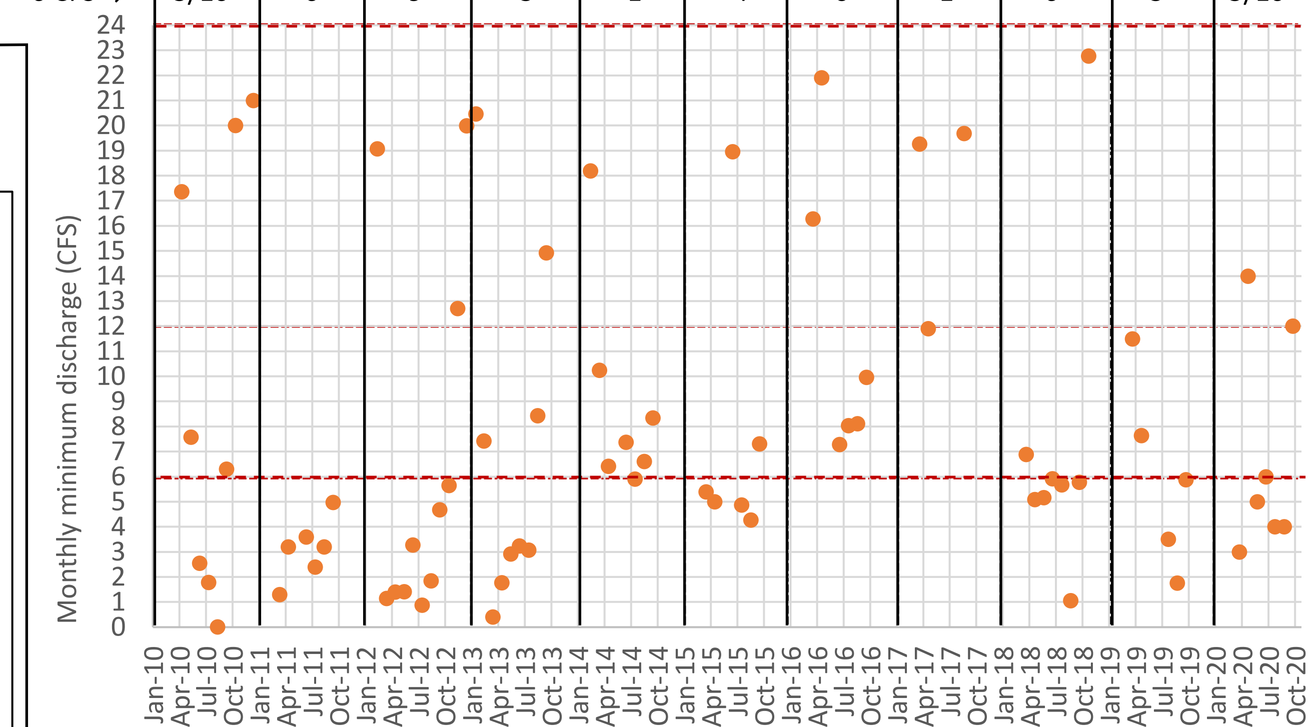
↑ **Peak flows** Monthly maximum discharge at the SOAKTECO gage (blue line) is shown relative to predicted peak flow statistics. Results indicate significantly to severely diminished peaks.

Predicted 2-year peak discharge (Q_2) is 468 CFS, observed is approximately 220 CFS (n=11). Predicted Q_{10} is 919 CFS, observed is 620 (n=11)

↓ **Base flows** Daily average discharge at the SOAKTECO gage below 20 CFS (blue line) is shown relative to predicted several low flow statistics.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Months w/min flow < 24 CFS →	8/10	6	12	9	7	6	6	3	8	5	7/10
Months w/min flow < 12 CFS →	5/10	6	9	7	6	5	4	2	7	5	6/10
Months w/min flow < 6 CFS →	3/10	6	9	5	1	4	0	1	6	3	5/10



↑ **Base flows** Monthly minimum flows at the SOAKTECO gage (orange points) are shown relative to several threshold values. The table above shows the number of months per year that had minimum discharge below 24, 12, and 6 CFS. Critically low discharge appears to be as frequent as suggested in the 2014 SAWC assessment.

Materials supply	SWS	VS	LT	TR
Sediment supply	B	B	B	B
Organics (wood, detritus)	C+	B-	C+	C+
Materials supply	B-	B	B-	B-

Materials supply describes the supply of sediment, wood and detritus to the reach from the contributing watershed. The upper watershed has little development (1%) or other intense land use and is 60% forested. Sediment often comes to the reach in pulses during acute rain events on erodible tributary drainages (see sheet 26). The greatest potential impact to sediment supply is related to the increasing risk of extreme forest fires in the watershed. Many of the depositional streams that would naturally capture sediment runoff rom burn scars are nonfunctional, so fire-related sediment loads will pass more directly to the reach without much potential for attenuation or buffering in the watershed.

Photo from 2014 SAWC report

↑ The 2014 SAWC report expressed concern about potential for increased sedimentation due to land use disturbance on erodible soil in the watershed (left), and channel erosion due to local vegetation impacts, and conversion or wetland to upland or bare ground (right).

→

Wood jams (above)and wrack (below) are indicators of recent large woody material supply.

→

Photo from 2014 SAWC report page 33, 49, 92

← The 2014 SAWC report expressed concern about excessive sediment deposition on the reach downstream of CR 107 based on observed silt and detritus accumulation after thunderstorms in 2012. Silt and fine organic material like this does accumulate temporarily, but it rapidly flushes when flows reach moderate discharge. Areas of fine sediment substrate and detritus accumulations such as leaf packs are in fact extraordinarily rare on this reach of the South Arkansas.

Wood and detritus supply. ↑

Any increases to fine sediment supply may be offset by artificially high scour energy on the reach. In its channelized form with high velocity flows and high stream power, shear stress keeps sediment moving. Fine material and detritus are flushed through and rifle embeddedness is extremely low. High rates of bedload transport are observed in years with significant peak flows. →

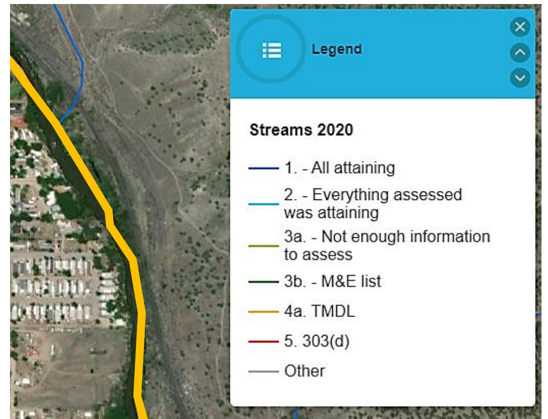
→

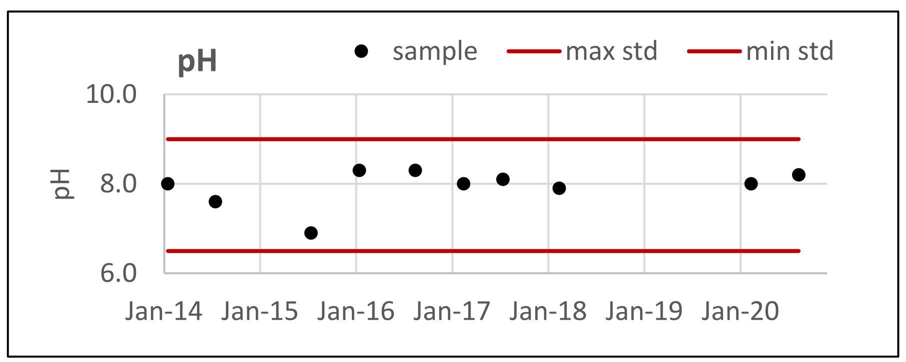
Systematic wood removal from the stream (as evidenced by wood spoils like those in the upper photo) is part of maintenance plans on the South Arkansas to reduce the risk of clogging crossings (like the one at Highway 50 in the lower photo) that were not designed to pass natural loads of large woody material.

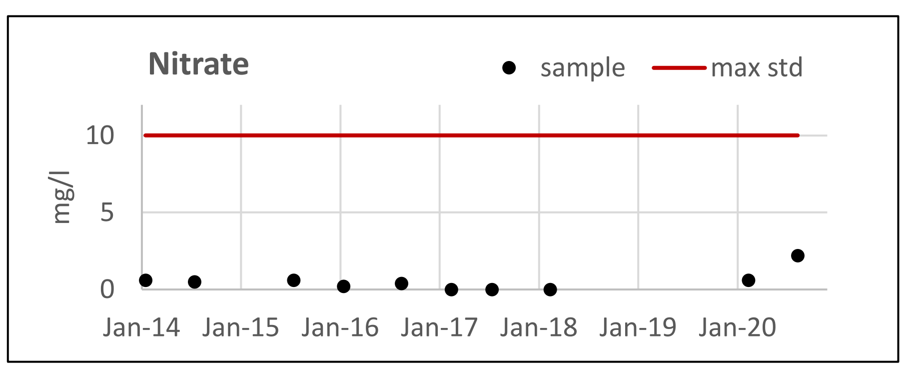
→

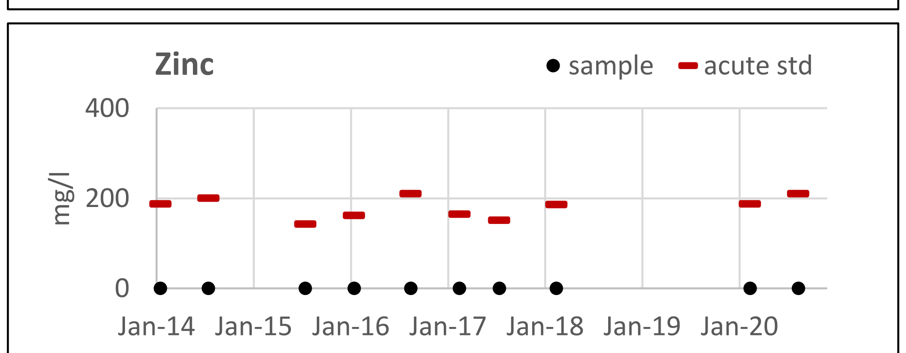
Water quality	SWS	VS	LT	TR
Temperature	B-	B-	B-	B-
Nutrients, organics	B	B	B	B
Chemical conditions, inorganics	B+	B+	B+	B+
Water quality	B	B	B	B

Water Quality describes the physicochemical condition of water supplied to the reach from its watershed. Because it is important to human health and so many other designated uses, water quality is one of the most carefully monitored aspects of stream health. Colorado Department of Health and Environment (CDPHE) reports based on these data rate the South Arkansas in the highest category (level 1) of water quality with all designated uses assessed and found to be attaining (see legend to right).









↑ There are several stressors in the watershed that could potentially impair water quality (most notably the industrial mines and agricultural land uses along the valley bottom). But given the positive report from state regulatory agencies and lack of any other indicators, only mild impairment is predicted.

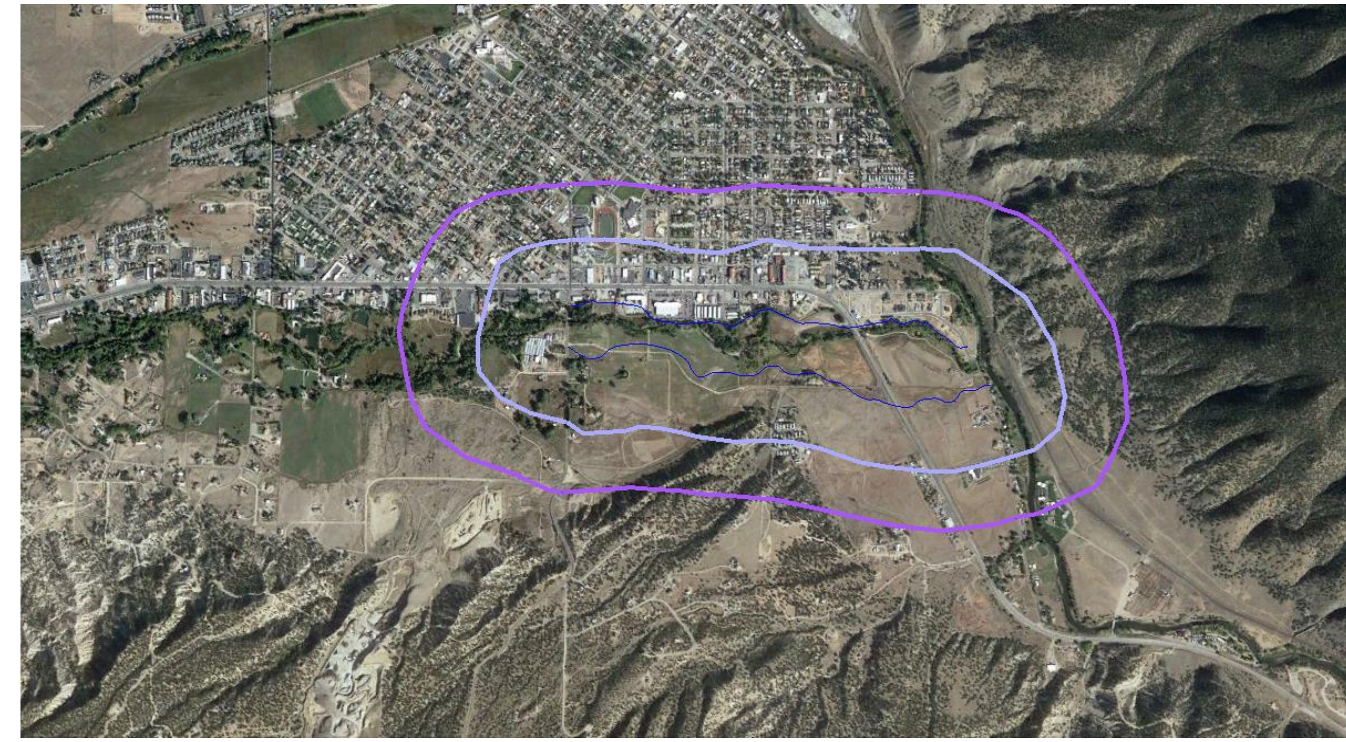
← Central Colorado Conservancy is one of several organizations monitoring water quality parameters. None of their results suggest anything more than mild water quality impairment. Measurements for 3 analytes are shown (left) compared to CDPHE standards for the sampling location on this reach. The Conservancy is also monitoring standard indicators for nutrient loading, metals contamination, and *E. coli.*

Landscape Support	SWS	VS	LT	TR
Land use and buffer	C	C	C-	D
Terrestrial habitat connectivity	C-	C-	D+	D+
Aquatic habitat connectivity	B+	B+	B	B-
Landscape support	C	C	C-	D+

Landscape support concerns the influence of the surrounding landscape on riverscape health including potential impacts from surrounding land use and ability of adjacent land to buffer them. Terrestrial and aquatic connectivity are landscape-scale factors affecting the flow of energy, matter, and organisms between the reach and surrounding areas. The assessment focuses on a 250-m buffer area (light purple inner area) and 500-m habitat connectivity envelope (darker purple outer area).

Stressors to landscape support include the high-intensity land use adjacent to the reach to the north (the town of Salida), lower-intensity land uses to the south and east, and barriers to migration and dispersal throughout. →

The biggest impediment to fish and wildlife movement through the South Arkansas corridor may be the constriction of the riverscape and effective riparian zone to a fraction of its natural historical extent (see sheet 12).



← Connectivity to the main stem of the Arkansas River (background in the photo below) is particularly important. The biggest migration/dispersal barrier between these two critical habitat corridors is Highway 50 which bisects the South Arkansas riverscape on the reach. Connectivity is limited to movement through the two culverts (left), or over the 3-meter-tall highway embankment, restricting migration and causing habitat fragmentation. ↓

← Weirs and other hydraulic jumps are thought to be potential migration barriers to fish and other aquatic species.

Riverscape hydrology	SWS	VS	LT	TR
Frequently saturated area	D+	C-	D	D
Valley bottom/ASC	D-	B-	D+	D-
Flood-prone area	D	C+	D	F+
Riverscape hydrology	D	C	D	D-

Riverscape hydrology is defined by the extent of saturated or inundated area during low flow periods, seasonal peaks, and floods. The ability of aquatic habitats to function depends greatly on the distribution of water at these regular frequencies.

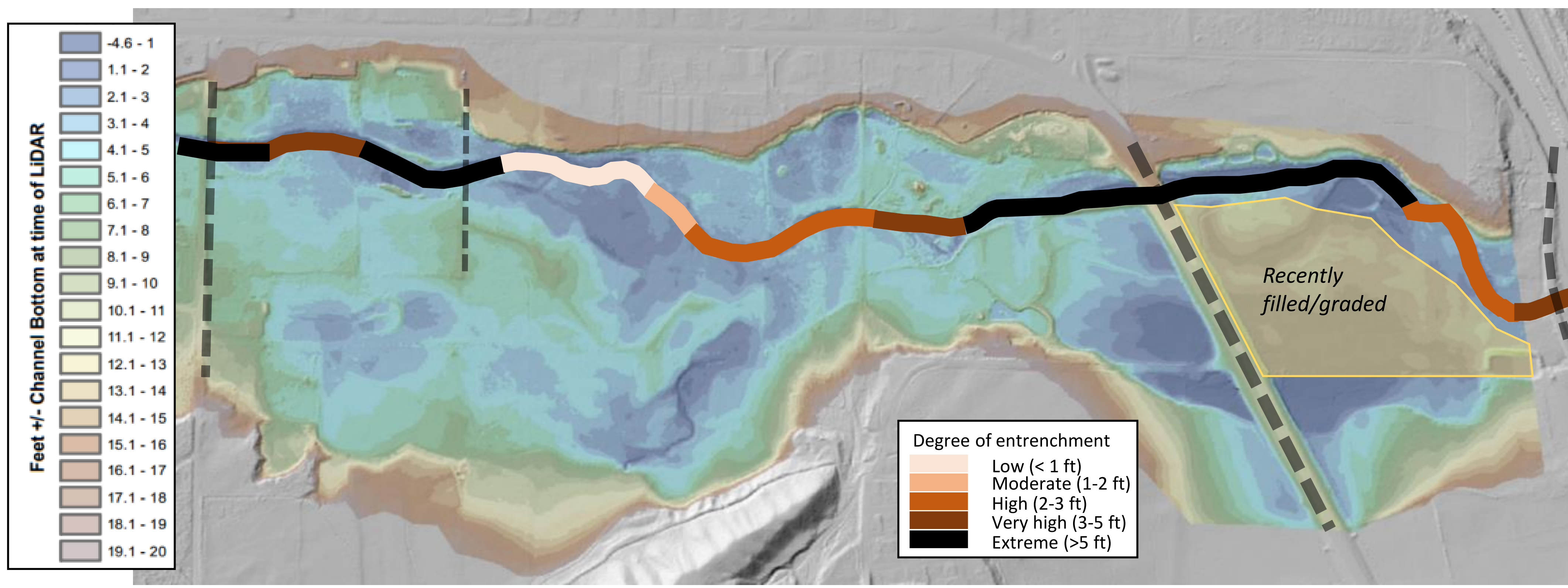
Frequently saturated area →

Frequently saturated area may be identified by the distribution of aquatic habitat and hydric vegetation (shaded blue), which is currently limited to 19% of the stream corridor (outline) over the reach. Values range from 10% on the SWS and TR segments, 16% on the LT segment, to 44% on the VS segment.

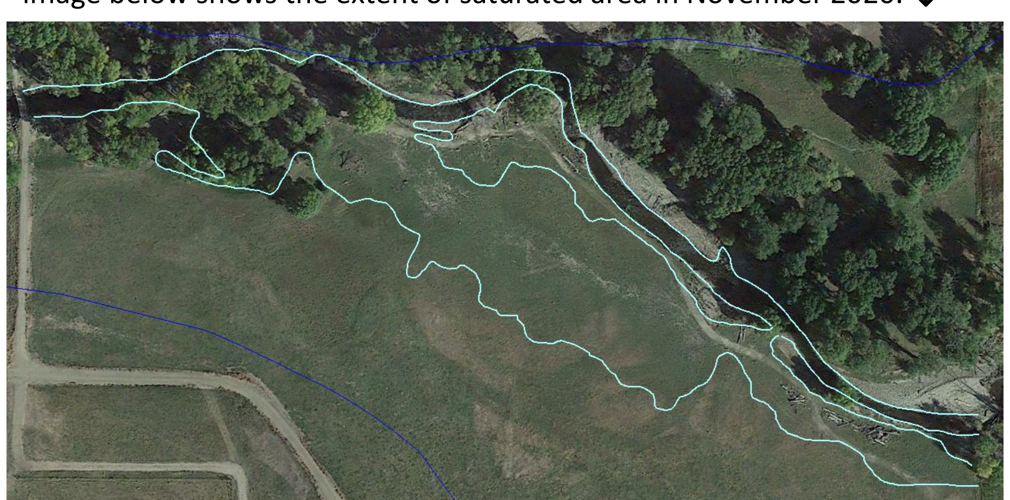
segment	% hydric
SWS	10%
VS	44%
LT	16%
TR	10%
all	19%

↑ On the segments that are not entrenched, and where natural processes like aggradation and wood accumulation are tolerated, frequently saturated area is much wider than on more highly impaired segments.

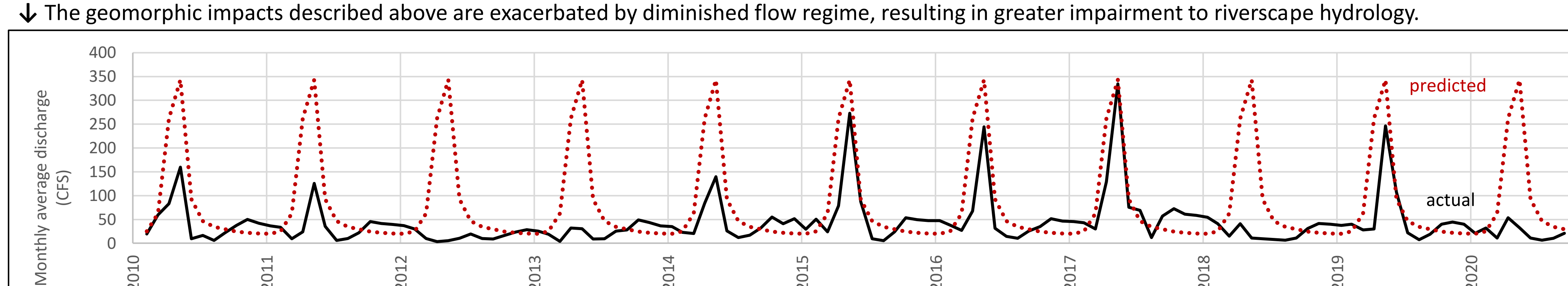
Entrenchment severely limits riverscape hydration and flood-prone area on this reach even during runoff and peak flows, leaving channel-adjacent lands high and dry. A relative elevation map (topography data from 2011) illustrates the degree to which areas of the riverscape and floodplain are perched above the channelized riverbed. The degree of channel entrenchment (low to extreme) and cross-valley road fills (dashed lines) are also shown. Entrenchment and floodplain disconnect is caused by both channel bed lowering (degradation and floodplain raising (fill or levees). Four cross-valley roads act as dikes that constrict overbank flows through narrow openings at bridges or culverts, preventing both surface water and groundwater from accessing portions of the riverscape downstream. The combined effect of entrenchment, fill, levees, and dikes is severe impairment to riverscape hydrology at base flow, seasonal peak flows, and floods ↓



Riverscape hydrology is improving on the VS segment as channel entrenchment heals following aggradation and wood accumulation. The image below shows the extent of saturated area in November 2020. ↓



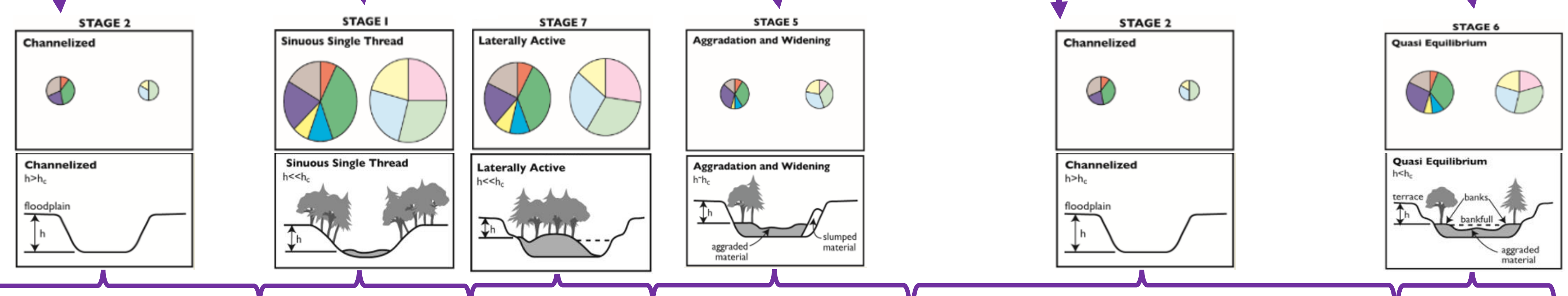
↓ The geomorphic impacts described above are exacerbated by diminished flow regime, resulting in greater impairment to riverscape hydrology.

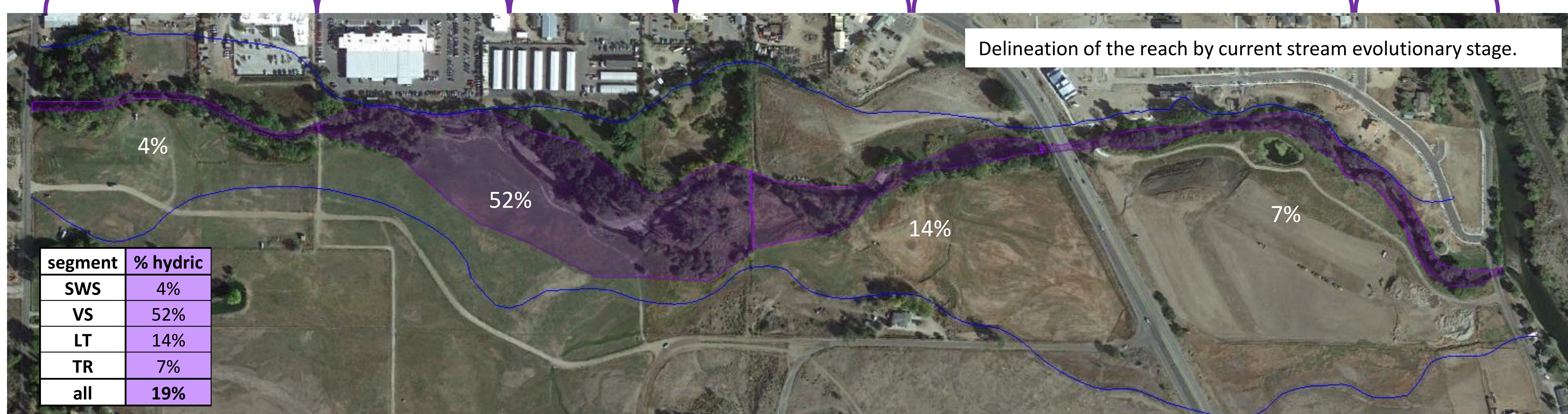


Riverscape dynamics	SWS	VS	LT	TR
Geomorphic plasticity	D	B-	C-	D-
Fluvially active zone	D	C+	D	D-
Stream evolution	D-	C+	D+	D-
Riverscape dynamics	D	C+	D	D-

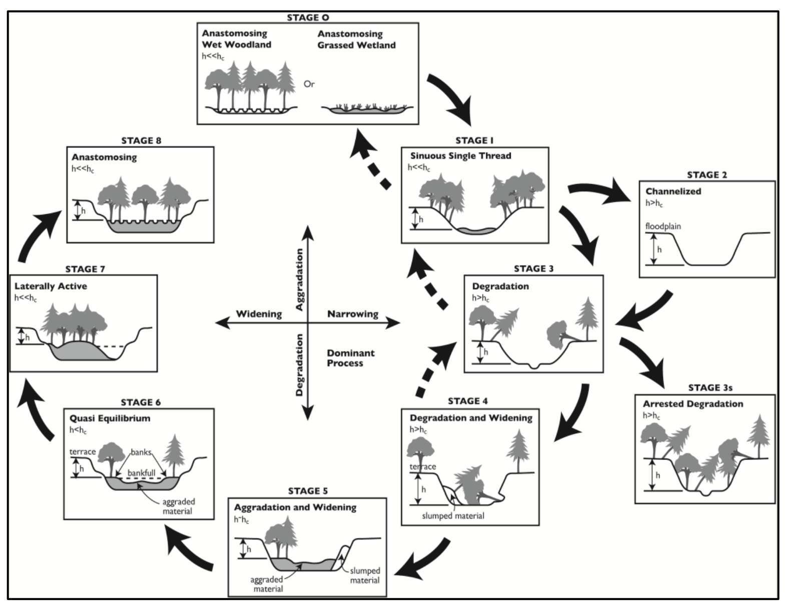
Riverscape dynamics is the extent to which geomorphic riverine processes are operating across the riverscape, including stability and evolutionary stage. Dynamic processes are severely limited on most of this reach due to the channelized, entrenched, and straightened condition.

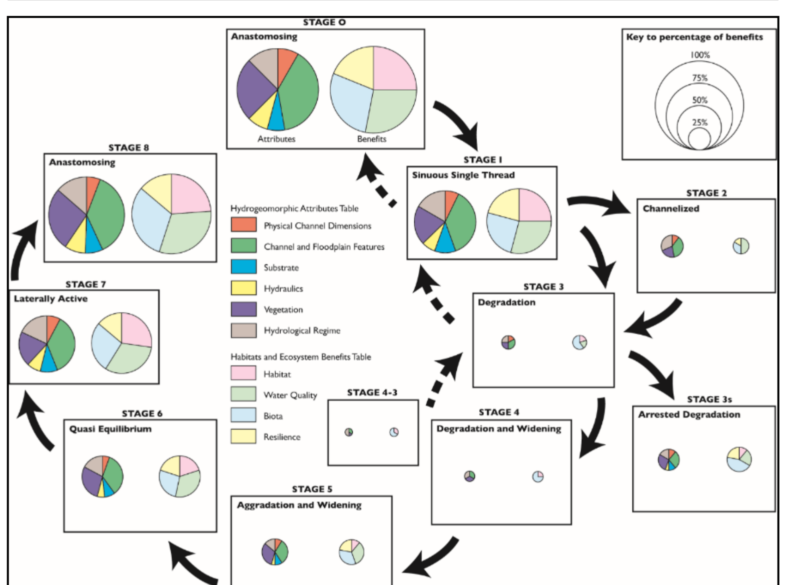
The static condition is fine for control and containment of the stream and protection of land and infrastructure (at least during periods of low or normal flows though perhaps not during extreme floods), but it stagnates important stream health processes such as the maintenance of riparian vegetation, wetland, habitat quantity and diversity, physical heterogeneity, biodiversity, and floodplain connectivity. The VS segment is in the best condition due to natural recovery. The stream is becoming less entrenched, better connected, and more dynamic, following recent sediment aggradation and wood accumulation.





↑ The extent of dominant hydric vegetation, which varies from 4% to 52% on the reach, is key indicator of entrenchment, connectivity, and evolutionary stage.



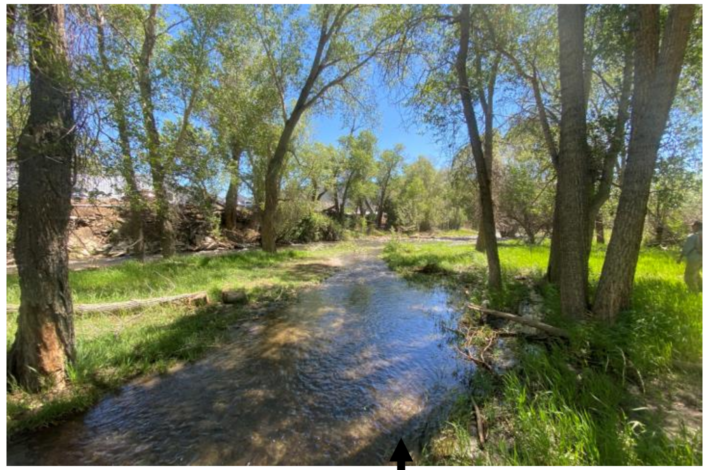


From: Cluer & Thorne (2013) DOI: 10.1002/rra.2631

Riparian vegetation	SWS	VS	LT	TR
Riparian extent	D	C	D	F+
Biodiversity and endemism	C	B-	B-	C
Regeneration/succession	D-	C	C-	D+
Riparian vegetation	D	C	C+	D

Riparian vegetation is on of the most important indicators of system health since the extent, distribution, diversity, and regeneration reflects the full suite of hydrological, geomorphological, and biological processes. Vegetation along the margins of the channel is good, but it is highly altered over most of the rest of the riverscape.

↓ Wet woodland



↓ Recent disturbance, dry herbaceous

↓ Constructed wetland, likely to develop into wet herbaceous

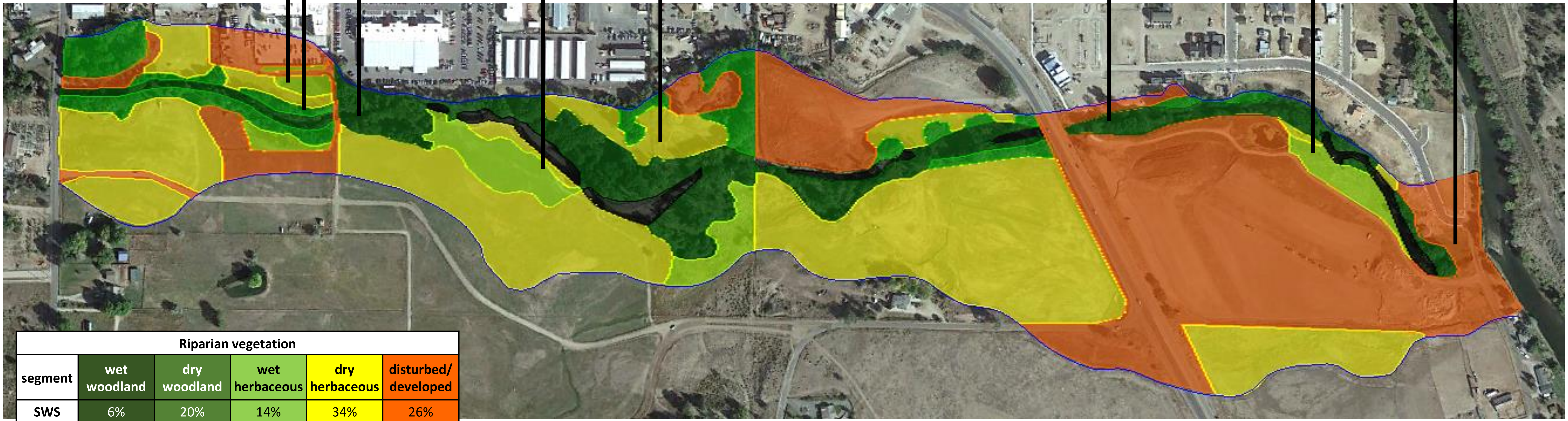
↑ Constructed herbaceous wetland

↓ Dry woodland on levees

↓ Wet woodland (left), wet herbaceous (right)

↓ Developed area with narrow band of wet woodland

↓ Developed area with recent landscaping



Riparian vegetation					
segment	wet woodland	dry woodland	wet herbaceous	dry herbaceous	disturbed/ developed
SWS	6%	20%	14%	34%	26%
VS	30%	7%	15%	44%	4%
LT	10%	4%	0%	66%	20%
TR	7%	1%	0%	13%	79%
all	13%	6%	6%	36%	39%

↑ Simple remote vegetation mapping shows the relative percentage of basic functional guilds in the riverscape. 13% is wet or mesic woodland (primarily cottonwood and willow with hydric or mesic understory) and 6% is dry woodland (primarily cottonwood with mesic to xeric understory). Wet herbaceous is 6% (a mix with of sedges, rushes, and grasses with dominated by hydric and mesic species) and 36 % is dry herbaceous (mostly mesic and xeric grasses and rushes, including some areas that are irrigated hay meadow). 39% is disturbed/ developed area (mostly bare or developed areas such as roads, buildings or construction areas under development with mixed sparse vegetation or landscaping). Constructed ponds are counted in developed area. Open channel area with no canopy was not counted.

Physical heterogeneity	SWS	VS	LT	TR
Riparian heterogeneity	D+	C	D+	D
Aquatic heterogeneity	D-	D+	D	D
Micro-scale heterogeneity	D+	C-	D+	D+
Physical heterogeneity	D	C-	D	D

↑ Aquatic and riparian habitat heterogeneity is severely lacking on most of the reach due to channelization.

Aquatic habitat is homogenous gravel-cobble-bed riffle with few pools or other structural features except where wood initiates scour and deposition. Much of the riparian zone is homogenous pasture. ↓

←

Habitat complexity in the VS segment is improving where wood and coarse sediment has been accumulating to create scour pools, backwater pools, slack water, wood cover, detritus packs, side channels, emergent wetland, and both coarse and fine structural heterogeneity to add diversity to the otherwise homogenous plane-bed riffle bedform that exists over most of the rest of the reach.

←

←

More importantly, wood accumulation, log jams, and beaver activity induces bedload deposition to reverse the effects of channelization and entrenchment, promoting the natural processes that sustain habitat complexity for the long term. Fluvial activation of floodplain areas and a raised water table across the riverscape are prerequisites to riparian vegetation recovery, regeneration, and maintenance.

←

Aquatic biota	SWS	VS	LT	TR
Trophic structure	B-	B-	B-	B-
Biodiversity and endemism	C+	C+	C+	C+
Aquatic biota	C+	C+	C+	C+

Aquatic biota is the most difficult aspect of stream health to evaluate empirically. Studies to accurately quantify aquatic biodiversity, community structure, and population dynamics are rare and often challenging to interpret due to the complexity of trophic structure (food webs) and intricacies of intra- and interspecific interactions. Nevertheless, biotic processes are often key drivers of stream health, especially on broad low-gradient riverscapes like this reach of the South Arkansas, so we do our best to account for impairment caused by impacts to aquatic biota.

Our assessment of trophic structure, biodiversity, and endemism comes largely from indirect evidence of potential limiting factors. Water quality and chemical environment is relatively unimpaired (sheet 17), and routine benthic macroinvertebrate samples from riffle habitats tend to corroborate this. At the same time, the channelized condition (sheet 11 and 19) and diminished flow regime (sheet 14-15) means that there is far less aquatic habitat compared to reference, and much less habitat diversity. Macroinvertebrate species that thrive in fast gravel-cobble bed riffles are well-represented, but others that require slow water, fine sediment, wood, leaf-pack substrates, or emergent vegetation are probably severely lacking.

Algae, aquatic macrophytes, and emergent vegetation are rare or absent on this reach due to the entrenched channelized condition, potentially limiting primary production. From a trophic perspective, however, the supply of energy from allochthonous organic material is a greater contribution of energy to food webs on mountain streams compared to *in situ* photosynthesis. Detritus supply is depressed given the impairments to riparian vegetation, but there is still good cover of deciduous trees and shrubs on upstream reaches to supply leaf and wood material (sheet 16).

Another important factor to biotic integrity is connectivity to neighboring habitats, allowing the dispersal and migration of organisms into and out of the reach, as well as the flow of energy and materials. Lateral connectivity across terrestrial landscapes, as assessed in the landscape support factor (sheet 17), is poor due land use and habitat loss in the surrounding area. Longitudinal connectivity along the stream corridor, tributaries, and the main stem of the Arkansas River is more important to aquatic organisms and probably less impaired. However, numerous weirs, poor habitat , and frequent periods of critically low flow may create seasonal barriers to aquatic migration.

Another very important influence that aquatic biota has on stream health is the activity of keystone species. Beaver, which one played a keystone role in hydrological, geomorphological, and biological processes on the South Arkansas are absent on the reach. Historical aerials and anecdotal evidence suggests that they have been largely inactive on the reach for at least the last 70 years. When they have colonized the reach in recent past, the animals have been quickly removed and their dams destroyed. Absence of this keystone ecosystem engineer species is a key factor in the degree of impairment to riverscape hydrology, riverscape dynamics, riparian vegetation, and physical heterogeneity.

Conservation and restoration opportunities

Framing the question

The 2014 SAWC study concluded that the causes of stream health impairment of the South Arkansas River are (1) that flow regime is diminished, (2) that the currently active portion of the stream corridor has been greatly reduced, and (3) that the that the stream within the narrowed active corridor is channelized, entrenched, and greatly simplified. Our limited assessment very much agrees with these findings. Similarly, the articulation of the problem and potential for restoration on page 95 of the SAWC report is very much in line with our conclusions and that of a practical process-based approach: *"As the river has reacted to these changes* (the altered flow and sediment regimes and the greatly narrowed and channelized active stream corridor)*, humans have responded in many small ways at isolated locations as if the stream and the floodplain are separate, which they are not. Successful restoration requires clear understanding of the nature and extent of the disturbance as well as the nature of the channel and floodplain processes where restoration is planned."* Restoring stream health requires we take an approach that is *"based on the natural processes at work—or that are missing—in the watershed or stream system. In addition to improving the chances of project success, this process-based approach has the added benefit of increasing the likelihood that watershed and riparian system will respond to future changes, such as extended drought* (or flood or wildfire or other natural or human-caused disturbance), *through natural physical and biological adjustments without the need for additional intervention."*

If improving stream health and resilience is our goal, and if we want the improvements to be sustainable and long-lasting, we need to account at appropriate scales for these natural processes and address the nature and extent of disturbance and underlying causes of impairment. We need to be looking for opportunities to protect natural processes where they are operating and to restore them where they are disrupted. We need to be thinking on the scale of watersheds and riverscapes, not focused singularly on dressing a channel. The SAWC report reminds us that *"Successful watershed and riparian restoration projects require an understanding of the natural components and processes operating in the watershed as well as of the social context in which restoration projects are developed."* That is the purpose of this study and this report.

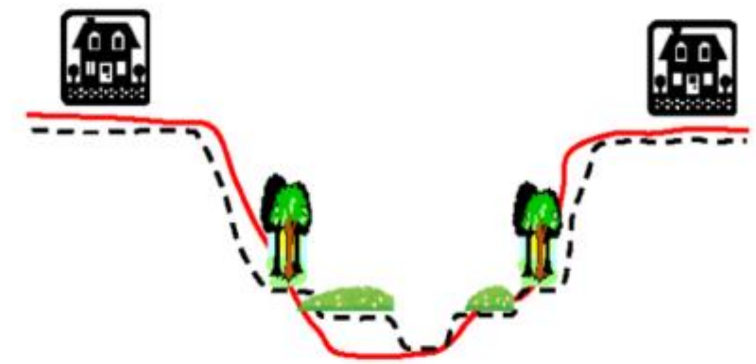
So, what opportunities for process-based conservation or restoration exist on this reach of the South Arkansas? The question forces us to be practical because, as the 2014 SAWC reports states: *"Some aspects of past and current impacts can be changed, while others cannot, whether for political, social, or economic reasons."* This is why it is so important to understand the anthropogenic causes of impairment. Some stressors can be practically alleviated, while others cannot.

The impacts to flow regime, for instance, probably cannot be changed, at least not in a practical and meaningful way. While it would undoubtedly be beneficial, restoring a healthier flow regime would involve major changes to the allocation and use of water in the basin. Some people would have to be asked to give up legal rights to divert water for other beneficial uses. These concepts may be feasible on some level, but they are beyond the scope of reach-scale restoration or conservation efforts. Other watershed- and landscape-scale impacts such as sediment regime, water quality, and landscape support are similarly out of scope and are best thought of as practical limitations. Improving these aspects of stream health are worthwhile endeavors, but they require larger-scale actions and collaboration to change the situation at the appropriate watershed or landscape scale.

Similarly, many of the on-site stressors cannot be feasibly remediated or mitigated for *"political, social, or economic reasons"* due to constraints from land use, development, or infrastructure. Any opportunities to reverse past impacts should be explored, but many will simply be off the table. The cross-valley fills, constrictions, channelized and entrenched stream forms at CR 107 and Highway 50 are probably here to stay Likewise, historical land use, developments, and infrastructure in the riverscape must be respected and protected. The South Arkansas was engineered, channelized, entrenched, leveed, and armored to meet specific needs; and the riparian areas were disconnected, cleared, cultivated, and developed for desired land uses. On reaches where these needs still exist, there may be little opportunity to reconnect the riverscape to natural fluvial and ecological processes.

Problems with traditional engineering solutions

The alternative that the SAWC report offers for coping with diminished flows and channelized entrenched streams on occupied riverscapes—to decrease the footprint of the existing channel—seems like a bad idea, however. Although it is a common engineering practice, the concept of redesigning "*a smaller river-within-a-river*" to improve function on entrenched and constrained stream corridors via a *stepped floodplain redesign* (as recommended in the 2014 SAWC report, pages 104-105 and 110-111) is not a viable path to restoring stream health or resilience on a significant scale because it does not address the causes of impairment nor restore natural processes or functions.



↑ Diagram from the 2014 SAWC report illustrating the *stepped floodplain redesign* approach to stabilizing and enhancing entrenched streams. (The dotted line reflects reconfigured floodplain inside the entrenched channel.)

If applied, this approach would best be described as an example of artificial **enhancement** or **containment**, not **restoration** (see the glossary on sheet 3 for clear definitions of these terms). Treatments proposed under this approach (*e.g.,* creating narrow floodplain benches within the entrenched channel, stabilizing banks, installing weirs and other artificial structures, *etc.*) might meet short-term enhancement, containment, or stabilization objectives on local scale, but they are no substitute for the natural processes which have become disrupted. These treatments cannot confer much benefit in the way of restoring riverscape health, functional lift, or resilience because they operate at the wrong scale. They cannot improve watershed-scale stream health factors and can only make marginal gains in reach-scale stream health factors such as riverscape hydrology, riverscape dynamics, riparian vegetation, physical heterogeneity, and aquatic biota.

Moreover, enhancing the existing channelized river condition to create habitat on a miniaturized channel in a narrower corridor with diminished flows is a step in the wrong direction with respect to resilience. While the magnitudes of day-to-day discharge and year-to-year peak events are clearly diminished by water use, the potential for extreme flood events remains relatively unchanged. If anything, the potential for extreme events is increasing due to climate change, poor forest health, and increasing development in the watershed. The lessons to be learned from around the state of Colorado are that the potential for large flood events is still very real and that entrenched streams with shrunken floodplains do not accommodate them. Flood energy rises exponentially when historically wide active floodplains are confined to narrow entrenched floodways. Miniature floodplain benches, stepped multi-stage channels, and other enhancements within the artificially confined and entrenched reaches of the South Arkansas would do little to reduce exposure to fluvial hazard or improve resilience.

Conservation and restoration opportunities

A natural process-based approach

A better approach that is more line with the process-based thinking promoted throughout the SAWC report would be to restore other aspects of stream health to make the system more resilient to diminished flows while still being able to accommodate floods and other disturbance events. Such an approach also critically would provide refugia, habitat diversity and complexity that has otherwise been diminished through past stream corridor interventions. Opportunities where local restoration and conservation efforts can feasibly improve stream health and resilience on the South Arkansas are limited to properties where on-site stressors can be effectively treated. The on-site stressors responsible for most impairment on this reach are: (1) channelization and levees, (2) land use and development within the stream corridor, (3) roads, bridges, and structures and (4) biotic impacts such as wood recruitment, beaver activity, and riparian vegetation regeneration/succession.

Working closely with landowners towards mutual restoration and conservation goals is the cornerstone of Central Colorado Conservancy and Trout Unlimited's stewardship mission. It is also an absolute prerequisite to successful process-based restoration. Given the current land ownership, land use, and development pattern, the best opportunity to improve stream health through conservation or restoration on this reach is on the VS segment (land currently owned by the City of Salida and the Snyder family) extending upstream to include a portion of the SWS segment (land currently owned by the Southwest Conservation Corps and the Wykoff family) because this is where landowner goals and values align with process-based restoration strategies. (1) These are the properties where the effects of channelization and levees might be feasibly removed without harming current land use or risking damage to infrastructure. (In fact, restoring these may actually better protect these properties and infrastructure in the active stream corridor) ; (2) these are the properties where current land uses exist or can be planned in a way that accommodates fluvial processes over much of the riverscape; (3) these properties have no important roads, bridges, or structures that must be accommodated or and protected (or where they do exist there is potential to remove them); and (4) these are properties where biotic processes like wood recruitment, beaver activity, and riparian vegetation regeneration/succession can be tolerated and even promoted.

Land use on this section of the stream corridor has moved on from historical industrial-scale ranching, the stream is much less entrenched and beginning to recover naturally, and most of the direct causes of impairment can be practically and feasibly mitigated. Past levees and cross-valley road fills can be removed to reverse the impacts of channelization, entrenchment, and floodplain disconnect; and with improved hydrology native riparian vegetation and wetland can be reestablished. Simple treatments can be applied to promote natural fluvial processes such as sediment capture, scour, structural complexity, and riparian forest regeneration. In short, this segment provides a rare opportunity where natural stream ecosystem processes may occur over a broader portion of the historical riverscape without threatening infrastructure or infringing on property owner's needs. Conservation and process-based restoration of the riverscape aligns well with landowner values of increased natural habitat, floodplain function, open space, recreation, and environmental education. It is a perfect fit with the vision of the Ecosystems Learning Center (ELC) based on this site.

On other segments where stream functions are constrained by land use, development, or infrastructure, marginal stream health gains or limited enhancement benefits might be possible using costly engineering-based or artificial approaches such as the "river-within-a-river" or stepped floodplain redesign alternatives.

Planning concepts for conservation and restoration of the priority segment

A process-based restoration plan for the priority segment would involve the following:

1. Planning future development to allow expansion of the riverscape to the full extent of the stream corridor. Land uses within the active stream corridor would have to be planned to tolerate and accommodate natural processes such as regular floodplain activation, ground saturation and/or inundation, scour, deposition, development of riparian vegetation communities, and wetland.

2. Prescribing treatments that mitigate the dominant stressors of past channelization, historical land uses (i.e., cleared and drained pastureland), wood removal, and beaver extirpation by mimicking, promoting, and sustaining natural processes that these stressors disrupted. Active interventions may include treatments such as temporary structures that use natural materials to promote aggradation and more frequent activation of natural flow paths and floodplains, structures that mimic wood accumulation and beaver activity, and revegetation efforts such as planting and managing for native riparian species. Passive treatments would involve management that allows for the accumulation and transport of woody material and beaver dams.

3. Identifying potential conflicts with neighboring properties and planning solutions beforehand. If the active stream corridor is expanded on this segment, there would have to be a plan to address potential for expanded hydration and more frequent overland flows on downstream segments. The natural accumulation of woody material may make more wood available for transport, potentially increasing maintenance demands at the Highway 50 culverts downstream. If beavers are permitted to colonize, the potential for beaver conflicts on neighboring properties should be anticipated and addressed with appropriate coexistence strategies. The plan must also address needs to maintain the two existing diversion points on the segment as well as meet legal dry-up requirements on all properties.

4. To extending restoration efforts upstream from Salida's Vandeveer property to tie into the Ecosystems Learning Center at the Southwest Conservation Corps property would involve breaching the existing levees and removing road/trail and pedestrian bridge that were recently constructed between these properties. The constructed wetland on SCC (currently separated from the stream by a levee) could be incorporated into the riverscape which, because it was built for compensatory mitigation, could involve some federal regulatory hurdles. Land use on the Wykoff property, south of the current channel, would also have to be planned appropriately if the levee on that side is removed.

The combined effect of these activities could potentially improve all the reach-scale stream health factors including improved riverscape hydrology, riverscape dynamics, riparian vegetation, physical heterogeneity, and aquatic biota to improve stream function, habitat, and resilience via natural processes.

Evaluation criteria for watershed-scale stream health factors

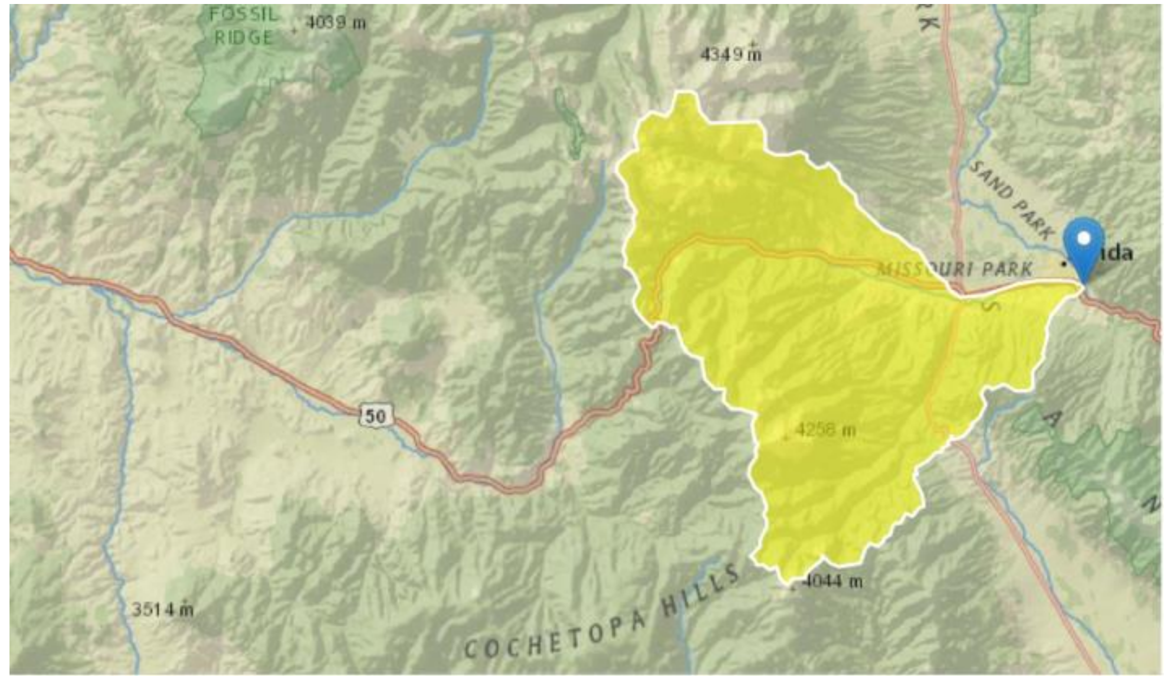
Watershed-scale variables	A	B	C	D	F
	Negligible impairment	**Mild impairment**	**Significant impairment**	**Severe impairment**	**Profound impairment**
	No significant impact to processes that support ecosystem health and function.	Mild or episodic impact to processes that support ecosystem health and function.	Significant or chronic impact to processes that support ecosystem health and function.	Severe and chronic impact to processes that support ecosystem health and function.	Profound or irreversible impact to processes that support ecosystem health and function.
Total volume	Net change from augmentations and depletions less than 10% of the total annual volume.	Net change from augmentations and depletions 10-25% of the total annual volume.	Net change from augmentations and depletions 25-40% of the total annual volume.	Net change from augmentations and depletions 40-70% of the total annual volume.	Net change from augmentations and depletions more than 70% of the total annual volume.
Peak flow	Magnitude and duration of annual discharge peaks closely resembles natural hydrograph. Departure from natural peak flow magnitude less than 10%.	Hydrograph has a natural seasonal pattern but peaks are attenuated, elevated, extended, or shortened. Departure from natural peak flow magnitude 10-25%.	Hydrograph has a natural seasonal pattern but peaks are attenuated, elevated, extended, or shortened. Departure from natural peak flow magnitude 25-40%.	Disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude 40-70%.	Disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude greater than 70%.
Base flow	Magnitude and duration of base flows closely resembles the natural hydrograph. Departure from natural seasonal minimum discharge less than 10%.	Hydrograph has a natural seasonal low-flow pattern. Seasonal minimum discharge diminished 10-25% or increased by 10-50%.	Periods of biologically critical low flows occur occasionally. Seasonal minimum discharge diminished 25-40% or increased by more than 50%.	Periods of biologically critical low flows are frequent. Seasonal minimum discharge diminished 40-40%.	Frequent and extended periods of biologically critical low flows and/or periods of no flow occur. Seasonal minimum discharge diminished by more than 70%.
Rate of change	Flow rates of change closely resemble natural hydrograph. Departure in rise and/or fall rates less than 10%	No rapid artificial flow changes. Departure in rise and/or fall rates 10-25%.	Occasional rapid artificial flow changes. Departure in rise and/or fall rates 25-40%.	Frequent rapid artificial flow changes. Departure in rise and/or fall rates 40-70%.	Artificially uniform hydrograph or hydrographs in which rapid daily fluctuations are common. Departure in rise and/or fall rates greater than 70%.
Flow regime	Flow regime is natural for the contributing watershed with minimal anthropogenic impacts. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic impacts to flow regime are present, but mild or episodic, causing mild impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to flow regime are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic impacts to flow regime are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to flow regime are profound, resulting in complete disruption or irreversible impairment to natural hydro, geo, and ecological processes.
Sediment supply	Natural rates of sediment supply. Net effect on sediment supply to the reach are minimal (less than 10%) .	Land uses that affect contributing hillslope erosion or upstream fluvial erosion are present, but the net effect on sediment supply to the reach is less than 25%.	Land uses that affect contributing hillslope erosion or upstream fluvial erosion are significant. Net effect on sediment supply to the reach is 25-40%.	Land uses that affect contributing hillslope erosion or upstream fluvial erosion are severe. Net effect on sediment supply to the reach is 33-50%.	Anthropogenic sediment sources overwhelm natural rates of sediment supply. Net effect on sediment supply to the reach is greater than 50%.
Organic materials	Natural rates of organic materials supply. Net effect on volume supplied to the reach are minimal (less than 10%) .	Land uses that affect organic material production or entrainment are present, but the net effect on supply to the reach is less than 25%.	Land uses that affect organic material production or entrainment are significant. Net effect on supply to the reach is 25-40%.	Land uses that affect organic material production or entrainment are severe. Net effect on supply to the reach is than 40-70%.	Land uses that affect organic material production or entrainment are profound and overwhelming. Net effect on supply to the reach is greater than 70%.
Materials supply	The supply of materials to the reach is natural for the contributing watershed with minimal anthropogenic impacts. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic impacts to the supply of materials are present, but mild or episodic, causing minimal impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to the supply of materials are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic impacts to the supply of materials are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to the supply of materials are profound, resulting in disruption or irreversible impairment to natural hydro, geo, and ecological processes.
Temperature	Temperature regime is natural and appropriate for a well-functioning river in its process domain. Negligible anthropogenic influence present.	Temperature impacts present, but regime is within the range of natural variability. Natural aquatic biota are minimally impaired and regulatory standards not exceeded.	Temperature regime impacts significant enough to *potentially* affect natural aquatic biota. Regulatory standards are occasionally exceeded, Category 3 M&E reaches.	Temperature regime is altered to a degree that *is known* to affect natural aquatic biota and/or regulatory standards are regularly exceeded. Category 5 303(d) listed reaches.	Temperature regime is fundamentally altered. Natural biota are known/observed to be severely impaired and regulatory standards are chronically exceeded.
Nutrients, organics	Nutrient levels are natural and appropriate for a well-functioning river in its process domain.	Nutrient levels are within the range of natural variability, natural aquatic biota are minimally impaired and regulatory standards are not exceeded.	Nutrient levels are altered to a degree that they significantly affect natural aquatic biota and/or regulatory standards are occasionally exceeded. Category 3 M&E reaches.	Nutrient levels are altered to a degree that is known to affect natural aquatic biota and/or regulatory standards are frequently exceeded. Category 5 303(d) listed reaches.	Nutrient levels have fundamentally altered the physicochemical environment. Natural biota are severely impaired and/or regulatory standards are chronically exceeded.
Chemical conditions, inorganics	Physico-chemical conditions are natural and appropriate for a well-functioning river in its process domain.	Physico-chemcial conditions are within the range of natural variability, natural aquatic biota are minimally impaired and regulatory standards not exceeded.	Physico-chemical conditions are altered to a degree that could potentially limit natural aquatic biota and/or regulatory standards are occasionally exceeded. Category 3 M&E list	Physico-chemical conditions are altered to a degree that is known to be limiting to natural aquatic biota and/or regulatory standards are regularly exceeded. Category 5 303d listed waters.	The physico-chemical environment is fundamentally altered. Natural biota are severly impaired and/or regulatory standards are chronically exceeded.
Water quality	Water quality is natural for the contributing watershed with minimal anthropogenic impacts. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic impacts to water quality are present, but mild or episodic, causing minimal impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to water quality are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic impacts to water quality are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to water quality are profound, resulting in disruption or irreversible impairment to natural hydro, geo, and ecological processes.
Land use and buffer	High-intensity land uses or development with impervious surfaces, bare soil, and structures covers less than 10% of the buffer area.	High-intensity land uses or development with impervious surfaces, bare soil, and structures covers 10-25% of the buffer area.	High-intensity land uses or development with impervious surfaces, bare soil, and structures covers 25-40% of the buffer area.	High-intensity land uses or development with impervious surfaces, bare soil, and structures covers 40-70% of the buffer area.	High-intensity land uses or development with impervious surfaces, bare soil, and structures covers more than 70% of the buffer area.
Terrestrial habitat connectivity	Less than 10% habitat loss within the habitat connectivity envelope (HCE) and no significant barriers to migration or dispersal of terrestrial organisms.	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.	25-40% 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.	40-70% 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.	More than 70% 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.
Aquatic habitat connectivity	There are no significant barriers that prevent migration or dispersal of aquatic organisms within the entire ecoregion and upstream to headwaters.	Impermeable migration/dispersal barriers are within 10 miles and/or there are minor migration/dispersal impediments on the reach or adjacent reaches.	Impermeable migration/dispersal barriers exist within 5 miles and/or there are multiple migration/dispersal impediments on the reach or adjacent reaches.	Impermeable migration/dispersal barriers exist within 2 miles and/or migration/dispersal is severely impeded on the reach or adjacent reaches.	The reach is effectively isolated. migration/dispersal is completely impeded on the reach or adjacent reaches.
Landscape support	The surrounding land and buffer area is in natural condition, with minimal anthropogenic impacts. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic impacts to the surrounding land and buffer area are present, but mild or episodic, causing minimal impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to the surrounding land and buffer area are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic impacts to the surrounding land and buffer area are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to the surrounding land and buffer area are profound, resulting in disruption or irreversible impairment to natural hydro, geo, and ecological processes.

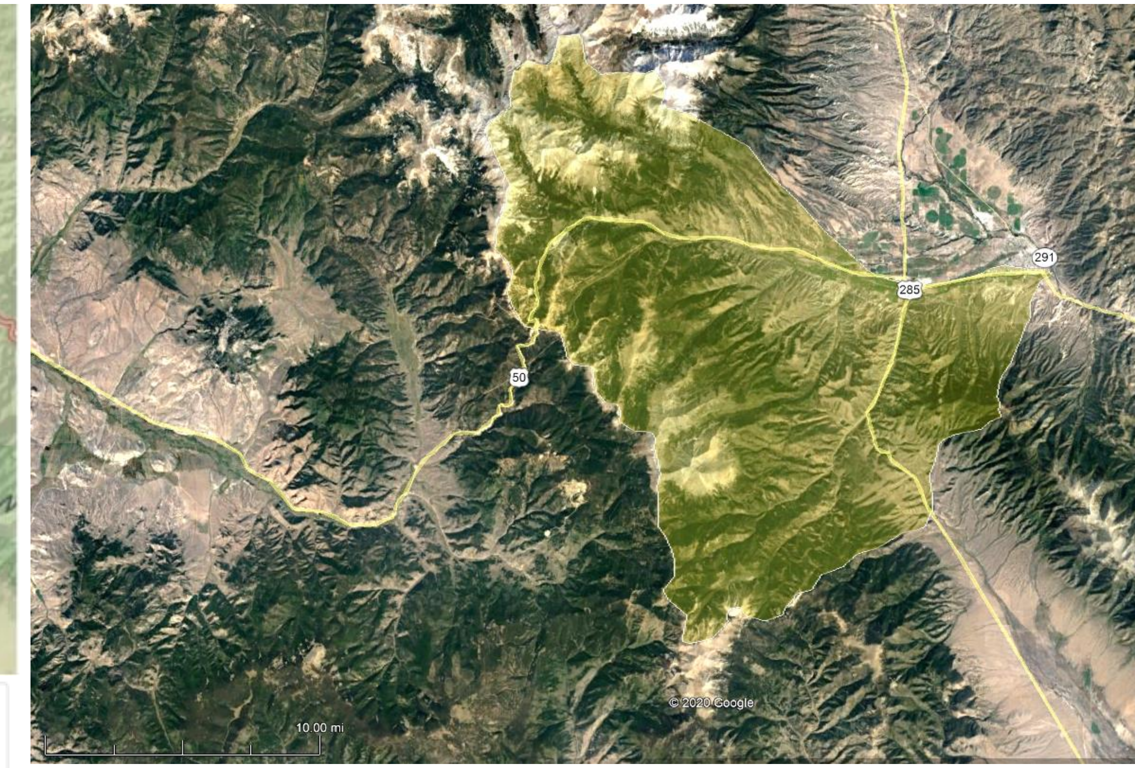
Evaluation criteria for reach-scale stream health factors

Reach-scale variables	A	B	C	D	F
	Negligible impairment	**Mild impairment**	**Significant impairment**	**Severe impairment**	**Profound impairment**
	No significant impact to processes that support ecosystem health and function.	Mild or episodic impact to processes that support ecosystem health and function.	Significant or chronic impact to processes that support ecosystem health and function.	Severe and chronic impact to processes that support ecosystem health and function.	Profound or irreversible impact to processes that support ecosystem health and function.
Frequently saturated area	Natural pattern of hydration during average annual flow regime. Area of land saturated during growing seasons is decreased less than 10%. (> 90% intact).	Area of land normally saturated during growing seasons is decreased 10-25%. (75-90% intact).	Area of land normally saturated during growing seasons is decreased 25-40%. (60-75% intact).	Area of land normally saturated during growing seasons is decreased 40-70%. (30-60% intact).	Area of land normally saturated during growing seasons is decreased more than 70%. (<30% intact).
Valley-bottom (ASC)	Natural pattern of hydration during average annual flow regime. Area of land saturated during normal runoff is decreased less than 10%. (> 90% intact).	Area of land normally saturated or inundated during normal runoff and frequent high flow events is decreased 10-25%. (75-90% intact).	Area of land normally saturated or inundated during normal runoff and frequent high flow events is decreased 25-40%. (60-75% intact).	Area of land normally saturated or inundated during normal runoff and frequent high flow events is decreased 40-70%. (30-60% intact).	Area of land normally saturated or inundated during normal runoff and frequent high flow events is decreased more than 70%. (<30% intact).
Flood-prone area	Less than 10% decrease in natural flood-prone area where inundation can be tolerated. (> 90% intact).	10-25% decrease in natural flood-prone area where inundation can be tolerated. (75- 90% intact).	25-40% decrease in natural flood-prone area where inundation can be tolerated. (60-75% intact).	40-70% decrease in natural flood-prone area where inundation can be tolerated. (30-60% intact).	More than 70% decrease in natural flood-prone area where inundation can be tolerated. (<30% intact).
Riverscape hydrology	Riverscape hydrology is natural for the reach context with minimal anthropogenic impacts. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic impacts to riverscape hydrology are present, but mild or episodic, causing minimal impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to riverscape hydrology are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic impacts to riverscape hydrology are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to riverscape hydrology are profound, resulting in disruption or irreversible impairment to natural hydro, geo, and ecological processes.
Geomorphic plasticity	Less than 10% corridor length impacted by channelization, revetment, or other activities that prevent normal erosion and deposition processes. (> 90% fluvially active).	10-25% corridor length impacted by channelization, revetment, or other activities that prevent normal erosion and deposition processes. (75-90% fluvially active).	25-40% corridor length impacted by channelization, revetment, or other activities that prevent normal erosion and deposition processes. (60-75% fluvially active).	40-70% corridor length impacted by channelization, revetment, or other activities that prevent normal erosion and deposition processes. (30-60% fluvially active).	More than 70% corridor length impacted by channelization, revetment, or other activities that prevent normal erosion and deposition processes. (<30% fluvially active).
Fluvially active zone	Less than 10% decrease in fluvially active area where natural geomorphic processes and disturbance is tolerable. (> 90% intact).	10-25% decrease in fluvially active area where natural geomorphic processes and disturbance is tolerable. (75- 90% intact).	25-40% decrease in fluvially active area where natural geomorphic processes and disturbance is tolerable. (60-75% intact).	40-70% decrease in fluvially active area where natural geomorphic processes and disturbance is tolerable. (30-60% intact).	More than 70% decrease in fluvially active area where natural geomorphic processes and disturbance is tolerable. (<30% intact).
Stream evolution	The stream is in a natural geomorphic state of evolution appropriate to its geological and ecological setting.	Some anthropogenic shift in evolutionary stage but with a trend towards the native state.	Significant anthropogenic shift in evolutionary stage and stabilized or slightly altered with a trend away from the native state.	Severe anthropogenic shift in evolutionary stage and stabilized or significantly altered with a trend away from the native state.	Artificially entrenched and channelized reaches with no potential for natural recovery.
Riverscape dynamics	Anthropogenic limitations or impacts to riverscape dynamics are minimal or nonexistent. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic limitations or impacts to riverscape dynamics are present, but mild or episodic, causing minimal impairment to natural hydro, geo, and ecological processes.	Anthropogenic limitations or impacts to riverscape dynamics are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic limitations or impacts to riverscape dynamics are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic limitations or impacts to riverscape dynamics are profound, resulting in disruption or irreversible impairment to natural hydro, geo, and ecological processes.
Riparian vegetation extent	More than 90% of potential riparian area is occupied by typical native riparian vegetation.	75-90% of potential riparian area is occupied by typical native riparian vegetation.	60-75% of potential riparian area is occupied by typical native riparian vegetation.	40-60% of potential riparian area is occupied by typical native riparian vegetation.	Less than 40% of potential riparian area is occupied by typical native riparian vegetation.
Vegetation biodiversity and endemism	Preponderance of native flora and fauna, without spread of aggressive or noxious species.	Native species predominate with only minor invasion by exotic species. Noxious species rare. Diversity decreased 10-25%	Small populations of noxious species may occur, and/or a significant proportion of the species are exotic or aggressive natives. Diversity decreased 25-40%	Noxious weeds, aggressive species, or exotics may be prevalent or dominant. Diversity decreased 40-70%	Riparian area has little to no characteristic vegetation. Diversity decreased >70%
Regeneration/succession	Riparian community is in a natural seral state appropriate to its geological and ecological setting and characteristic vegetation is regenerating sustainably.	Some anthropogenic shift in riparian community composition but with a trend towards the native state and sustainable regeneration.	Significant anthropogenic shift in riparian community composition and stabilized or slightly altered with a trend away from the native state. Poor regeneration.	Severe anthropogenic shift in riparian community composition and stabilized or significantly altered with a trend away from the native state. Poor to no regeneration.	Characteristic riparian vegetation not present or no longer regenerating.
Riparian vegetation	Riparian vegetation is natural for the reach context with minimal anthropogenic impacts. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic impacts to riparian vegetation are present, but mild or episodic, causing minimal impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to riparian vegetation are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic impacts to riparian vegetation are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to riparian vegetation are profound, resulting in disruption or irreversible impairment to natural hydro, geo, and ecological processes.
Riparian heterogeneity	Structural guilds present with distribution, patchiness, interspersion, canopy cover and vertical distribution of plant material in ASC differ less than 10% from native reference.	Structural guilds present with distribution, patchiness, interspersion, canopy cover and vertical distribution of plant material in ASC differ 10-25% from native reference.	Structural guilds present with distribution, patchiness, interspersion, canopy cover and vertical distribution of plant material in ASC differ 25-40% from native reference.	Structural guilds present with distribution, patchiness, interspersion, canopy cover and vertical distribution of plant material in ASC differ 40-70% from native reference.	Structural guilds present with distribution, patchiness, interspersion, canopy cover and vertical distribution of plant material in ASC differ more than 70% from native reference.
Aquatic heterogeneity	Diversity, distribution, and richness of geomorphic structure and micro-scale velocity/depth combinations differ less than 10% from native reference.	Diversity, distribution, and richness of geomorphic structure and micro-scale velocity/depth combinations differ 10-25% from native reference.	Diversity, distribution, and richness of geomorphic structure and micro-scale velocity/depth combinations differ 25-40% from native reference.	Diversity, distribution, and richness of geomorphic structure and micro-scale velocity/depth combinations differ 40-70% from native reference.	Diversity, distribution, and richness of geomorphic structure and micro-scale velocity/depth combinations differ more than 70% from native reference.
Micro-scale heterogeneity	Diversity, distribution, and richness of substrate and micro-scale micro-scale velocity/depth combinations differ less than 10% from native reference.	Diversity, distribution, and richness of substrate and micro-scale velocity/depth combinations differ 10-25% from native reference.	Diversity, distribution, and richness of substrate and micro-scale velocity/depth combinations differ 25-40% from native reference.	Diversity, distribution, and richness of substrate and micro-scale velocity/depth combinations differ 40-70% from native reference.	Diversity, distribution, and richness of substrate and micro-scale velocity/depth combinations differ more than 70% from native reference.
Physical Heterogeneity	Anthropogenic limitations or impacts to physical heterogeneity are minimal or nonexistent. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic limitations or impacts to physical heterogeneity are present, but mild or episodic, causing minimal impairment to natural hydro, geo, and ecological processes.	Anthropogenic limitations or impacts to physical heterogeneity are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic limitations or impacts to physical heterogeneity are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic limitations or impacts to physical heterogeneity are profound, resulting in disruption or irreversible impairment to natural hydro, geo, and ecological processes.
Trophic structure	No significant stressors exist. Community structure is representative of the native, undisturbed condition.	Some significant stressors are present, but all functional guilds are appropriately represented and filled by native species.	Food web complexity and depth lacking, but most important functional guilds are appropriately represented even when composed of nonnative species.	Food web complexity and depth lacking. Some important functional guilds are impacted or poorly represented.	Food web profoundly simplified or altered. Important functional guilds are absent or severely diminished.
Aquatic biodiversity and endemism	No significant stressors exist. Reference community structure with predominantly native species, characteristic distribution, age structure, and biomass.	Community structure consists of mostly native species. Distribution, age structure, or overall biomass of species may be slightly altered.	Community structure is altered. Exotic species may be common, diversity lacking, and/or species distributions skewed, but exotic species generally fill natural niches.	Community structure is severely altered and may include a preponderance of exotic species, major loss of diversity or severely limited keystone species.	Community structure is fundamentally altered. Examples include communities dominated by exotic species, monocultures, severely depauperate biodiversity.
Aquatic biota	Aquatic biota diversity and trophic structure is natural and characteristic with minimal anthropogenic impacts. Impairment to hydro, geo, and ecological processes are negligible.	Anthropogenic impacts to aquatic biota diversity and trophic structure are present, but mild or episodic, causing minimal impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to aquatic biota diversity and trophic structure are significant or chronic, contributing to significant impairment of natural hydro, geo, and ecological processes.	Anthropogenic impacts to aquatic biota diversity and trophic structure are chronic and extreme, resulting in severe impairment to natural hydro, geo, and ecological processes.	Anthropogenic impacts to aquatic biota diversity and trophic structure are profound, resulting in disruption or irreversible impairment to natural hydro, geo, and ecological processes.

Watershed characteristics

Summary watershed characteristics obtained from USGS Colorado StreamStats



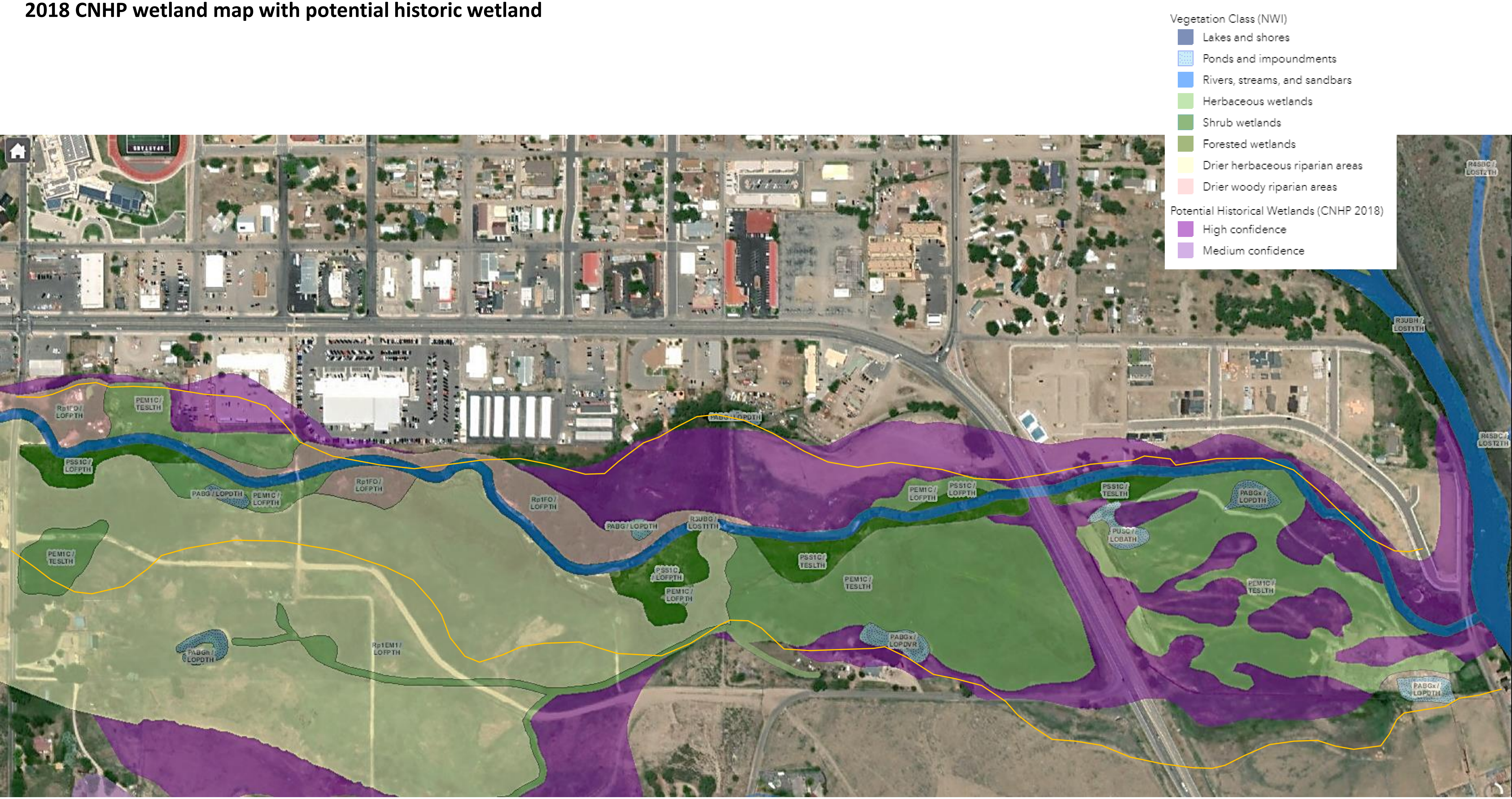


Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	212	square m
BSLDEM10M	Mean basin slope computed from 10 m DEM	35	percent
PRECIP	Mean Annual Precipitation	18.31	inches
ELEV	Mean Basin Elevation	10085	feet
TOC	Time of concentration in hours	8.5	hours
STORNHD	Percent storage (wetlands and waterbodies) determined from 1:24K NHD	0.2	percent
STATSCLAY	Percentage of clay soils from STATSGO	17.13	percent
SSURGOD	Percentage of area of Hydrologic Soil Type D from SSURGO	1.33	percent
SSURGOC	Percentage of area of Hydrologic Soil Type C from SSURGO	0.75	percent
SSURGOB	Percentage of area of Hydrologic Soil Type B from SSURGO	8.88	percent
SSURGOA	Percentage of area of Hydrologic Soil Type A from SSURGO	3.47	percent
RUNCO_CO	Soil runoff coefficient as defined by Verdin and Gross (2017)	0.4	dimensic
RCN	Runoff-curve number as defined by NRCS (http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=17758.wba)	58.74	dimensic
OUTLETELEV	Elevation of the stream outlet in feet above NAVD88	7002	feet
MINBELEV	Minimum basin elevation	7000	feet
LONG_OUT	Longitude of Basin Outlet	-105.97822	degrees
LFPLENGTH	Length of longest flow path	27.2	miles

Parameter Code	Parameter Description	Value	Unit
LC11WETLND	Percentage of wetlands, classes 90 and 95, from NLCD 2011	1.8	percent
LC11WATER	Percent of open water, class 11, from NLCD 2011	0.1	percent
LC11SNOIC	Percent snow and ice from NLCD 2011 class 12	0.1	percent
LC11SHRUB	Percent of area covered by shrubland using 2011 NLCD	5	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	2.9	percent
LC11GRASS	Percent of area covered by grassland/herbaceous using 2011 NLCD	19.1	percent
LC11FOREST	Percentage of forest from NLCD 2011 classes 41-43	59.2	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	1.1	percent
LC11CRPHAY	Percentage of cultivated crops and hay, classes 81 and 82, from NLCD 2011	1.6	percent
LC11BARE	Percentage of barren from NLCD 2011 class 31	10.2	percent
LAT_OUT	Latitude of Basin Outlet	38.520892	degrees
I6H2Y	Maximum 6-hour precipitation that occurs on average once in 2 years	0.94	inches
I6H100Y	6-hour precipitation that is expected to occur on average once in 100 years	2.44	inches
I24H2Y	Maximum 24-hour precipitation that occurs on average once in 2 years - Equivalent to precipitation intensity index	1.46	inches
I24H100Y	Maximum 24-hour precipitation that occurs on average once in 100 years	2.95	inches
ELEVMAX	Maximum basin elevation	14200	feet

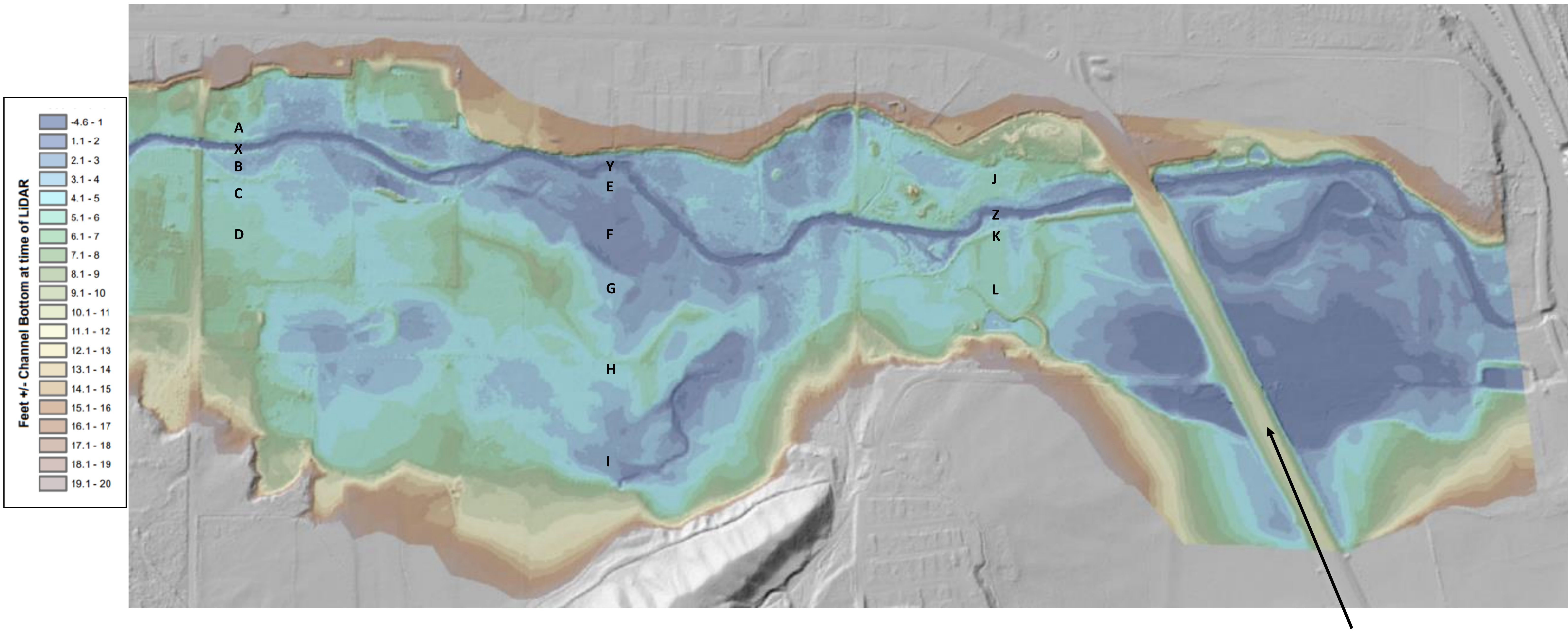
2018 CNHP wetland map with potential historic wetland



Map produced using the Colorado Natural Heritage Area watershed planning toolbox:
https://cnhp.colostate.edu/cwic/tools/toolbox/

Relative elevation map

A relative elevation map shows terrain elevations relative to the elevation of the channel bed at corresponding longitudinal position, by color, according to the legend. Topographic data are from a 2011 LiDAR survey and do not reflect land changes that occurred since.



Examples:

Point A is 6-7 feet higher than the channel bed at point X.
Point B is 2-3 feet higher than the channel bed at point X.
Point C is 5-6 feet higher than the channel bed at point X.
Point D is 5-6 feet higher than the channel bed at point X.

This segment is deeply entrenched below the natural pre-disturbance riverscape surface elevation (or geomorphic floodplain) marked by Points A, C, and D.

Point E is 2-3 feet higher than the channel bed at point Y.
Point F is 1-2 feet higher than the channel bed at point Y.
Point G is 3-4 feet higher than the channel bed at point Y.
Point H is 5-6 feet higher than the channel bed at point Y.
Point I is 1-2 feet higher than the channel bed at point Y.

This segment is only slightly entrenched. The ridge at Point H is either a natural geomorphic feature or possibly fill.

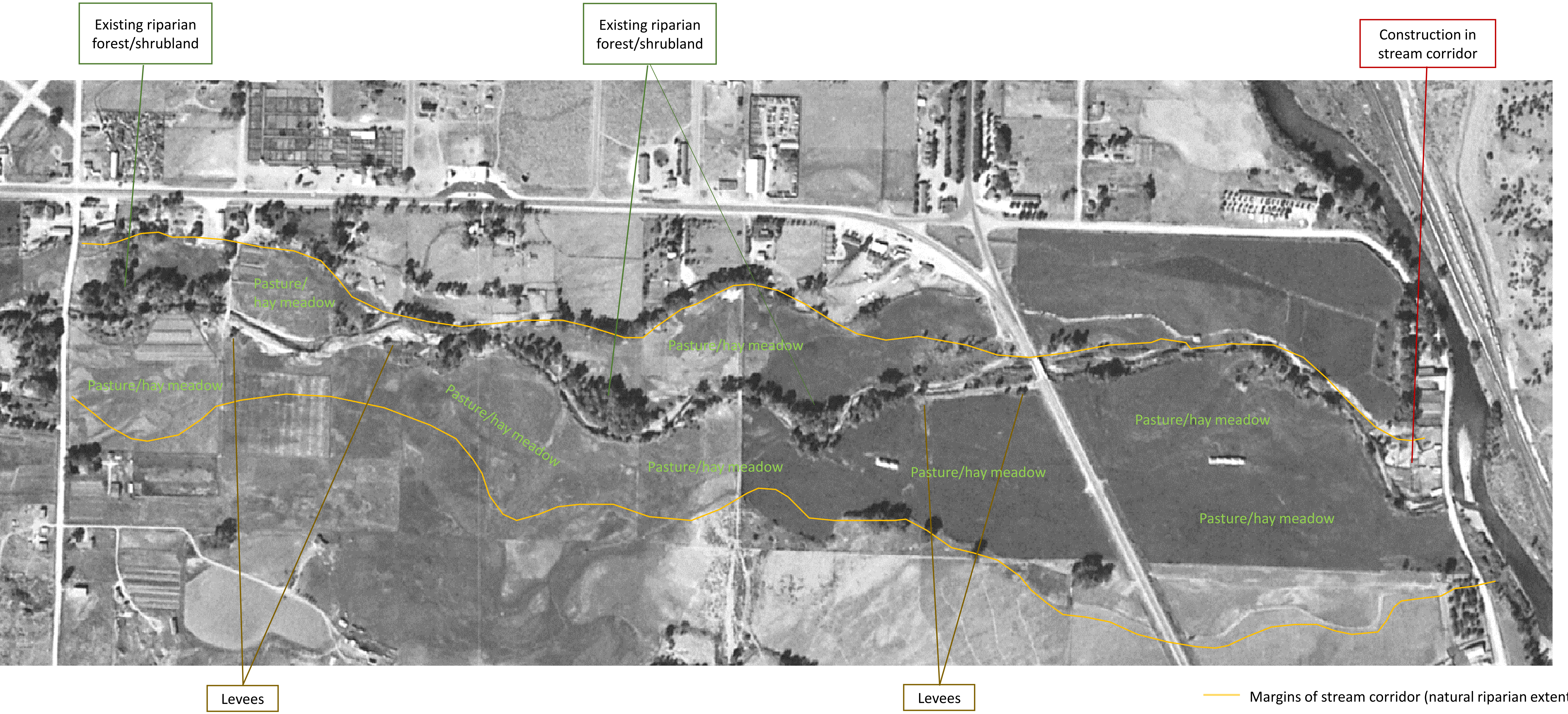
Point J is 7-8 feet higher than the channel bed at point Z.
Point K is 9-10 feet higher than the channel bed at point Z.
Point L is 6-7 feet higher than the channel bed at point Z.

This segment is severely entrenched.

Cross-valley fill for Highway 50 sits 10-14 feet above the riverscape surface elevation. Areas downstream have been filled and graded for development since the 2011 LiDAR survey.

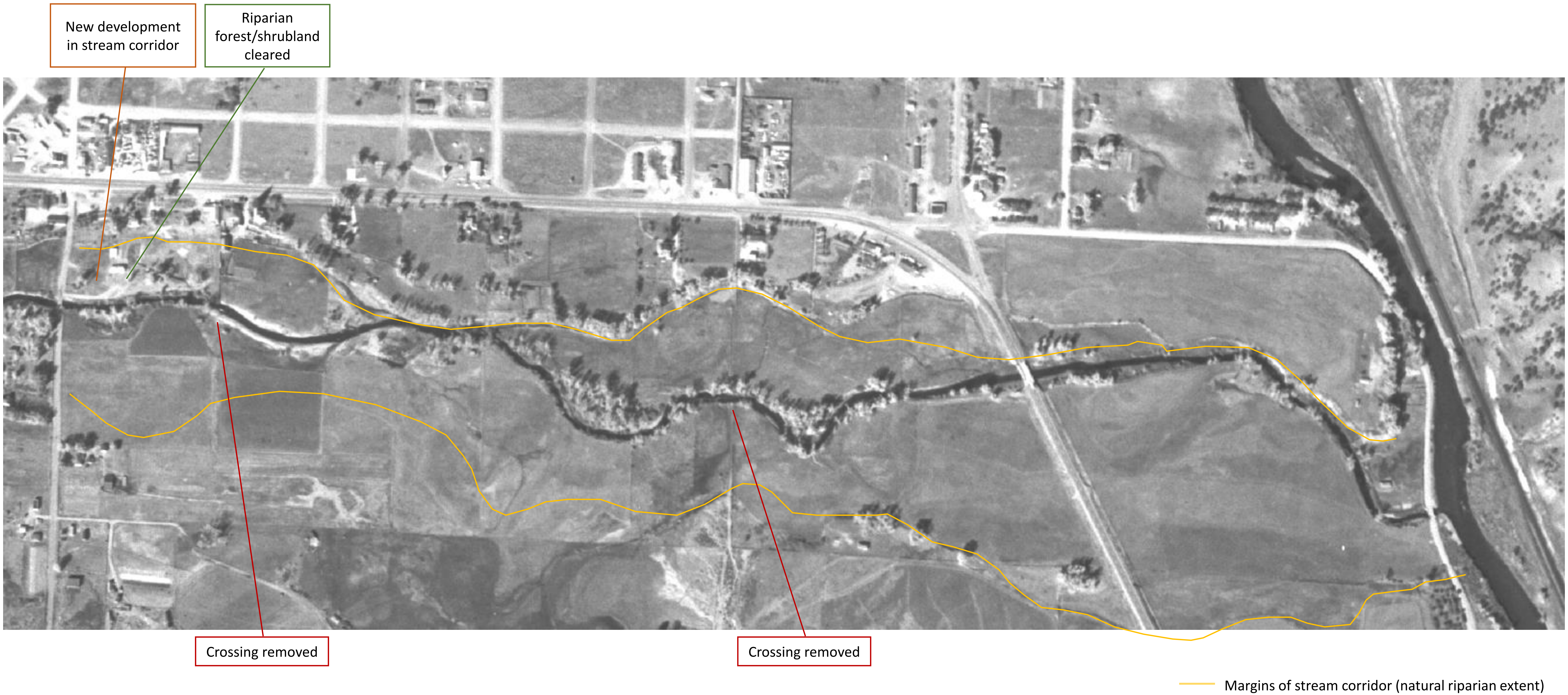
1954

By 1954, the reach was already highly channelized. Most of the riverscape had been converted for rural and agricultural uses, especially irrigated hay meadow and pastureland. Riparian cottonwood forest and shrubland had been cleared, with less than 3% remaining. There were 5 road crossings (bridges or culverts) and 3 major roads with significant fill spanning the stream corridor. Levees were present on several segments, and apparently recently constructed.



1961

Between 1954 and 1961, two of the road-stream crossings were removed. Additional development occurred in the stream corridor at the upper end of the reach, and a section of riparian forest/shrubland was cleared.



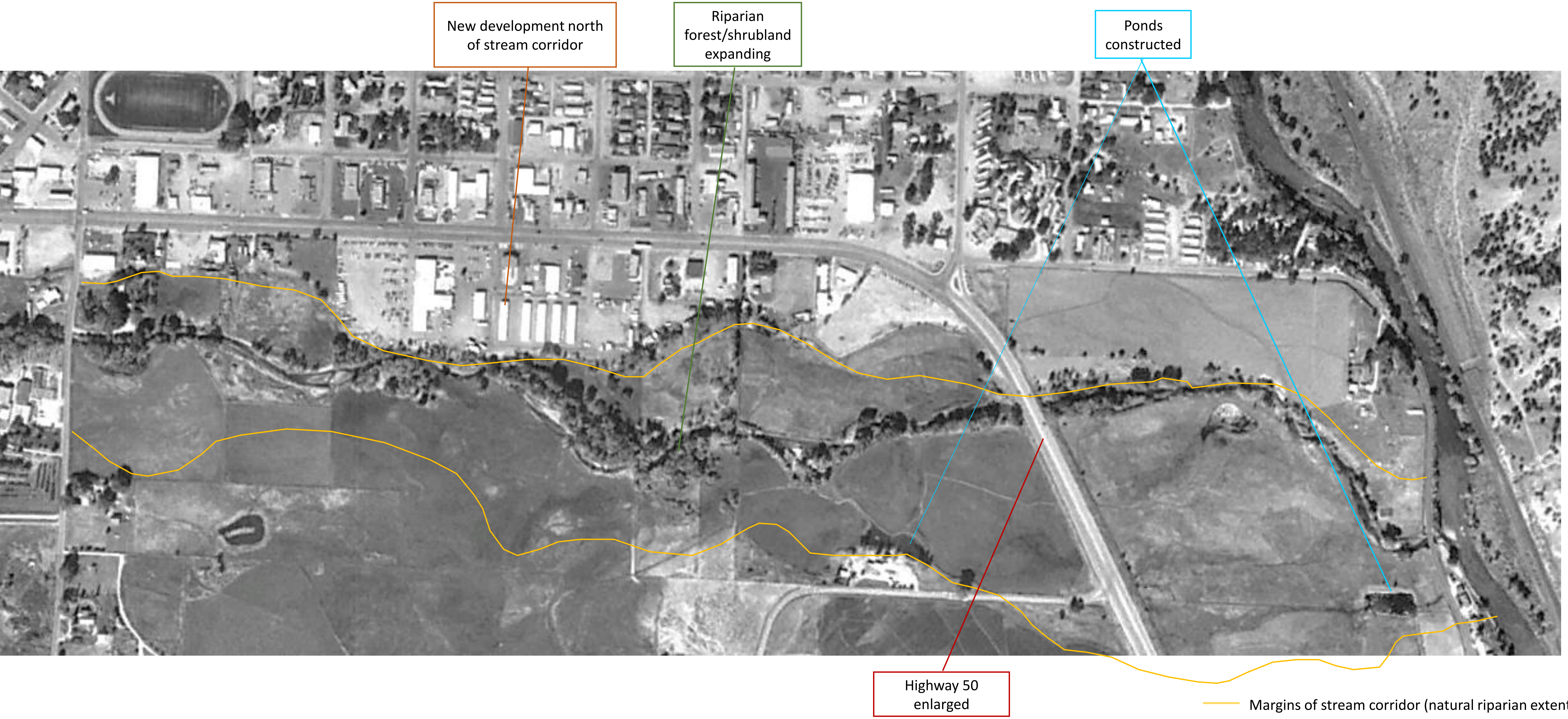
1976

Between 1961 and 1976, there were no new major land use changes in the riverscape corridor.

Margins of stream corridor (natural riparian extent)

1999

Between 1976 and 1999, Highway 50 was enlarged, creating a larger physical and hydrological barrier across the stream corridor. There was extensive urban development in town north of the riverscape corridor. Riparian forest/shrubland expanded on segments in the middle of the reach segment, but the total riparian forest/shrubland area was still less than 5% in 1999. Two ponds were constructed on riverscape margins.



2005

Between 1999 and 2005, riparian forest/shrubland continued expanded further on segments in the middle of the reach. Two more new ponds were constructed in the stream corridor. New construction disturbance was evident upstream of Highway 50.

2011

Between 2005 and 2011, urban development encroached on the riverscape with the construction of a hotel and parking lot in the stream corridor on the upper portion of the reach.

2013

Between 2011 and 2013, there appeared to be little significant land use change in the stream corridor.

Margins of stream corridor (natural riparian extent)

2018

Between 2013 and 2018, construction disturbance was evident above and below Highway 50. Floodplain fill, drainage, and new roads for the Two Rivers housing development that will occupy most of the stream corridor below Highway 50 were in progress in 2018 A new road/trail and bridge were built, creating a new corridor-spanning physical and hydrological barrier and constriction point.

2019

In 2019, construction of the Two Rivers housing development within and adjacent to the stream corridor was well underway. New roads and trails were constructed in and adjacent to the corridor upstream.