Technical Report

River Channel Characteristics of the Uncompahgre River in Ridgway, CO

SUBMITTED: 12/3/2021

Prepared For:

DHM DESIGN

DHM Design
311 Main Street
Carbondale, CO 81623

Town of Ridgway
P.O. Box 10
Ridgway, Colorado 81432

Prepared By:

Lotic Hydrological, LLC
P.O. Box 1524
Carbondale 81623

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Project background

Town of Ridgway requested a River Corridor Assessment of approximately 120 acres of river segments adjacent to the Uncompahgre River. The Assessment's purpose is to "characterize river function, ecosystem health, and channel stability within the river corridor". Specific concerns for the river corridor highlighted by local stakeholders include the need for frequent channel maintenance near Rollans Park, and potential problems with sedimentation and water quality. Lotic Hydrological completed a rapid geomorphological assessment of the channel corridor in the project area to support DHM Design and the Town of Ridgway in achieving the overall project goals.

The geomorphological assessment activities employed during this project focused on:

- Assessing current conditions, placing the town reach within the greater watershed setting and geological context of the upper Uncompahgre Valley,
- Understanding the purposes and efficacy of past work by the town or other entities to manipulate the river corridor, and
- Providing conceptual river corridor management strategies for the town to pursue in the future.

At this time, Lotic's understanding that the town's management goals for the reach of the Uncompahgre River through town have been expressed, generally, but they are not fully defined or prioritized in policy. Future management strategies and recommendations are heavily dependent on the set of specific and, potentially, evolving goals and priorities that local stakeholders articulate for the river corridor.

Several concurrent local plans have a nexus to this assessment. These plans identify strategies, goals, or objectives for the Uncompahgre River in Ridgway. Notably, Goal #2 from the 2018-2020 Uncompahgre Watershed Partnership Strategic Plan[1] sets forth that the local community should strive to:

"*Improve and maintain riverine ecosystem function including in streams and riparian areas"*.

The associated sub-objectives associated with Goal #2 are defined as follows:

- Understand the factors that lead to instability and unpredictability of the river channel,
- Protect environmentally sensitive and recently restored areas,
- Improve flood management within the Uncompahgre Valley, and
- Encourage development of riparian buffers and new wetlands.

[1] https://www.uncompahgrewatershed.org/reports-plans/

1.2 Existing information sources

Document or source	Description/Relevant Concepts or Sections
2019 Town of Ridgway Master Plan and Future Land Use Map	Provides overall planning vision and strategies/goals for managing growth. Includes anticipated future land use maps in the project corridor area.
2018 Uncompahgre Watershed Plan	Goal 2: "Improve and maintain riverine ecosystem function including in streams and riparian areas"
Ordinance 18-01, Uncompahgre Overlay District	Amendments to the town's zoning map creating special regulations for river corridor development
2018 Uncompahgre Watershed Plan and 2018-2020 Strategic Plan	Specifies goals for maintaining riverine ecosystem function and prioritizes current project list.
Additional data sources: Digital elevation models (10m resolution), aerial photography (1m+ resolution), surficial geology.	Acquired via USGS Earth Explorer web interface, USDA Geospatial Gateway, Google Earth imagery, and Colorado Geological Survey web portals.
2020 Uncompahgre Watershed Partnership River Watch Report	Elevation models for project area, geologic layer information, and comparative aerial imagery from different time periods supported interpretation of channel characteristics.
2012 Uncompahgre Water Quality Report	Metals at Potters Ranch above town River Watch site are elevated in fall, but in general much reduced from upstream watershed and below chronic standards with exception of dissolved iron, which has a site specific standard in the area. Appendix A reports data for a site in town ('Ridgway Town'), also showing slight concern levels for aluminum and iron, originating from upper watershed legacy mine sources.
Western Stream Works 2008	Metals generally decrease to below aquatic life standards by Ridgway, however aluminum levels tends elevate in spring runoff, presumably from re-suspension during high flows. Fine sediments on the reach above town may smother interstitial spaces, affecting macroinvertebrate life and fish spawning. 50th % of total iron concentrations often indicate levels that may be contributing to habitat degradation in the area from Ouray to Ridgway Reservoir. Aluminum toxicity may also

Document or source	Description/Relevant Concepts or Sections
	continue to directly contribute to degraded fisheries in Ridgway. As of 2012, CPW described the fishery above the reservoir and into Ridgway as 'seasonal', meaning that adult brown trout moved into the town reach during the spawn, but a self-sustaining population was not present. The number and diversity of macroinvertebrate taxa collected above the reservoir continues to be depressed over time, with only 9 taxa observed in 2009. Although most metals standards are met in the Ridgway area, the holistic picture of water quality health created by chemical data, fish data, aquatic macroinvertebrate data, and habitat observations continues to indicate a river and fishery strongly impacted by legacy mining impacts from upstream.
Riverbend Engineering, 2003/2004	No report or other documentation readily found, however, it is noted on company website that instream structures were installed to improve the mixing zone at effluent discharge locations in 2008. The fate and condition of these structures cannot be further assessed without specific knowledge of their original installation. *"WSW within U.S. Army Corps Nationwide permit compliance designed and built instream structures to maximize stream flow volume towards effluent discharge location ensuring State of Colorado dilution requirements, create floodplain and minimize stream-braiding during peak discharge events."* http://www.westernstreamworks.com/projects/stream-restoration/
Western Stream Works 2001-2006	Website materials provided a project description for the purposes, goals, and implementation strategies of the 2003/2004 channel reconfiguration work, completed under project management of Western Stream Works.
	No report or other documentation readily found. "WSW acted as Project Manager and Town Representative

Document or source	Description/Relevant Concepts or Sections
	during all phases of project in excess of $1,000,000. Led land owner meetings leading to subsequent approval of land easements, pursued and attained U.S. Army Corps of Engineers permits, Division of Wildlife approval, Colorado Department of Transportation approval, budget development, budget expenditures, rock procurement, heavy equipment contracting, managed all phases of construction following a National Park Service Design including: stream channel meanders, cross veins, J hooks, riffle reaches, bank stabilization, pond creation, wetland creation, etc.; solicited grants, grant writing, site walks, educational outreach, and media contacts." http://www.westernstreamworks.com/projects/stream-restoration/

2 Channel Morphology Conditional Assessment

Stream geomorphic assessments attempt to relate the physical processes of the river, including streamflow regimes and sediment transport characteristics, to the landforms and vegetative community present along the stream corridor. A channel conditions assessment seeks to document the set of past and present influences controlling channel shape and function. Investigations in the Ridgway corridor sought to identify dominant processes and relate those to identified stakeholder concerns. Additional fine-scale quantitative field investigations may yield more-detailed answers to stakeholder questions, albeit at a much greater resource investment.

The rapid assessment described here sought to create a conceptual model of channel processes that may help stakeholders pursue more-directed investigations and management actions in the future. It utilizes a multiple-lines-of-evidence approach to characterize river corridor conditions. Assessment activities included:

- Review of existing information and sources from Town of Ridgway regarding previous management actions and purposes of alteration/restoration/enhancement activities to the channel within the town corridor.

- Reconnaissance-level GIS assessments of the corridor within the town reach and the greater context of the Upper Uncompahgre Valley, and *especially*;
- Rapid field investigations of the town reach.

2.1 Channel Morphology Background

Geomorphological processes in the Uncompahgre watershed help create and alter the basin's landforms, channel forms, and aquatic ecosystems. Stream channel morphology and evolution tend to reflect the dominant boundary conditions present in a given landscape, creating distinct channel at different landscape positions in the Uncompahgre watershed. The Uncompahgre River near Ridgway traverses through several significant landscape transitions that collectively influence and control channel form. Human alterations in the last century provide another set of major impacts to the stream channel. Impacts result both from the historical activities in the upper watershed, such as increased sediment generation from extensive mining histories and construction of the railroad corridor in the valley, as well as more recent or localized floodplain activities like agriculture use, gravel mining, and urban development in the Ridgway town reach. More recently, active channel reconfiguration occurred in the Ridgway town reach occurred including the imposition of a single-thread channel type, floodplain and riparian reconfiguration, and establishment of in-channel structures for habitat, infrastructure protection, and water quality and habitat benefits. These human impacts are overlaid on the natural landscape context.

2.2 Geological Setting

The Uncompahgre River drains the northern slope of the San Juan Mountain Range, a region of complex geologic history. While various technical reports by USGS and more layperson-oriented geological descriptions are available[2], the primary interest here is not the technical characteristics of rock formations and age of geological formations. Rather, the relevant information for understanding current river function lies in the current functional characteristics of the geologic units or formations in the Ridgway vicinity.

[2] Hail, WJ. 1989. Reconnaissance geologic map of the Ridgway Quadrangle, Ouray County, Colorado. US Geological Survey. Miscellaneous Field Studies Map 2100. https://doi.org/10.3133/mf2100

Moore GE. 2004. Mines, Mountain Roads, and Rocks. Ouray County Historical Society, Ouray, CO.

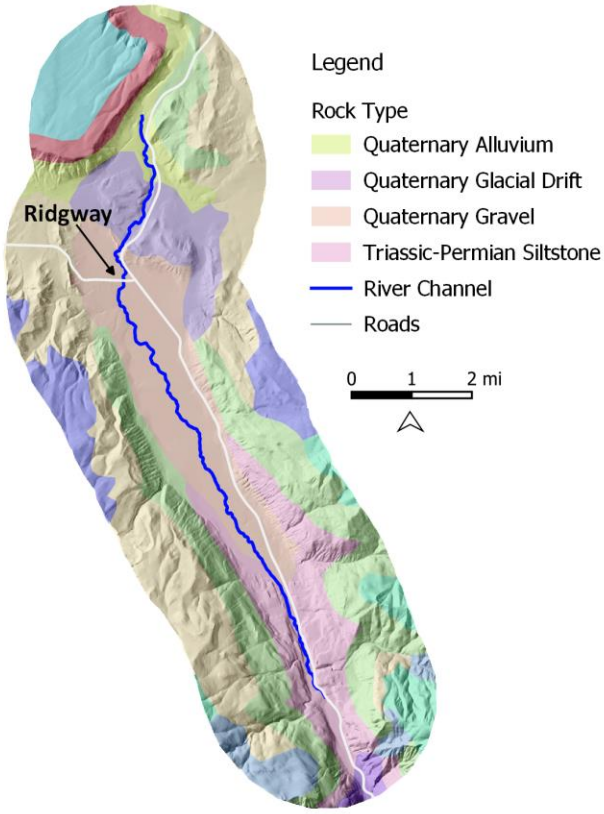

Figure 1. Surficial geology of the Uncompahgre River valley above Ridgway.

The Uncompahgre Valley and floodplain near Ridgway were deposited as a large alluvial glacial outwash plain at the slope of the San Juans. High sediment production in the river's headwaters occurred in previous, long-past geologic time periods due to mountain uplift, volcanic activity, and later subsequent mass-wasting and glacial activity. Steep headwaters were able to transport high sediment loads downstream out of the core range, then deposit them in wide floodplains. The Uncompahgre Valley upstream of Ridgway consists of deep alluvial gravel deposits resulting from this transport. Downstream of the town, in the vicinity of Dennis Weaver park, surficial geology shifts to glacial drift (unsorted glacial sediments), which have greater relief above the river but still provide relatively little long-term resistance to erosive forces on channel banks.

2.3 River Styles Channel Classification

The River Styles Framework[3] uses stream geometry, planform, and geomorphic features of the floodplain and instream segments to classify stream reaches in terms of channel character and behavior. The

[3] Brierley GJ and Fryirs K. 200. RiverS Styles, a geomorphic approach to catchment characterization: Implications for river rehabilitation in Bega catchment, New South Wales, Australia. Enviromental Management. 25: 6 pp. 661–679.

framework is a hierarchical classification tree, beginning broadly with valley characteristics and increasing in specificity with floodplain geomorphic features, in-stream geomorphic features, and substrate (Figure 2). This assessment implemented a modified Stage 1 River Styles framework (reconnaissance level) for the upper Uncompahgre watershed. Results from the assessment of river segments between Ouray and Ridgway Reservoir provide context for understanding drivers of current and historical channel forms.

Assessment results produce insight into the likely physical responses of different stream reaches to existing management practices or anticipated flow regime or land use changes (Table 1, Figure 3). For example, steep confined streams may undergo little geomorphologic change as a result of flow regime modification, while meandering unconfined streams can experience rapid shifts in channel form and ecosystem function following human-induced changes to flow or riparian integrity. Characterization of geomorphological behavior is also useful when predicting channel response to human infrastructure like bridges, culverts, and surface water diversion structures.

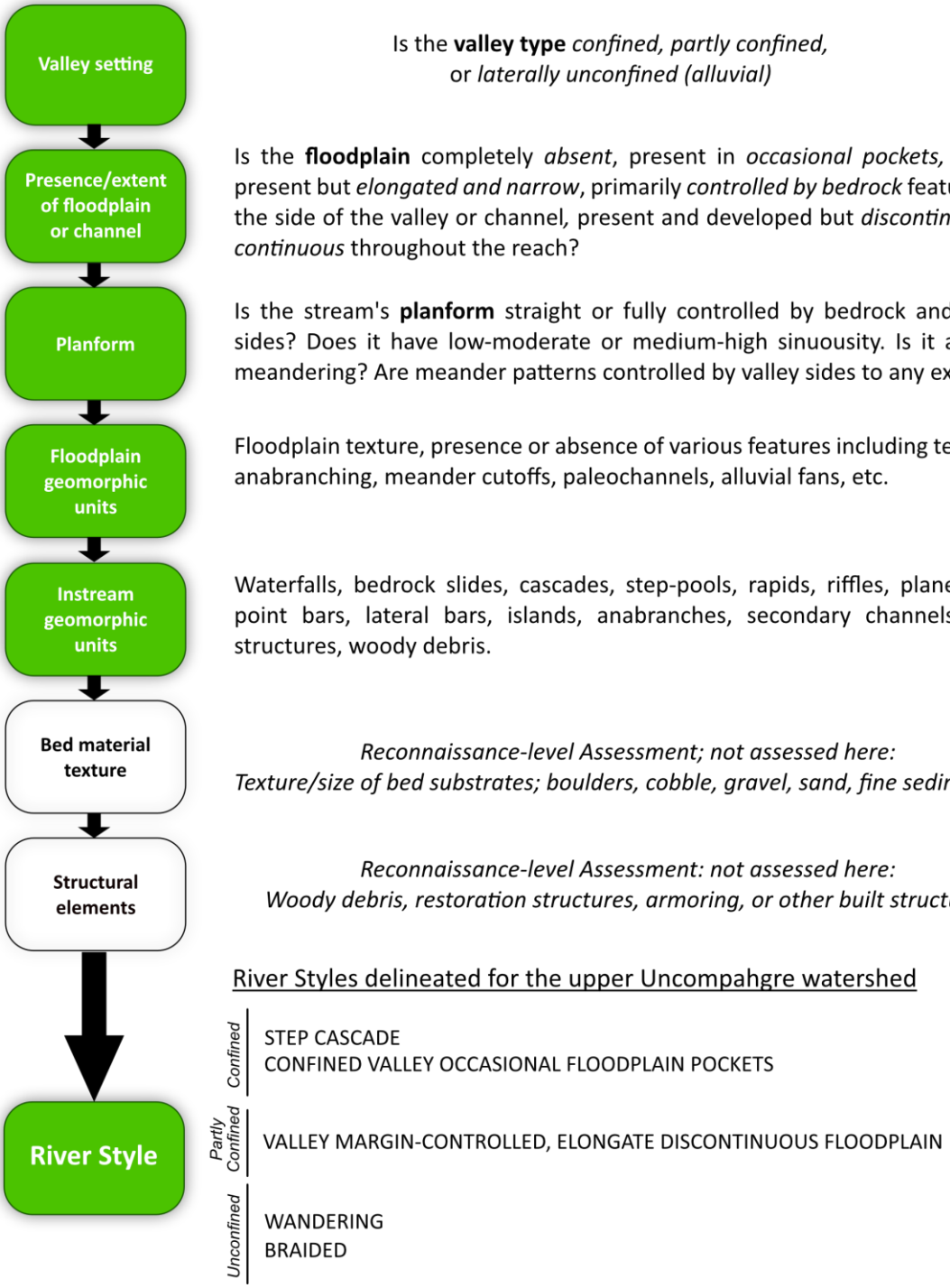

Figure 2. River Styles channel classification workflow.

Table 1. River Styles channel type descriptions for Uncompahgre River project area.

Characteristics	River Style	Key features
Confined valley setting. High-energy streams closely coupled to hillslopes. Narrow riparian zones. Very sensitive to upland land use activities.	Step cascade	High gradient, predominantly steep cascades and occasional steep runs and waterfalls. Increasing amounts of cobble and gravel deposits with partially recognizable recurring step structure and frequency. Substrate includes bedrock, boulders and colluvium.
	Confined valley occasional floodplain pockets	Small and discontinuous floodplain pockets, riffles, runs and rapids with occasional larger wood-generated or step pools. Median substrate decreasing in size compared to headwaters; fewer boulders and more sands and gravels. Occasional but irregular instream bar formations.
Partially confined valley setting. Moderate energy streams exhibiting some floodplain development and weak connections to hillslopes. Variable riparian zone widths. Somewhat sensitive to both land and water use activities.	Valley-margin controlled, elongate discontinuous floodplain, bedrock confined	Low to moderate sinuosity reaches in partially confined valleys; channel bed in predominately alluvial materials; various bar types, run and pool complexes, well-developed floodplain typically on one side of river; lateral channel movements occur but are largely confined by valley margins for a majority but not all of linear channel distance. Confining margins variously include bedrock, terraces, alluvial fans, and extensive colluvium stretches.
Laterally unconfined valley setting. Lower-energy alluvial streams exhibiting well-developed floodplains. Very weak connections to hillslopes and strong interactions with overbank areas. Well-developed riparian zones. Sensitive to land use changes in floodplains and water use activities.	Wandering	Unconfined, planform-controlled channel with low-moderate sinuosity, active sidebar and in-channel bar formation and destruction, partially developed meandering and associated geomorphic forms.
	Braided	Unconfined, planform-controlled multi-threaded channel with intermediate channel slopes (steeper than meandering reaches, shallower slopes than step-pool, plane bed, or other confined reaches), lacking dominant thalweg, frequent in-channel bars with ephemeral/sub-decadal or intra-annual shifting in location and form.

River segments above and through town are classified with *braided* and *wandering* channel types (Figure 3). These forms are often found on stream systems with high sediment loads and unconfined or partially confined valley margins. Numerous fluvial signatures (signs that a location was previously occupied or impacted by active river channel) are visible in the valley floor between Orvis Hot Springs and downtown Ridgway. The channel at this location underwent significant lateral movements ranging between 100-1000ft from its current course over time. Although the low-flow channel frequently makes a tortuous, pseudo-meandering path within its active channel corridor, the bankfull river channel is not highly sinuous and the plan form across the alluvial valley upstream of town is not fully meandering at any point. Several other channel forms were classified above and below the project area in confined valley reaches, but these are not relevant to issues on the downtown segment. Additional discussion of the characteristics of braided and wandering channel types, and their relevance for channel management in Ridgway, follows in Section 2.7.

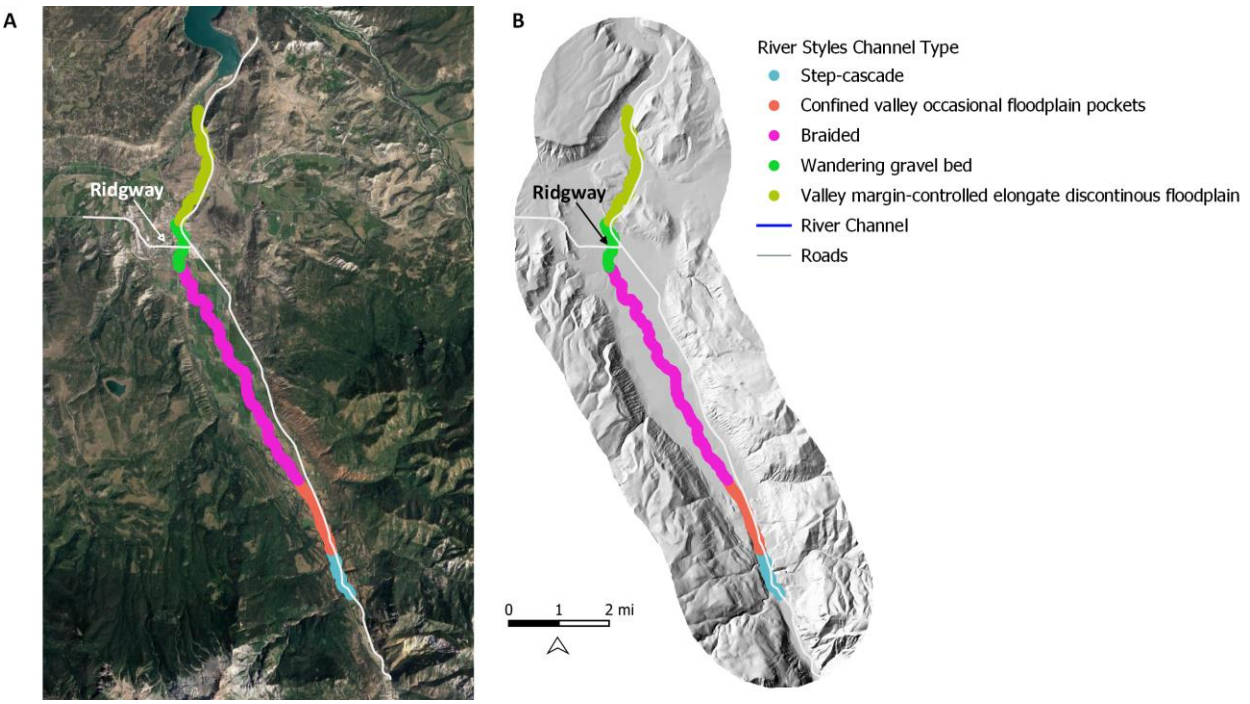

Figure 3. River Styles channel classification map overlaid on aerial imagery (A) and shaded topography (B).

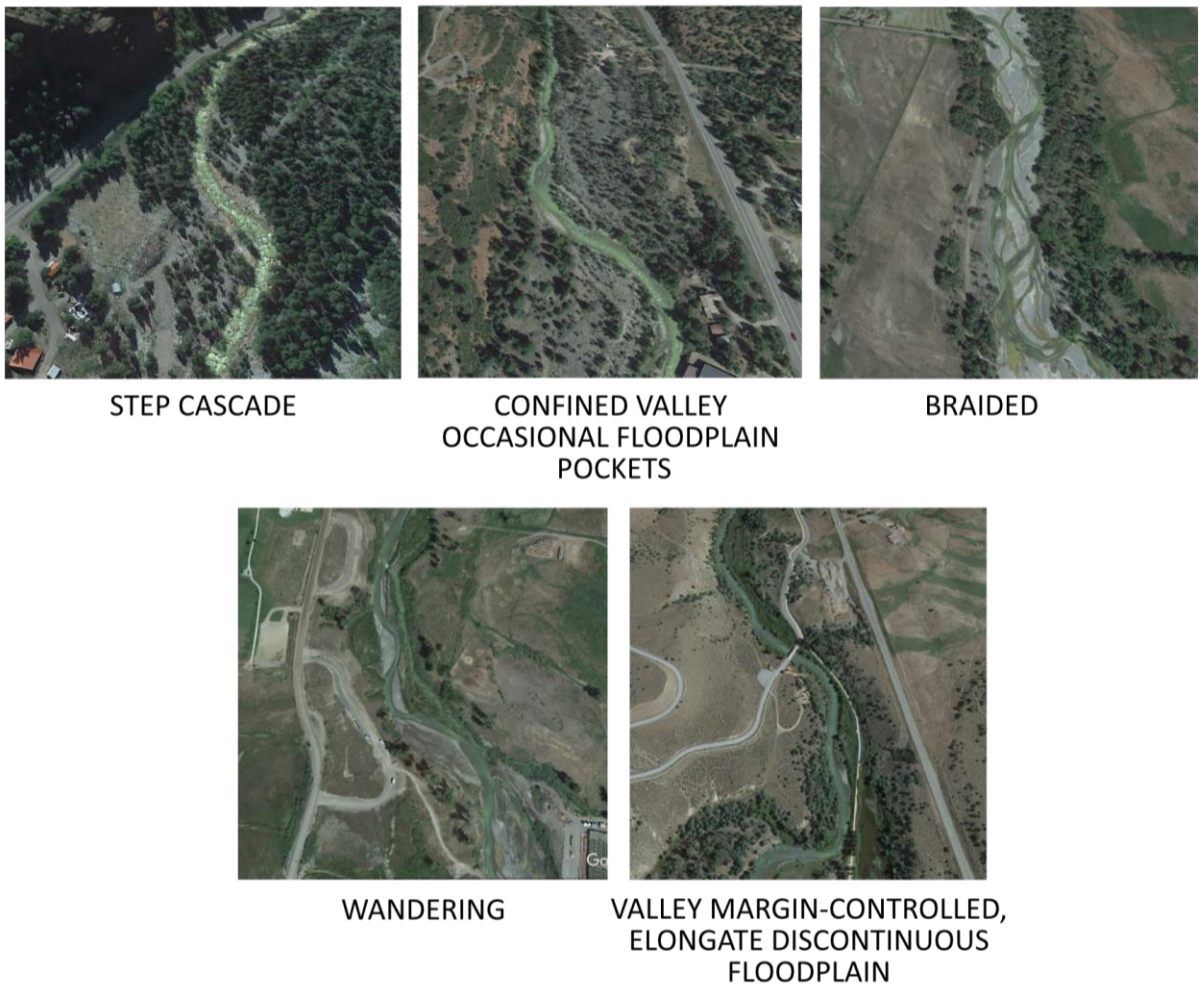

Figure 4. Example channel types observed in the Ridgway area.

2.4 Previous Human Interventions

The overlay of human activities, including headwaters mining, agricultural utilization of upstream floodplains, alluvial gravel mining near Ridgway, and recent urban and suburban development of floodplains, all contribute to past channel changes, current channel forms, and future channel trajectories. Understanding landscape processes and the impact of previous human interventions helps to explain current conditions and stream channel processes in the reach of the Uncompahgre River through Ridgway.

Over a century of human interventions in the watershed continue to impact the Ridgway town reach. Extensive hardrock mining, including placer mining, coupled with forest denudation to supply the mines provided increase sediment source supplies in the upper watershed from the late 19th century to early 20th century. Continual downstream transport of coarse bedload substrates and unstable channel beds are evidenced downstream of Ouray. These sediment loads and instabilities may contribute to the braided

channel observed as the river exits the mountain canyons and enters the alluvial floodplains above Ridgway. Gravel and coarse sand sediment supplies are likely to continue moving downstream and out of these reaches during the highest spring floods. Any sediment leaving these reaches will, eventually, make its way into the town reach.

The upper Uncompahgre Valley also has a history of irrigated hay production in floodplain areas. Like many other regions in the intermountain west, these practices frequently involved grading or leveling of floodplains, and mechanical removal or denudation of woody riparian vegetation from grazing. These practices often de-stabilized streambanks in the early and mid-20th centuries, and initiated periods of channel widening and shallowing. These changes were often accompanied by increases in sediment delivery to the active channel and to downstream reaches. Although this assessment did not quantitatively or qualitatively explore historical information related to near-stream agricultural practices (i.e., historical records and photos, historical aerial photography), it is reasonable to suspect they may have provided some influence on river forms and behaviors upstream of Ridgway.

In Colorado, the most-viable location for transportation infrastructure historically has been in river valleys near the stream channel due to the constraints imposed by the rugged topography of valley margins. Establishment of raised earth berms or dikes across floodplain areas is common for both railroad corridors, local road networks, and irrigation ditch/canal infrastructure. Over time, these structures constrain river channel lateral migrations, potentially driving changes to channel geometries like increased slope and depth. These structures also contribute to a loss of hydrological connectivity between channels and floodplains and a commensurate loss of riparian function.

In-channel and channel-adjacent aggregate extraction is an important commodity supplied by river corridors. However, some practices are often extremely damaging to riverine function and form. Loss of floodplain connectivity, loss of in-channel habitat heterogeneity, and loss of streambank competence and stability due to vegetation and soil removal are all common results of in-channel and floodplain gravel mining. In some locations, the socioeconomic values provide by aggregate extraction may outweigh ecological/aesthetic concerns in the river corridor, and appropriate reclamation and restoration can help offset long-term impacts. Significant historical aggregate extraction activity is evident along the river corridor in the immediate vicinity of Ridgway. The influence on channel form, local channel sediment supply, and bank instability persists. Aggregate extraction still occurs upstream in the braided reaches between Ouray and Ridgway. However, these practices have largely ceased along the river near Ridgway. Many old gravel mining sites near town underwent some amount of remedial work.

Channel reconfiguration work conducted in between 2001 and 2006 affected approximately 3000’ linear feet of the Uncompahgre River downstream of the CO 62 bridge. This work sought to address in-channel and riparian conditions deriving from the combined historical influences noted above. Project actions included reconfiguration of the low-flow channel to a single-thread course and installation of in-channel

structures targeting channel stability and habitat improvement. More recently, bridge replacement in the corridor also contributed to this outcome. Project types also included some floodplain and bank regrading, addition of structural boulders and construction of in-channel features including boulder cross veins/weirs/j-hooks. A contractor for the project noted that it included "complete river restoration, addressing decades of in-stream gravel mining. Restoration work included grading of a stable single thread channel, bank stabilization with large woody debris and large boulders, grade control and fish habitat structures, construction of multiple wetlands (open water and shallow depression types), and construction of two whitewater wave features."[4] Restoration project monitoring at this site was also included as part of a USGS regional program called the Reconfigured Channel Monitoring and Assessment Program (RCMAP). Fieldwork in 2005 included photo points, sediment surveys and channel cross sections.[5] Current results of this study were not readily available and regional USGS staff should be consulted for further information.

2.5 Rapid Field Assessment

A rapid field assessment of conditions on the town reach occurred in mid-September, 2021. Streamflow at USGS stream gauge 09146200 (*Uncompahgre River Near Ridgway CO)* was approximately 54 cfs. Field investigations included photo points of representative channel geometries; in-channel structures including lateral rock placements; in-channel vein/weir/hook rock structures; in-channel large woody debris (human-placed); riparian conditions including cut banks, point bar formation, and floodplain connectivity; riparian vegetation age structure/successional states on banks and lateral channel bar forms; in-channel habitat heterogeneity including riffle/pool habitat prevalence and structure; the presence of aquatic life including salmonid fish species; and other attributes.

Photo points were collated in a Google Earth tour file that includes location and azimuth of all site photos in an interactive viewable map (Figure 6). A small sample of photo points is included in this section to illustrate notable geomorphic features highlighted in the narrative segment descriptions.

[4] http://www.riverrestoration.com/uncompahgre-river-in-ridgway-co/

[5]https://www.usgs.gov/centers/co-water/science/rcmap-uncompahgre-river-ridgway-colorado?qt-science_center_objects=0#qt-science_center_objects

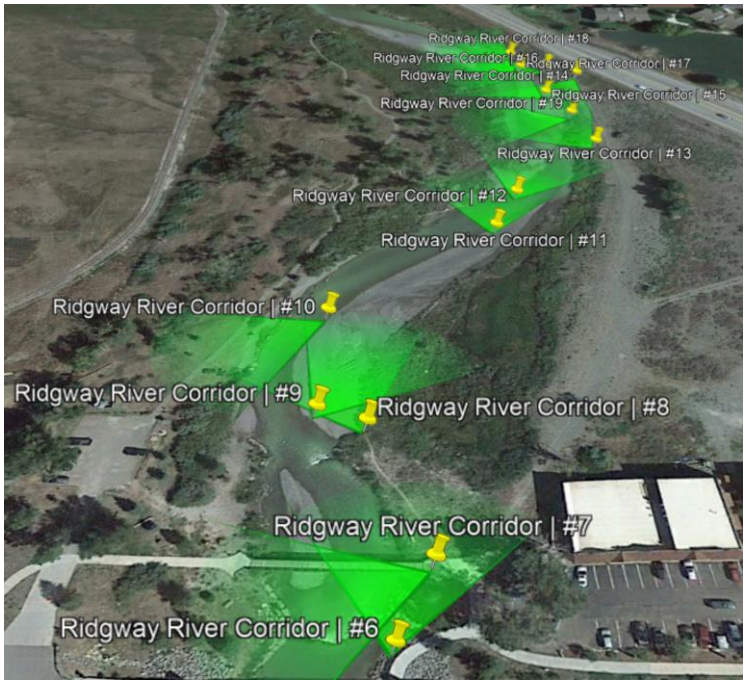

Figure 5. Screenshot from Google Earth photo point tour.

Ridgway Athletic Park to CO 62 Bridge

Upstream of the CO 62 bridge, the channel displays the wandering form, transitionary between braided reaches above and a more-meandering geometry style. Unlike a fully-meandering channel type, sinuosity is relatively low and large unvegetated side bars and alternating bars exist. Multiple secondary channels and chute cut-offs likely active at moderate and high flows are present. In locations where active point bar development is evident, cutbanks often exist on the opposing outer bend. Early seral successional stages of riparian vegetation appear to be colonizing active point bars. Although cutbank forms may appear to be unstable or out of equilibrium, their presence opposite a growing point bar indicate normal meandering processes in an unconfined floodplain setting. These lateral planform movements may be problematic for infrastructure in certain locations downtown. For example, near the cul-de-sac on Liddell Drive where the channel migration trajectory is pushing towards a road and eroding residential parcels. The Route 62 bridge acts as a knick-point on the floodplain that constrains lateral channel movements and likely promotes localized sediment deposition and channel aggradation immediately upstream. In this way, the presence of the bridge may partly explain the persistent lateral and mid-channel bars that are built upstream of the bridge during spring flood conditions and are subsequently winnowed and dissected throughout the later portions of the year. A mid-channel bar formed below the whitewater feature scour pool divides the current, pushing the channel outward toward both stream banks.

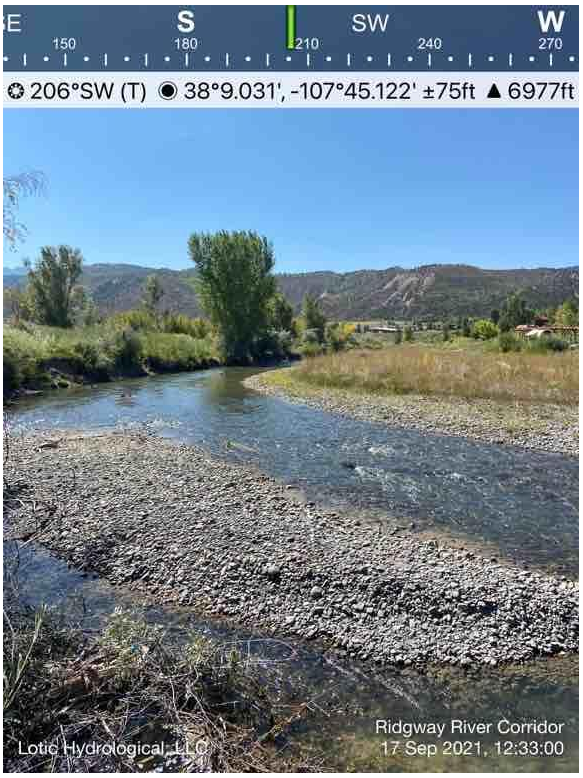

Photo point # 4. Upstream of the CO 62 Bridge looking south. The channel is sometimes multi-threaded, but exhibits many typical characteristics of meandering rivers including point bar development opposed by a cutbank form on the opposite bank. Some larger woody riparian vegetation communities (willows, cottonwood) exist on the east bank, while early successional vegetation (grasses) have colonized the point bar on the west bank.

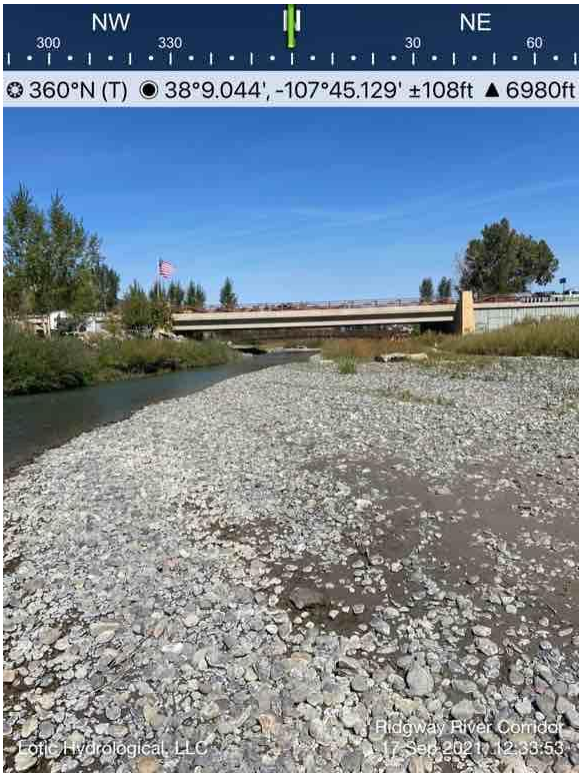

Photo point # 45. Upstream of the CO 62 Bridge looking north. A long slender bar is deposited from the east bank into the center of the river just upstream of the highway bridge constriction.

CO 62 Bridge to Ridgway WWTP

This reach is adjacent to the core of Ridgway's downtown business district and the open space associated with the railroad museum. Lateral movements on the east side of the channel are directly constrained in a small reach by US Route 550 or by what appears to be fill material serving as levies and, in general, by the raised alluvial terrace upon which the road travels. The highway alignment limits the extent of riparian vegetation (and the water quality buffering functions riparian areas provide) along this side of the channel. Successional riparian vegetation stages are present on the west bank bordering the railroad museum, potentially indicative of a recovering functional riparian community. Straightening or alteration of the channel in the past from extensive gravel mining operations has been overlaid by alternating sidebar forms and more recently, the contemporary restoration project-induced semi-meandering channel form established in 2003 and 2004. Here, the low-flow channel was re-graded to a single thread meandering geometry and imbued with numerous natural-design bank stabilization features such rock emplacements and large woody debris, grade control structures, and riparian wetlands.

Physical restoration projects of this variety have a long history in Colorado with varying degrees of success. However, single-threaded channel geometries, while often aesthetically desirable and functionally useful for human communities, were not necessarily the historical or dominant channel geometry on the landscape prior to 19th and 20th century human intervention. In addition, at locations where floodplain substrate is primarily composed of smaller-clast sized alluvial deposits like coarse gravels and sand, large physical channel structures added to create pool habitat or redirect current may not persist over time. Placed boulders of large size classes not otherwise present on the reach run a significant risk of being run-around during overbanking flow conditions. Eventually these structures will be rendered ineffectual.

Former high-water cutoff channels and meander avulsions are visible in aerial imagery adjacent to the channel created in 2003 in the vicinity of the wastewater treatment plant. Large snowmelt floods are likely to reactive these channels and may achieve shear stresses sufficient to scour vegetation and dissect bar forms or avulse channels behind the constructed meander bends. Several bank-emplaced log vane structures are evident from the channel reconfiguration project. The channel has end-run several of these structures along their outer edges. Remnant rock structures that appear to have been lateral veins or j-hooks also exist in several locations. These structures, while no longer fully functioning in their grade control or channel-stabilizing capacities, still continue to provide habitat heterogeneity for aquatic life in the form of varying pool depths and water velocities.

Immediately downstream of the whitewater park wave feature scour pool, a significant mid-channel bar divides the current and focuses high water velocities and shear stress to the east and west banks, potentially inducing increase scour around the pedestrian bridge abutments. In the period since 2004, significant riparian recolonization by early seral communities (grasses, woody shrubs) has occurred on many of the former bar forms, creating an increasingly-vegetated floodplain area in the downtown reach.

Overall, although many of the restoration structures appear to no longer function as originally intended and the channel shows evidence of trying to abandon the induced single thread meander geometry, this reach shows many signs of improvement via the re-establishment of native riparian communities, the continued existence and maintenance of heterogenous instream habitats, and channel geometries consistent with wandering-bed channel types.

Photo point # 10. Downstream of whitewater park looking SW. Large boulders likely placed for bank protection have been undercut by deep scouring below a bare gravel bank slope. Because this is the outside of a meander bend that is currently opposed by an actively growing point bar, a cutbank is an expected geomorphic form. However, the small/medium clast sizes of floodplain substrates coupled with the area's prior history of gravel mining and vegetation alteration means the bank in this location has little competence to resist shear stress forces.

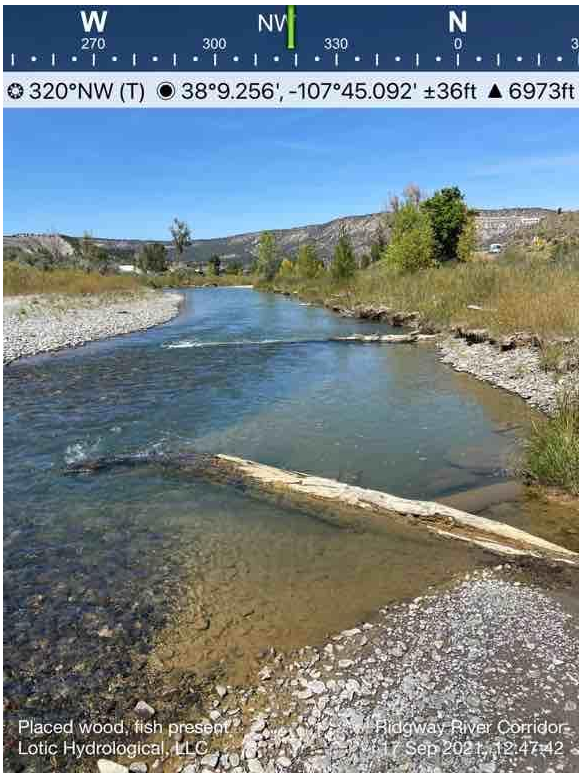

Photo point # 18. Looking NW at the downstream end of the railroad museum open space. Placed logs functioning as lateral vanes or barbs are still present, although the bank anchoring stability is beginning to degrade. Because this is the outside of a channel bend, a cutbank on the right bank is an expected form as shear stresses during high flows pile against the channel margin. Further establishment of native woody vegetation on the currently grassy banks may slow channel migration. The logs continue to maintain some in-channel habitat heterogeneity.

Photo point # 17. Looking west at the railroad museum open space. Multiple successional stages of riparian vegetation indicate functional community processes are in place.

Photo point # 26. Looking NW towards the N Railroad St turn and San Miguel Power campus. The river has performed an end-run around a placed rock structure during high flows, scouring a new channel laterally around the outside of the structure.

Ouray Branch Recreation Path Bridge to Dennis Weaver/Dallas Creek

Below the recreation path bridge, the river enters a small confined canyon between resistant alluvial terraces or elevated glacial till deposits. Channel gradients increase again as the stream enters a supply-limited reach that is capable of moving sand, gravel, and small cobble-sized clasts downstream towards the reservoir. A thin riparian strip is present on either side of the active channel margin, rapidly transitioning to more mesic hillslope vegetation types (dry meadow, sage, etc.) This segment is resilient to changes in sediment supply and flow regimes that may strongly influence upstream channel geometries in the town reach.

Shortly after the first canyon section below the recreation path bridge, a wide bottomland opens where the river has incised large scallop-like cuts into the surrounding terraces in the past. This area contains numerous fluvial signatures indicative of previous channel movements such as floodplain wetlands and meander scrolls or paleo channel patterns in the vegetation communities that are visible on aerial photo inspection. A mix of more-mesic vegetation types (juniper) exists among the cottonwood communities. Several large and decadent cottonwood galleries exist; some of which appear to have died away perhaps due to changes in groundwater flow patterns as the active channel moved laterally away from the tree stands over time. Establishment of the railroad grade may have cut off the channel from floodplain access in this area, initiating channel steepening over time that resulted in loss of connectivity to adjacent floodplain riparian communities.

Below this area, as the river flows past Dennis Weaver Memorial Park, it once again enters a more-confined reach type. However, discontinuous narrow floodplain strips and pockets appear to support healthy riparian vegetation exist throughout.

Photo point # 38. Looking SW back upstream towards the recreation path bridge. The confined river corridor is resilient to channel changes, with a narrow riparian strip and heterogenous in-channel clast sizes.

Photo point # 41. Looking NE downstream towards Dennis Weaver Park areas. Subtle armoring and/or slight imbrication of clasts on this point bar or lateral bar form indicate this reach may not experience the transport-limited conditions apparent in reaches upstream.

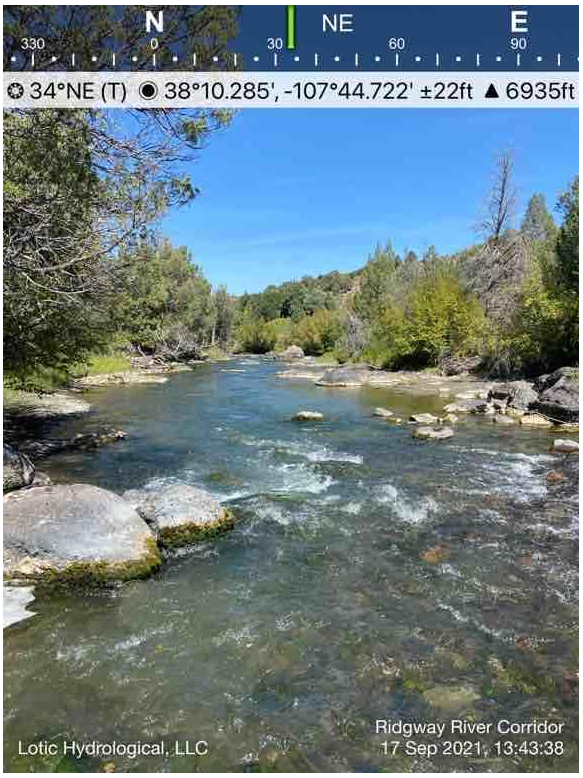

Photo point # 51. Looking NE downstream near the northern boundary of Dennis Weaver Park near the town's municipal boundary. Large and heterogeneous in-channel substrates provide a diverse aquatic habitat patchwork. Narrow but vibrant riparian communities transition rapidly to upland plant species in this confined channel zone.

2.6 Aerial Photographs: Recent Channel Evolution Comparison

Comparison of channel movements over time via aerial photography may yield insights into channel conditions and potential future trajectories. In the Ridgway town reach, although high sediment fluxes from both upstream influences and from current or legacy management practices in the town area itself such as riparian clearing/alteration and past gravel extraction have provided strong drivers of channel form over time, consideration of the town reach in context of its landscape position in the alluvial valley as well as comparison to nearby reaches that are relatively unimpacted from gravel mining suggests that a single-thread meandering channel was not necessarily the 'natural' pre-disturbance channel form. Figure 7 provides three panels that illustrate river conditions downtown during the contemporary pre-restoration time period (1998), soon after channel and floodplain reconfiguration, and in the current time period (2019).

Inspection of channel characteristics including curve radius, vegetated riparian and floodplains zones, and especially; in-channel bar features and types, suggest the river may be trying to re-establish a more wandering gravel bed style planform within its channel migration zone rather than remaining a single-thread. For example, rather than consistent growing point bar growth, the channel is readily dissecting newer point bars with multiple cutoff channels, similar to a diagonal bar. Confining terraces and constraints on meandering imposed by the highway to the east and downtown road and parking lot infrastructure on the west bank also contribute the inability of a fully-meandering pattern to develop and maintain itself in a stable form over extended time period. If a single-thread channel is in fact the historical

natural type, it also appears that the floodplain widths available in the town reach for the meanders to form and evolve are simply too narrow between Railroad Drive and Highway 550. As a result, within the lateral active channel and floodplain widths available in the downtown area for the channel to migrate and meander, a single-threaded channel may not be a self-sustaining form over relevant human time scales (decades).

Figure 6. Channel evolution downtown, pre/post restoration and current conditions.

2.7 Landscape Setting Discussion

Stream power is a measure of the ability of a river to do physical work such as carrying sediment or eroding its banks and channel bed. While it can be quantitatively estimated with channel geometry and flow regime data, it is used here only at the conceptual level to describe the anticipated channel-forming processes occurring on the Ridgway town reach. High stream flow volumes associated with spring snowmelt runoff and steep channel slopes combine to create high stream power in steep headwaters and confined bedrock canyon reaches above and below Ouray. These confined channel reaches are sometimes described as *supply-limited*, meaning the stream is capable of carrying more sediment supply than it actually receives. They are generally highly resilient to changes in hydrologic regimes and sediment inputs,

although the reach downstream of Ouray still evidences a deeply unstable channel bed, with high transport of coarse cobble and boulder-sized substrate.

When these steep, confined streams exit the mountains and enter the outwash floodplains, channel gradient decreases rapidly and so does stream power. At these locations on the landscape, rivers like the Uncompahgre can no longer carry the large sediment loads from their mountain sources, and the loads are deposited directly in the channel bed. Longitudinal profiles of river elevation and slope can help illustrate the landscape locations where this condition may occur (Figure 5). This condition is frequently termed *transport-limited*; the flow volume and slope of the channel is incapable of moving and carrying its sediment load except during the largest flood conditions. Reaches where sediment is deposited and the channel bed aggrades are also termed *response* reaches. These stream reaches serve as long/medium-term sediment storage areas where the channel shape is constantly and dynamically undergoing geomorphic change in response to sediment supply influences from upstream. The town of Ridgway lies at the lower end of this response reach, and the channel form in town is likely still relatively sensitive to changes in sediment and flow inputs and floodplain alterations, resulting in overall channel stability characteristics that are often undesirable from the human point of view.

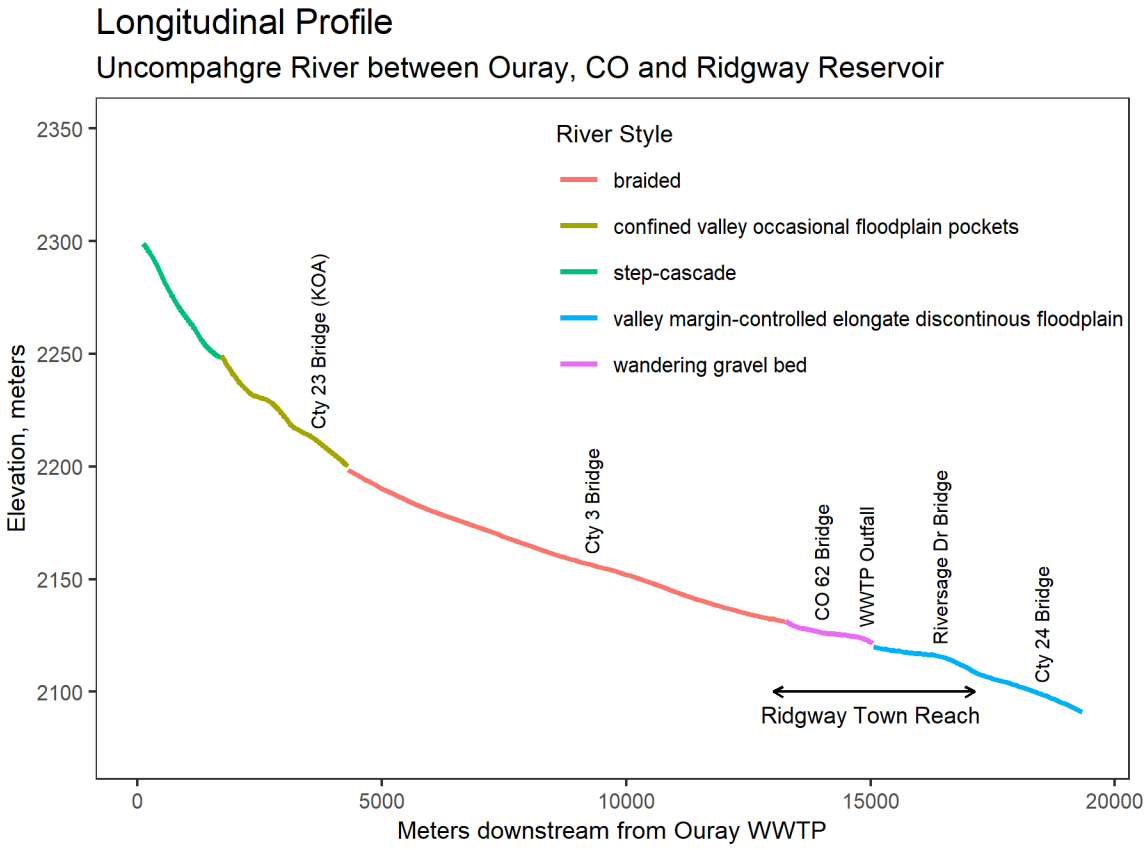

Figure 7. Longitudinal elevation profile of project area and upstream reaches.

Continual aggradation of the channel bed from upstream sediment causes the river to respond by continually moving its channel laterally, resulting in channel types ranging from meandering, to wandering, to braiding. These channel forms are evident upstream of Ridgway as the river leaves the steep confined downstream of Ouray. Near the County Rd 23 bridge and Ouray KOA campground, the river leaves this confined valley type and enters a wide alluvial gravel floodplain. A braided geomorphology is present here, characterized by multiple channel threads, constantly shifting gravel bars and chutes. Although braids are sometimes considered an 'unstable' form, they are actually a natural channel form that may be highly 'stable' on the landscape where sediment inputs and valley slope support their formation, such as mountain front alluvial outwash plains. In this setting, although the exact planform is constantly shifting, the overall channel type persists on the landscape over long timeframes.

As the river progresses north towards Ridgway and crosses under the County Road 3A bridge upstream of Orvis Hot Springs, the channel slope continues to decrease and the braided morphology smoothly transitions towards a *wandering* form. Wandering channels are intermediate between braided and meandering forms. They tend to feature a more dominant semi-meandering thalweg within the gravel bars of the active channel, with point bar deposits that are less-characteristic of braided reaches and more-typical of meandering. Overall sinuosity is significantly less than true meandering streams. Avulsions, cutoff chutes and high-flow channels across these bars are still regularly maintained, and little successional riparian vegetation is able to establish on bars. Lateral instabilities driven by high upstream sediment loads persist, but as the annual coarse sediment load drops into temporary channel storage in the braided reaches above, they lessen.

Braided and wandering channel types may not be very resilient to changes in streamflow and sediment supply; they are likely to rapidly (years-to-decades timescale) self-adjust their channel geometries when input conditions change. Unconfined and partly-confined channel segments in this region are likely to be the most-sensitive to changes in flow regimes and sediment inputs. Changes may result in relatively rapid shifts to channel structure and aquatic habitat. Human-caused changes to riparian corridors may also trigger significant localized changes in channel form.

The Ridgway town reach occurs on the downstream end of this wandering geomorphology. As the river enters a more-confined valley type and the slope again steepens near Dennis Weaver Memorial Park, the single-thread channel morphology returns (Figure 5). Ridgway's landscape location at the tail-end of this wandering channel zone means the river through town features characteristics of both single and multi-threaded channels. Like a fully meandering single-thread channel, it tends towards a defined and dominant meandering thalweg with alternating riffle/pool sequences and alternating point-bar and cutbank features throughout. Heterogenous successional stages of riparian vegetation are constantly establishing and re-establishing on the dynamic patchwork of channel bank and floodplain forms. However, characteristic of a wandering gravel-bed nature, overall sinuosity is lower and the channel bed

and banks remains highly mobile, with repetitive and shifting development of side bar and in-channel bar forms. The dynamic coarse sediment inputs from upstream are still capable of storing and pushing large sediment pulses through this reach. Significant movements and changes in a single season or over decadal time period during very high flow flood events should be expected as 'normal' in this area. Lateral channel instabilities in this area, which have a significant natural component, are also likely exacerbated by recent time period land use and management activities, including gravel mining and alteration or removal of woody riparian vegetation communities during agricultural or urban developments.

3 Findings and Recommendations

Modification of the hydrological regime, altered patterns of erosion, adjustments to the structure of the channel bed, or changes in riparian community composition and extent may yield fundamental shifts in the geometry and behavior of the stream channel. As documented elsewhere in historical work and existing scientific and engineering studies of the channel reaches in town, these factors have all influenced the Ridgway town reach of the Uncompahgre River to various degrees.

Primary findings produced by this rapid assessment include:

- Anthropogenic impacts from legacy land use practices including upstream mining, extensive local aggregate extraction in the town vicinity, riparian alteration/destruction, and urban/suburban encroachment continue to provide important geomorphic influences on the town reach.
- Riparian communities within the Ridgway town boundary are historically heavily altered, but many show recovery/improvement trajectories that may continue to progress towards more-functional conditions that benefit channel stability and habitat values.
- Assumptions that town reach was historically a single-threaded channel have informed past restoration activities, but may be based, in part, on human aesthetic preferences for river channels. They may not accurately reflect the existing and natural physical constraints set by the alluvial floodplain substrates and unconfined channel setting upstream and within the downtown core.
- Some field observations as well as aerial photograph comparison indicate the river may be attempting to re-establish a wandering bed form or multi-threaded over the imposed single-thread meander channel form.
- Width constraints on natural lateral channel migration processes in the town reach may prohibit a single thread channel (meandering channel) from self-maintaining for extended periods of time.
- Local stakeholder dissatisfaction with conditions in the town section are understandable, but in some cases may be based on misunderstanding of natural river processes appropriate to the landscape setting.
- Although some in-channel and bank structures are no longer functioning in their original intended form, they continue to promote heterogenous channel habitats in the town reach that are beneficial to aquatic life. The previous channel reconfiguration and structure creation has also created a corridor environment in which, over time, early successional stage riparian communities

have recolonized many bar and floodplain areas extending downstream of Rollans Park to the recreation path bridge. Within this reach in some locations, the river appears to be partially abandoning its induced meandering geometry in favor of a wandering geometry with occasional multiple threads and more complex in-channel bar forms.

- Active lateral channel migrations, although part of natural processes in this landscape setting, remain on trajectories that may impact town infrastructure such as N Railroad Drive, the wastewater treatment plant, and the San Miguel Power Association Campus. Residential and commercial structures in the vicinity of Liddell Drive may also be at risk from channel migration processes. Channel banks in the Rollans Park area and on the east bank downstream of the highway 62 bridge may require active stabilization in perpetuity to support the social preference/need for human uses/development over natural river processes in these areas.
- At the downstream end of town boundaries (to the north), the river enters a confined channel setting and both channel processes and riparian conditions appear to be largely consistent with functional riverine settings elsewhere in the region.

Recommendations

Recommendations for river management actions on the Ridgway Town reach are highly dependent on further articulation of stakeholder goals surrounding the stream corridor. Because of this, the following recommendations remain conceptual in nature and will benefit from further elicitation of local values and priorities.

Goal	Recommendation	Additional comments/concerns
Infrastructure Protection	Revisit select locations for bank stabilization.	Utilize 'soft restoration' techniques for naturalized appearances and minimizing loss of habitat function. These may include techniques such as toe wood and active establishment of shrub/tree woody riparian communities. In locations where bank shear stresses are excessive and little margin exists for further channel migration, hardened stabilization techniques may be necessary. These may include the left bank near the Liddle Drive cul-de-sac, the left bank downstream of the whitewater park and pedestrian bridge at Rollans Park, the right bank opposite Rollans park near proposed new developments, and the left bank near the N Railroad Ave and San Miguel Power Assoc. campus. However, hardened engineering techniques may not be compatible with stakeholder aesthetics or desire for natural channel functions and efforts to both maintain a naturalized river appearance yet counteract natural channel movements to protect development and infrastructure are unfortunately in conflict.
	Complete Fluvial Hazard Zone mapping (FHZ)	Classic floodplain inundation modelling and mapping used in FEMA hazard zone delineation may fail to account for the rapid and significant channel changes and movements that can occur during large flood events. The Colorado Water Conservation Board recently developed an FHZ mapping protocol to identify locations that are at risk from fluvial processes including rapid bank erosion and avulsion that may be missed in normal FEMA delineations. An FHZ mapping exercise can more-precisely identify hazard locations in the town boundary than this rapid assessment is designed to do. Once developed, the town's development regulations should specify staff conduct consultation with the current FHZ map to inform planning and decision-making. FHZ may suggest some locations would benefit from a greater bank setback and safety margin than currently realized.
Promote riparian habitat and in-channel ecological function	Promote/allow natural river processes in lieu of active management on some reaches.	Allow the continuance of non-managed channel migrations (wherever socially/economically acceptable) in order to create and maintain diverse habitat patchworks and acknowledge the difficult-to-manage natural sediment transport characteristics present in the area.
	Engage in active vegetation establishment and restoration at locations where infrastructure or social use values and aesthetic values exceed natural habitat functions.	The pace and trajectory of natural re-establishment of riparian communities may not meet societal expectations at some locations in the town reach. Although natural processes may prove successful over time, a 'helping hand' including additional active planting and maintenance (irrigation until successful establishment) of native riparian species at select locations may yield significant benefits to natural habitat and bank stability functions.
	Provide stakeholder education on natural channel processes in the area	Provide education on riverine processes within the area's landscape processes in order to reduce/deflect local stakeholder dissatisfaction with the sometimes-undesirable aesthetics of natural channel forms and processes like cutbanks, meander formation, meander avulsion and point bar cutoff. Increase local understanding that stable, single-threaded channel types are potentially not supported by landscape context in the Ridgway area.

Goal	Recommendation	Additional comments/concerns
	Incorporate channel migration allowances and fluvial hazard zones into future development planning and permitting.	The large undeveloped parcel on the west bank to the north of the San Miguel Power Association campus has been identified in the 2019 Future Land Use Planning maps for additional single-family residential development, while the east bank in the same region has been identified for rural neighborhood development. Maintain or establish strong channel setbacks for new construction to allow for continued natural channel processes including lateral movements that may erode the raised terraces that confine this reach over time. Precautionary landuse planning will also serve to better protect habitat and wildlife values associated with riparian corridors. The UROD currently specifies as 100' setback in these areas, which in most or perhaps all cases may be highly suitable to protect riparian areas for habitat and water quality function. However, in locations where extended floodplains, bottomlands wetlands, or lands with obvious previous fluvial signature marks are present, protecting areas beyond the 100' setback up to the fluvial terrace edges could be recommended to allow for natural channel migrations and simultaneous habitat and infrastructure/development protection. If FHZ mapping is completed, some locations beyond the 100' UROD setback may potentially could be identified as high risk for fluvial impacts, even though they care not currently identified in FEMA-type SFHA mapping outputs.

Table 2. Recommendations for further work.