Site Recommendations for Stream Discharge Gaging on Top Tier Priority Reaches in the Roaring Fork Watershed

Prepared for

Roaring Fork Conservancy

and

Friends of Rivers and Renewables

In conjunction with

Roaring Fork Watershed Stream Gage Needs Workshop

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Terms and Conditions of This Document:

1. This is an unofficial, nonbinding document for the purpose of communicating approximate pricing and product options for installation, operation and maintenance of a gaging network in the Upper Roaring Fork and Crystal River watersheds.

2. Equipment prices provided by the vendor are subject to change at any time without notice and do not include sales tax, shipping, or insurance.

3. All pricing options assume that the stakeholders will own all stream gaging equipment outright.

4. Operation and maintenance plans provided by S.K.Mason Environmental, LLC do not include replacement, repair, or calibration costs incurred due to sensor drift, equipment loss or damage resulting from environmental conditions or normal wear-and-tear.

5. Cost estimates for operation and maintenance plans rely on access to stakeholder-owned stream discharge measurement device(s) that can be used to measure streamflow at each of the identified gaging locations (e.g. Sontek FlowTracker ® and/or Sontek RiverSurveyor®).

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1.0 Introduction

1.1 Purpose and Scope

Friends of Rivers and Renewables (FORR) recently identified a need for a comprehensive stream gaging[1] system in the Roaring Fork Watershed to inform multiple stakeholders involved in natural resource management decisions with timely, unified, and scientifically defensible stream flow data. This need was also classified as a priority in the Roaring Fork Conservancy's (RFC) 2011 Watershed Management Plan. In April 2012, FORR and RFC held a collaborative Stream Gage Needs Workshop, the results of which have been compiled in a Draft Summary Report for free distribution to all interested parties (hereafter referred to as the *'Workshop Summary'*). Participants at the Workshop identified 7 specific development goals for a proposed gaging network, and selected 8 stream reaches in the watershed as top-ranked priorities for gaging. These reaches are termed *first tier priorities*.

The purpose of this report is to recommend physical locations for stream gages on each first tier reach, provide a brief analysis of the strengths or notable weaknesses for a particular site, and discuss alternative options for a given site where appropriate. Site recommendations are driven by a combination of technical and non-technical factors, and follow USGS-based guidelines for gaging locations. Technical factors include the existence of stream channel morphology amenable to gaging discharge, and locations favorable to wireless communications network needs. Non-technical factors include site accessibility, land ownership, and stakeholder criteria as specified in the Workshop Summary and other communications.

1.2 Stream Channel Requirements for Gage Sites

In order to obtain accurate, repeatable, and easily measurable discharge information, a gage site on a stream channel should be judged on several characteristics (USGS 1983):

- The channel should be relatively straight for some distance above and below the site
- Discharge must be confined to a single channel at all flows
- The bed is geomorphically stable and unchanging (i.e. not subject to frequent scour or fill, stable banks, stable channel type),
- Banks are relatively free of vegetation
- Channel type allows for accurate gage readings even during low-flow conditions

[1] The USGS-preferred spelling of *gage* is adopted throughout, rather than the also-common *gage.*

- Accessibility needs for installation, maintenance, and wireless communication are met

Often an ideal site for a gage consists of a pool coupled with a run. A run is a segment of stream with non-turbulent flow over a relatively flat stream bottom. Runs often occur where a steepened riffle section transitions into a flatter pool section. The run provides a location to collect discharge measurements, and the nearby pool provides a suitably calm area for the placement of a staff gage or sensor to measure water depth. Meeting all criteria at every site can prove difficult, and requires careful judgment to maximize a given site's advantages while minimizing its shortcomings. The Roaring Fork Watershed comprises some of the most mountainous terrain in the United States; the steep and rocky nature of its waterways and the high variability in annual environmental conditions can pose special problems for siting and operating stream gages.

Stream gages function by relating physically measured discharge values to a corresponding height or depth of water at a specific stream location using what is known as a stage-rating curve. Discharge measurement at a given river depth, or stage, is the product of a stream channel's cross-sectional area and its average velocity. By measuring discharge at a given site over a variety of flows states, a rating curve (a mathematical function describing the relationship between depth and discharge) is established. Subsequent to the creation of a rating curve, discharge may be calculated by observing only water depth at the gaging location. Because the cross sectional geometry of a stream is subject to change over time (especially in steep mountain streams) it is necessary to periodically return to a given gaging location for calibration of the rating curve. An in-depth explanation of these methods is beyond the scope of this report. Interested parties may wish to review a hydrologic text such as *Physical Hydrology* (Hornberger et al, 1998) for a full treatment.

1.3 First Tier Priority Reaches

The Workshop Summary identifies the following reaches as Top Tier Priority Reaches:

1) Maroon Creek below the Stapleton Ditch
2) Roaring Fork above Castle Creek (Suite of gages in Aspen)
3) Lower Crystal River
4) Roaring Fork River near Lost Man Creek (upper Roaring Fork headwaters)
5) Coal Creek Sub-basin
6) Fryingpan-Arkansas Project Bypasses (Carter, Mormon, and M. Cunningham Creeks)
7) Brush Creek in Snowmass

8) Maroon Creek (below the City of Aspen municipal diversion)

In each of these reaches, one or more gaging stations meet stakeholder needs regarding water resource management decisions. Workshop participants selected these reaches using multiple criteria. The remainder of this report provides details on proposed gage locations, and alternatives to gage installation where appropriate. Reaches are presented in parallel order to the Workshop Summary. Accompanying maps and images are intended as aids to understand gage site locations relative to other landmarks; they are not intended as definitive statements of final site selection or property ownership lines.

1.4 Structure of this document

This body of this report strives simultaneously to 1) recommend an ideal gaging option based on identified stakeholder needs in the Workshop Summary and 2) provide a clear road map for any party to proceed with gage installation at a given site. Site recommendations include both a physical location discovered through field work to be suitable for gage installation based on the criteria listed in Section 1.2 and specifications for the infrastructure required at each site to meet stakeholder needs. Stream gaging station development possibilities cover a wide spectrum, ranging from the very simple (a staff gage and periodic manual flow measurements) to the complex (USGS-type real-time stage sensor with satellite uplink and web publishing). Infrastructure recommendations here are made based on the stakeholder needs for each priority reach as communicated by the stakeholders to S.K.Mason Environmental, LLC.

2.0 Gaging Recommendations for Priority Reaches

2.1 Maroon Creek at the Stapleton Ditch

Site:
Below Stapleton Ditch Diversion

Location:
N 39°11'10" W 106°41'15"

Access:
The site may be accessed by foot via Maroon Creek Trail from the Aspen Rec Center parking lot on Maroon Creek Road, or from Tiehack Road.

Looking downstream from the Stapleton diversion

Permission and Land Ownership:
Land ownership in the creek corridor by the footpath on river-left and right banks up to the Rec Center is Aspen Highlands Open Space. Installation would need approval with City of Aspen and Pitkin County. City of Aspen Parks and Open Space, Brian Flynn (970) 429-2035, Pitkin County Public Works Director Brian Pettet (970) 920-5392. A US ACE Nationwide Permit 5 (for scientific measuring devices) may be required for structures along watercourses. US Army Corps of Engineers Grand Junction (970) 243-1199.

Discussion:
Immediately below the Stapleton Ditch lies a channel-run section of Maroon Creek approximately 30 meters long. The right bank is steep and moderately vegetated, with some small exposures of bedrock. The Stapleton Ditch road makes up the left bank, 1-2 meters above the creek. Maroon Creek is well-confined in this section with a bed of cobble to boulder-sized substrate. Two alternative sites exist in this area: one approximately 30m downstream of the diversion point, and a second just below the Maroon Creek Trail Footbridge. The left bank is steep and loose, the right may easily be accessed by walking downstream from the footbridge. Finding an ideal channel-run on lower Maroon Creek is difficult because of the constant gradient of the streambed. Most sections near the ditch and footbridge are suitable but not perfect. Rocky substrate and turbulence may hinder some measurements at the lowest flows at any site on this reach. Further downstream the valley widens and the creek is prone to meandering and multiple channels in a wider floodplain.

Supporting Infrastructure:
The infrastructure to meet stakeholder needs for Maroon Creek at Stapleton Ditch includes a real-time streamflow measurement gage and telemetry system for transmitting collected data from the site. Specifically, a sensor for measuring stream depth must be installed in the stream channel. In order for data produced by the station to be considered by the Colorado Department of Water Resources (CDWR), the accuracy and precision of the water depth sensor must comply with the standards outlined in the USGS Techniques and Methods Report 3-A7 (Sauer and Turnipseed, 2010). Depth measurements at the site will be collected in real-time (e.g. every 15 minutes) by a Campbell Scientific controller/datalogger. The datalogger will be programmed to calculate stream discharge from stage measurement using the best-fit rating curve coefficients.

The site characteristics and CDWR's need to view data in near real-time dictate that data be transmitted from the site using satellite telemetry. The station will transmit data over the GOES satellite system. Data transmission and collection will follow National Environmental Satellite, Data, and Information Service (NESDIS) protocols and will require the development of an MOU between a city government, county government, or non-profit entity and the NESDIS.

Estimated Cost: **See Section 3.1**

Installation
Installation and initial setup of the gaging station and telemetry network requires design and assembly of electrical components, programming the datalogger to collect stage measurements at a selected time interval, securely installing the gaging station on the stream bank, and setting up the GEOS telemetry system to enable transmission of data from the site and subsequent aggregation of data on a client network or machine.

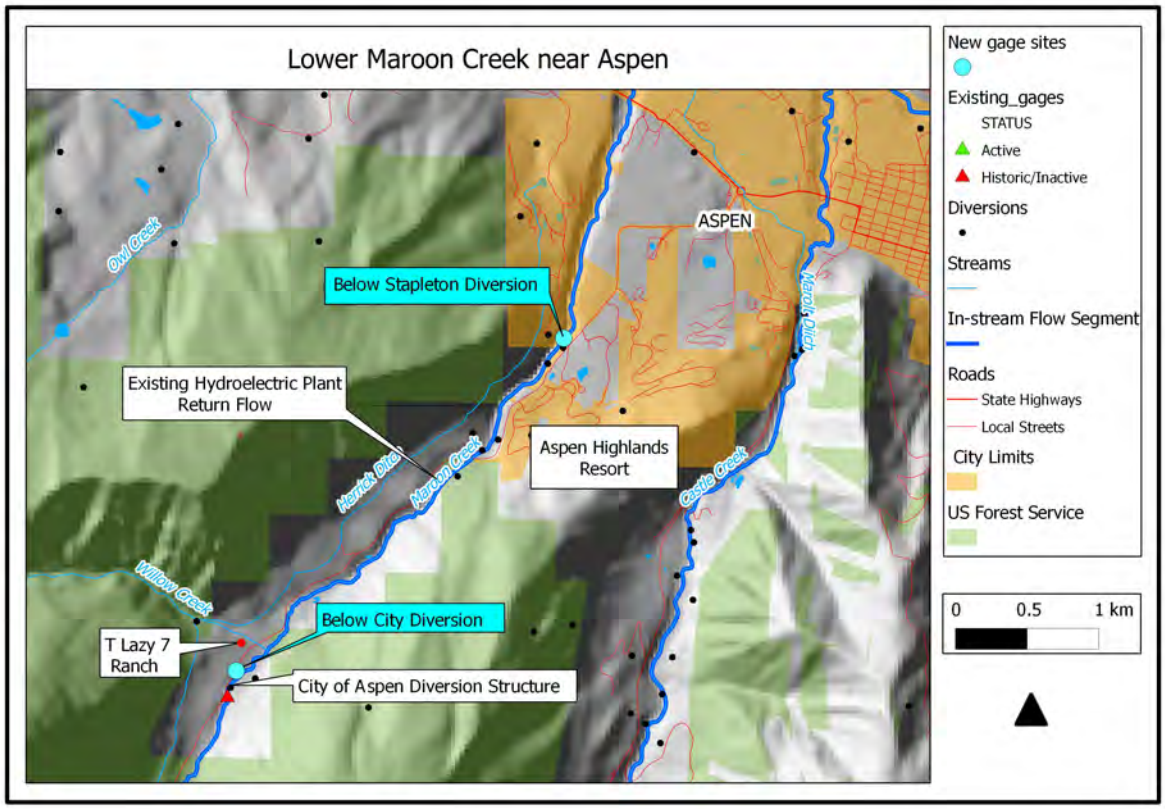
Estimated Cost: **$ 2,500.00**

Operation and Maintenance
The operation and maintenance of this station requires periodic site visits for instrument cleaning, rating curve calibration and as-needed troubleshooting of the datalogger, sensor, or telemetry network. A stage-discharge rating curve developed on the site over a range of flow states and following methods outlined in the USGS Techniques and Methods Report 3-A8 must be used to relate stream depth measurements to stream discharge. The gaging station must be leveled by a licensed surveyor each year for the first three years following installation and

periodically thereafter following the methods outlined in USGS Techniques and Methods Report 3-A19 (Turnipseed and Sauer, 2010). This station will be operated year-round.

Estimated Cost: **$ 3,000.00**

Location Map:



2.2 Lower Crystal River

Site:
Colorado Parks and Wildlife Fish Hatchery

Location:
N 39°22'38" W 107°12'16"

Access:
County Road 118 bridge, 1.9 miles on the right from the Carbondale stoplight on Rt. 113.

Seasonal Gage site at CPW Fish Hatchery

Permission and Land Ownership:
Colorado Parks and Wildlife administers the fish hatchery, and the bridge easement may require Pitkin County permission. Crystal River Hatchery, John Riger (970) 963-2665. For access to easements near the county road bridge, contact Pitkin County Public Works Director Brian Pettet (970) 920-5392.

Discussion:
This is the site of a current gage administered by the Colorado Division of Water Resources. It is well-placed to capture flows on the most dewatered section of the Crystal—below several large diversions but above significant irrigation return flows. In spring of 2012, USGS removed all remaining infrastructure at the lower site near CRMS campus (USGS Crystal River below Carbondale). That site is co-located with macroinvertebrate sampling sites monitored by River Watch and CRMS; due to the significant return flows above CRMS it does not characterize the most dewatered section of the lower Crystal in the same way as the fish hatchery site. The site is seasonally active from April to September.

As an alternative to the recommended infrastructure below, stakeholders may desire to re-enter discussion and negotiation with CDWR regarding year-round operation of the existing hatchery gage. Correspondence with CDWR places the approximate average cost for year-round gage operation at similar near-by sites as $9000 per year. Actual costs vary based on factors including stream channel stability control, data publishing needs, and winter operation costs. The Crystal River Hatchery site is low in the watershed, where the stream is wider and less steep, it is likely that channel stability is good at the site, and icing issues would be less frequent than higher elevation sites and smaller streams. However, whether CDWR will take on

additional gages should not be assumed a certainty. CDWR currently faces an administrative workload beyond existing employee capacity. The agency retains discretion to accept or decline new gage work based on decisions by local Division 5 staff , who must determine themselves whether a new gage materially benefits water administration needs. CDWR operates the hatchery gage from May to September specifically to capture low flow summer conditions on the lower Crystal. An earlier effort by CWCB to secure local cooperators for annual gage O/M did not succeed. Focus at the sight now is to monitor low flows and maintain an accurate low-end ratings curve for CWCB ISF administration. For a fuller treatment of CDWR considerations for shared gage operation, please refer to **Section 4.** Section 4 further discusses CDWR and USGS criteria for constructing and cost-sharing of new gage work.

Supporting Infrastructure:

The infrastructure necessary to meet stakeholder needs for the Lower Crystal River includes a real-time streamflow measurement gage and the possible addition of several real-time water quality sensors. Specifically, a sensor for measuring stream depth must be installed in the stream channel. The accuracy and precision of the water depth sensor should comply with the standards outlined in the USGS Techniques and Methods Report 3-A7 (Sauer and Turnipseed, 2010). It is also possible to install pH, temperature, turbidity, or specific conductance sensors alongside the depth sensor. Depth measurements (and any additional parameters) at the site will be collected in real-time (e.g. every 15 minutes) by a Campbell Scientific controller/datalogger. The datalogger will be programmed to calculate stream discharge from stage measurement using the best-fit rating curve coefficients. Data will be stored on the datalogger and must be manually downloaded periodically.

Estimated Cost: **See Section 3.2**

Installation

Installation and initial setup of the gaging station requires design and assembly of electrical components, programming the datalogger to collect stage measurements (and any other selected parameters) at a selected time interval, and securely installing the gaging station on the stream bank.

Estimated Cost: (single sensor): **$ 800.00**

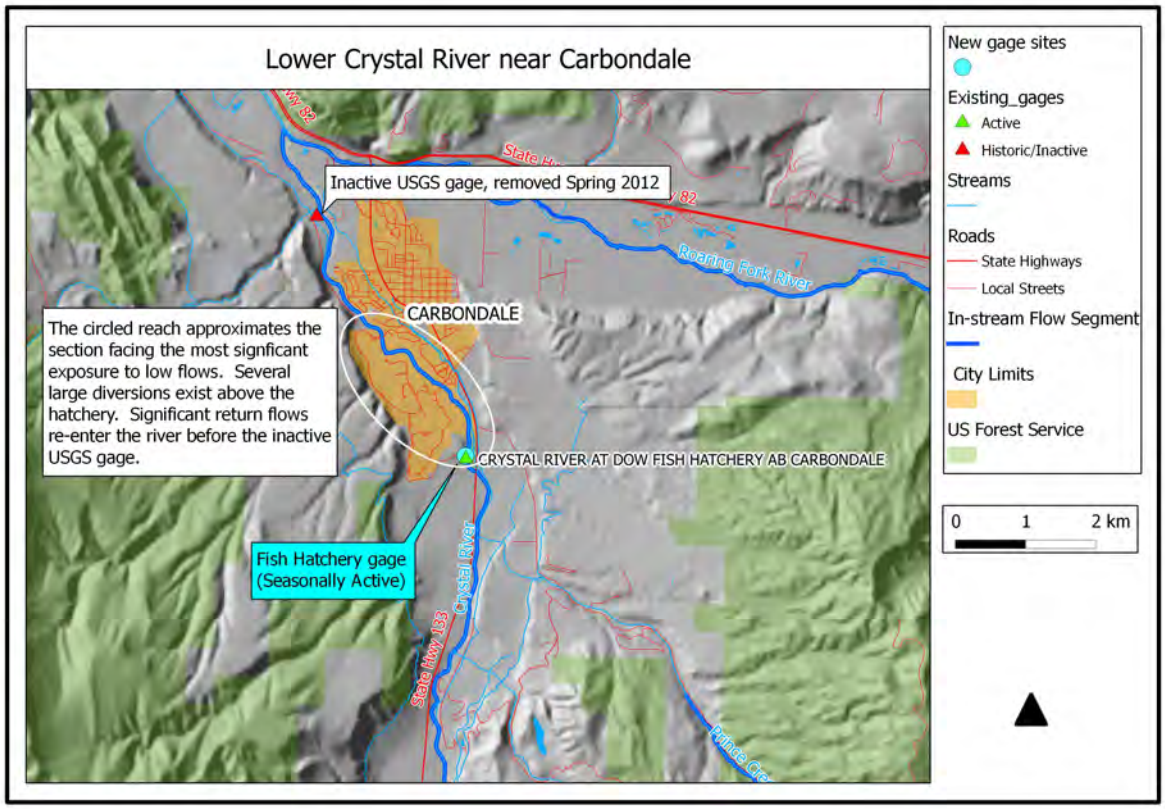
Operation and Maintenance

The operation and maintenance of this station requires periodic site visits for instrument cleaning, rating curve calibration and as-needed troubleshooting of the datalogger and sensor(s). A stage-discharge rating curve developed on the site over a range of flow states and

following methods outlined in the USGS Techniques and Methods Report 3-A8 must be used to relate stream depth measurements to stream discharge. The gaging station does **not** need to be leveled following USGS standards as this data will not be used by CDWR, but will instead be used in assessments of water quality. This station will be operated seasonally to correspond with the months of the year that streamflow data is not captured by the CDWR gage co-located at this site.

Estimated Cost: (single sensor): **$ 800.00**

Location Map:



2.3 Brush Creek

Culvert below roundabout at Brush Creek and Highline Rds

Site:
Intersection of Brush Creek Rd and Highline Rd

Location:
N 39°13'31" W 106°55'15"

Access:
Brush Creek Road in Snowmass Village.

Permissions and Land Ownership:
This site may be accessed through permission with the Town of Snowmass Village. Contact: Kit Hamby, Snowmass Water and Sanitation Manager (970) 923-2056.

Discussion:
This site is below the confluence of both forks of Brush Creek. From a water quality standpoint it captures the combined effects of both the Water Treatment Plant effluent and the Snowmass Club Golf Course. The WTP has a SCADA system with real time monitoring of effluent volume, allowing for separation of WTP and natural load sources of water quality parameters. Brush Creek in the vicinity of Snowmass resort development is a fairly complicated 'plumbed system' with many diversion and return points upstream. This site is likely the best located to address water quality issues identified in the Workshop Summary and correspondence with stakeholders. An alternate location for the gage idenitified by Snowmass Water exists approximately 200 meters upstream at a small concrete box constriction in the stream.

Supporting Infrastructure:
The infrastructure necessary to meet stakeholder needs for Brush Creek includes a real-time streamflow measurement gage, pH sensor, and specific conductivity sensor. All three sensors must be installed in the stream channel. The accuracy and precision of the water depth sensor should comply with the standards outlined in the USGS Techniques and Methods Report 3-A7 (Sauer and Turnipseed, 2010). Depth, pH, and specific conductance measurements at the site will be collected in real-time (e.g. every 15 minutes) by a Campbell Scientific controller/datalogger. The datalogger will be programmed to calculate stream discharge from stage measurement using the best-fit rating curve coefficients. Data will be stored on the datalogger and must be manually downloaded periodically.

Estimated Cost: **See Section 3.3**

Installation

Installation and initial setup of the gaging station requires design and assembly of electrical components, programming the datalogger to collect stage, pH, and specific conductance measurements at a selected time interval, and securely installing the gaging station on the stream bank.

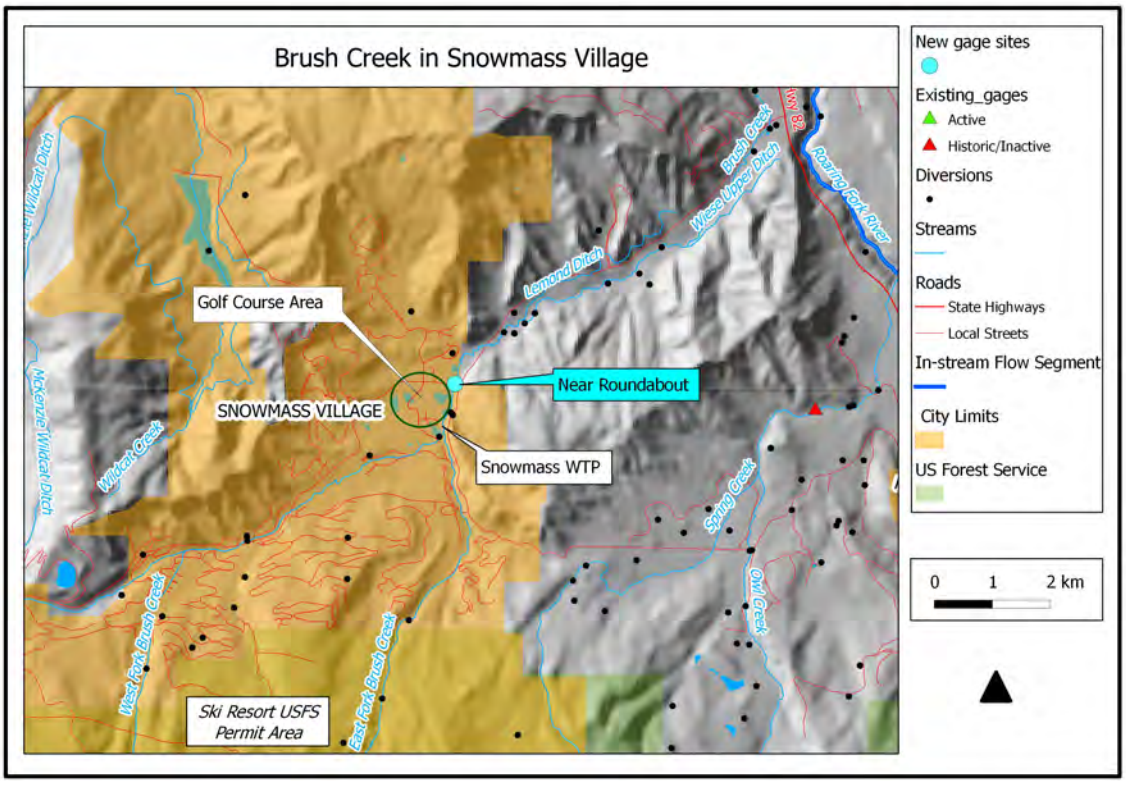
Estimated Cost: **$ 1200.00**

Operation and Maintenance

The operation and maintenance of this station requires periodic site visits for instrument cleaning, rating curve calibration and as-needed troubleshooting of the datalogger and sensors. A stage-discharge rating curve developed on the site over a range of flow states and following methods outlined in the USGS Techniques and Methods Report 3-A8 must be used to relate stream depth measurements to stream discharge. The gaging station does **not** need to be leveled following USGS standards as this data will not be used by CDWR, but will instead be used in assessments of water quality. This station will be operated year-round.

Estimated Cost: **$ 2000.00**

Location Map:



2.4 Roaring Fork at Lost Man Creek

Site:
Below Independence Pass Trans-mountain Diversion System

Location:
N 39°07'01" W 106°37'12"

This V-notch weir is the current USGS-run gage setup on the upper Roaring Fork at Lost Man. Only able to measure flows below 5 cfs, it does not operate in the winter due to icing.

Access:
Park at the a pull-off on the switchback on Rt 82 Independence pass road where the diversion ditch goes under the road and walk approximately 0.25 miles down the ditch road (right side of ditch) until reaching the diversion structure. Or park at the Lost Man Campground, walk off-trail towards the Roaring Fork, then follow it upstream (no trail) to reach the diversion structure.

Permissions and Land Ownership:
This area is USFS administered land, White River National Forest Aspen-Sopris Ranger District Office in Aspen (970) 925-3445. Diversion structures are owned by the Twin Lakes Reservoir and Canal Company, Ordway Colorado. Contact: Scott Campbell (719) 267-4411.

Discussion:
A V-notch weir structure operated by USGS is currently in place to monitor bypass flows into the upper Roaring Fork. Flows are controlled by the Twin Lakes Reservoir and Canal Company (TLRCC) which owns Independence Pass Transmountain Diversion System (IDPTS). TLRCC owns rights to more water from the headwaters than it currently diverts. Bypass flows are provided by TLRCC pursuant to the Twin Lakes Exchange, in which 'foregone diversions' to Twin Lakes from the upper Roaring Fork are repaid to TLRCC via water from diversions above Ruedi in the upper Fryingpan tributaries. Another inactive USGS gage exists a few hundred meters downstream near Lost Man campground. The weir can monitor flows up to approximately 6.8 cfs seasonally from May to October. During the winter months, the site is inaccessible and subject to extreme environmental conditions due to its high altitude location. Summer flows

greater than the total tunnel diversion capacity and bypass weir exit over a concrete spillway and are unmeasured.

Streambed morphology downstream at the inactive gage provides no preferred natural channel sites for discharge measurement, and is subject to the same harsh environmental conditions and freezing problems as the active weir site. Current bypass flows at the weir are designed specifically to meet the 3000 af/yr agreement, the Twin Lakes Exchange. This is administered with various federal and local agencies with the TLRCC through joint flows to both the upper Roaring Fork, and its tributary Lincoln Creek. Correspondence with TLRCC staff indicates the current flow division was originally set up to address a fisheries concern in Lincoln Creek.

Communication with current USGS employee and former BOR staff Mark Henneberg identified previously discussed possible technical solutions. These included a snow-shed and heating unit at the bypass to measure winter flows, and the possibility for a larger weir to measure larger flows during the summer. Any new installation or change to current facilities would need to be fully self-sufficient in terms of operation and maintenance during winter months. Traversing the closed Independence Pass road from December to May not only requires long snowmobile travel on an un-maintained (non-groomed) route, it also entails crossing several large avalanche paths which add a difficult risk-management component to site visits. For these reasons, changes to the set up were previously identified as cost-prohibitive or infeasible. Informal communication with the TLRCC indicates that company is not opposed to changes in operation schedules that still fall within the 3000 af/yr agreement, and that a winter-operating diversion structure is technically feasible. However, it is important to note that TLRCC is not currently legally obligated to make such changes to release schedules, and the Twin Lakes Exchange could also be subject to revision in the future. Currently, excess flows are spilled over the diversion spillway and are not measured by the weir or counted in the 3000 af/yr bypass regime. An alternative weir design might be installed to measure flows over 6.8 cfs, but would lose measurement resolution during low flow. According to Mark Henneberg, accurate low-flow measurement for the 3000 af/yr exchange agreement is the primary reason for the type and size of the current weir.

Construction of a new gage in this area is problematic for the reasons listed previously. The most cost-effective option for procuring year-round streamflow data from this reach is likely the extension of the months of operation of the current USGS gage. This would require the development of a new cooperators agreement between the USGS, TLRCC, and stakeholders. Please refer to **Section 4.4** for a better understanding of how USGS determines potential cost-match schedules and ranks funding priorities for new gage sites. Further discussion of stakeholder interests and realistic agency options is warranted before proceeding.

2.5 Roaring Fork in City of Aspen

Introduction:
This area was targeted in the Workshop for installation of a 'suite of gages'. This approach intended to meet multiple diverse stakeholder needs. These include but are not limited to: evaluation of urbanization effects and refinement of regional waterway assessments, monitoring of ISF segments not currently captured by existing gages, assessment of city stormwater management practices, and education/outreach. No single location in the area satisfies all interests fully, so a combination of 2 to 4 gages in conjunction with existing gages above and below the city was identified as best-meeting these interests in the Workshop Summary.

An existing gage upstream of town administered by USGS and the one below Maroon Creek administered by CDWR may be used in conjunction with any new sites to fully address stakeholder interests. The total number of gages through this reach will likely be determined by the combination of cost feasibility and prioritization of stakeholder goals as determined by FORR, RFC, and others. All sites utilize right-of-ways near bridges and parks, installation would need county or city approval respectively. The high pedestrian traffic in these areas may warrant more-secure installation housing than other locations to prevent incidental equipment damage or vandalism.

Site 1:
Mill Street Bridge (Jenny Adair, John Denver Sanctuary)

Location:
N 39°11'38.7" W 106°49'02.2"

Access:
The site under the bridge may be accessed from Mill St by parking at the Aspen Art Museum.

Permissions and Land Ownership:
This site and the two alternatives are situated in city parks. Contact: Brian Flynn, City of Aspen Parks Department, (970) 429-2035. Additionally, a US ACE Nationwide Permit 5 (for scientific measuring devices) may be required for structures along watercourses. Contact: US Army Corps of Engineers Grand Junction (970) 243-1199.

Discussion:

This site was picked from three similar sites in the vicinity (including the Jenny Adair wetlands and the John Denver Sanctuary). All three sites satisfy the same requirements and should be viewed as interchangeable in a final decision. Other possible sites are located at the Neale St Bridge and the Rt. 82 Bridge. The reach through town faces significant exposure to dewatering and the attendant problems for aquatic life during low flows. The Roaring Fork in this area is provisionally 303(d)-listed as impaired due to aquatic life. Multiple stakeholder interests on this reach include monitoring ISF rights, understanding how flow relates to aquatic macroinvertebrate impairment, and background water quality for city stormwater assessment. One of the city's primary stormwater treatment outflows is at the Jenny Adair Wetlands, just downstream of the gaging location. Gages are sited in downtown pedestrian parks and in close proximity to the Aspen Center for Environmental Studies Hallam Lake campus, adding potential for an education/outreach component.

Roaring Fork River at Mill St

Roaring Fork at John Denver Sanctuary

Supporting Infrastructure:

The infrastructure necessary to meet stakeholder needs for the Roaring Fork at Mill Street Bridge includes a real-time streamflow measurement gage and telemetry system for transmitting collected data from the site. Specifically, a sensor for measuring stream depth must be installed in the stream channel. In order for data produced by the station to be considered by the Colorado Department of Water Resources (CDWR), the accuracy and precision of the water depth sensor must comply with the standards outlined in the USGS Techniques and Methods Report 3-A7 (Sauer and Turnipseed, 2010). Depth measurements at the site will be collected in real-time (e.g. every 15 minutes) by a Campbell Scientific controller/datalogger. The datalogger will be programmed to calculate stream discharge from stage measurement using the best-fit rating curve coefficients.

The site characteristics and CDWR's need to view data in near real-time dictate that data be transmitted from the site using a telemetry system. Two alternative communication systems are possible: a 900 MHz radio telemetry system or the GOES satellite system. If the 900 MHz alternative is selected, data transmission and collection will follow the Federal Communications Commission (FCC) protocols for radio transmissions. If the GOES alternative is selected, data transmission and collection will follow National Environmental Satellite, Data, and Information Service (NESDIS) protocols and will require the development of an MOU between a city government, county government, or non-profit entity and the NESDIS. The 900 MHz system presents a considerable cost savings, but will require placement and maintenance of a receiving base station within the City of Aspen. This base station will consist of a datalogger and an omni-directional radio antenna and must to be connected to a computer hosting the necessary data aggregation software. See **Sections 3.4.1 and 3.4.2** for a full description of equipment and cost differences between a GOES and 900 MHz systems.

Estimated Cost: **See Sections 3.4.1 and 3.4.2**

Installation

Installation and initial setup of the gaging station and telemetry network requires design and assembly of electrical components, programming the datalogger to collect stage measurements at a selected time interval, securely installing the gaging station on the stream bank, and setting up the selected telemetry system to enable of transmission of data from the site and subsequent aggregation of data on a client network or machine.

Estimated Cost: (single sensor): **$ 2,500.00**

Operation and Maintenance

The operation and maintenance of this station requires periodic site visits for instrument cleaning, rating curve calibration and as-needed troubleshooting of the datalogger, sensor, or telemetry network. A stage-discharge rating curve developed on the site over a range of flow stages and following methods outlined in the USGS Techniques and Methods Report 3-A8 must be used to relate stream depth measurements to stream discharge. Calibration of the rating curve during peak flows will likely require the use of a floating platform. A licensed surveyor must level the gaging station each year for the first three years following installation and periodically thereafter following the methods outlined in USGS Techniques and Methods Report 3-A19 (Turnipseed and Sauer, 2010). This station will be operated year-round.

Estimated Cost: (single sensor): **$ 4,000.00**

Site 2:
Cemetery Lane at Henry Stein Park

Location:
N 39°12’39.08” W 106°50’22.53”

Access:
The site may be accessed from Cemetery Lane by crossing to the north side of the river and parking at Henry Stein Park. The gage site is on the upstream end of the park under the bridges.


Roaring Fork River at Henry Stein Park

Permissions and Land Ownership:
This site is located in Henry Stein Park. This park is owned by the Aspen Valley Land Trust and maintained by City of Aspen Parks. Installation of any structures on Cemetery Lane Bridge itself would also need to be approval with the City and County. A US ACE Nationwide Permit 5 (for scientific measuring devices) may be required for structures along watercourses. Contacts: City of Aspen Streets, Jerry Nye (970) 920-5133; City of Aspen Parks, Bryan Flynn (970) 429-2035; County Public Works Director, Bryan Pettet (970) 920-5392; US Army Corps of Engineers Grand Junction (970) 243-1199.

Discussion:
This is an easily accessible site with good channel morphology under the bridges for discharge measurements. The park is a mixture of public property that should be amenable to gage infrastructure placement since both the County and City are considered interested stakeholders. The Rio Grande trail is a county right-of-way, the bridges are also a public right-of-way, and Henry Stein Park is run by the city and owned by the Aspen Valley Land Trust. This site sits approximately at the downstream city limit, and serves as a good catch point for water quality parameters potentially influenced by Aspen. It is also an existing macroinvertebrate monitoring site. Cemetery Lane is below the confluence of Castle Creek but above Maroon Creek. Above Castle Creek is the potentially most-de-watered section of the Roaring Fork. The difference between flows measured here and flows on the newly-installed Castle Creek gage should provide additional cross-validation to flows at any new gage on the Roaring Fork upstream of Castle Creek.

Supporting Infrastructure:

The infrastructure to meet stakeholder needs for the Roaring Fork at Cemetery Lane includes a real-time streamflow measurement gage and the possible addition of several real-time water quality sensors. Specifically, a sensor for measuring stream depth must be installed in the stream channel. The accuracy and precision of the water depth sensor should comply with the standards outlined in the USGS Techniques and Methods Report 3-A7 (Sauer and Turnipseed, 2010). It is also possible to install pH, turbidity, or specific conductance sensors alongside the depth sensor. Depth measurements (and any additional parameters) at the site will be collected in real-time (e.g. every 15 minutes) by a Campbell Scientific controller/datalogger. The datalogger will be programmed to calculate stream discharge from stage measurement using the best-fit rating curve coefficients. Data will be stored on the datalogger and must be manually downloaded periodically.

Estimated Cost: **See Section 3.5**

Installation

Installation and initial setup of the gaging station requires design and assembly of electrical components, programming the datalogger to collect stage measurements (and any other selected parameters) at a selected time interval, and securely installing the gaging station on the stream bank.

Estimated Cost: (single sensor): **$ 1000.00**

Operation and Maintenance

The operation and maintenance of this station requires periodic site visits for instrument cleaning, rating curve calibration and as-needed troubleshooting of the datalogger and sensor(s). A stage-discharge rating curve developed on the site over a range of flow states and following methods outlined in the USGS Techniques and Methods Report 3-A8 must be used to relate stream depth measurements to stream discharge. Calibration of the rating curve during peak flows will likely require the use of a floating platform. The gaging station does **not** need to be leveled following USGS standards as this data will not be used by CDWR, but will instead be used in assessments of water quality. This station will be operated year-round

Estimated Cost: (single sensor): **$ 2500.00**

Site 3:
Smith Way Road Bridge

Location:
N 39°15’31” W 106°52’56”

Access:
The site may be accessed via Smith Hill Way from Hwy 82. Access to this site would need to be managed through an agreement permitting the installation and maintenance of gaging equipment on the Pitkin County’s right-of-way.


Smith Way Road Bridge and pedestrian bridge

Permissions and Land Ownership:
This site is located near Jaffee Park, which is administered by Pitkin County Open Space and Trails. Installation of any structures County Land in the park or along the Rio Grande Trail easement would require approval through the County. County Public Works Director, Bryan Pettet (970) 920-5392. Installation on the bridge may also require an agreement with CDOT. A US ACE Nationwide Permit 5 (for scientific measuring devices) may be required for structures along watercourses. Contact: US Army Corps of Engineers Grand Junction (970) 243-1199.

Discussion:
Immediately below the Smith Hill Way Bridge lies a channel run section of the Roaring Fork River. Rip-rap material on both banks provides excellent channel stability at this site. The bridge provides a platform for gage calibration during high flows. This location lies sufficiently downstream from the city of Aspen and most major points of diversion to capture the cumulative effects of urbanization and consumptive water use on water quantity and quality.

Supporting Infrastructure:
The infrastructure necessary to meet stakeholder needs for the Roaring Fork at Smith Hill Way includes a real-time streamflow measurement gage and the possible addition of several real-time water quality sensors. Specifically, a sensor for measuring stream depth must be installed in the stream channel. The accuracy and precision of the water depth sensor should comply

with the standards outlined in the USGS Techniques and Methods Report 3-A7 (Sauer and Turnipseed, 2010). It is also possible to install pH, turbidity, or specific conductance sensors alongside the depth sensor. Depth measurements (and any additional parameters) at the site will be collected in real-time (e.g. every 15 minutes) by a Campbell Scientific controller/datalogger. The datalogger will be programmed to calculate stream discharge from stage measurement using the best-fit rating curve coefficients. Data will be stored on the datalogger and must be manually downloaded periodically.

Estimated Cost: **See Section 3.6**

Installation

Installation and initial setup of the gaging station requires design and assembly of electrical components, programming the datalogger to collect stage measurements (and any other selected parameters) at a selected time interval, and securely installing the gaging station on the stream bank.

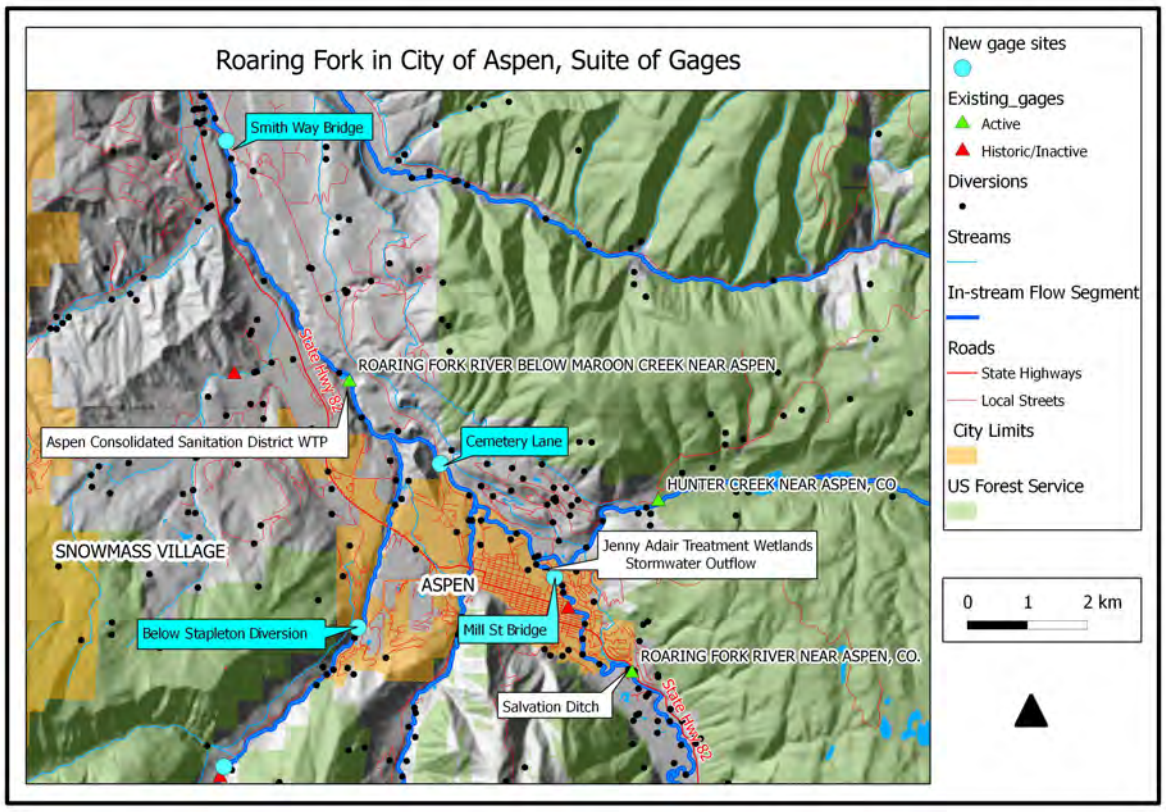
Estimated Cost: (single sensor): **$ 1000.00**

Operation and Maintenance

The operation and maintenance of this station requires periodic site visits for instrument cleaning, rating curve calibration and as-needed troubleshooting of the datalogger and sensor(s). A stage-discharge rating curve developed on the site over a range of flow states and following methods outlined in the USGS Techniques and Methods Report 3-A8 must be used to relate stream depth measurements to stream discharge. Calibration of the rating curve during peak flows will likely require the use of a floating platform. The gaging station does **not** need to be leveled following USGS standards as this data will not be used by CDWR for ISF rights, but will instead be used in assessments of water quality. This station will be operated year-round

Estimated Cost: (single sensor): **$ 2500.00**

Location Map:



2.6 Coal Creek Sub-basin

Introduction:
Coal Creek drains a large tributary basin to the Crystal River near the town of Redstone. RFC and other partners have multiple project interests in the area including water quality monitoring and assessment, mine lands reclamation, and channel restoration at the confluence with the Crystal. The high sediment volume, steepness, and instability of mine lands in the basin contribute to stream channel instability, adding difficulty to gage siting. In the event that property ownership clarification prohibits the first site, two alternative sites are identified here within 1 km of the Forest Service property boundary.

Permissions and Land Ownership:
By establishing any prospective site on USFS land, private property ownership issues may be avoided. All Coal Creek restoration and research currently conducted by RFC is in collaboration with USFS, which should be assumed as willing a cooperator for installation. Contact: White River National Forest Aspen-Sopris Ranger District Office in Aspen (970) 925-3445.

Site:
National Forest Boundary

Location:
N 39°11'25.7" W 107°15'42.5"


Coal Creek at the USFS boundary

Access:
Via Coal Creek Road. The location resides on river right, 30m above the culvert at the National Forest Boundary. Access to this site on river right would need to be granted by the property owner. Due to the close proximity to the National Forest boundary, a survey may be necessary to determine exact property lines.

Discussion:
A short run section located 30m upstream of the culvert on Coal Creek provides an ideal location for characterizing the meteorology, hydrological behavior and the water quality of the Coal Creek watershed. The proposed gaging location is situated along a narrow and deep section of the creek, improving the likelihood of continuous data collection during low-flow

periods. The channel appears relatively stable throughout this reach and large boulder along the stream banks will allow instrumentation to be installed in such a way that it should be protected from debris moving down the channel during high flows. Instrumentation may be installed well above the floodplain at this site due to steep stream banks and flashy hydrography.

Alternate Site #1:

Location:
N 39°11'24.4" W 107°15'43.6"

Access:
Via Coal Creek Rd.


Alternate Site 1 on Coal Creek

Discussion:
The proposed gaging location resides on river left, adjacent to a shallow and relatively stable run. It is located approximately 200m upstream from the Forest boundary. A large boulder on river right that extends into the stream provides protection from downstream debris movement. Installation of equipment on the top of the boulder will prevent it from being inundated during high flow events. The channel is relatively wide and shallow, which may make low flow measurements challenging.

Alternate Site #2:

Location:
N 39°11'22.3" W 107°16'03.2"

Access:
Via Coal Creek Rd.


Alternate Site 2 on Coal Creek

Discussion:
The proposed gaging location resides on river left, adjacent to shallow and relatively stable run. It is located

approximately 600m upstream from the Forest boundary. A terrace on river left provides a satisfactory location for gaging equipment that will be protected from inundation during all but extremely high flow events. The channel here is relatively wide and shallow, which may make consistent gaging during low flows challenging.

Supporting Infrastructure:

The infrastructure necessary to meet stakeholder needs for Coal Creek includes a real-time streamflow measurement gage, pH sensor, turbidity/ total suspended solids (TSS) sensor, and specific conductivity sensor. All sensors must be installed in the stream channel. The accuracy and precision of the water depth sensor should comply with the standards outlined in the USGS Techniques and Methods Report 3-A7 (Sauer and Turnipseed, 2010). Depth, pH, turbidity, TSS, and specific conductance measurements at the site will be collected in real-time (e.g. every 15 minutes) by a Campbell Scientific controller/datalogger. The datalogger will be programmed to calculate stream discharge from stage measurement using the best-fit rating curve coefficients. Data will be stored on the datalogger and must be manually downloaded periodically.

Estimated Cost: **See Section 3.7**

Installation

Installation and initial setup of the gaging station requires design and assembly of electrical components, programming the datalogger to collect stage, pH, turbidity, TSS, and specific conductance measurements at a selected time interval, and securely installing the gaging station on the stream bank.

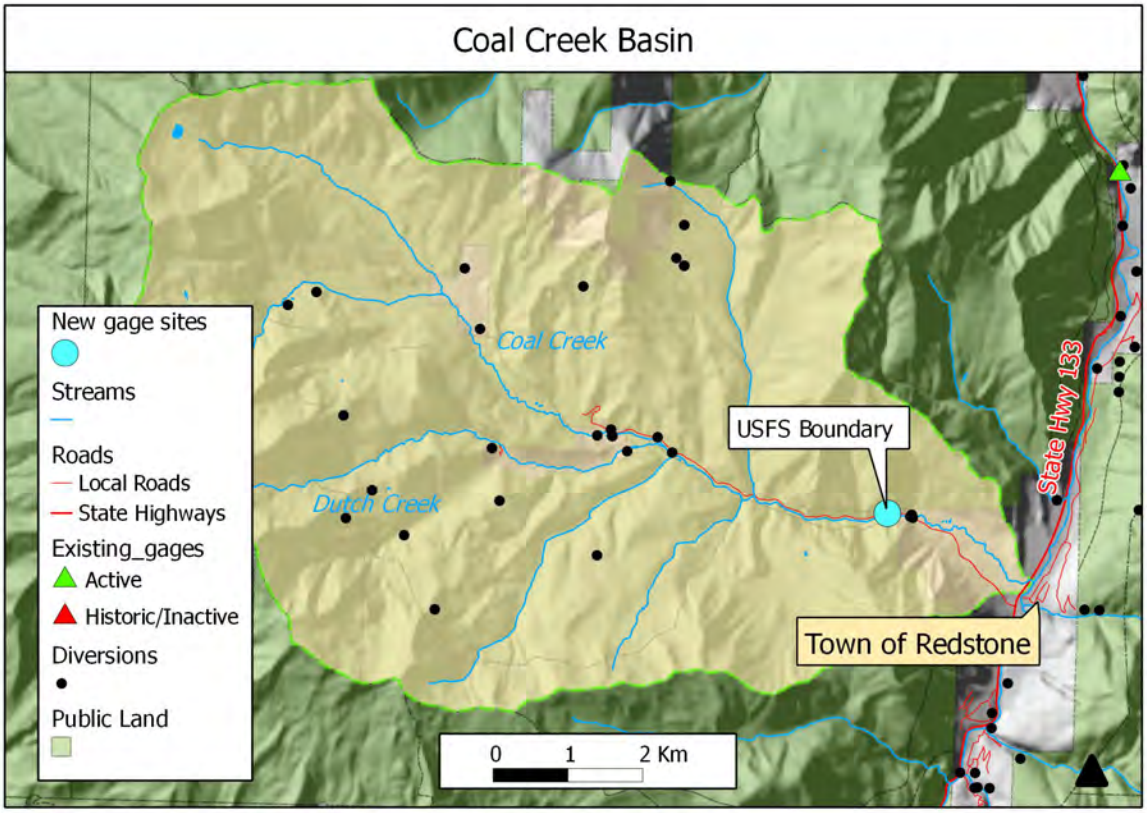
Estimated Cost: **$ 1500.00**

Operation and Maintenance

The operation and maintenance of this station requires periodic site visits for instrument cleaning, rating curve calibration and as-needed troubleshooting of the datalogger and sensors. A stage-discharge rating curve developed on the site over a range of flow states and following methods outlined in the USGS Techniques and Methods Report 3-A8 must be used to relate stream depth measurements to stream discharge. The gaging station does **not** need to be leveled following USGS standards as this data will not be used by CDWR for ISF rights, but will instead be used in assessments of water quality. This station will be operated year-round.

Estimated Cost: **$ 4000.00**

Location Map:



2.7 Fryingpan-Arkansas Project bypass flows

Discussion:

In the Workshop Summary, the stakeholders identify the need to monitor flows in the upper Fryingpan watershed above Ruedi Reservoir in un-gaged streams subject to trans-mountain diversions. The three streams specified in the Workshop Summary are Carter (priority), Mormon (priority), and Middle Cunningham. In each of these, a CWCB ISF right ranging from 0.5 cfs to 2 cfs was established in 1973.

The Workshop Summary states that each of the aforementioned reaches is currently un-gaged. However, at each diversion intake in the Fryingpan-Arkansas project (the trans-mountain diversion project affecting these three streams), the Bureau of Reclamation monitors various parameters including bypass flows using its own system. This data is publicly available in real time (15 minute instantaneous values) and daily-averaged increments at the BOR's Hydromet web portal (http://www.usbr.gov/gp/hydromet/station_list_by_state.cfm). The data may be viewed at the web address http://www.usbr.gov/gp/hydromet/dayfile_colorado.cfm by selecting the respective links for Carter, Mormon, and Middle Cunningham. The parameter of interest in the real-time link is 'Q', which represents the total bypass flow in cubic feet per second. For daily-averaged data, the bypass flow parameter is 'QD'. Only the most recent 24-hour values for the current calendar day are published online. For a longer period of record or archived data, a special request to BOR or the site webmaster may be necessary (gpwebmaster@usbr.gov).

CDWR believes the current infrastructure in the Fryingpan watershed is adequate to meet administrative needs regarding Ruedi Reservoir, local ISF rights, and trans-basin compact decrees. Installation of 3 new gages in Fry-ark diversion tributaries will face the same difficulties of infrastructure maintenance and access risk-management for year-round maintenance as the Roaring Fork at Lost Man: extreme environmental conditions and icing, lack of winter access, and channel morphology that makes gage calibration difficult. If BOR data-sharing or stakeholdershared operational QA/QC oversight at Carter, Mormon, and Cunningham Creeks are desired goals, along with possible alteration of bypass flow schedules (i.e. even if an ISF right cannot be fully met, can the creek at least be 'kept a little wet'?), these goals may be better pursued administratively within existing decree frameworks rather than allocating resources to infrastructure that the two key parties controlling flow, CDWR and BOR, may not be willing or legally able to recognize and use.

2.8 Maroon Creek at City of Aspen diversion

Site:
Below city diversion intake

Location:
N 39°10'42" W 106°51'42"

Access: Maroon Creek Road, T Lazy 7 property

Permissions and Land Ownership:
The large majority of Maroon Creek below the city diversion and extending downstream to the Stapleton Brothers diversion is privately owned land with small home sites. The T Lazy 7 Ranch also comprises a significant parcel immediately downstream-of and surrounding the diversion. In informal communication, the T Lazy 7 owner has indicated he would decline permission for access or installation of stream gages on the property. City of Aspen maintains an easement around the diversion structure, this may provide one potential avenue for access, but discussion is ongoing. Contact: City of Aspen, Dave Hornbacher, Director of Utilities and Environmental Initiatives (970) 429-1983.

Discussion:
This site presents unique circumstances that may need further exploration to determine an appropriate stream gaging option. The City of Aspen municipal intake diverts a significant amount of water from Maroon Creek just upstream of the T Lazy 7 ranch. Water flows to the existing city hydroelectric generating plant and returns to the creek a few hundred meters above the bridge on Maroon Creek Rd near Aspen Highlands Resort. Between the diversion and return flow, the creek sometimes faces exposure to very low-flow conditions. A 1976 ISF right of 14 cfs exists from the confluence of East and West Maroon Creeks to the Roaring Fork River.

Nearly the entire reach from the city diversion to the bridge on Maroon Creek Road lies on private land. A small wedge of USFS ownership near the T Lazy 7 Ranch was investigated, but the stream channel morphology on that reach is steep with braids and divided flow, yielding no desirable gage location on the public right-of-way. The other publicly accessible site is at the Maroon Creek Rd Bridge just past Aspen Highlands Resort, but this site is below the hydroelectric return flow and does not monitor the potentially most de-watered sections of stream. A reach immediately downstream of the city diversion (on the ranch property) crossed by a small footbridge presents suitable channel morphology for gaging. However, in personal

phone communication, the land owner has indicated unwillingness to allow a gage to be sited on T Lazy 7 property.

The City of Aspen maintains some monitoring capability on the diversion intake; potentially including bypass flows to Maroon Creek. A dialogue regarding the timing and accessibility of this data is currently underway. If the city intake data is permissible to the CDWR for administrative oversight, it may obviate the need for an additional gage at the site unless 3rd-party verification of city diversions is a specific stakeholder interest. In that case, further engagement of T-Lazy-7 landowners or other downstream landowners in the reach above the hydroelectric return flow will be necessary. The majority of the creek below T Lazy 7 lies well below and distant from Maroon Creek Road, with poor access and generally unsuitable stream channel morphology.

City of Aspen currently takes manual flow measurements 3 times per week in low flow conditions within their easement below the diversion structure to correlate with their system readings and monitor flow conditions. S.K.Mason Environmental questioned the city regarding interest in joint stakeholder management of a permanent gage just downstream of the diversion on the city easement. Due to the questions concerning the legal, administrative, and cost aspects of this option, as well as the political nature of current events regarding diversions in Maroon and Castle Creeks, definitive resolutions to gaging at this site are not yet available.

Potential gage site at Footbridge below city diversion structure, access is currently prohibited.

City of Aspen diversion structure on Maroon Creek

Supporting Infrastructure:

The infrastructure necessary to meet stakeholder needs for Maroon Creek at the City of Aspen Diversion includes a real-time streamflow measurement gage and telemetry system for

transmitting collected data from the site. Specifically, a sensor for measuring stream depth must be installed in the stream channel. In order for data produced by the station to be considered by the Colorado Department of Water Resources (CDWR), the accuracy and precision of the water depth sensor must comply with the standards outlined in the USGS Techniques and Methods Report 3-A7 (Sauer and Turnipseed, 2010). Depth measurements at the site will be collected in real-time (e.g. every 15 minutes) by a Campbell Scientific controller/datalogger. The datalogger will be programmed to calculate stream discharge from stage measurement using the best-fit rating curve coefficients.

The site characteristics and CDWR's need to view data in near real-time dictate that data be transmitted from the site using satellite telemetry. The station will transmit data over the GOES satellite system. Data transmission and collection will follow National Environmental Satellite, Data, and Information Service (NESDIS) protocols and will require the development of an MOU between a city government, county government, or non-profit entity and the NESDIS.

Estimated Cost: **See Section 3.8**

Installation

Installation and initial setup of the gaging station and telemetry network requires design and assembly of electrical components, programming the datalogger to collect stage measurements at a selected time interval, securely installing the gaging station on the stream bank, and setting up the GEOS telemetry system to enable of transmission of data from the site and subsequent aggregation of data on a client network or machine.

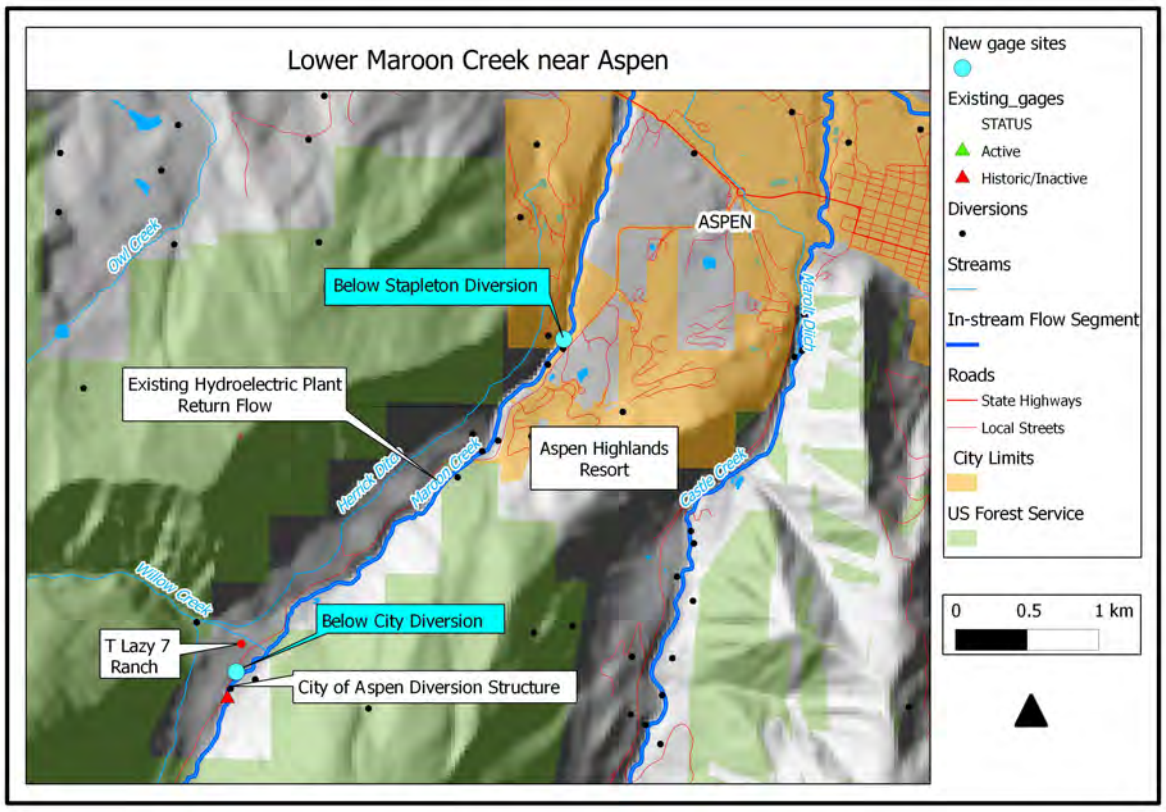
Estimated Cost: **$ 2,500.00**

Operation and Maintenance

The operation and maintenance of this station requires periodic site visits for instrument cleaning, rating curve calibration and as-needed troubleshooting of the datalogger, sensor, or telemetry network. A stage-discharge rating curve developed on the site over a range of flow states and following methods outlined in the USGS Techniques and Methods Report 3-A8 must be used to relate stream depth measurements to stream discharge. The gaging station must be leveled by a licensed surveyor each year for the first three years following installation and periodically thereafter following the methods outlined in USGS Techniques and Methods Report 3-A19 (Turnipseed and Sauer, 2010). This station will be operated year-round.

Estimated Cost: **$ 3,000.00**

Location Map:



2.9 Data Management

Management of data produced by gaging stations must be tailored to the particular needs and data collection/communication platform ultimately selected by the stakeholders for each location. An example: for a gaging station installed to monitor in-stream flow rights and relying on GEOS satellite telemetry, data must be retrieved from a NESDIS downlink station and published in a manner to make it useful to the Water Commissioner for the administration of water rights. This will require development of software designed to retrieve data at a fixed time interval and subsequently display it in graph and numerical form on a website. Furthermore, data must pass through quality assurance and quality control procedures in a timely manner following collection. Options for permanent data storage include storage in raw data files, archival in an existing database, or archival in a custom-built database, the selection of which will incur widely varying costs. Contrast this scenario with a gage installed to inform local decision making processes about stormwater management or non-point source pollution. If such a gage is not part of a telemetry system, it may be sufficient to periodically download data from the gage and store it as appended, raw data files. The level of QAQC procedures that this

data must pass through will largely follow the requirements of the particular study or assessment that the data is used for.

Determination of data management costs is thus beyond the scope of this report and will require further guidance from the stakeholder group. Important considerations for the development of a Data Management Plan include, but are not limited to, the following:

- Who owns the data?
- Who is responsible for storage and backup of the data?
- What level of data quality (raw data files vs. QAQC'd data sets) is required?
- What level of data control (restricted user access vs. publicly accessible) is required?
- How will requests for data be handled?
- What sort of metadata needs to be managed with the data?
- How should data/metadata be formatted?

References

Hornberger, G.M. et al. *Elements of Physical Hydrology*. Johns Hopkins University Press. 1998.

Kenney, T.A., 2010, Levels at gaging stations: U.S. Geological Survey Techniques and Methods 3-A19, 60 p.

Sauer, V.B., and Turnipseed, D.P., 2010, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A7, 45 p. (Also available at http://pubs.usgs.gov/tm/tm3-a7/.)

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p. (Also available at http://pubs.usgs.gov/tm/tm3-a8/.)

US Geological Survey, 1983, Volume 1: Measurement of Stage and Discharge. Chapter 2: Selection of Gaging-Station Sites. U.S. Geological Survey Water-Supply Paper 2175. 603 pp.

3.0 Equipment Costs

3.1 Section Overview

This section provides detailed equipment specifications for gaging sites identified in **Section 2**. Infrastructure requirements are made based on the stakeholder needs for each priority reach as communicated to S.K.Mason Environmental, LLC. Gaging locations are presented in an order paralleling that laid out in the Workshop Summary Report. The goal here is to provide a complete 'shopping list' for instrumentation needs at each site.

Summary of Infrastructure and Operation Needs:

Priority Reach	**Stakeholder Needs**	**Recommended Set-up**	**Equip Cost*** (w/o optional sensors)	**Install**	**Annual O/M**
Maroon Ck blw Stapleton	ISF	Real-time w/ GOES satellite telemetry	$6,610	$2,500	$3,000
Lower Crystal	ISF, WQ link to flows	Real-time, periodic manual download, WQ sensors	$2,900	$800	$800
Brush Creek	WQ	Real-time, periodic manual download, WQ sensors	$5,124	$1,200	$2000
RF City of Aspen Mill St Area	ISF, WQ, Stormwater Assessment	Real-time w/ GOES satellite telemetry	$6,470 [Satellite] $4,486 [900 MHz]	$2,500	$4,000
RF City of Aspen Cemetery Lane	WQ, Stormwater Assessment	Real time, periodic manual download	$2,900	$1,000	$2,500
RF City of Aspen Smith Way Road	WQ	Real time, periodic manual download	$2,900	$1,000	$2,500
RF at Lost Man Ck	ISF	*See Section 2.4*	--	--	--
Coal Creek	Hyrologic regime, WQ, sediment transport	Real time, periodic download, WQ sensors	$7,196	$1,500	$4,000
Fryingpan Tributaries	ISF	*See Section 2.7*	--	--	--
Maroon Ck blw City Diversion	ISF	Real-time w/ GOES satellite telemetry	$6,610	$2,500	$3,000

* Does not include tax or shipping charges

3.1 Maroon Creek at Stapleton Ditch

Item	Description	Each	Quantity	Cost
DCP200-MM	GOES Data Collection Platform (Mast Mounting)	$4,560.00	1	$4,560.00
	(1) 25316 GOES Yagi antenna			
	(1) 10873 9-Pin Female to 9-pin Male serial cable, 6 ft			
	(1) 7623 3/4" IPS aluminum pipe for mounting GPS antenna			
	(1) BP24 24-Ahr Sealed Rechargeable Battery			
	(1) SC12 Serial Cable			
	(1) 18134 Transmitter Support Software			
	(1) CR295X GOES Datalogger			
	(1) 4905 Desiccant			
	(1) 1113 Flat-bladed screwdriver			
	(1) COAXNTN-L GOES Antenna Cable			
	(1) 6186 External Battery Cable			
	(1) CM220 Right Angle Mounting Kit			
	(1) 18133 Power Cable, 2 ft (includes one 18889 Fuse)			
	(2) 2376 Cable Tie Mounts			
	(1) 17992 GPS Antenna 3.3 V, 30 dB			
	(1) 8125 Flat-bladed screwdriver			
	(1) SP20 20 W solar panel			
	(1) TX320 HDR GOES Satellite Transmitter			
	(1) 18017-L GPS Antenna Cable			
	(1) ENC16/18 Environmental Enclosure			
	(1) 7363 Enclosure supply kit			
	(1) CH100 Regulator			
CS460	Keller America Acculevel pressure transducer	$710.00	1	$710.00
CS460-L	ft cable per sensor	$1.62	50	$81.00
LoggerNet	Datalogger support software	$599.00	1	$599.00
UT10	10ftTower with adjustable mast, base and grounding kit	$565.00	1	$565.00
Style A Stream Gage	Staff Gage	$45.00	1	$45.00
MISC	Miscellaneous mounting hardware	$50.00	1	$50.00
Total	**Does not include tax or shipping charges**	**Total**		**$6,610.00**

3.2 Lower Crystal River

Item	Description	Each	Quantity	Cost
CR200	Datalogger	$450.00	1	$450.00
SPM010P-D	Solartech 10-Watt 12-Volt ES polycrystalline PV solar panel	$69.95	1	$69.95
RBC4	PowerStar AGM 12V 12AH sealed battery	$35.00	1	$35.00
SG-4	SunGuard 4.5-amp 12-Volt solar charge controller regulator	$35.00	1	$35.00
ENC 10/12	Weather resistant 10x12in enclosure	$200.00	1	$200.00
ENC 10/12-MM	Tripod mast mounting	$60.00	1	$60.00
CS460	Keller America Acculevel pressure transducer	$710.00	1	$710.00
CS460-L	ft cable per sensor	$1.62	50	$81.00
LoggerNet	Datalogger support software	$599.00	1	$599.00
UT10	10ftTower with adjustable mast, base and grounding kit	$565.00	1	$565.00
Style A Stream Gage	Staff Gage	$45.00	1	$45.00
MISC	Miscellaneous mounting hardware	$50.00	1	$50.00
Total	**Does not include tax or shipping charges**	**Total**		**$2,899.95**

Optional Water Quality Sensors

Item	Description	Each	Quantity	Cost
CS526	pH sensor w/ 50ft cable	$852.50	1	$852.50
CS547A-50	Water conductivity probe w/ 50ft cable	$382.00	1	$382.00
OBS-3+ -TB -21308	Titanium turbidity sensor w/ 15m cable	$1,530.00	1	$1,530.00

3.3 Brush Creek

Item	Description	Each	Quantity	Cost
CR1000	Measurement and control datalogger	$1,440.00	1	$1,440.00
CS547A	Water conductivity probe	$345.00	1	$345.00
CS547A--L	ft cable per sensor	$0.74	50	$37.00
CS460	Keller America Acculevel pressure transducer	$710.00	1	$710.00
CS460-L	ft cable per sensor	$1.62	50	$81.00
LoggerNet	Datalogger support software	$599.00	1	$599.00
CS526	pH sensor	$815.00	1	$815.00
CS526-L	ft cable per sensor	$0.75	50	$37.50
ENC 10/12	Weather resistant 10x12in enclosure	$200.00	1	$200.00
ENC 10/12-MM	Tripod mast mounting	$60.00	1	$60.00
UT10	10ftTower with adjustable mast, base and grounding kit	$565.00	1	$565.00
SPM010P-D	Solartech 10-Watt 12-Volt ES polycrystalline PV solar panel	$69.95	1	$69.95
RBC4	PowerStar AGM 12V 12AH sealed battery	$35.00	1	$35.00
SG-4	SunGuard 4.5-amp 12-Volt solar charge controller regulator	$35.00	1	$35.00
Style A Stream Gage	Staff Gage (Optional)	$45.00	1	$45.00
MISC	Miscellaneous mounting hardware	$50.00	1	$50.00
Total	**Does not include tax or shipping charges**	**Total**		**$5,124.45**

3.4 Roaring Fork in City of Aspen: Mill Street Bridge

3.4.1 Mill Street Bridge (GEOS Communication System)

Description	Each	Quantity	Cost
GOES Data Collection Platform (Mast Mounting)	$4,560.00	1	$4,560.00
(1) 25316 GOES Yagi antenna			
(1) 10873 9-Pin Female to 9-pin Male serial cable, 6 ft			
(1) 7623 3/4" IPS aluminum pipe for mounting GPS antenna			
(1) BP24 24-Ahr Sealed Rechargeable Battery			
(1) SC12 Serial Cable			
(1) 18134 Transmitter Support Software			
(1) CR295X GOES Datalogger			
(1) 4905 Desiccant			
(1) 1113 Flat-bladed screwdriver			
(1) COAXNTN-L GOES Antenna Cable			
(1) 6186 External Battery Cable			
(1) CM220 Right Angle Mounting Kit			
(1) 18133 Power Cable, 2 ft (includes one 18889 Fuse)			
(2) 2376 Cable Tie Mounts			
(1) 17992 GPS Antenna 3.3 V, 30 dB			
(1) 8125 Flat-bladed screwdriver			
(1) SP20 20 W solar panel			
(1) TX320 HDR GOES Satellite Transmitter			
(1) 18017-L GPS Antenna Cable			
(1) ENC16/18 Environmental Enclosure			
(1) 7363 Enclosure supply kit			
(1) CH100 Regulator			
Keller America Acculevel pressure transducer	$710.00	1	$710.00
ft cable per sensor	$1.62	50	$81.00
Datalogger support software	$599.00	1	$599.00
Stainless steel tripod	$425.00	1	$425.00
Staff Gage	$45.00	1	$45.00
Miscellaneous mounting hardware	$50.00	1	$50.00
Does not include tax or shipping charges	**Total**		**$6,470.00**

3.4.2 Mill Street Bridge (900 MHz Communication System)

Description	Each	Quantity	Cost
Datalogger w/ 915-MHz Radio	$685.00	2	$1,370.00
900 MHz 9dBd Yagi Antenna w/ mounting	$195.00	1	$195.00
900 MHz 3dBd Omni Antenna w/ mounting	$210.00	1	$210.00
Solartech 10-Watt 12-Volt ES polycrystalline PV solar panel	$69.95	1	$69.95
PowerStar AGM 12V 12AH sealed battery	$35.00	1	$35.00
SunGuard 4.5-amp 12-Volt solar charge controller regulator	$35.00	1	$35.00
ft cable per antenna	$2.04	20	$40.80
Surge supressor kit	$110.00	2	$220.00
Weather resistant 10x12in enclosure	$200.00	1	$200.00
Tripod mast mounting	$60.00	1	$60.00
Keller America Acculevel pressure transducer	$710.00	1	$710.00
ft cable per sensor	$1.62	50	$81.00
Datalogger support software	$599.00	1	$599.00
10ftTower with adjustable mast, base and grounding kit	$565.00	1	$565.00
Staff Gage	$45.00	1	$45.00
Miscellaneous mounting hardware	$50.00	1	$50.00
Does not include tax or shipping charges	**Total**		**$4,485.75**

Optional Water Quality Sensors

Description	Each	Quantity	Cost
pH sensor w/ 50ft cable	$852.50	1	$852.50
Water conductivity probe w/ 50ft cable	$382.00	1	$382.00
Titanium turbidity sensor w/ 15m cable	$1,530.00	1	$1,530.00

3.5 Roaring Fork in City of Aspen: Cemetery Lane at Henry Stein Park

Item	Description	Each	Quantity	Cost
CR200	Datalogger	$450.00	1	$450.00
SPM010P-D	Solartech 10-Watt 12-Volt ES polycrystalline PV solar panel	$69.95	1	$69.95
RBC4	PowerStar AGM 12V 12AH sealed battery	$35.00	1	$35.00
SG-4	SunGuard 4.5-amp 12-Volt solar charge controller regulator	$35.00	1	$35.00
ENC 10/12	Weather resistant 10x12in enclosure	$200.00	1	$200.00
ENC 10/12-MM	Tripod mast mounting	$60.00	1	$60.00
CS460	Keller America Acculevel pressure transducer	$710.00	1	$710.00
CS460-L	ft cable per sensor	$1.62	50	$81.00
LoggerNet	Datalogger support software	$599.00	1	$599.00
UT10	10ftTower with adjustable mast, base and grounding kit	$565.00	1	$565.00
Style A Stream Gage	Staff Gage	$45.00	1	$45.00
MISC	Miscellaneous mounting hardware	$50.00	1	$50.00
Total	**Does not include tax or shipping charges**	**Total**		**$2,899.95**

Optional Water Quality Sensors

Item	Description	Each	Quantity	Cost
CS526	pH sensor w/ 50ft cable	$852.50	1	$852.50
CS547A-50	Water conductivity probe w/ 50ft cable	$382.00	1	$382.00
OBS-3+ -TB -21308	Titanium turbidity sensor w/ 15m cable	$1,530.00	1	$1,530.00

3.6 Roaring Fork in City of Aspen: Smith Way Bridge

Item	Description	Each	Quantity	Cost
CR200	Datalogger	$450.00	1	$450.00
SPM010P-D	Solartech 10-Watt 12-Volt ES polycrystalline PV solar panel	$69.95	1	$69.95
RBC4	PowerStar AGM 12V 12AH sealed battery	$35.00	1	$35.00
SG-4	SunGuard 4.5-amp 12-Volt solar charge controller regulator	$35.00	1	$35.00
ENC 10/12	Weather resistant 10x12in enclosure	$200.00	1	$200.00
ENC 10/12-MM	Tripod mast mounting	$60.00	1	$60.00
CS460	Keller America Acculevel pressure transducer	$710.00	1	$710.00
CS460-L	ft cable per sensor	$1.62	50	$81.00
LoggerNet	Datalogger support software	$599.00	1	$599.00
UT10	10ftTower with adjustable mast, base and grounding kit	$565.00	1	$565.00
Style A Stream Gage	Staff Gage	$45.00	1	$45.00
MISC	Miscellaneous mounting hardware	$50.00	1	$50.00
Total	**Does not include tax or shipping charges**	**Total**		**$2,899.95**

Optional Water Quality Sensors

Item	Description	Each	Quantity	Cost
CS526	pH sensor w/ 50ft cable	$852.50	1	$852.50
CS547A-50	Water conductivity probe w/ 50ft cable	$382.00	1	$382.00
OBS-3+ -TB -21308	Titanium turbidity sensor w/ 15m cable	$1,530.00	1	$1,530.00

3.7 Coal Creek

Item	Description	Each	Quantity	Cost
CR1000	Measurement and control datalogger	$1,440.00	1	$1,440.00
TE525WS	Texas Electronics Tipping Bucket Rain Gage (0.01in)	$385.00	1	$385.00
TE525WS--L	ft cable per sensor	$0.45	6	$2.70
TE525WS--CM300	23in mounting pol w/ cap	$56.00	1	$56.00
CS547A	Water conductivity probe	$345.00	1	$345.00
CS547A--L	ft cable per sensor	$0.74	50	$37.00
OBS-3+	Turbidity sensor	$990.00	1	$990.00
OBS-3+ -TB	Titanium sensor body	$150.00	1	$150.00
OBS-3+ -21308	OBS300 15m cable	$390.00	1	$390.00
CS460	Keller America Acculevel pressure transducer	$710.00	1	$710.00
CS460-L	ft cable per sensor	$1.62	50	$81.00
LoggerNet	Datalogger support software	$599.00	1	$599.00
CS526	pH sensor	$815.00	1	$815.00
CS526-L	ft cable per sensor	$0.75	50	$37.50
ENC 10/12	Weather resistant 10x12in enclosure	$200.00	1	$200.00
ENC 10/12-MM	Tripod mast mounting	$60.00	1	$60.00
UT10	10ftTower with adjustable mast, base and grounding kit	$565.00	1	$565.00
CM206	Sensor crossarm w/ one CM2120 mounting kit, 6ft	$98.00	1	$98.00
SPM010P-D	Solartech 10-Watt 12-Volt ES polycrystalline PV solar panel	$69.95	1	$69.95
RBC4	PowerStar AGM 12V 12AH sealed battery	$35.00	1	$35.00
SG-4	SunGuard 4.5-amp 12-Volt solar charge controller regulator	$35.00	1	$35.00
Style A Stream Gage	Staff Gage (Optional)	$45.00	1	$45.00
MISC	Miscellaneous mounting hardware	$50.00	1	$50.00
Total	**Does not include tax or shipping charges**	**Total**		**$7,196.15**

3.8 Maroon Creek at City of Aspen Diversion

Item	Description	Each	Quantity	Cost
DCP200-MM	GOES Data Collection Platform (Mast Mounting)	$4,560.00	1	$4,560.00
	(1) 25316 GOES Yagi antenna			
	(1) 10873 9-Pin Female to 9-pin Male serial cable, 6 ft			
	(1) 7623 3/4" IPS aluminum pipe for mounting GPS antenna			
	(1) BP24 24-Ahr Sealed Rechargeable Battery			
	(1) SC12 Serial Cable			
	(1) 18134 Transmitter Support Software			
	(1) CR295X GOES Datalogger			
	(1) 4905 Desiccant			
	(1) 1113 Flat-bladed screwdriver			
	(1) COAXNTN-L GOES Antenna Cable			
	(1) 6186 External Battery Cable			
	(1) CM220 Right Angle Mounting Kit			
	(1) 18133 Power Cable, 2 ft (includes one 18889 Fuse)			
	(2) 2376 Cable Tie Mounts			
	(1) 17992 GPS Antenna 3.3 V, 30 dB			
	(1) 8125 Flat-bladed screwdriver			
	(1) SP20 20 W solar panel			
	(1) TX320 HDR GOES Satellite Transmitter			
	(1) 18017-L GPS Antenna Cable			
	(1) ENC16/18 Environmental Enclosure			
	(1) 7363 Enclosure supply kit			
	(1) CH100 Regulator			
CS460	Keller America Acculevel pressure transducer	$710.00	1	$710.00
CS460-L	ft cable per sensor	$1.62	50	$81.00
LoggerNet	Datalogger support software	$599.00	1	$599.00
UT10	10ftTower with adjustable mast, base and grounding kit	$565.00	1	$565.00
Style A Stream Gage	Staff Gage	$45.00	1	$45.00
MISC	Miscellaneous mounting hardware	$50.00	1	$50.00
Total	**Does not include tax or shipping charges**	**Total**		**$6,610.00**

4.0 CDWR and USGS Streamflow Monitoring

4.1 Section Overview

This section is intended to clarify the procedures by which the CDWR and USGS—the two entities responsible for the vast majority of surface water quantity and quality data collection in the State of Colorado--conduct real-time stream gaging.

4.2 CDWR Requirements for Locally Operated Gaging Stations

In Colorado, water rights are administered by the State Engineer's Office in the Colorado Division of Water Resources (CDWR). To administer In-stream Flow rights, which are held only by the Colorado Water Conservation Board (CWCB), the Division of Water Resources maintains its own network of gages, as well as relying upon those managed federally by USGS or other cooperators. CDWR gage sites are operated and maintained based on standards and protocols laid out by USGS. Data produced by gage sites that are operated by parties other than CDWR or USGS may be used for ISF-rights actions, however these sites must operate to the same standards and protocols as the state and federal sites in order to provide legally actionable flow information.

Colorado Division of Water Resources adopts protocols established by USGS regarding technical aspects of gage installation and maintenance. These protocols are laid out in the USGS Techniques and Methods Reports 3-A7, 3-A8, 3-A19. In brief, some of the essential criteria that must be met for real time water administration follow:

- Gage height measurement accuracy of 0.01 ft.
- Height collected every 15 minutes and transmitted hourly to the web for processing, discharge computation, and visual display.
- Levels run annually at all new gages and every 2-3 years at established sites to confirm stability of the primary reference gage against nearby benchmarks.
- Data telemetry on the State's satellite system must adhere to CDWR equipment requirements and methods. Data from other providers such as USGS, NCWCD may be posted via website link with disclaimer.
- Gages with man-made controls must be developed and maintained accurate to within +/-5% to +/-8%; maintaining rating accuracy means regular discharge measurements throughout the expected range in stage using standard discharge measurement methods and equipment accurate to within +/-5% accuracy

- Gages with natural controls and channel controls ratings must be developed and maintained accurate to within +/-5% to +/-8%; maintaining rating accuracy means regular discharge measurements throughout the expected range in stage using standard discharge measurement methods and equipment accurate to within +/-5% accuracy
- For data to be useful to CDWR for real-time water administration, near real-time (hourly) data telemetry and processing are necessary. Some administration decisions are made using daily average flows

CWCB may install or use data from temporary gages or gages that do not meet the above standards. This data will be used for the purposes of studying river reaches for potential ISF filing. If a filing is made, CWCB may then choose to work with CDWR or USGS and local cooperators to fund a permanent gage at the location.

As mentioned in **Section 2.2, CDWR may not consent to stakeholder requests to develop new gages** due to an administrative workload beyond existing employee capacity. The agency retains discretion to accept or decline new gage work based on decisions by local Division 5 staff, who must determine whether a new gage or change in existing gage operation materially benefits water administration needs. In those cases where CDWR does consent to stakeholder requests for monitoring, the Division charges third parties approximately $9000 for yearly operation. This amount should be understood as a starting point that is subject to changes as a function of many site-specific factors.

4.3 USGS Streamflow Monitoring

The USGS installs and manages many streamflow gages throughout Colorado. These gages may be funded solely by the USGS, or may be jointly funded by local stakeholder groups. In cases where local groups request gage installation and management, USGS will endeavor to determine the need for the gage and will subsequently designate it with a priority rating and a corresponding match rate. The funding match USGS provides helps offset the cost of gaging stations on a site-by-site basis.

USGS match rates for streamflow gages vary depending on a variety of factors. For a given site, a criteria point system is used to determine a rank: high, medium, low, or very low. Match rates for each rank vary over time from one fiscal year to the next, depending on the availability of funds in the Cooperative Water Program, and the funds are limited. In any given year, there is no guarantee that the USGS will be able to provide matching funds, regardless of gaging station's rank.

Rank match rates for cooperatively funded stream gages in Colorado:

Points	Rank	USGS match (FY12)	Cooperator match (FY12)
>7	**High**	**43.5%**	**56.5%**
4-7	**Medium**	**36.5%**	**63.5%**
2-3	**Low**	**10%**	**90%**
0-1	**Very Low**	**0%**	**100%**

The prioritization schema developed to aid in determining match rates is summarized below:

Goal 1--Quantify Streamflow in Major Colorado Watersheds

3 points--Gages on major rivers (North Platte, South Platte, Arkansas, Rio Grande, San Juan, Animas, Dolores, Gunnison, Colorado, White, and Yampa) that have a > 20% change in annual flow from downstream gage(s). Gages are selected by beginning with state-line gage and moving upstream until flow is less than 5% of the flow at the gage that has the largest average annual flow on that river.
2 points--Gages on tributaries to major rivers: 1) Up to three gages on very large tributaries (tributary flow is > 20% of the flow at the gage that has the largest average annual mainstem flow); 2) Up to two gages on large tributaries (tributary flow is > 20% of the mainstem flow upstream from the tributary); or 3) One gage on medium tributaries (tributary flow is > 10 % of the mainstem flow upstream from the tributary).
1 point--One gage on small tributaries (tributary flow is > 5% of the mainstem flow upstream from the tributary).
0 points--All other gages**.**

Goal 2--Support Colorado Flood and Water-Supply Forecasting

3 points--Gage is an NWS, COE, USBR, State, or local flood forecast gage**.**
2 points--Gage is an NRCS or NWS water-supply forecast gage**.**
1 point--Gage is a State or local water-supply forecast gage**.**
0 points--All other gages.

Goal 3--Support Colorado Water Administration and Management

3 points--Gage is a National Streamflow Information Program (NSIP) 'Compact or Border' gage or is needed to administer water to meet interstate compact requirements.
2 points--Gage is critical for water administration or is a key gage for water administration within a water division.

1 point--Gage is used for water administration or is important for water administration within a water district.
0 points--All other gages.

Goal 4--Support Streamflow Gages for Determination of Trends in Flow

3 points--Gage is an NSIP 'Sentinel' gage (monitors streamflow in response to changes in climate, land use, and water use in largely unregulated basins), or is one of up to 3 gages per major river basin, and no more than one gage per tributary to a major river, that has < 5% of the gaged flow in annual diversions into or out of the stream, and has > 25 years of record.
2 points--Gage has > 50 years of record, regardless of diversions.
1 point--Gage has > 25 years of record, regardless of diversions.
0 points--All other gages.
Goal 5--Support Water-Quality Networks in Colorado

3 points--Gage is an active site in a USGS National water-quality network or the USGS Idealized Statewide Surface Water-Quality Network (see attached description of concepts for this network).
2 points--Gage is an active site in a long-term water-quality network operated by USGS in Colorado or an inactive site in the USGS Idealized Statewide Surface Water-Quality Network.
1 point—Gage is an active site in a long-term state or local water-quality network operated by others.
0 points--All other gages.