Review of City of Aspen's Castle Creek Hydroelectric Project Aquatic Resource Documents

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Purpose

This report is based on a review of the City of Aspen's Castle Creek Hydroelectric Project documents pertaining to the stream health and aquatic resources of Maroon Creek and Castle Creek. The purpose of this report is to evaluate whether Aspen's documents, reports, studies and conclusions adequately addressed the potential biologic impacts that may accrue to Maroon Creek and Castle Creek as a result of the proposed hydroelectric operations.

The organization of the report is as follows:

1. **Aspen's Contracts with MEC:** Summary of Aspen's contracts with Miller Ecological Consultant's, Inc. (MEC) and a discussion regarding the scope of those contracts.
2. **MEC's Environmental Report:** Summary of MEC's environmental report prepared in support of Aspen's Federal Energy Regulatory Commission license and an evaluation of MEC's assessment of the potential aquatic impacts associated with the proposed project.
3. **Aspen's Proposed Monitoring Plan:** Summary and evaluation of Aspen's proposed monitoring and adaptive management plan and Memorandum of Understanding (MOU) with the Colorado Division of Wildlife (CDOW).
4. **Conclusions:** Summary of overall conclusions regarding Aspen's contracts, aquatics impact analysis, and proposed monitoring plan.
5. **Additional Recommendations**
   - Adapting Aspen's process to fit into Richter's Framework for Ecologically Sustainable Water Management (Richter 2005)
   - Standards for a "Low Impact" hydropower certification.

1. Aspen's Contracts with MEC

Original Miller Ecological Consultant, Inc. Contract (2009)

In February 2009, Miller Ecological Consultants, Inc (MEC) was awarded a contract to assist the City of Aspen with "Exhibit E preparation of the Castle Creek Hydroelectric facility's Federal Energy Regulatory Commission (FERC) license, as well as continued assistance on aquatic resource issues for the new hydroelectric facility" (Memo from John Hines and Phil Overeynder to Mayor and City Council dated January 26, 2009). The Scope of Work at that time, as outlined in Exhibit A to the Professional Services Agreement attached to that January 2009 memo, were to include:

- Contacting the various agencies to acquire data for the project area and vicinity,
- Summarizing and analyzing data,

- Site visit to the Project area to verify the existing conditions,
- Determining environmental consequences and the biological assessment for the Threatened and Endangered species,
- Determining environmental consequences of the proposed action,
- Preparation of the appropriate section of the Exhibit E (draft and final), and
- Meetings and Coordination with the utilities staff and consultants during the project.

In this 2009 Scope of Work, Dr. Miller states that he has "assumed that the existing information, including minimum instream flow data, is adequate for preparation of Exhibit E". He goes on to say that FERC "may recommend additional studies" and that "the one study that may be recommended is an updated instream flow analysis using more current methods to quantify change in habitat with flow." MEC's Scope of Work goes on to provide a cost estimate for an "optional PHABSIM study" but the study was not funded.

Amended Miller Ecological Consultant, Inc. Contract (2010)

"In late 2009, the city circulated "Preliminary Project Information" and held a required public meeting to solicit comments from interested members of the public and other stakeholders including natural resource agencies" (Memo from Phil Overeynder to the Mayor and Aspen City Council dated March 1, 2010). The most prevalent comment Aspen received was a request to evaluate the effect of stream flow changes in the reach between the point of diversion and point of return on Castle Creek.

Aspen received detailed comments from CDOW including their "request for additional studies on flow levels necessary to support a healthy aquatic environment" (undated letter from CDOW Statewide Aquatic Section Manager, Greg Gerlich, to Phil Overeynder). CDOW requested that Aspen:

- Explain why the project qualifies for a conduit exemption,
- Explain why Instream Flow Decrees are considered "points of municipal consumption within the meaning of FERC's organic law",
- Provide additional information regarding the effects of the project diversions on CWCB decreed instream flow water rights on Maroon and Castle Creeks,
- Collect additional R2Cross data on Castle Creek,
- Consider R2Cross data that was recently collected by CDOW on Maroon Creek,
- Meet with CDOW to discuss how operations and future diversions from Maroon and Castle Creeks can be optimized to minimize impacts and maximize protection of the natural environment,
- Collect additional fish population data and quantify existing winter stream habitat conditions on both creeks, and
- Collect additional boreal toad data on both creeks.

The CDOW specifically requested that Aspen collect R2Cross data at two additional points on Castle Creek "using the standard methods described in the publication "Development of Instream Flow Recommendations in Colorado using R2Cross".

Aspen also received written comments from the Aspen Wilderness Workshop (letter from Aspen Wilderness Workshop to Phil Overeynder dated January 15, 2010). The Wilderness Workshop applauded Aspen's green energy policy but expressed concern that the current hydroelectric plan will adversely affect aquatic resources of Maroon and Castle Creek. The Wilderness Workshop requested that Aspen:

- Consider the findings of a study conducted for the Wilderness Workshop on Maroon Creek by William Walsh and Associates,
- Not let minimum flows on either creek fall below 20 cfs, and
- "Conduct further studies on both Maroon and Castle Creek to define and adopt minimum Ecologically Sustainable Flows for these creeks (in the sense of Richter et al. 2010)[1]".

In response to the additional studies that were requested by CDOW and the Aspen Wilderness Workshop, Aspen amended its contract with MEC. The amended scope of work was summarized in a memo from MEC to Phil Overeynder dated February 15, 2010. The Tasks were identified as:

- Task 1 – Collection of additional R2Cross Data at two additional points on Castle Creek (one in the reach between the diversion and return flow point and one in the reach between the return flow point and the confluence with the Roaring Fork River),
- Task 2 – Fish Population Data (and information regarding existing winter stream habitat conditions for Maroon and Castle Creeks),
- Task 3 – Boreal Toad Surveys,
- Task 4 – Data Analysis ("using standard R2Cross and fish populations")[2]
- Task 5 – Technical Memorandum, and
- Task 6 – Meetings.

Evaluation of Aspen's Contracts with MEC

Aspen's original contract with MEC limited the scope of work for determining the environmental consequences of the proposed hydroelectric project to the summary and analysis of existing data collected by others. Based on input from CDOW and the Aspen Wilderness Workshop, Aspen's contract with MEC was amended in 2010 to include some newly collected data on both Maroon and Castle Creek. However, the scope of work limited the data analysis method for determining aquatic impacts to the use of the R2Cross methodology.

While the state of Colorado has adopted R2Cross as its preferred methodology for developing instream flow recommendations, it has not been universally adopted by the biologic community. An Instream Flow Council (IFC 2002) review of R2Cross concluded that "the method does not address flow needs for intra- or inter-annual hydrologic variability" and "does not provide the necessary regime of flows that are critical to riverine ecology, but may be a component of a flow regime that includes

[1] This paper was published in Hydro Review in August 2005. A full citation appears in the References section of this report.

[2] Task 4 also states that "the new data combined with the stream hydrology allows the evaluation of ecologically sustainable flows as recommended by the Wilderness Workshop" (pg. 4).

recommendations for other ecosystem purposes derived from other models". The IFC further concludes that R2Cross "should not be used to prescribe a year-round base flow unless other models that address other ecosystem components support that level of flow". In its 2009 Scope of Work, MEC recognized that FERC may require additional studies using "more current methods to quantify change in habitat with flow" but these studies were never completed.

Based on a review of Aspen's contracts with MEC, it appears that emphasis on the use of existing data and the R2Cross methodology created a scope that was too narrow to provide a complete assessment of the potential impacts that may be associated with the proposed hydroelectric project.

2. MEC's Environmental Report

Summary of MEC's Environmental Report

The original (2009) and amended (2010) contracts between the City of Aspen and MEC culminated in a final biologic report from MEC titled "Castle Creek Hydroelectric Plant Environmental Report" dated October 8, 2010. A summary of the MEC report follows.

The stated objectives of the MEC report are to:

- Describe the existing environmental conditions, and
- Evaluate the potential impacts (positive and negative) from the proposed hydroelectric plant (*MEC report, pg. 2*)

Figure 1 (below) is MEC's vicinity map of the Castle Creek Hydroelectric facility.

The MEC report evaluated the potential impacts from the proposed hydroelectric plant by examining water resources and physical flow issues as well as ecological stream flows and aquatic health.

MEC evaluation of water resources and physical flow issues:

MEC developed streamflow predictions using data from gages on Maroon and Castle Creek that were operational from 1969 to 1994. Gaged flows were apportioned using changes in drainage area to estimate streamflows at various locations on the creeks under both existing conditions and with the proposed Castle Creek hydroplant in operation. MEC assumed the maximum capacity of the Midland Flume on Castle Creek to be 25 cfs and the maximum capacity of the Maroon Creek Pipeline as 27 cfs. Under current conditions, Aspen's municipal demands are typically met with Midland Flume diversions from Castle Creek. Up to 68 cfs is currently diverted from Maroon Creek to the Maroon Creek hydroelectric plant and returned to Maroon Creek below the plant. Under the proposed plan, Aspen has agreed to recognize the 14 cfs instream flow below its Maroon Creek diversion structure. When the flow below the Maroon Creek diversion structure is greater than 14 cfs, Aspen will first divert up to 10 cfs to the Maroon Creek hydroelectric plant and then up to 27 cfs to the Castle Creek hydroelectric plant. If additional water is available, Aspen may elect to increase its diversions into the Maroon Creek plant by an additional 31 cfs for a cumulative hydropower diversion amount of 68 cfs.

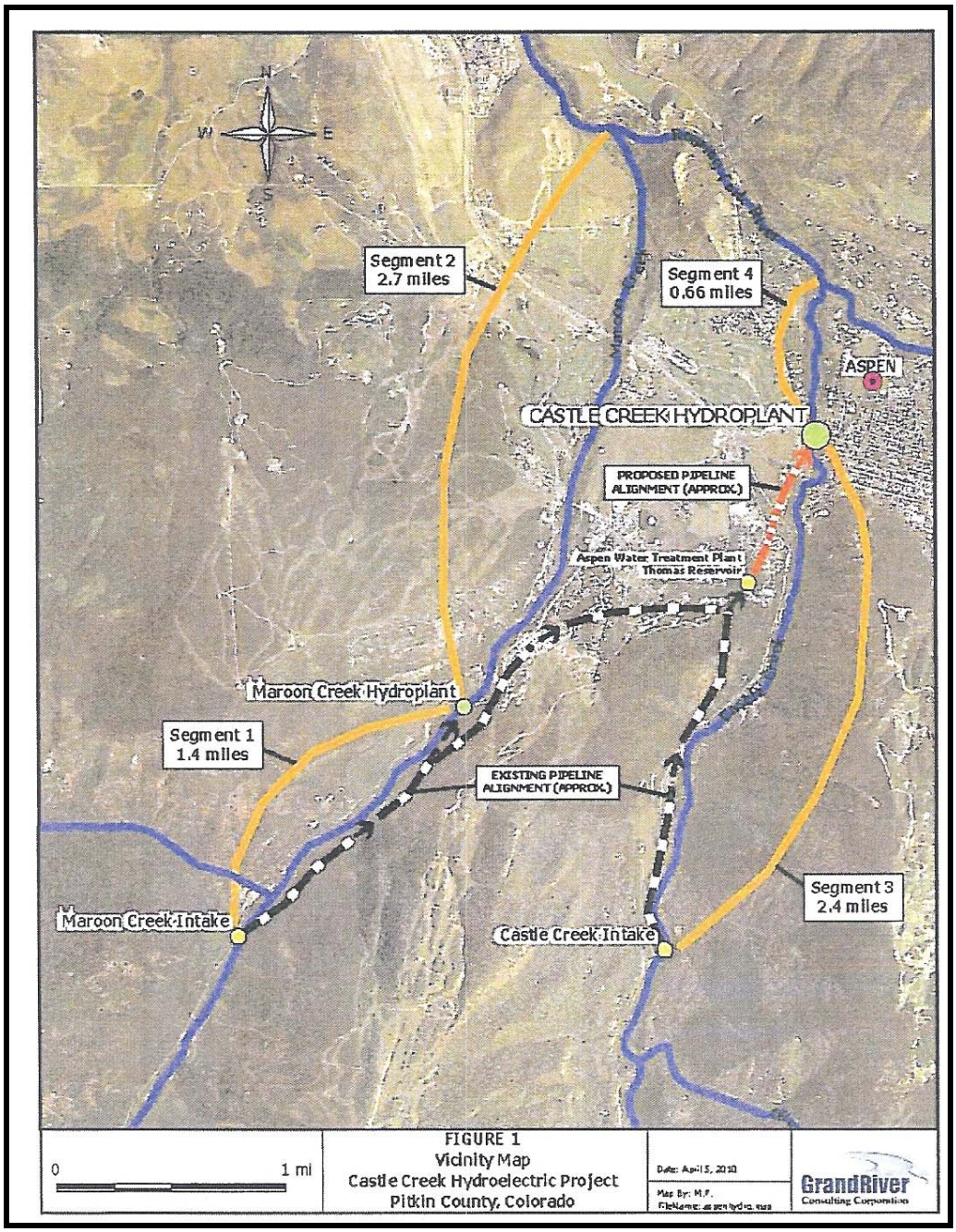

Figure 1. MEC's Castle Creek Hydroelectric Plant Vicinity Map

Figures 7 through 10 of the MEC report compare expected changes in streamflow on Maroon Creek at Highway 82 between pre- and post-project conditions for wet, average and dry years. These graphs indicate that the greatest percentage changes in flow between "existing" conditions and "with Hydro" on Maroon Creek will occur during the late summer, fall, and early spring months (see Figure 2 below). Reductions in winter flow may also be expected in wetter than normal years (*MEC report Figure 10*).

Figures 11, 14, 15, and 16 of the MEC report compare expected changes in streamflow on Castle Creek in the 2.4 mile stream reach below the diversion structure and above the hydropower return flow point for pre- and post-project conditions in wet, average and dry years. Once again, these graphs indicate that the greatest percentage changes in flow between "existing" conditions and "with Hydro" on Castle Creek will occur during the late summer, fall, and early spring months. These graphs also indicate that winter flows will be reduced to baseflow amounts for extended periods of time in all year types (see Figure 3 below).

Figures 17 through 20 of the MEC report compare expected changes in streamflow on Castle Creek in the 0.66 mile stream reach between the hydropower return flow point and the confluence with the Roaring Fork River for pre- and post-project conditions in wet, average and dry years. Streamflows in this reach of Castle Creek are increased by the combined amounts of water diverted to the Castle Creek Hydroelectric Plant from both Castle and Maroon Creeks

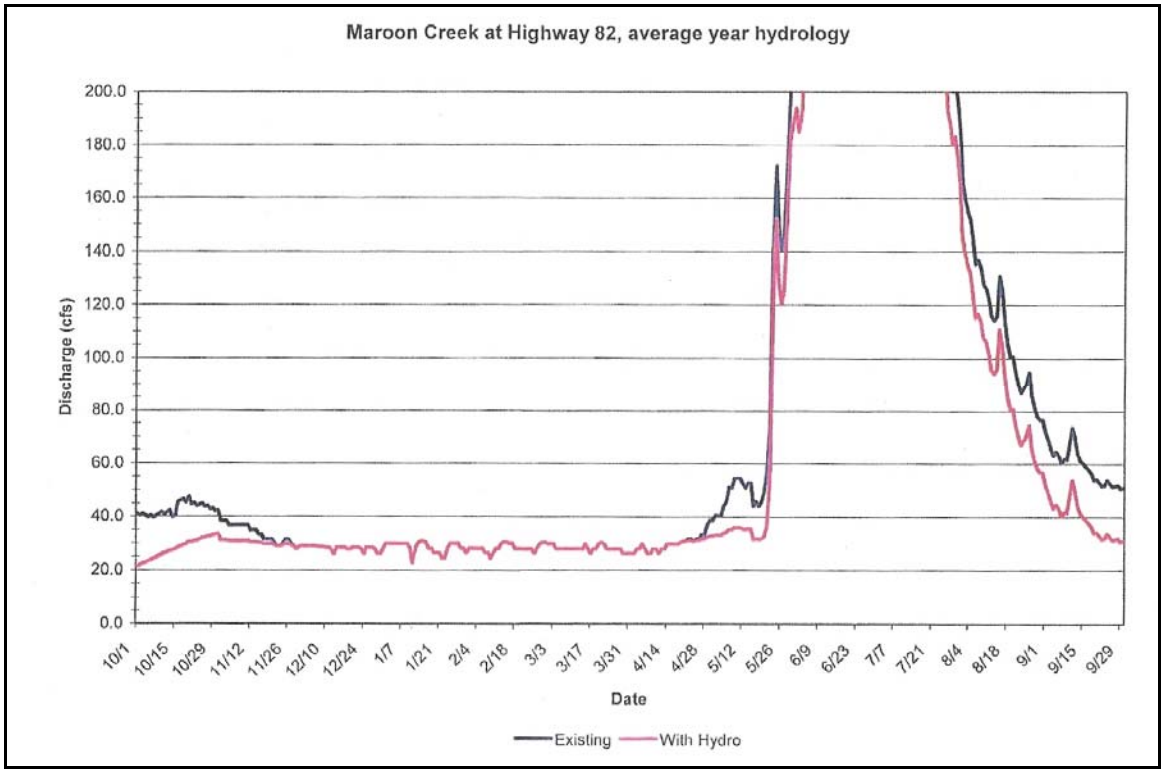

Figure 2. Maroon Creek Average Year Hydrology (MEC Figure 8)

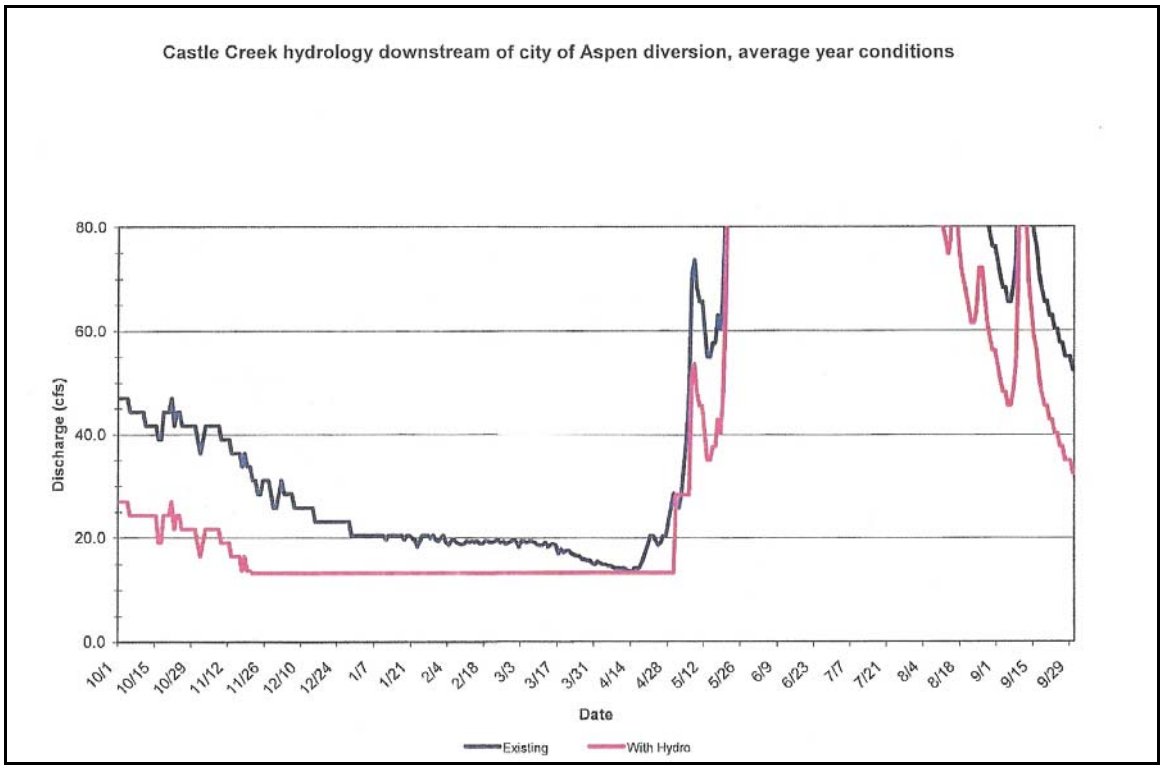

Figure 3. Castle Creek Average Year Hydrology (MEC Figure 14)

MEC evaluation of ecological stream flows and aquatic health

The report also discusses ecological flows and stream health citing several recent scientific research papers on natural flow regimes and the dynamic character of river systems (*MEC report pg. 38*). The MEC report describes the physical and biological components of Rocky Mountain streams and notes that the annual hydrograph can be categorized into several time periods including the ascending limb, peak runoff, descending limb, summer flows, and fall, winter, and spring baseflows and that each of these time periods has important physical and/or biological implications for stream health. The report acknowledges that "the dynamic character of river systems has been stated as one of the important features in maintaining ecological integrity" and that "any specified instream flow management should include a strategy for incorporating this natural variability".

The MEC review of the impact of the proposed hydropower facility on stream health starts from the premise that "the existing flow regimes in both Castle and Maroon Creeks include all of the components for stream health" (*MEC report pg. 44*) and further that "the city of Aspen is committed to maintaining base flows at the level that maintains aquatic health".

With that said, MEC's report acknowledges that there will be a reduction in flows in Castle Creek between the diversion structure and the hydro plant return but the maximum reduction of 25 cfs will only reduce peak flows by 5%. It also acknowledges an increase in streamflow of up to 25 cfs at some times of the year in the reach of Castle Creek below the hydropower return flow point. MEC's hydrologic analysis indicated that the Castle

Creek Hydropower Plant could be operated year-round from flows diverted from Castle Creek and supplemented by Maroon Creek. Peak flows would occur during spring and summer and the plant would operate at a lower capacity during the winter months to ensure that minimum instream flows are sustained. The MEC's report concludes that predicted flows with the plant in operation would include peak flows that change slightly from existing conditions but would still maintain riparian habitat, and create and maintain instream habitat.

MEC recognizes that overall stream productivity in natural systems is determined by baseflow, and towards that end, MEC examined the effect of the proposed hydropower facility on maintenance of baseflows on Maroon Creek and Castle Creek. The CWCB holds instream flow decrees for 12 cfs on Castle Creek and 14 cfs on Maroon Creek. On Castle Creek, the new R2Cross data collected by MEC in 2010 suggests summer minimum flows of 13.3 cfs[3] in the reach of Castle Creek downstream of Aspen's diversion structure and 17.2 cfs[4] in the reach downstream of hydropower return flow point. On Maroon Creek, Pitkin County and the CWCB entered in to an agreement in 2009 wherein Pitkin County would provide 4.3 cfs from the Stapleton Ditch for instream flow purposes in Maroon Creek. Under this agreement, the combined instream flow on Maroon Creek downstream of the Stapleton Ditch headgate would be 18.3 cfs.

The report states that while the CWCB's instream flow water rights on both Maroon and Castle Creek are junior in priority to Aspen's water rights, Aspen has "adopted a policy to ensure that the CWCB's rights are maintained downstream of its diversion facilities" and "the Maroon Creek hydroelectric plant is operated in such a way that the CWCB's water right is satisfied" (*MEC report pg. 46*). In addition, the City of Aspen is subject to a 1998 Intergovernmental Agreement under which it has committed to assisting CWCB in maintaining instream flows on Castle Creek.

Winter habitat conditions were also evaluated in Castle Creek using hydraulic simulations in pool habitats to determine water depth at various flow levels. The assumption is that pool depth provides refuge habitat at low flows. The report also notes that spawning habitat was observed at the downstream end of pools with spawning redd construction in several locations. The report concludes that the recommended minimum flows would provide winter habitat in Castle Creek from Aspen's diversion structure downstream to the confluence with the Roaring Fork River. Although the report does

[3] The R2Cross data used to develop the 13.3 cfs flow recommendation was collected at a flow of 38 cfs (*MEC Figure 23, pg. 48*). Hydraulic parameter estimates resulting from R2Cross are most accurate when predicted flows fall within a range of 0.4 to 2.5 times measured flow (Espegren 1996). Therefore, data interpretation for this cross section should be limited to modeled flows between 15.2 cfs and 95 cfs. The 13.3 cfs flow recommendation falls slightly below this recommended flow range.

[4] The R2Cross data used to develop the 17.2 cfs flow recommendation was collected at a flow of 40 cfs (*MEC Figure 25, pg. 51*). Hydraulic parameter estimates resulting from R2Cross are most accurate when predicted flows fall within a range of 0.4 to 2.5 times measured flow (Espegren 1996). Therefore, data interpretation for this cross section should be limited to modeled flows between 16.0 cfs and 100 cfs. The 17.2 cfs flow recommendation falls within this recommended flow range.

not cite any companion winter habitat studies in Maroon Creek, it concludes that Walsh's winter base flow recommendations of 14 cfs (upper reach) and 20 cfs (lower reach) in Maroon Creek below Aspen's diversion will protect the natural environment in winter.

With regard to baseflows, MEC concludes that minimum flows in Castle Creek of 13.3 cfs, above the return flow point, and 17.2 cfs, below the return flow point, would provide habitat to protect the aquatic biota during base flow periods and refuge habitat in winter. Conditions on Maroon Creek would be similar to Castle Creek with baseflows immediately downstream of the Maroon Creek diversion maintained at 14 cfs and baseflows of approximately 25 cfs in lower Maroon Creek. The report concludes that "no change in aquatic biota is expected with the hydro plant in operation" (*MEC report pg. 57*).

Overall, the MEC report concludes that by retaining the peak flow regime and the new recommended minimum flows under the proposed operations, "there are no measurable impacts expected to stream health or the fish community or macroinvertebrates" and that "Castle Creek and Maroon Creek should maintain their current level of stream health". (pg 72).

Evaluation of MEC's conclusions regarding biologic impacts

MEC evaluated the hydrology of Castle and Maroon Creeks and concluded that the post-project peak flow regimes of both creeks would be similar in shape, magnitude and duration to pre-project peak flows. Based on this evaluation, they conclude that by retaining the peak flow regime, riparian health, channel morphology and aquatic habitat would be maintained after the project. Given that Aspen's current maximum diversion capacity on both Castle and Maroon Creeks is physically limited to approximately 5% of their respective peak flows, MEC's conclusions are probably valid today. However, this conclusion relies on maintenance of these peak flows into the future. At this point, Aspen has not proposed a legal mechanism to assure that this peak flow regime will be protected.

MEC also evaluated baseflows in both Castle and Maroon Creek. As specified in MEC's contract with Aspen, this baseflow evaluation was based almost exclusively on the R2Cross methodology. MEC considered the state's existing instream flow decrees on both Castle Creek (12 cfs) and Maroon Creek (14 cfs), some additional R2Cross data that was collected by CDOW on Maroon Creek in 2009, and the new R2Cross data that MEC collected on Castle Creek in 2010. MEC concluded that minimum flows in Castle Creek of 13.3 cfs, above the return flow point, and 17.2 cfs, below the return flow point, would provide habitat to protect the aquatic biota during base flow periods and refuge habitat in winter. MEC also stated Aspen would recognize the CWCB's decreed instream flow on Maroon Creek and maintain flows downstream of its Maroon Creek diversion at 14 cfs. MEC reasons that this would result in flows around 25 cfs in lower Maroon Creek, presumably as a result of return flows from the Maroon Creek hydropower facility and other accretions to the stream. At these baseflows, MEC expects no change in biota.

Aspen's willingness to ensure that the CWCB's instream flows are maintained below its diversion structures and MEC's recommendation to increase baseflows in Castle Creek above the amounts currently decreed to the CWCB would benefit the aquatic environment of these creeks during the baseflow period. However, there is currently no legal mechanism to ensure that the flows Aspen leaves in the stream above the CWCB instream flow amounts won't be diverted by another water right holder. In addition, the ecological consequences of drawing these creeks down to baseflow amounts for extended periods of time can not be evaluated with the R2Cross methodology.

The use of R2Cross to evaluate changes in aquatic habitat with changes in flow has significant limitations. The R2Cross methodology is often used by the State of Colorado to determine "minimum stream flows" that are required to "to preserve the natural environment to a reasonable degree" (CRS 37-92-102(3). However, the use of R2Cross as a habitat modeling tool has been criticized by the biologic community as it does not address flow needs for intra- or inter-annual hydrologic variability and does not provide the necessary regime of flows that are critical to riverine ecology (IFC 2002). The IFC recommends that R2Cross "should not be used to prescribe a year-round base flow unless other models that address other ecosystem components support that level of flow". MEC's 2009 scope of work anticipated this when it acknowledged that FERC "may recommend additional studies" and that "the one study that may be recommended is an updated instream flow analysis using more current methods to quantify change in habitat with flow." MEC provided Aspen with a price estimate for an additional PHABSIM study but it was not funded at that time.

MEC's report acknowledges that "recent research has focused on comprehensive ecologically-based management of riverine systems to provide function for both instream aquatic biota as well as near-stream riparian areas". The natural flow regime and the dynamic character of river systems are two of the most important features in maintaining ecological integrity (Poff et al. 1997). Poff recognizes five critical components of the flow regime that regulate ecological processes in river ecosystems. The five components are:

1) Magnitude,
2) Frequency,
3) Duration,
4) Timing, and
5) Rate of change.

Poff notes that these five components characterize the entire range of flows and specific hydrologic phenomena that are critical to the integrity of river ecosystems. Aspen should conduct a more thorough evaluation of the potential aquatic impacts that may be associated with its proposed changes to the natural flow regime on both Castle Creek and Maroon Creek.

MEC cites Bunn and Arthington (2002), "Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity", a study that provides an excellent discussion of these components of ecological integrity. Figure 4 is a reproduction from

the Bunn and Arthington paper that illustrates the ecological connections between the aquatic biodiversity and natural flow regimes.

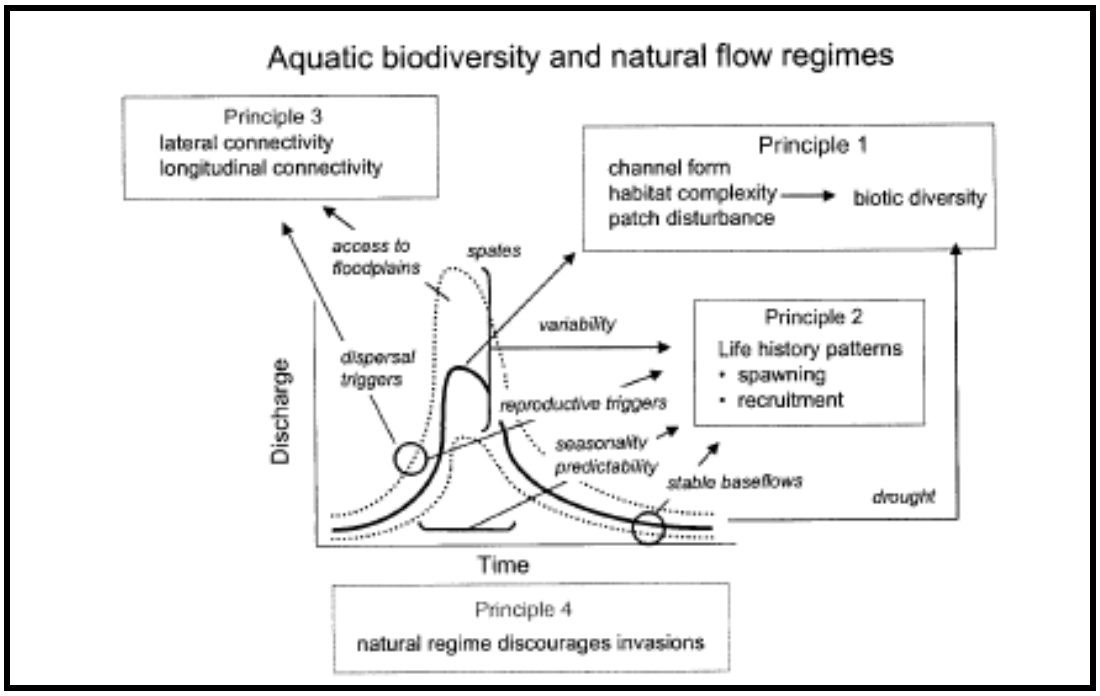

Figure 4. Aquatic biodiversity and natural flow regimes from Bunn and Arthington (2002)

The MEC report recognizes certain of the concepts described in Bunn and Arthington (2002). For example, MEC acknowledges that annual hydrograph can be categorized into several time periods including the ascending limb of runoff, peak runoff, the descending limb of runoff, summer flows, and fall, winter and spring baseflows, and that flows during each of these time periods can be linked to certain physical processes and biological responses in streams. However, the report limits the scope of its discussion to project impacts associated with only the peak flow and baseflow components of the hydrograph and does not evaluate impacts during other biologically-important components of the annual hydrograph. Consequently, certain critical biologic processes were not evaluated in the context of the proposed hydropower facilities.

For example, alterations in the natural flow patterns during the fall, winter, and spring components of the hydrograph may impact spawning success of both spring and fall spawning trout species. As Walsh reported (Walsh and Walsh 1995), brook trout and brown trout spawn in October or November as water temperatures fall below 50˚ F. By contrast, rainbow and cutthroat trout spawn in the spring as flows are increasing. Trout use physical cues like streambed substrate, water temperature, water depth, velocity, and cover to select optimum spawning sites (Walsh 2000). In addition, eggs from fall spawning trout species (brook and brown trout) reside in stream beds throughout the winter. In Snowmass Creek[5], Walsh and Walsh (1995) found that brown trout had completed spawning activities by early November and that eggs were predicted to hatch

[5] Castle Creek, Maroon Creek, and Snowmass Creek are all tributary to Roaring Fork River.

in late March with fry emergence in early to late May. They concluded that "winter streamflow reductions caused significant decreases in water velocity around trout redds and changed suitable incubation habitat to unsuitable habitat. Icing effects will further exacerbate the impacts of streamflow reductions on trout redd velocities". Increases in sedimentation and decreases in velocity over trout redds may compromise the survival of these eggs as depletions create baseflow conditions for extended periods of time during the winter (Walsh 2000). Prolonged periods of low winter baseflow may negatively impact overwinter survival of brook and brown trout eggs on both Castle Creek and Maroon Creek as well.

In his paper titled "Instream Flow Assessment of Maroon Creek", Walsh (2000) states that over-winter habitat is one of the major factors limiting salmonids densities. Walsh goes on to say that winter mortality is usually associated with collapsing snow banks, de-watering as a result of streamflow obstruction by ice, anchor ice or physical damage from ice scouring. Over-winter habitat for all trout species may be compromised by prolonged reductions in current baseflow conditions as instream velocities and water depths are decreased and the likelihood of icing is increased. Hillman and Chapman (1996) prepared a paper for the Snowmass/Capitol Creek Caucus describing the winter ecology of trout and the implications for Snowmass Creek. They concluded that "trout require specific habitat during winter in ice-covered streams like Snowmass Creek, and ice conditions and streamflows greatly affect these habitats". They stated that "any reductions in streamflows then will increase the risk of overwinter mortality; the greater the flow reduction, the higher the risk".

A review of Figures 14 and 15 from the MEC report indicates late summer and early fall flows will be rapidly depleted and that the period of time Castle Creek will experience baseflow conditions will be extended from November to May of average and dry years. In contrast, baseflow conditions were rare or nonexistent under pre-project conditions. Figures 7, 8, and 9 show similar depletions to Maroon Creek during the late summer, early fall and spring portions of the hydrograph. The Walsh and Hillman and Chapman studies referred to above on Snowmass Creek and Maroon Creek suggest these prolonged baseflow periods on Maroon and Castle Creek may negatively impact overwinter survival of adult trout and trout eggs.

The conclusions of the MEC report do not fully address the concept of ecologically sustainable flows as suggested by the Aspen Wilderness Workshop. The report focuses on impacts associated with changes in peak flows and base flows, but does not evaluate the potential impacts associated with changes in flow during the ascending and descending limbs of the hydrograph or late summer, fall and winter time periods. Aspen should evaluate the ecological impacts associated with changes in flow during these equally critical components of the hydrograph and consider some additional legal mechanisms for protecting flows during these time periods to ensure that the impacts of the hydropower project do not compromise the ecological integrity of Maroon Creek and Castle Creek.

The MEC report does not discuss the proposed daily operations of the hydropower facility in detail or how natural diurnal fluctuations in streamflow will be consider in meeting flow targets. While it is assumed that diversions from Maroon Creek and Castle Creek would remain relatively constant on an hourly/daily basis, dramatic changes in stream flow over short periods of time (ramping) should be avoided and diversions should not reduce the instantaneous minimum flow below the proposed flow targets.

The SHI identified a one mile reach of Maroon Creek from the Roaring Fork confluence upstream to a "small private bridge" as a Conservation Area of Concern (CAC) and considers stream diversions that contribute to dewatering to be one of the threats to this CAC. The MEC report concludes that "The SHI's CAC will not be affected because dewatering will not occur." However, to the extent that new hydropower diversions from Maroon Creek are returned to Castle Creek, MEC's conclusion seems incorrect.

Lastly, the MEC does not address fish passage issues associated with Aspen's diversion structures on both Maroon and Castle Creek. These diversion structures are significant and appear to completely block upstream fish migration. Fish sampling conducted by MEC and CDOW in the fall of 2010 revealed numerous fall spawning brown trout below the diversion structures on Maroon and Castle Creek and few trout above the diversion structures. Presumably these fish were attempting to migrate up these creeks to spawn but their trip was cut short by the diversion structures. Fish passage alternatives should be considered to ensure that the trout populations in Maroon and Castle Creek remain robust.

MEC's conclusions regarding impacts on biologic stream health from operation of Aspen's proposed hydropower facility should be applicable throughout the entire year. However, MEC's analysis was limited to evaluating impacts during only the peak flow and baseflow components of the hydrograph. In addition, the report should discuss potential aquatic impacts from daily operation of the hydropower facility and fish passage issues at Aspen's diversion structures. It should also reconsider whether additional hydropower withdrawals from Maroon Creek will threaten the CAC that was identified by SHI.

3. Aspen's Proposed Monitoring Plan

On September 30, 2010, MEC submitted a "Proposal for additional work during fall 2010 on Castle and Maroon Creek in support of the Monitoring of Stream Health". This memo states that "Aspen is in the process of completing the Monitoring Program to assess stream health associated with the Castle Creek hydroelectric plant". Under this contract, MEC specified six study sites; three on Maroon Creek and three on Castle Creek. The sampling regime for the proposed monitoring plan would collect baseline data in the fall of 2010 followed by annual fall monitoring in 2011, 2012, 2013, and 2014 and then fall sampling every other year in 2016, 2018 and 2020. The sampling tasks at each of the six sites would include:

- Collecting macroinvertebrate samples,
- Habitat inventories,

- Fish population sampling (by CDOW), and
- Water temperature monitoring (at hourly intervals).

A draft MOU between Aspen and CDOW provides some additional detail regarding Aspen's proposed monitoring and adaptive management plan. The draft MOU states that Aspen will operate its hydroelectric plants on both Castle Creek and Maroon in manners which will allow maintenance of the MEC's flow recommendations. It also proposes an adaptive management plan with a goal of maintaining stream health by:

- Maintaining steady or increased macroinvertebrate populations,
- Maintaining steady or increased fish populations, and
- Maintaining habitat as determined by USFS protocol.

Under the MOU, Aspen agrees that "if a statistically significant decrease in any one or more of the above criteria is detected after any monitoring episode, the CDOW, in concert with the City will review the data to determine the cause" and "if the cause is found to be due to hydroelectric operations at the Castle Creek plant, the City will work with CDOW to change plant operations in accordance with the mutually developed adaptive management plan".

Evaluation of Aspen's proposed monitoring and adaptive management plan

Under Aspen's proposed monitoring and adaptive management plan, baseline macroinvertebrate and fish population metrics are based on a single year of data collection (Fall 2010). However, a single year of pre-project baseline data can not capture the natural variability that is inherent in fish and macroinvertebrate populations between years. Consequently, it would not be possible to determine whether a "statistically significant decrease" has occurred in one of Aspen's biologic criteria since a confidence interval can not be calculated to describe this year-to-year variability based on a single year of baseline data. Pre-project, baseline metrics for fish and macroinvertebrate data should be collected over several years to capture the inherent natural variability in the fish and invertebrate populations in Maroon and Castle Creek and to establish statistically significant confidence intervals on this year-to-year variability.

Richter (2005) notes that water managers are embracing the concept of adaptive management as a means to address uncertainties in ecosystem water needs and future human demands. He also states that "rather than trying something and seeing what happens, adaptive management needs to be a carefully designed process of deliberate learning using planned experiments". Aspen's proposed adaptive management plan does not incorporate Richter's concept of deliberate learning using planned experiments. Consequently, it will be difficult, if not impossible, to determine cause and effect relationships associated with operations at the hydropower plant under the current design of Aspen's adaptive management plan.

Aspen's current MOU with CDOW defines the "Interested Governmental Entities" as CDOW, Aspen Utilities Department, Aspen Engineering Department and the United States Forest Service (USFS). Aspen should consider including a representative from

Pitkin County's Healthy Rivers and Streams Board, and possibly others, as interested parties on the adaptive management plan team.

4. Conclusions

- Aspen's contracts with MEC were narrowly focused on the analysis of existing data and the utilization of the R2Cross methodology. As a result, MEC was unable to evaluate potential aquatic impacts that may be associated with the proposed hydropower facility during all ecologically important components of the annual hydrograph.

- With regard to peak flows, MEC stated that the current capacity of Aspen's diversion structures on Maroon and Castle Creek could only physically divert approximately 5% of the peak flow. Based on this physical limitation, MEC concluded that operation of the proposed hydroelectric plant would not have significant impacts to the aquatic ecology of either Maroon or Castle Creek during the high flow season since post-project flows would continue to be large enough to provide channel maintenance and flushing flow functions. The data supporting this conclusion seems reasonable, however, there is no legal mechanism proposed to assure that adequate channel maintenance and flushing flows will continue in the future.

- With regard to baseflows, MEC concluded that with "the proposed operation and the new recommended minimum flows maintained during baseflow periods, there are no measurable impacts expected to stream health, the fish community or macroinvertebrates" (*MEC report pg. 72*) on either Castle or Maroon Creek. MEC's conclusion is based on various instream flow studies and existing instream flow water rights, most of which were based on R2Cross analyses. The report does not address the potential impacts associated with hydropower diversions that will draw these creeks down to minimum flow amounts for extended periods of time during the fall and winter months. Previous studies on Maroon Creek and Snowmass Creek suggest that water withdrawals during the fall and winter months may have dramatic negative consequences for fish and macroinvertebrate populations (Hillman and Chapman 1996, Walsh 2000, Walsh and Walsh 1995).

  In addition, the use of R2Cross to evaluate changes in aquatic habitat and establish year-round baseflows has been questioned by the scientific community (Instream Flow Council 2002). As acknowledged in the MEC report, "recent research has focused on comprehensive ecologically-based management of riverine systems to provide function for both instream aquatic biota as well as near-stream riparian areas". While the MEC report acknowledged the importance of the natural flow regime and ecologically sustainable flows, it did not evaluate aquatic impacts associated with changes in streamflow amounts during the rising and falling limbs of the hydrographs or the late summer and early fall time periods.

Aspen's willingness to ensure that the CWCB's instream flows are maintained below its diversion structures and MEC's recommendation to increase baseflows in Castle Creek above the amounts currently decreed to the CWCB will benefit the aquatic environment of these creeks during the baseflow period. However, Aspen should also take a more comprehensive look at the potential year-round impacts of the proposed hydroelectric facility and consider legal mechanisms to protect these environmentally important components of the natural flow regime.

- With regard to Maroon Creek, the SHI identified the one-mile reach of Maroon Creek just above its confluence with the Roaring Fork River as a Conservation Area of Concern (CAC) and considers dewatering a threat to this CAC. The MEC report states that this reach will not be dewatered by the proposed hydropower diversions. However, MEC's conclusion seems incorrect since diversions from Maroon Creek to the Castle Creek hydropower facility will return to Castle Creek, not Maroon Creek. Based on the findings of the SHI, it appears that these depletions could threaten the Maroon Creek CAC.

- With regard to Castle Creek, MEC collected some additional R2Cross data at two new locations. In the reach of Castle Creek between the hydropower diversion point and return flow point, MEC recommended a flow of 13.3 cfs based on a measured flow of 38 cfs. Hydraulic parameter estimates resulting from R2Cross are most accurate when flow recommendations fall within a range of 0.4 to 2.5 times the field measured flow (Espegren 1996). The 13.3 cfs flow recommendation falls just below the 15.2 cfs lower end of the recommended R2Cross modeling range. Therefore, the modeled hydraulic parameters that led to the 13.3 cfs flow recommendation may be questionable. Some additional data collection at a lower measured flow would help substantiate the 13.3 cfs flow recommendation.

- The MEC report does not discuss the proposed daily operations of the hydropower facility in detail or how natural diurnal fluctuations in streamflow will be consider in meeting streamflow targets. While it is assumed that diversions from Maroon Creek and Castle Creek would remain relatively constant on an hourly/daily basis, dramatic changes in streamflow over short periods of time (ramping) should be avoided. Aspen should also clarify how natural daily fluctuations in streamflow will be considered in meeting flow targets on both Maroon and Castle Creek.

- Aspen's diversion structures on both Castle Creek and Maroon Creek are significant barriers to fish passage. The MEC report should disclose this issue and discuss fish passage alternatives.

- Aspen's proposal to monitor changes in fish and macroinvertebrate populations based on a single year of baseline data collection cannot capture the inherent natural variability associated with year to year changes in fish and invertebrate populations under existing flow conditions. Detecting "statistically significant

decreases" in fish and macroinvertebrate populations will require several years of baseline data to establish statistically significant confidence intervals on the natural year-to-year variability of the baseline condition.

Aspen's current monitoring and adaptive management plan does not include the concept of "deliberate learning using planned experiments" (Richter 2005). Consequently it will be difficult, or impossible, to pinpoint a cause and effect relationship associated with declines in fish and macroinvertebrate population parameters under the current plan. Aspen should incorporate the concept of learning by experimentation into its adaptive management plan.

5. Additional recommendations

Richter's Framework for Ecologically Sustainable Water Management

In 2005, Richter et al. proposed a Framework for Ecologically Sustainable Water Management (ESWM). ESWM is a process that is designed to help address some of the issues and challenges associated with Federal Energy Regulatory Commission's (FERC) statutory duty to achieve a balance between energy generation and ecological health. Aspen may find the ESWM framework to be useful as it moves the Castle Creek Hydroelectric Project forward in the FERC process.

Figure 5 illustrates the six-step ESWM as presented by Richter et al.

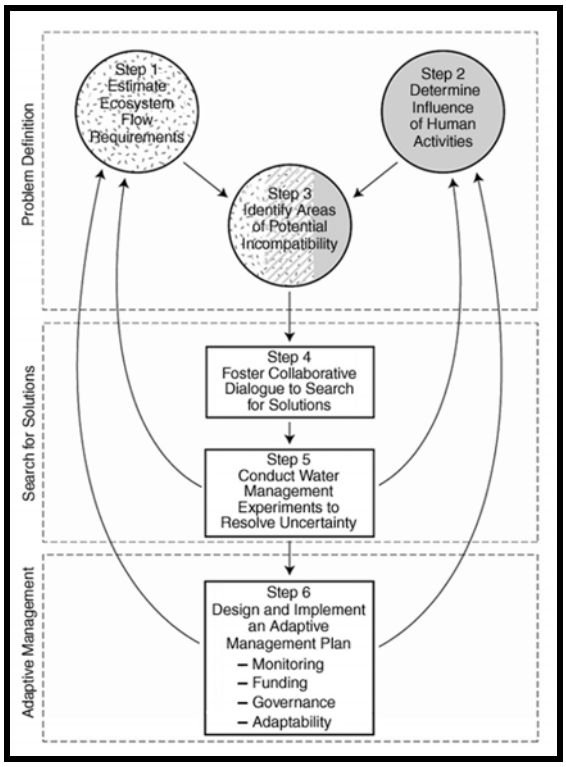

Figure 5. Ecologically Sustainable Water Management Framework (Richter et al 2005)

It appears that it would be relatively easy for Aspen to adapt its current impact analysis to fit Richter's ESWM model. The MEC report has provided an initial estimate of the ecosystem baseflow flow requirements through the use of R2Cross analyses (ESWM Step 1). To complete ESWM Step 1, and to address some of the issues raised in this report, Aspen should also consider flow targets for other ecologically important times of the year. These flow targets could be derived through additional PHABSIM studies. They might also be derived based on a variation of the Range of Variability Approach (RVA), proposed by Richter et al (1997).

The RVA utilizes 32 ecologically relevant hydrological parameters, known as the Indicators of Hydrologic Alteration (IHA), to characterize the current, pre-project flow regime. Richter notes that "the full range of natural intra- and inter-annual variation of hydrologic regimes, and associated characteristics of timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems". Gage records from Castle Creek and Maroon Creek could be utilized to develop these IHA parameters and characterize the existing flow regime on these creeks.

Aspen has completed ESWM Step 2 by determining the amount of water they propose to divert from Maroon Creek and Castle Creek for hydropower purposes.

ESWM Steps 3 and 4 involve identifying conflicts and searching for solutions. Within the ESWM process, Aspen could assemble an interdisciplinary science team to compare the projects diversion requirements against the current flow regime and attempt to set flow management targets for Maroon and Castle Creeks utilizing the RVA approach. The goal of this exercise would be to balance the flow requirements of the hydropower facility with the environmental flow requirements of the streams. The resulting flow management targets "may change from flat-line minimum flow targets into seasonally-varying prescriptions that might change in dry, average, or wet years" (Richter 2005).

Consistent with Richter's concept of "deliberate learning using planned experiments" and ESWM Steps 5 and 6, Aspen's interdisciplinary team could then design experiments to further refine these flow targets through monitoring and adaptive management.

The utilization of Richter's ESWM could help Aspen address many of the issues raised in this report regarding ecologically sustainable flows in Maroon and Castle Creek and the proposed monitoring and adaptive management plan.

Standards for "Low Impact" hydropower

The Low Impact Hydropower Institute[6] (LIHI) has developed a list of Goals and Standards that it requires to award a "Low Impact" certification to a hydropower facility. The Goals and Standards are:

- River flows that are healthy for fish, wildlife and water quality, including seasonal flow fluctuations where appropriate,

[6] Low Impact Hydropower Institute, 34 Providence Street, Portland, ME 04103 www.lowimpacthydro.org

- Water quality in the river is protected,
- Effective fish passage for riverine fish and protection from entrainment,
- Sufficient actions to protect, mitigate and enhance environmental conditions in the watershed,
- No negative impacts to state or federal threatened or endangered species,
- Protection of cultural resources,
- Accommodates recreational activities on the public's rivers.

Aspen may want to consider LIHI's "Low Impact" hydropower standards as the Castle Creek Hydroelectric Project moves forward in the FERC licensing process.

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