Geomorphic Assessment of the Stability of the Roaring Fork River Through the City of Aspen, Pitkin County, Colorado

OBJECTIVE

Through a sub-agreement with Miller Ecological Consultants Inc. (MEC), Pitkin County (County) requested that Ayres Associates Inc. (Ayres) conduct a geomorphic assessment of the stability of the river channel, in-channel structures, and man-made channel modifications along the Roaring Fork River within the City of Aspen, Pitkin County, Colorado. Initially there were concerns regarding a number of man-made boulder drop structures and channel modifications currently present within the river, which may have been installed in part to improve fish habitat. At one location, a kayak park was also constructed along the channel. However, these structures and channel modifications appeared to be creating detrimental impacts to both channel stability and fish habitat. Therefore, as defined in the Scope of Work (SOW) provided to the County, Ayres performed a number of tasks to document the current conditions within the river, assess the geomorphic impacts of these man-made features, and provide recommendations for rehabilitating the in-channel geomorphologic characteristics of the river in support of improving fish habitat within the project reach. This assessment is conducted in support of the Healthy Rivers and Streams Program (http://www.aspenpitkin.com/Departments/Attorney-Pitkin-County/Healthy-Rivers-and-Streams/).

BACKGROUND

The reach of the Roaring Fork River that was examined as part of this assessment extends from the confluence of Castle Creek upstream to the Salvation Canal diversion structure, a distance of approximately 3.2 river miles (**Figure 1**). However, the focus of this assessment was on the a portion of the reach starting from just below the Rio Grande Trail pedestrian bridge at Jenny Adair Park to just upstream of the Neale Avenue crossing (Florence and Fred Gilden Bridge) and Prockter Park (**Figure 2**). Within this subreach, there are a series of man-made structures, also shown in Figure 2, that are problematic with regard to degraded fish habitat, obstructed low flow fish passage, and sediment transport.

As indicated in the SOW, the first task was to conduct a brief review of available literature, maps, and data pertinent to the project reach and geomorphic conditions therein. This included obtaining and reviewing existing 2008 orthophotography and 1-ft contour mapping covering the project reach. This data was made available by the City of Aspen/Pitkin County GIS department (http://www.aspenpitkin.com/Departments/GIS-Mapping/). In addition, we also examined historical aerial imagery and USGS topographic maps that were available using Google Earth Pro (http://www.google.com/earth/businesses/).

Figure 3 shows the longitudinal profile of the overall project reach of the river as obtained from the 1-ft contour mapping provided by the County. **Figure 4** shows the subreach of interest as described above. **Table 1** shows the overall channel slope for segments of the river through town. As can be seen in Figures 3 and 4 and Table 1, river channel slopes are greatest between the Aspen Club and Neale Avenue, but decrease significantly below Neale Avenue. These slope changes can be tied directly to the geology of the valley floor in this area. Based on the geologic mapping of the valley (Bryant 1971), the relatively flat portion of the profile just upstream of the Aspen Club corresponds with a highly meandering segment of the river in a short but fairly wide, unconfined, alluvial section of the valley. An analysis of the contour mapping for the Aspen area also reveals that the valley floor in the area of the Aspen Club is highly constricted (see Figure 1), which may have contributed to the flat, meandering section of the river immediately upstream. Upstream, the Salvation Canal diversion structure and Stillwater Drive are situated on coarse-grained glacial moraine deposits. The steeper segments of the river downstream of the Aspen Club are situated on glacial outwash deposits. Thus, relict coarse-grained glacial material is the primary sediment found in the banks and bed of the river. Immediately downstream of the Aspen Club to about Neale Avenue, the river flows over and is slowly downcutting through older glacial outwash deposits. Below Neale Avenue, the river flows over younger glacial outwash deposits. In places along the lower portion of the reach, the river is bound by and flows between relict glaciofluvial terraces.

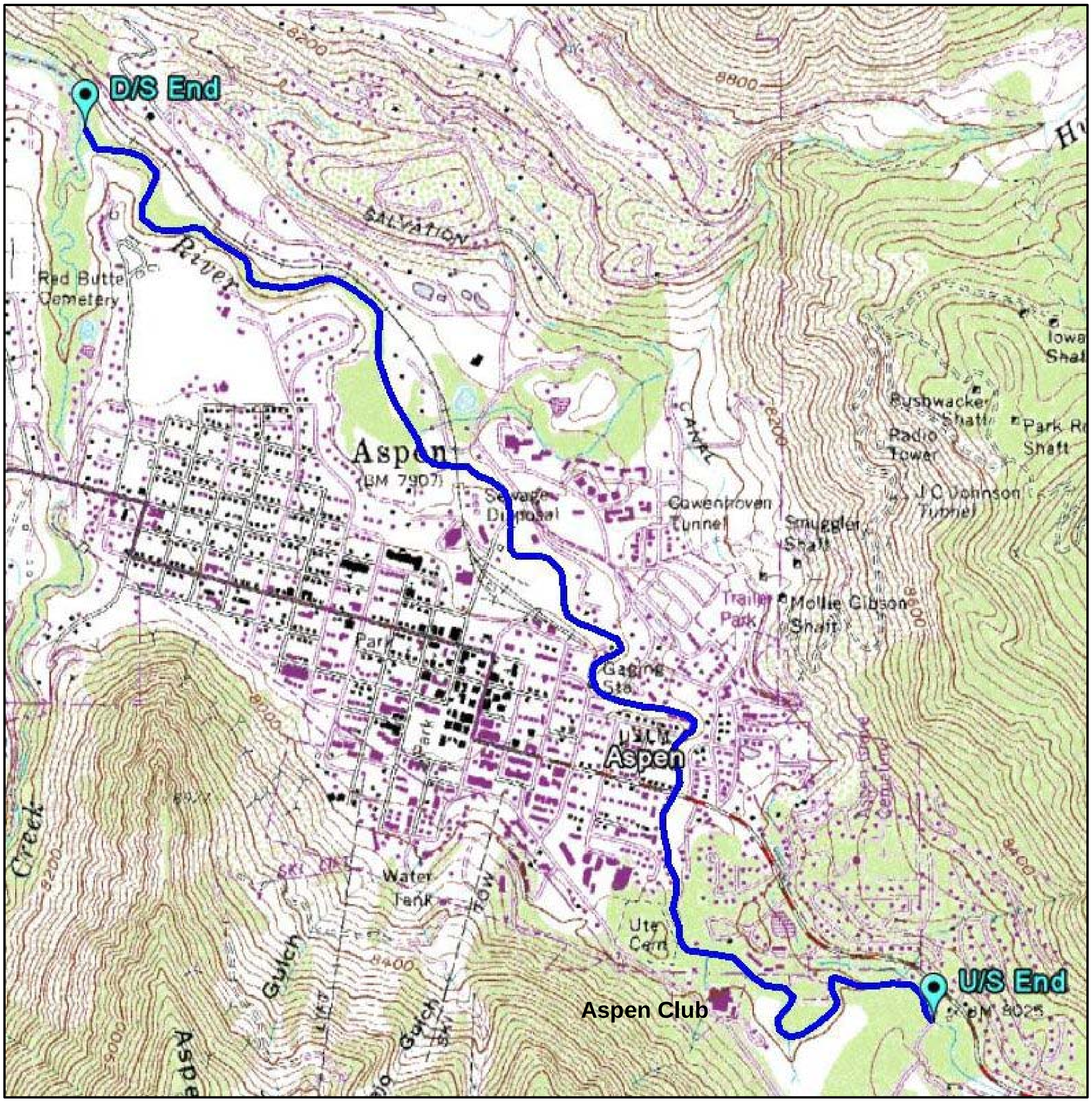

Figure 1. Location map of the project reach of the Roaring Fork River through Aspen, Colorado. Flow is from lower right (SE) to upper left (NW).

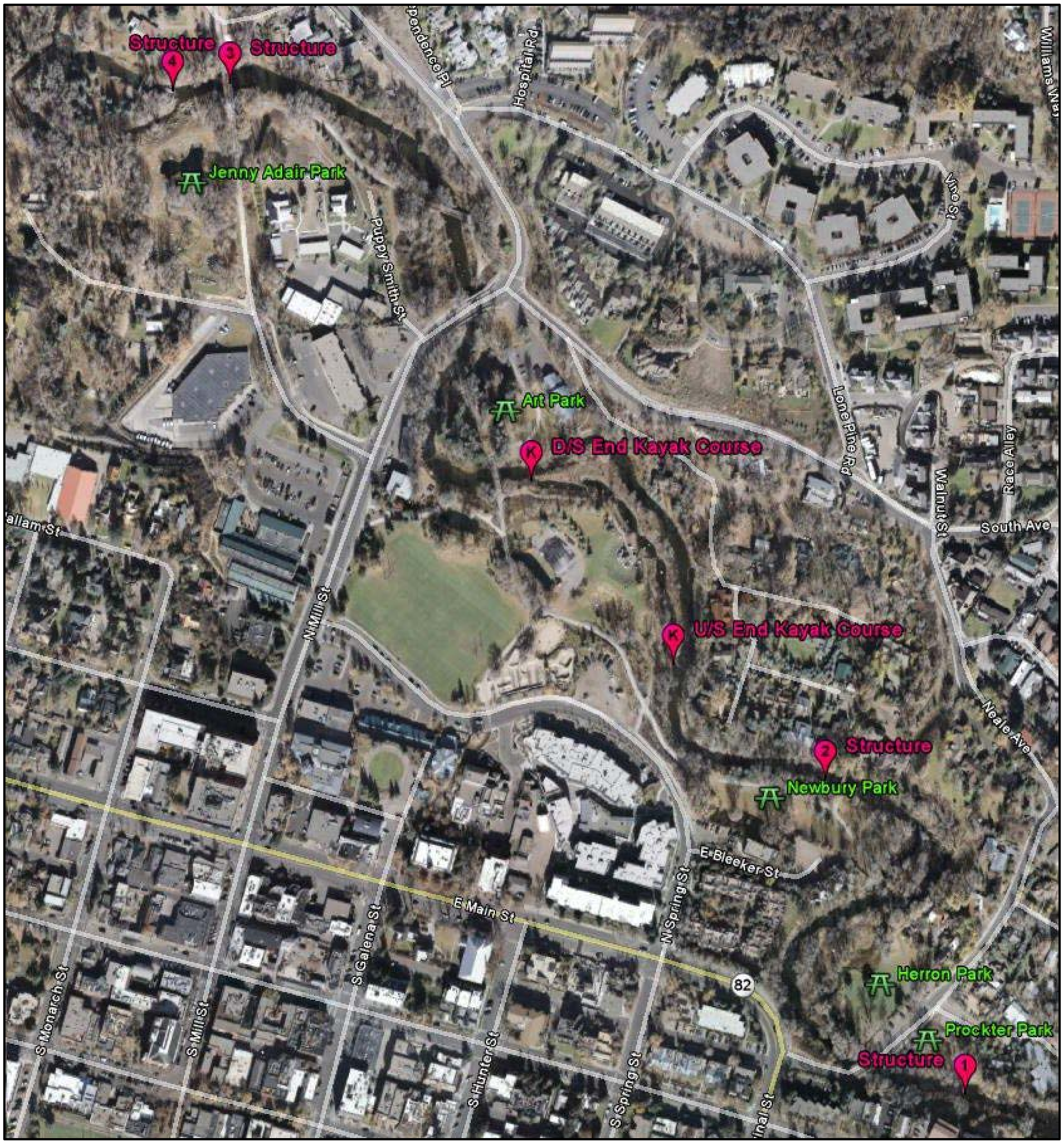

Figure 2. Aerial view (2008) of the subreach of the Roaring Fork River in which a more detailed geomorphic assessment was conducted. Man-made in-channel features are shown in red.

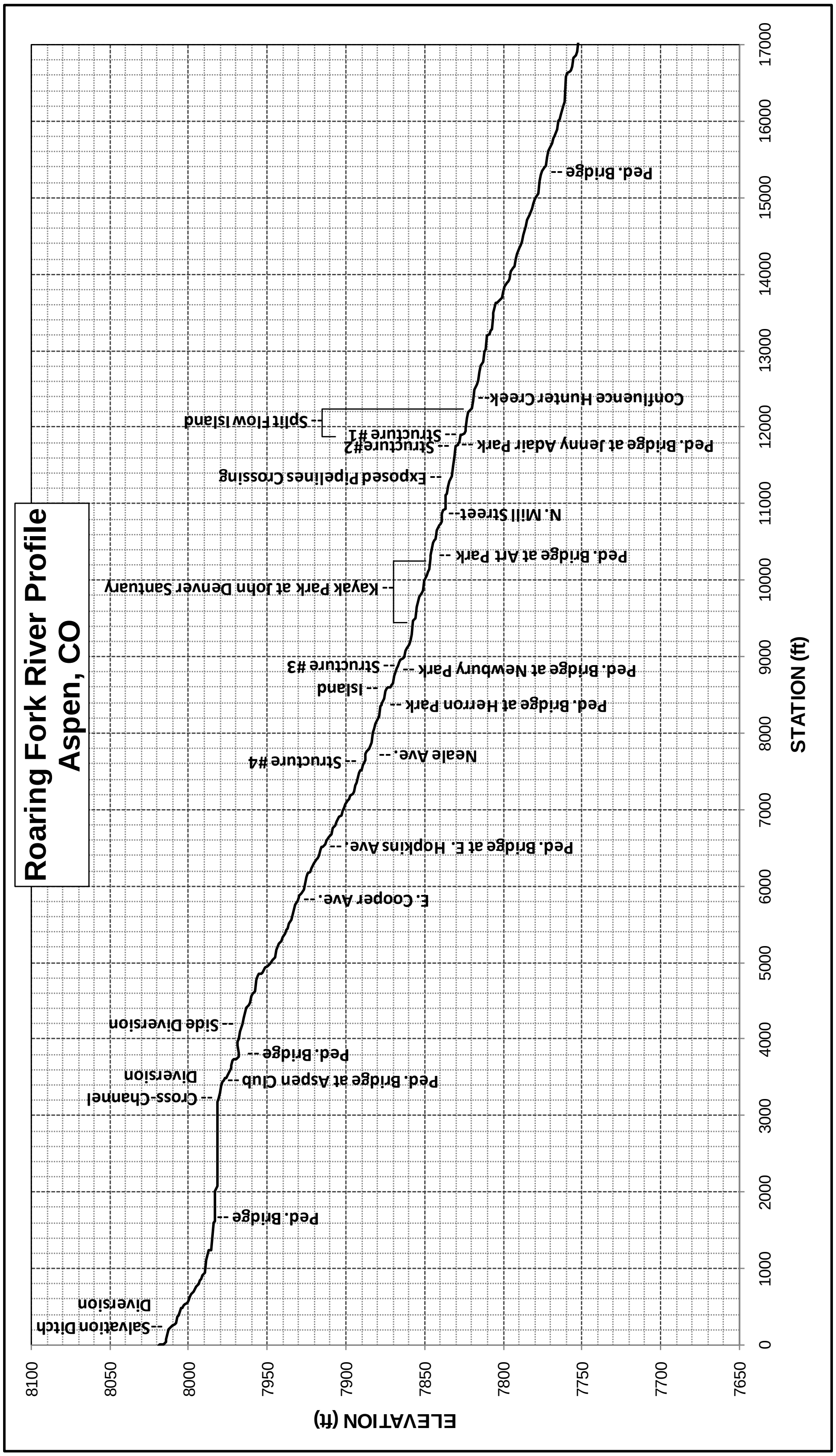

Figure 3. Longitudinal profile of the overall project reach of the Roaring Fork River through Aspen, CO.

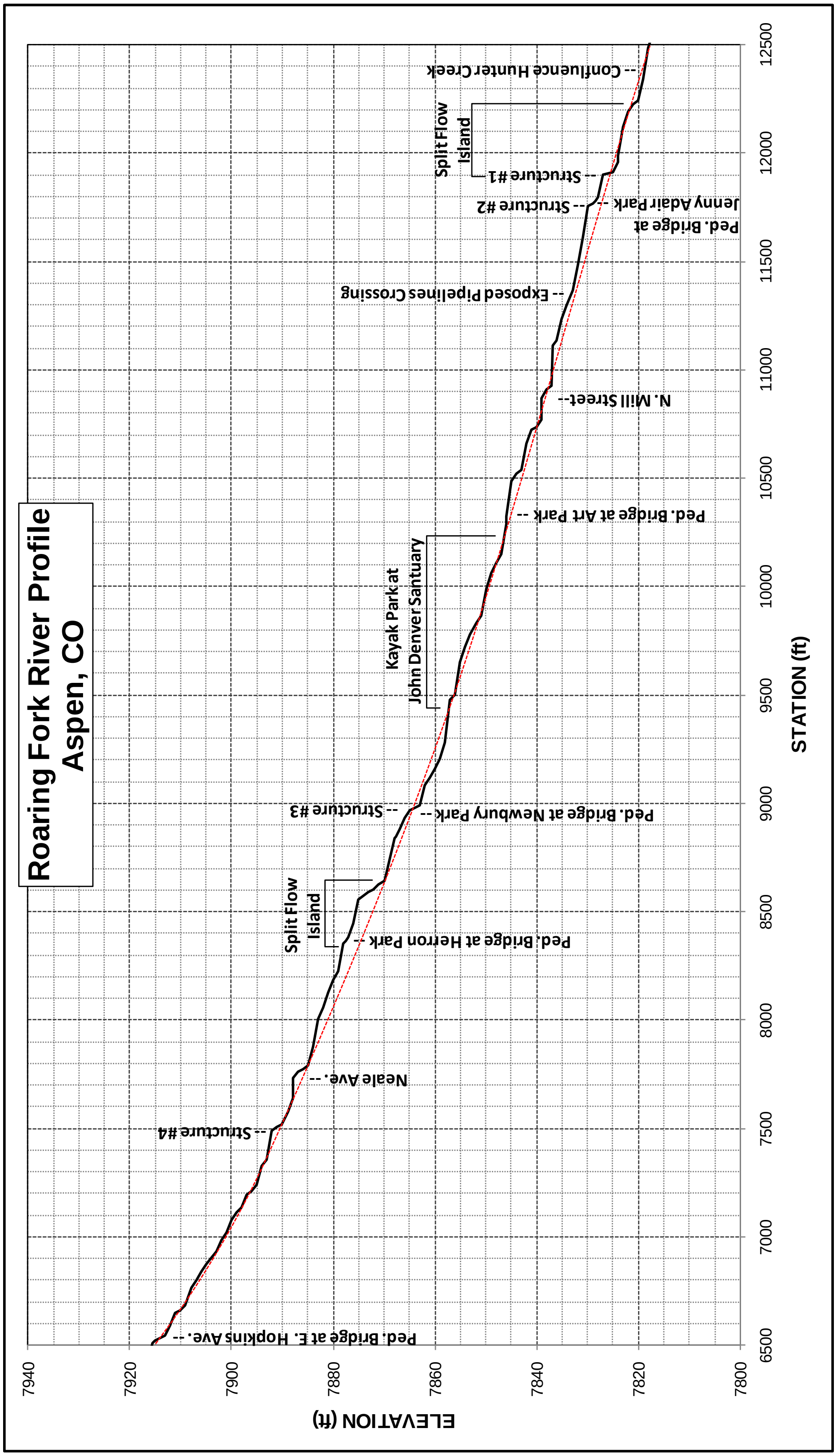

Figure 4. Longitudinal profile of the subreach of interest of the Roaring Fork River through Aspen, CO. The red line is a best fit line used to highlight significant channel profile changes.

Table 1. Slope Data for Segments of the Roaring Fork River in Aspen, CO.		
Reach	Slope (ft/ft)	Slope (ft/mile)
Aspen Club to E. Cooper Ave.	0.020261	107.0
E. Cooper Ave. to Neale Ave.	0.022344	118.0
Neale Ave. to N. Mill St.	0.015610	82.4
N. Mill St. to Hunter Creek Confluence	0.013609	71.9
Hunter Creek Confluence to Castle Creek Confluence	0.013643	66.8

Background information and other material relevant to the project reach is available from the Roaring Fork Conservancy website (http://www.roaringfork.org/). The principal document reviewed was the "State of the Roaring Fork Watershed" report (Clarke et al. 2008). As stated in the Executive Summary of the report, it "illustrates the current status of the Roaring Fork Watershed in terms of water quality and quantity and its water dependent eco-systems." Detailed information for the Upper Roaring Fork Sub-Watershed, which includes the project reach, is provided in Chapter 4 of the document (http://www.roaringfork.org/pub/collaborative/4.1_URF.pdf).

As indicated in the watershed report (Clarke et al. 2008), the in-stream and riparian habitat quality in this reach of the river is considered severely degraded. The poor quality of the habitat is attributed primarily to altered hydrologic conditions associated with in-basin and trans-mountain diversions, degraded water quality, channelization, in-stream and floodplain modifications and encroachments, and bankline armoring.

The altered river hydrology and decreased flows, channel modifications, and the Salvation Canal diversion structure in the channel at the upstream end of the city have contributed to the reduction of incoming sediment to the subreach within the City limits. The river channel in this subreach has been severely encroached upon by urban development and there is little remaining floodplain along the river. The resulting confinement, and in some places constriction, of the river channel as well as significant armoring of the banks within the City combined with the obstruction of incoming sediment from upstream have contributed to a reduction in the subreach sediment supply. However, it should be noted that, although limited, sediment is still supplied to the reach through winter road sanding operations, localized scour of the channel bed, small tributary contributions, and infrequent bank erosion. Nonetheless, the decreased sediment supply has resulted in the channel in this subreach becoming slightly entrenched with localized armoring of the channel bed.

SITE RECONNAISSANCE AND ASSESSMENT

A site visit to assess the current conditions of the river was conducted by the Ayres Project Geomorphologist, Mr. William Spitz, PG, on Tuesday, November 16, 2010. Mr. Spitz was accompanied by Dr. William Miller of MEC. The site reconnaissance was conducted by walking accessible portions of the project reach or making observations from bridges where access was limited. River conditions and geomorphic characteristics were documented through the use of field notes and photographs.

Beginning at the upstream end of the reach at the Stillwater Drive bridge, observations were made of the channel upstream and downstream of the bridge. The reach above the bridge consists of a gently meandering channel inset within a wide floodplain that covers much of the valley floor. Examination of the aerial imagery for this reach indicates that the river has been impacted by limited mining of the valley floor and artificial straightening of the channel for about

0.4 miles upstream of the Stillwater Drive bridge. Although natural and man-made cutoffs of meander bends are present along the river further upstream, the river generally appears to be freely meandering in the upper part of the valley.

Immediately downstream of the Stillwater Drive bridge, the channel is heavily confined by armored banks. The Salvation Canal diversion dam, which creates a significant grade drop in the river, is located about 180 feet downstream of the bridge. **Figure 5** shows the confined channel with armored banks and the Salvation Canal diversion structure. Downstream of the structure, the river returns to its relatively unconfined and freely meandering form until about the Aspen Club location. Two cobble/boulder diversion structures are present in the river in the area of the Aspen Club (**Figure 6**). One is a right bank cross-channel diversion structure present just to the east of the Aspen Club and one is a side-channel diversion structure located on the left bank just downstream of the club. Except for the Salvation Canal diversion structure, which is approximately 5-6 feet high, it appears that none of these structures is an impediment to fish passage during low flow.

Figure 5. View looking downstream from the Stillwater Drive bridge toward the Salvation Canal diversion structure.

From the Aspen Club downstream to the Neale Avenue bridge, the river steepens, is much less sinuous, and becomes confined by urban development that encroaches on the river. This segment of the river contains a number of typical boulder riffles and pools (**Figure 7**) with a long, narrow split flow island just upstream of the E. Cooper Avenue bridge. None of these features poses an impediment to fish passage at low flow. In fact, the boulder clusters, which do not obstruct fish passage, do produce localized upstream backwatering and scour on the downstream side of the boulders, which is optimal habitat for fish.

Figure 6. Aerial view of the river in the area of the Aspen Club showing the location of existing diversion structures and pedestrian bridges.

Figure 7. Aerial View of typical boulder riffles and pools just upstream of E. Cooper Avenue.

The first man-made cross-channel structure in the project reach occurs approximately 220 feet upstream of the Neale Avenue bridge (**Figure 8**). This structure, hereafter known as Structure #1, appears to be a grade control structure constructed of a series of boulders placed side by side across the channel (**Figure 9**). The vertical drop on the structure, which is evident in Figure 4, is about 1.5 to 2 feet. The structure is coincident with and downstream of a diagonal sewer pipeline crossing in the river. The pipeline, which was not evident at the time of the site visit, is about 15 feet from the grade control structure at its closest point (on the right bank) and about 65 feet at its furthest point (on the left bank). Although not observed at the time of the site visit, based on the 2008 aerial photos, a pool has developed just upstream the grade control structure and appears to be filling with finer grained sediment. Flattening of the channel slope upstream of the structure is also evident in Figure 4. It also appears that the right bank just upstream of the structure has been protected with revetment. A revetment is a form of bank protection, either as a slope paving or a retaining wall, constructed from a variety of materials including quarried stone, boulders, or other erosion resistant materials. In most cases, the bank revetment along the study reach of the Roaring Fork River consists of dumped or stacked quarry stone or boulders.

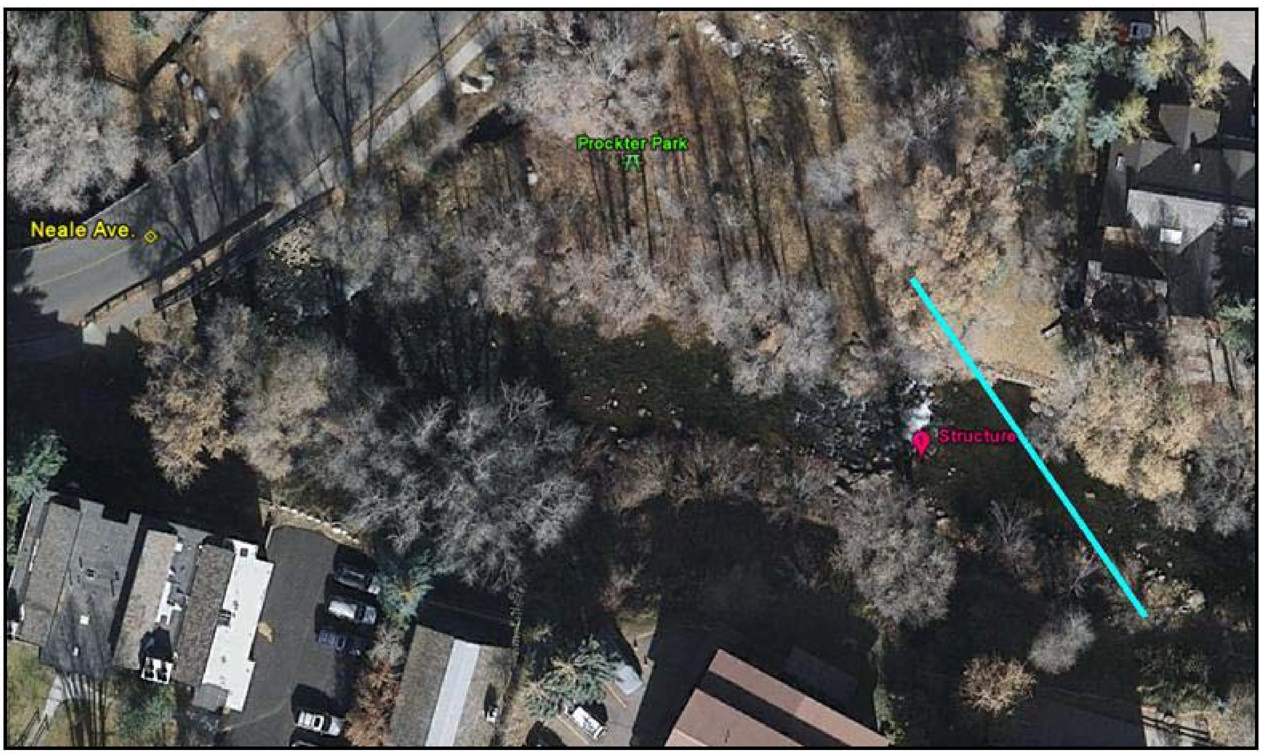

Figure 8. Aerial view of the location of boulder Structure #1 and a sewer pipeline crossing (light blue line) just upstream of the Neale Avenue bridge.

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Although Figure 8 would suggest that fish passage may be possible on the right side of Structure #1, the apparent 1.5 to 2-foot drop may be too much during lower flows for fish to overcome. In addition, the fine sedimentation in the pool upstream of the structure may ultimately fill the pool and create very shallow conditions immediately upstream of the structure. These shallow conditions may not be conducive for fish passage during low flows and may also induce bank erosion by forcing flow to the sides of the channel.

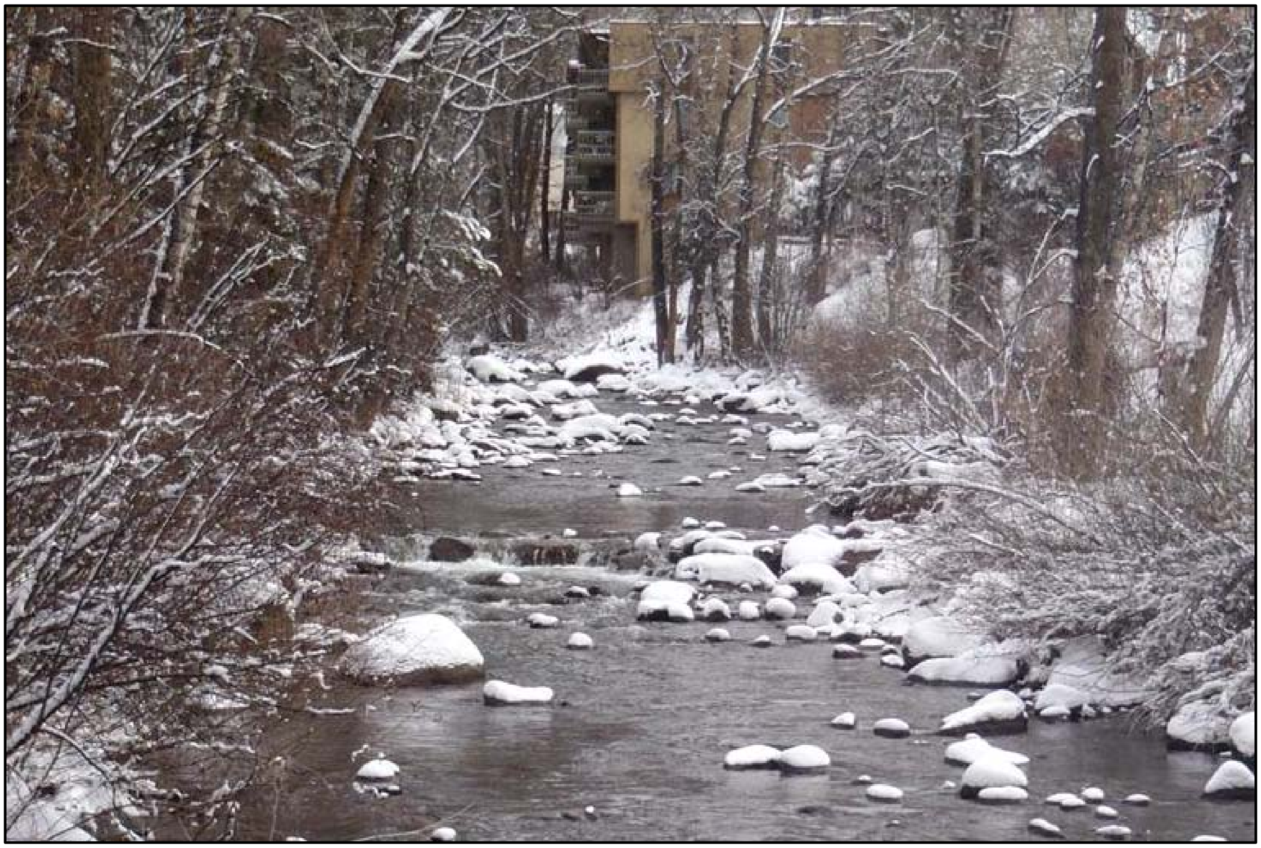

Figure 9. View looking upstream from Neale Avenue bridge toward the cross-channel boulder Structure #1.

The next segment, known as the Herron Park segment, extends from the Neale Avenue bridge to the pedestrian bridges about 600 feet downstream (**Figure 10**). This reach is represented by a large radius left hand bend. The inside of the bend is cut by a man-made channel that intersects a wetland pond at about the center of the bend. The man-made channel continues downstream and intersects the river just upstream of the pedestrian bridge. The left or outer bank of the bend is revetted over most of its length within this segment.

Although not evident during the site visit, a sewer pipeline crosses the river just upstream of the pedestrian bridge (see Figure 10). Just downstream of the pedestrian bridge at this location is the site of an avulsion or cutoff of the channel across the inside of a right hand bend. Although not evident at the time of the site visit, any grade control placed in the river to protect the sewer line crossing at this site may have contributed to or induced the cutoff of the channel and the formation of the island there. In addition, the upstream cutoff channel at Herron Park may also have contributed to the cutoff downstream of the pedestrian bridge by forcing flow toward the left side of the main channel where the Herron Park cutoff channel rejoins the river at the pedestrian bridge.

The river then makes a sharp turn toward the west below the Herron park pedestrian bridge and the island just downstream. The right bank at this location is a high steep bank composed of glacial outwash material, with the toe of the bank armored by boulders eroded from the bank. The river slope is fairly steep through this segment as seen in Figure 4.

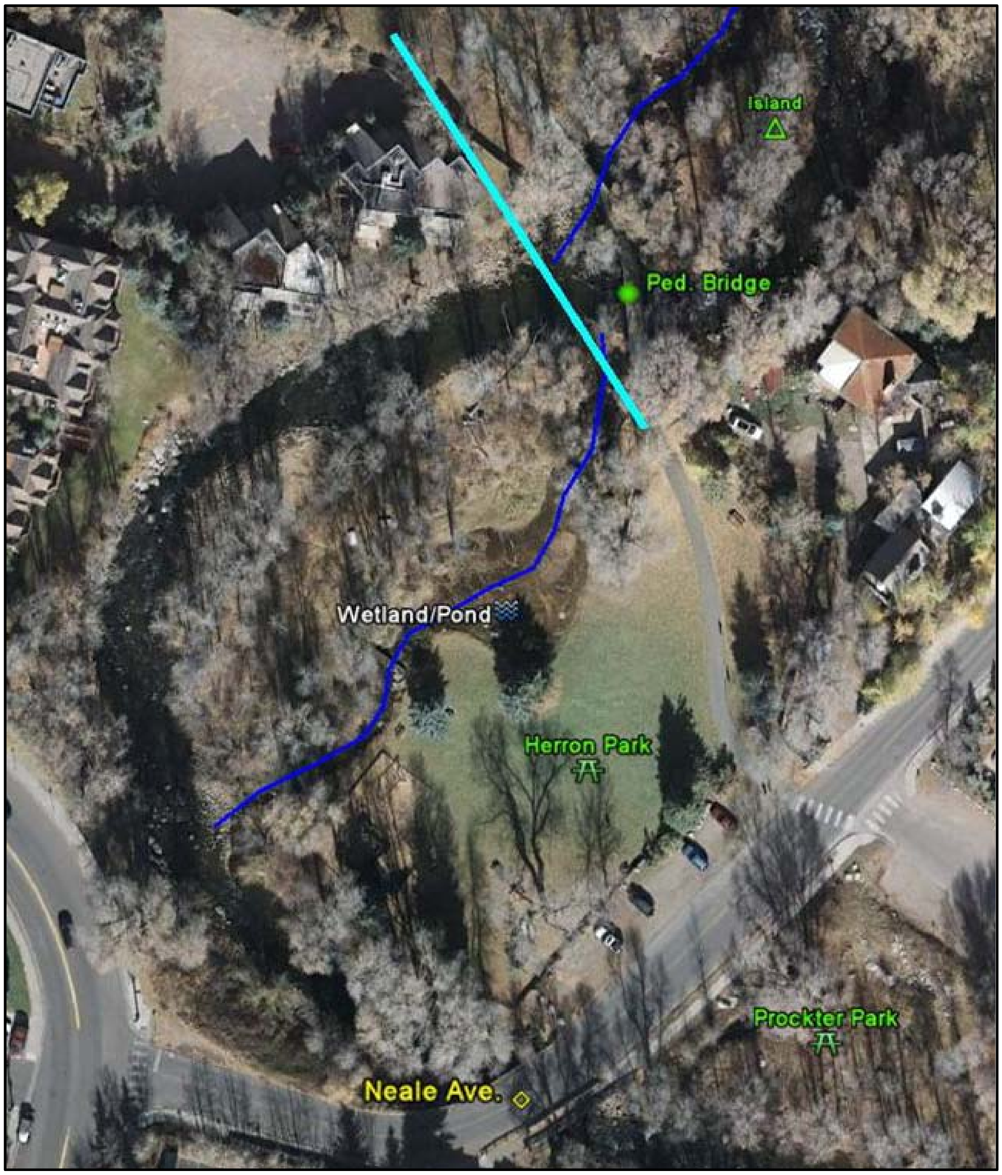

Figure 10. Aerial view of the Herron Park segment of the project reach showing the pedestrian bridges at the downstream end of the segment, the sewer pipeline crossing (light blue line) just upstream, and the man-made split flow channel (dark blue line) and wetland pond at the park.

The next man-made structures in the river are two old concrete bridge abutments on the banks of the channel about 140 feet upstream of the Oklahoma Flats Trail pedestrian bridge over the river at Newbury Park (**Figure 11**). These abutments do not obstruct flow or create any significant problems in terms of channel processes, but do create a slight constriction in the channel width. About 35 feet downstream of the pedestrian bridge is the another cross-channel boulder grade control structure, Structure #2, which also creates an impediment to fish passage at low flows. As shown in Figure 11, the structure was placed to protect an exposed sewer line crossing located about 20 feet upstream. Figure 11 shows the relationship of the structure to the channel and the sewer line crossing. **Figures 12** and **13** show the alignment of Structure #2, which has a drop of approximately 1.5 to 2 feet over the crest. The drop at Structure #2 is also evident in Figure 4.

Figure 11. Aerial view of Structure #2 relative to the sewer line crossing (light blue line) just downstream of the Oklahoma Flats Trail pedestrian bridge at Newbury Park.

Figure 12. View looking toward the right bank showing Structure #2 just downstream of the Oklahoma Flats Trail pedestrian bridge at Newbury Park.

Fiogure 13. View looking downstream from the Oklahoma Flats Trail pedestrian bridge. Note Structure #2 and boulder revetment along the right bank downstream.

Although the flows seen in Figure 12 appear to be sufficient to allow for fish passage, summer low flows may be significantly less and may not be sufficient to allow for fish passage. In addition, Structure #2 is creating sufficient backwater upstream to cause finer grained sedimentation in the channel for some distance upstream of the pedestrian bridge (**Figure 14**) due to the reduction in the energy slope created by the structure. This sediment appears to be finer than the substrate sizes necessary for spawning and appears to be partially burying or infilling the spawning substrate at this location. Small scour holes have developed off the downstream face of the structure.

The lower portions of both banks of the river are revetted with large boulders over much of the reach from the Oklahoma Flats Trail pedestrian bridge to the upstream end of the kayak park at the John Denver Sanctuary, a distance of about 590 feet. The kayak course located at the John Denver Sanctuary is situated on the inside of a large radius right hand bend which makes a sharp turn to the west near the Aspen art museum in Art Park (**Figure 15**). The kayak course, which diverts water from the main channel, covers a length of approximately 675 feet, whereas the river length over the same reach is approximately 815 feet. The grade drop for both the kayak course and the river in this reach is about 10-11 feet. Boulders placed in the river at the upstream end of the kayak course are strategically located in and across the channel to assist in the diversion of flow into the course (**Figure 16**). There are 7 pools and 8 boulder drop structures or sluiceways within the kayak channel. **Figure 17** shows one of the drop structures and upstream pools relative to the main channel of the river and the intervening island.

Figure 14. View looking upstream at aggradation induced by Structure #2 upstream of the Oklahoma Flats Trail bridge.

Figure 15. Aerial view of the kayak course reach of the river at the John Denver Sanctuary.

Figure 16. View looking downstream toward the right bank showing the boulder flow split and diversion into the kayak course channel.

Figure 17. View toward the right bank showing a typical boulder drop structure and upstream pool in the kayak course channel and the main channel of the river in the background. Note the high island between the river and the kayak channel. A remnant of the low floodplain is in the background. Note the house on pilings.

There are a number of potential problems associated with the kayak course that impact river function. First, the course diverts flow from the main channel for its use. Since the width of the main channel through this reach has been maintained, the flow diversion into the kayak course results in shallower flows in the main channel during low to moderate flows. Second, the reduced flows in the main channel can also result in fine grained sediment deposition, which may limit the availability of spawning substrate. Also, during higher spring flows, a significant amount of sediment eroded from the unprotected banks of the kayak course as well as sediment transported in from the main channel is deposited in the pools of the course. Deposition of fine sediment within the pools as well as the trapping and deposition of organic materials may limit the viability of the course if not regularly removed. Finally, there are boulder drop structures at both ends of the course with the downstream structure having a drop of about 3.5-4 feet and the upstream structure having a 1-1.5 foot drop. These upper and lower structures create an obstruction to fish passage during low flows. During the moderate to high flows, fish may migrate or be diverted into the kayak channel and can become trapped in the pools once flows recede (this was readily evident during our site visit). The sediment and organic material deposition in the pools, the limited habitat, and potential summer heating of the water in the pools can be detrimental to any fish stranded in the kayak channel during the summer months.

The river then passes under an old railroad bridge on the Rio Grande Trail just downstream of the end of the kayak course. From there, the river makes a sharp left hand bend, turning back to the north (**Figure 18**). The left or outer bank in this bend is revetted with large boulders, whereas the right bank and low floodplain of Art Park is defined by man-made wetlands/ponds. The river then passes under the N. Mill Street bridge and then under a Rio Grande Trail pedestrian bridge about 200 feet further downstream. Both banks of the river are revetted between the N. Mill Street bridge and the pedestrian bridge. An unexposed sewer line (light blue line in Figure 18) passes under the river about half way between these bridges. Fish passage through this reach is unobstructed.

Two exposed pipelines cross the river about 215 feet downstream of the Rio Grande Trail pedestrian bridge located just below the N. Mill Street bridge (**Figure 19**). The two exposed pipes are not included in the City's utility mapping database and are, therefore, assumed to be abandoned. These pipes appear to extend across the entire width of the river and produce less than 1 foot of drop each. It is not known if these pipelines create an impediment to fish passage at low flows.

Further downstream in the area of Jenny Adair Park (**Figure 20**), two additional structures were noted, Structures #3 and #4. Structure #3 is located on the upstream side of the Rio Grande Trail pedestrian bridge at Jenny Adair Park and Structure #4 is located about 115 feet downstream of the bridge. As seen in Figure 4, the vertical drop in the profile at both structures is well defined and the apparent backwater flattening of the channel slope upstream of the structures is also well defined

Structure #3 is a man-made boulder drop structure (**Figure 21**) that is associated with a previously exposed sewer line crossing about 15 feet upstream of the structure crest. The structure consists of structural boulders placed across the channel along the upstream face of the pedestrian bridge to protect the sewer line crossing located just upstream. The boulder structure creates about a 2-3 foot vertical drop in the channel gradient immediately below the pedestrian bridge and significant flattening of the upstream channel gradient. Plunging flow over the drop structure has created a significant scour hole along the downstream face of the structure directly under the bridge. Sediment from the scour hole has been deposited immediately downstream of the bridge.

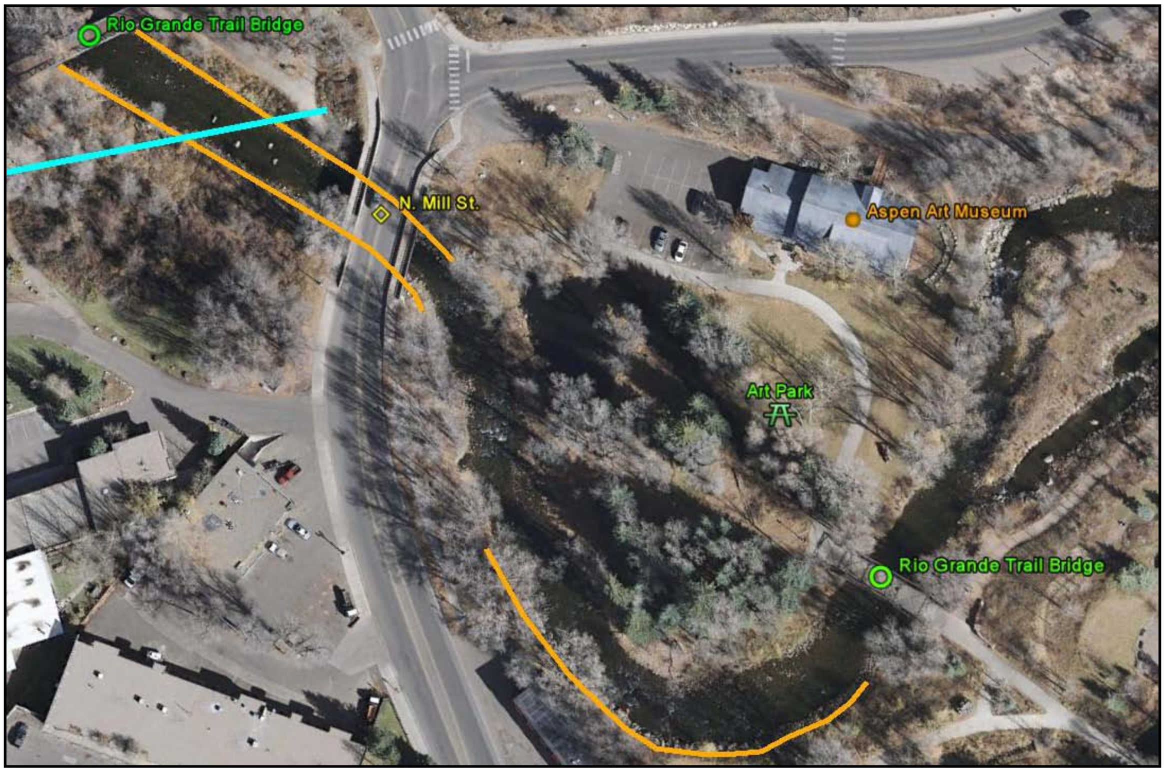

Figure 18. Aerial View of the river segment from the kayak course to the pedestrian bridge downstream of N. Mill Street. Note buried pipeline crossing (light blue) and revetment (orange).

Figure 19. Aerial view of two exposed pipelines in the river downstream of the Rio Grande Trail pedestrian bridge located just below the N. Mill Street bridge.

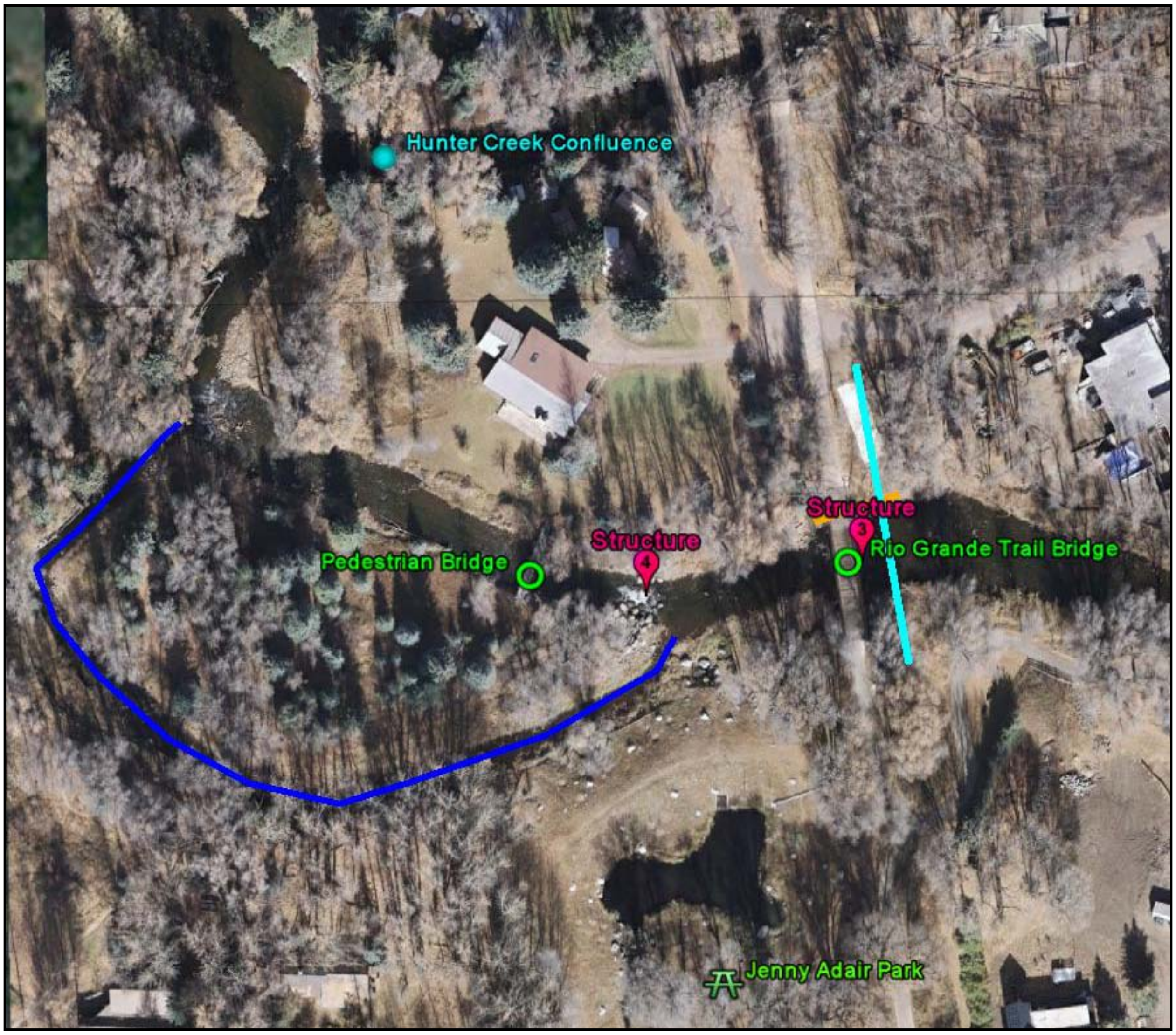

Figure 20. Aerial view of the river segment covering the area around Jenny Adair Park and the Hunter Creek confluence. Note the sewer line crossing (light blue line) and the man-made flow split (dark blue line) associated with Structures #3 and #4, respectively.

Structure #3 has also induced upstream aggradation, which has fully buried the previously exposed sewer line. Since this structure is located in a high radius bend and as is expected with regard to flow and sediment transport processes in a bend, the bulk of the upstream aggradation has occurred along the left (inner) bank portion of the channel (i.e. point bar) while some slow erosion is occurring along the right (outer) bank upstream of the structure. As seen in Figure 20, typical meander bend processes and the impacts of the structure have created a wider, shallower channel section immediately upstream of the structure. This structure is an impediment to fish passage during low flows and the fine-grained sedimentation that the structure induces for a short distance upstream creates a shallower channel and partially buries available spawning substrate at that location.

Figure 21. View of boulder Structure #3 on the upstream side of the Rio Grande Trail bridge at Jenny Adair Park.

Structure #4 is associated with a man-made split flow channel and island immediately to the south of the structure (see Figure 20). **Figure 22** shows the relationship of the boulder drop structure and the upstream end of the man-made flow split, the resultant island, and the upstream riffle and sedimentation induced by the features. The vertical drop over Structure #4, which is evident in the profile shown in Figure 4, is about 3-4 feet.

It appears that Structure #4 was constructed in conjunction with construction of the man-made split flow channel to the south. The structure appears to be used to divert flows from the main channel of the river into the split flow channel. Both the structure and the split flow channel appear to be associated with the nearby Aspen Center for Environmental Studies. These features are also detrimental to fish passage during low flows. The drop over the boulder structure is too precipitous during low flows to allow fish passage. In addition, an examination of the contour mapping of the area reveals that the upstream end of the split flow channel has a very flat slope, which likely results in either a dry channel or flows too shallow to allow for fish passage during periods of low flow.

Structure #4 also creates a significant flattening of the upstream channel gradient, as indicated by the upstream riffling and sedimentation seen in Figure 22. This riffled and aggraded segment of the river may be sufficiently shallow during low flows to preclude or limit fish passage.

The remainder of the river from the confluences of Hunter Creek to Castle Creek is generally stable and well confined between high terraces stable. No know man-made features that may be detrimental to fish habitat or impediments to fish passage exist within this remaining segment of the river.

Figure 22. View looking downstream from the pedestrian bridge at Jenny Adair Park showing the boulder drop Structure #4 in the river channel on the right and the narrower, shallow, man-made split flow channel on the left.

CONCLUSIONS AND RECOMMENDATIONS

The reach of the Roaring Fork River through the City of Aspen is significantly encroached upon as a result of urban development. Very little of the river's floodplain remains along the river corridor and upstream diversions, and man-made perturbations within the watershed have changed not only the hydrology of the system, but also a whole host of other functions and processes including the sediment transport characteristics of the river. As indicated in the watershed report (Clarke et al. 2008), the in-stream and riparian habitat quality in this reach of the river is considered severely degraded as a result of these perturbations.

Contributing to the degraded in-stream habitat is the presence of boulder grade control structures emplaced to protect exposed utility crossings and to provide flow to man-made split flow channels. These structures create significant vertical drops that are an impediment to fish passage as well as inducing localized upstream aggradation that reduces the flow depth, increases the channel width through bank erosion, and buries spawning substrates within the aggraded reach. For example, **Figure 23** shows the plan and profile view a typical steep, unobstructed, boulder/cobble bed channel like the Roaring Fork River. In this view, it can be seen that water "piles up" on the upstream side of a large boulder and then accelerates as it goes around the boulder. As flow passes around the boulder, flow acceleration and eddying may create a scour hole on the downstream side of the boulder. Minor amounts of localized sediment deposition may occur just downstream of the boulder, both a result of the scour and as a result of the boulder creating a shadow zone. The individual boulder, its scour hole, and the minor sediment deposition downstream all create diverse habitat for fish.

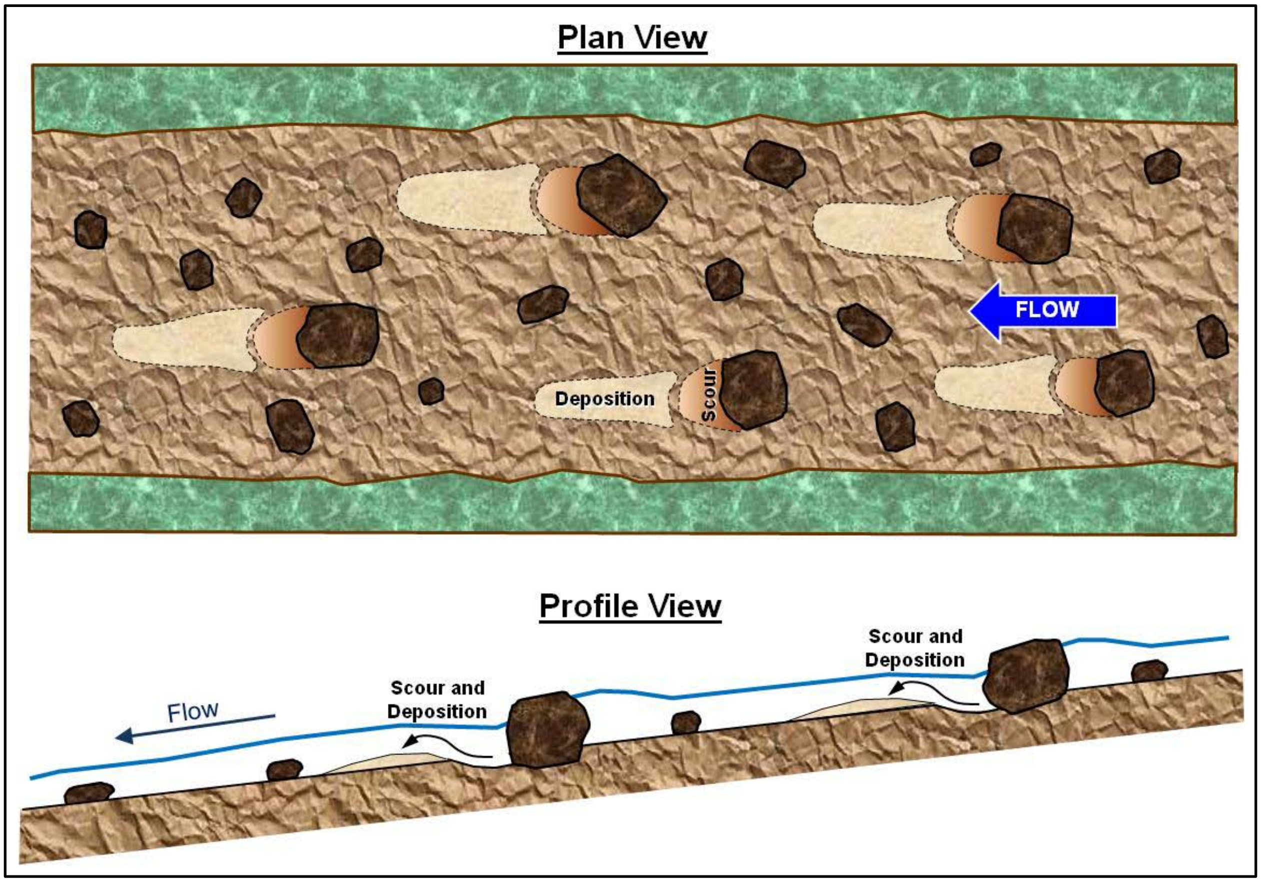

Figure 23. Typical flow, scour, and deposition patterns on a steep, boulder/cobble bed stream.

In comparison, **Figure 24** shows the plan and profile view of a typical boulder grade control structure that has been constructed on the river in at least 4 locations. As previously discussed, the boulder structure creates a significant impediment to fish passage during low flows, but may develop a large scour hole and depositional zone downstream that may provide some beneficial habitat. However, the structure also creates a significant flattening of the channel gradient for a short distance upstream, which in turn also induces localized aggradation which reduces the quality of in-stream habitat and spawning substrate at that location. Both the structure and upstream aggradation can also induce or contribute to bank erosion at the ends of the structure as well as immediately upstream of the structure. Bank erosion at the ends of the structure can result in flanking or significant damage to the structures.

The structures at three of the locations were constructed to protect exposed sewer pipleline crossings. Since it is imperative that these crossing be protected, it would be beneficial to river function to modify the protecting structures such that they still provide maximum protection to the pipelines as well as provide fish passage at all flows. A number of agencies (e.g. Forest Service 2008, Caltrans 2007) provide design guidance for grade control features that also allow for fish passage. For example, one method of grade control consists of a series of rock weirs placed such that flow is allowed to pass over and around the overall structure while maintain unobstructed fish passage as well as grade control. **Figure 25** provides a conceptual plan and profile view of a typical grade control structure using rock weirs.

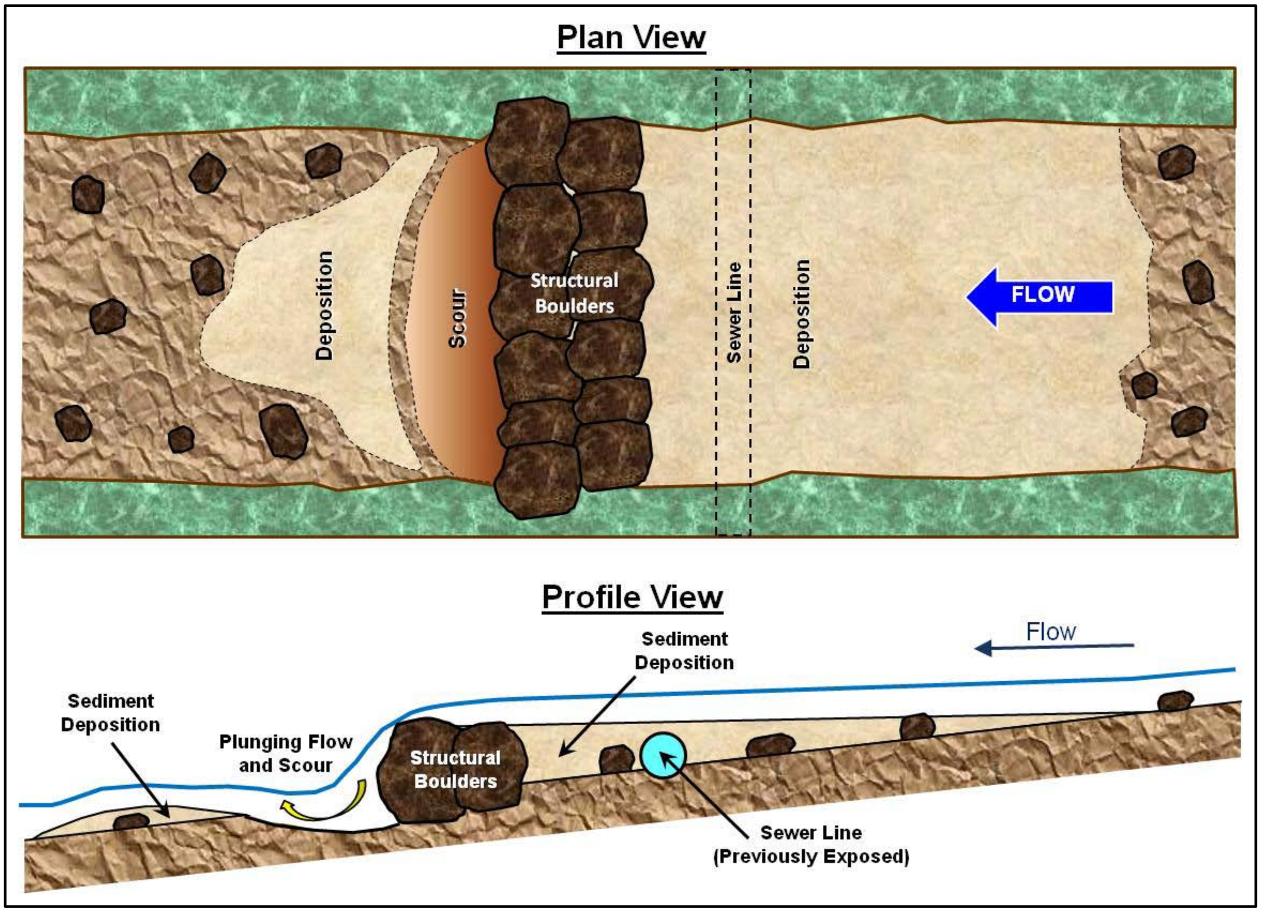

Figure 24. Modified flow, scour, and sedimentation patterns created by a boulder grade control structure on a cobble and boulder bed stream.

At this time, we would recommend that the Healthy Rivers and Streams Program, in cooperation with the City of Aspen and Pitkin County reconstruct Structures #1-3 using a series of weirs similar to that described in Figure 25.

We would also recommend the complete removal of Structure #4 at Jenny Adair Park as it appears to serve no other purpose than an aesthetic one. If the split flow channel at this location is, in fact, used by the Aspen Center for Environmental Studies and serves a useful purpose, we would recommend that the boulder grade control structure used to divert flows into the split flow channel still be removed, but that the diversion point be located much further upstream. This can be accomplished by extending the upper end of the split flow channel further upstream to a point where flow can be successfully diverted without requiring a diversion structure while maintaining adequate flow depths and widths as well as fish passage at all flow levels.

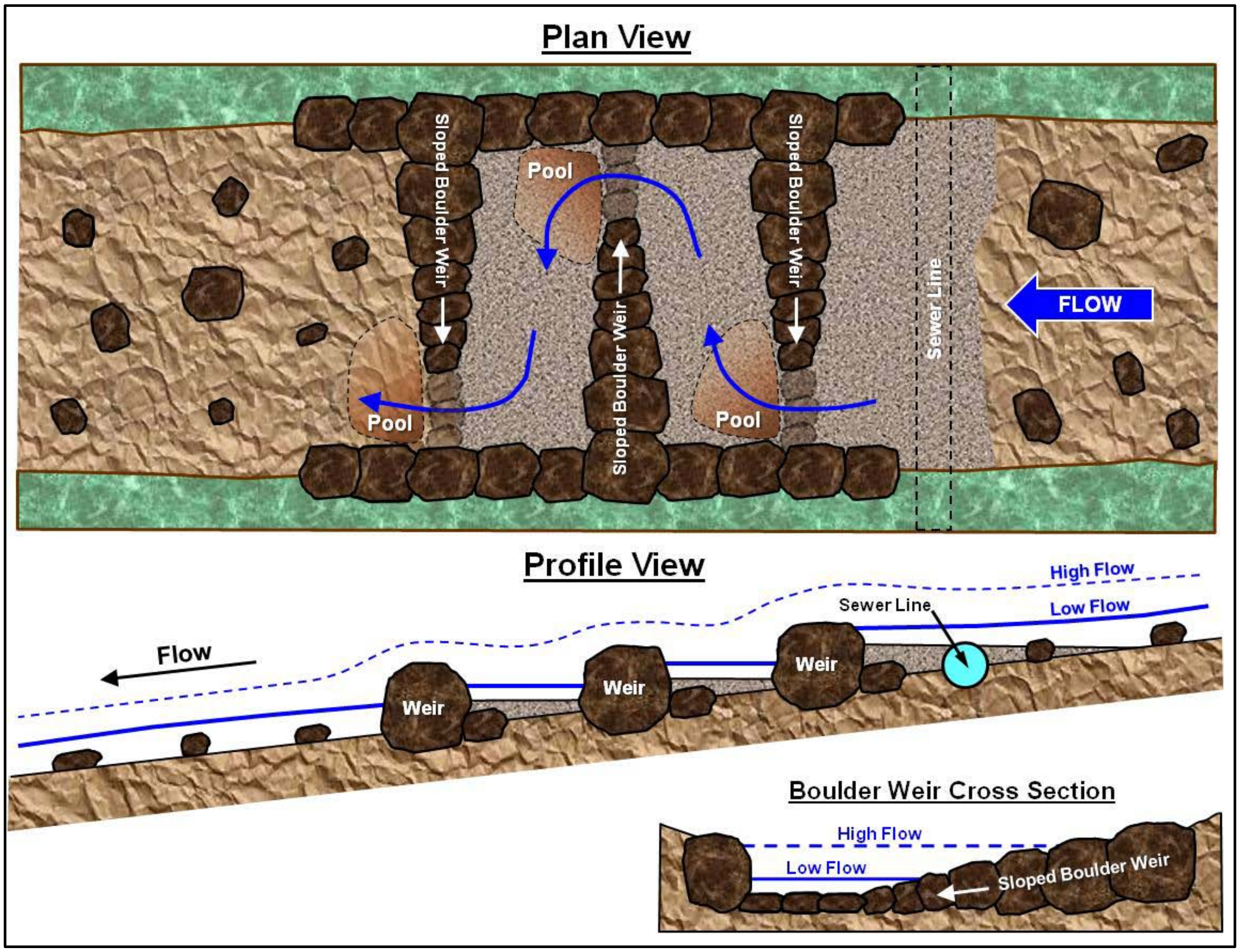

Figure 25. Plan, centerline profile, and cross section views of a typical grade control structure that consists of a series of boulder weirs.

With regard to the kayak park at the John Denver Sanctuary, we would recommend the complete removal of the course and reclamation of the area occupied by the course to a functional floodplain. Based on our knowledge of the course, it appears that the course is used infrequently and only when there is sufficient flow, such as during spring runoff. Thus, the course is only viable for a short period during the entire year and will likely require ongoing maintenance to keep the course pools clear of sediment and organic debris. The kayak channel could be reclaimed by removing the excavated material from the intervening island and refilling the kayak channel with little to no effect on in-stream habitat on the main channel of the river. By refilling the kayak channel, the floodplain area occupied by the island that was covered with the material previously excavated from the kayak channel would also be restored. Reshaping of the left bank of the river and replanting riparian vegetation on the reclaimed island/floodplain area would also contribute to habitat diversity in this reach.

Although these recommendations would likely require a significant budget as well as appropriate permitting to accomplish, the upfront costs should be offset and mitigated by the long-term advantages of restoring in-stream and floodplain habitat at the locations described above.

We suggest that Pitkin County, through its Healthy Rivers and Streams Board, initiate discussions with the appropriate city, county, and private entities regarding the above recommendations to restore stream channel function. These initial discussions could assist these groups to: 1) prioritize the recommended channel restorations in this report; 2) begin the process for channel restorations; and 3) develop a long term strategy for maintaining river health and function.

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