Introduction and Background

Gore Creek, in Eagle County, Colorado, is the primary source of domestic water supply for the Town of Vail, and the local community treasures its aesthetic, recreational, and economic resource values. The 102 square mile Gore Creek watershed is 94% Federal land (White River National Forest) and encompasses the Town of Vail, a major portion of the Vail Ski Area, highly pristine areas in the Eagles Nest Wilderness, and a designated Gold Medal trout fishery. Gore Creek and its tributary, Black Gore Creek, run parallel to I-70 for a distance of over 20 miles. Due to its proximity to this major state and national transportation corridor, the creek is highly visible and accessible for fishing, hiking, boating, and other recreational pursuits.

Stakeholders have been conducting water chemistry and biological monitoring in the Gore Creek and Eagle River watersheds for over 20 years to track water quality and aquatic health conditions. Recent studies of macroinvertebrate (aquatic insect) communities have shown that the biological health of Gore Creek is degraded based upon aquatic life use attainment metrics recently adopted by the Colorado Water Quality Control Commission (Policy 10-1). In early 2010, Eagle River Basin stakeholders formed the Urban Runoff Group (URG) and initiated work on the Gore Creek Water Quality Improvement Plan (WQIP) to guide the planning and implementation of measures to improve stream health. URG participants include representatives from Eagle County, the Towns of Vail and Avon, the Eagle River Water and Sanitation District (ERWSD), the Vail Recreation District, the Eagle River Watershed Council (ERWC), Vail Resorts, and the Colorado Department of Transportation (CDOT). The geographic scope of the WQIP includes Gore Creek from the confluence of Black Gore Creek downstream to the Eagle River with particular emphasis on the area through East Vail and Vail Village above the confluence of Red Sandstone Creek.
WQIP Purpose and Goals

The primary purpose of the WQIP is to identify management strategies and corrective actions to protect and improve the biological integrity of Gore Creek as indicated by macroinvertebrate community metrics. In 2012, Gore Creek was added to Colorado’s 303(d) List of impaired water bodies for aquatic life use impairment, with a provisional qualifier indicating that the cause of impairment is unknown. Development of specific management strategies and corrective actions to improve biological health, requires an understanding of the aquatic life stressors that may be causing the impairment. The goals of the WQIP, therefore, include the following:

- compilation of water chemistry and biological information from previous studies;
- thorough analyses of the data to better understand key stressors and identify the potential causes of impairment;
- identification of corrective actions needed to protect and restore stream health;
- identification of additional data needed for further analysis of site-specific stressors, identification of water quality improvements, and tracking of water quality and biological responses to corrective actions;
- identification of options for funding and institutional arrangements to manage and coordinate WQIP implementation; and
- the focus of the WQIP could be adapted to meet the requirements of the State and EPA for a Category 4b demonstration plan, which, if approved, would result in the removal of Gore Creek from the State’s 303(d) List of impaired water bodies.
The WQIP has been prepared for URG participants and entities that are responsible for making the resource management decisions that are necessary for protection and restoration of stream health in Gore Creek and other Eagle River Basin stream segments. Information from the WQIP provides direction and focus for implementation of specific corrective actions and management strategies, and it identifies issues and potential water quality improvement measures that require further evaluation and refinement. The WQIP also discusses institutional options for coordinated implementation of corrective actions that could provide the framework needed to establish permanent funding sources needed to support ongoing planning, design, implementation, and maintenance of water quality improvement measures and programs. It will also serve as a reference document to support ongoing program management and provide a template for planning and development of stream health improvements for other stream segments in Eagle River Basin.
WQIP Approach and Methodology

The first step in the planning process was the collection and compilation of data needed to thoroughly characterize existing conditions in the Gore Creek WQIP study area. This effort relied primarily on relevant existing information from previous studies and monitoring programs in the watershed that have been conducted during the last 5 to 10 years. Data compilation was a cooperative effort involving multiple stakeholders and included the following:

- geospatial information including topography, aerial photography, land use, land ownership, existing storm drainage infrastructure, riparian buffer zones and wetlands;
- biological data including fish, macroinvertebrates, and periphyton collected by the Eagle River Water and Sanitation District (ERWSD), US Geological Survey (USGS), US Forest Service (USFS), Colorado Department of Public Health and Environment (CDPHE), and Colorado Parks and Wildlife (CPW);
- water chemistry data collected by the ERWSD, USGS, USFS, CDPHE, and CDOT (including new stormwater data collected in 2011 for this study);
- reference information on stormwater best management practices (BMPs) and low impact development (LID) methods;
- information on water quality related educational programs from the Eagle River Watershed Council (ERWC), ERWSD, Town of Vail, Eagle County, and Colorado State University Extension; and
- field observations generally following the Natural Resources Conservation Service (NRCS) Stream Visual Assessment Protocol (NRCS, 1998).

The data summarized above was used to conduct detailed assessments of water chemistry and biological conditions in Gore Creek and identify stressors. Based upon the known stressors, corrective actions were identified and prioritized (high, medium, and low) according to their potential to improve water quality and stream health conditions.
Data Analysis Results

The analyses of macroinvertebrate community composition, water chemistry data, and field observations to determine the presence of biological stressors is summarized below.

Biological Conditions

- Macroinvertebrates
  - Macroinvertebrate Multi-Metric Index (MMI) scores and other biological indices for areas through upstream reference sites (above Vail), East Vail, Vail Village, and the lower reaches of Gore Creek showed significant stress compared with reference conditions found in Gore Creek above Black Gore Creek and in Gore Creek tributaries.
  - The most severely degraded biological conditions occur in the stream reaches extending from Big Horn Park downstream to the Vail Wastewater Treatment Facility (WWTF) outfall.
  - The spatial pattern of degraded biological conditions and other types of macroinvertebrate indices indicate stresses associated with urban development and urban land use activities.

- Periphyton (algae and other microorganisms that are attached to or in close proximity to the stream bottom)
  - Periphyton conditions in Gore Creek are highly variable from location to location and from year to year due to the complex interaction of factors including:
    - nutrient and sediment loading;
    - water temperature;
    - sunlight intensity;
    - streamflow patterns and scouring;
    - water velocity; and
    - grazing by aquatic insects.
  - Studies conducted annually from 2004 through 2007 show an increase in the invasive species Didymosphenia geminata in Gore Creek above the wastewater treatment facility (WWTF).
  - The filamentous green algae Cladophora glomerata is present in dryer than normal years in Gore Creek above the Vail WWTF, and is the dominant species found downstream of the Vail WWTF in dry and average years.
  - Chlorophyll a monitoring results (attached algae) in Gore Creek at all sites in most years were better than interim water quality criteria values adopted by the Water Quality Control Commission.
Fish
- Results of a fish survey conducted by Colorado Parks and Wildlife in 2011 indicated healthy populations of sculpin, brown trout, brook trout, and rainbow trout in Gore Creek above Red Sandstone Creek. The large number of sculpin found at the East Vail and Nature Center sites generally indicates good water quality conditions including high dissolved oxygen, clean substrate, abundant food resources, and low trace metals concentrations. (Note that macroinvertebrate community characteristics are better indicators of biological diversity than fish.)
- The reach of Gore Creek, from the confluence of Red Sandstone Creek downstream to the Eagle River, continues to exceed the minimum requirements for Gold Medal fishery designation (12 trout > 14” per acre and 60 lbs. of trout per acre). However, in Colorado, aquatic life use attainment is based upon benthic macroinvertebrate metrics.

Water Quality Conditions
- Gore Creek
  - Water quality monitoring efforts over the last 10 years have generated a large quantity of data for Black Gore Creek, Gore Creek above Black Gore Creek, Gore Creek above the Vail WWTF and Gore Creek at the mouth.
  - Data analysis results indicate that Gore Creek is meeting all of the applicable water quality standards and criteria, including those established for protection of aquatic life use, for trace metals (e.g., cadmium, copper, lead, zinc, etc.), nutrients (e.g., total phosphorus and total nitrogen), major ions (e.g., chloride, iron, etc.), and physical/biological parameters (e.g., dissolved oxygen, pH, etc.). The results of this analysis indicate that exceedances of chronic standards for aquatic life use are not likely the cause of aquatic life use impairment in Gore Creek.
  - Gore Creek appears to be meeting the acute and chronic temperature standards for aquatic life with the possible exception of minor exceedances of the winter standards in early October immediately following the shoulder season transition from the summer to the winter standards. These exceedances would not adversely affect aquatic life, and additional data is being collected to further evaluate temperature conditions.
• **Stormwater**
  o Stormwater data analysis indicated potential for rain event exceedances of acute aquatic life standards for dissolved copper and chronic aquatic life standards for copper, zinc, and total recoverable iron in Gore Creek below Vail Village.
  o Elevated chloride concentrations in Black Gore Creek and Gore Creek during snowmelt events likely contribute to aquatic life stress. Recent studies indicate that chloride may be more toxic to certain benthic macroinvertebrates found in Gore Creek than previously believed.
  o Stormwater impacts to Gore Creek in areas upstream from Vail Village likely contribute to aquatic life stress but do not appear to be the primary cause of impairment.
  o Additional stormwater monitoring is needed to fully assess potential stormwater impacts in Gore Creek particularly in areas through Vail Village.
  o It is important to note that stormwater samples were collected from ditches and pipes that convey runoff directly to the stream. Sample analyses did not include pesticides because the sampling dates did not coincide with the period when these pollutants would likely be detected.

**Key Aquatic Life Stressors**

Field observations, combined with the data compilation and analyses outlined above and the review of literature from other similar studies and research, indicate that biological impairment in Gore Creek is caused by the cumulative impacts of multiple stressors. There are three categories of stressors present in the study area that are well documented in the literature as potential causes of aquatic health impairment: 1) riparian buffer degradation; 2) impacts of impervious cover and urban runoff; and 3) pollutants associated with land use activities.

• **Riparian buffer degradation** – Development in the Town of Vail is concentrated along a relatively narrow 10-mile long corridor extending from above the confluence of Black Gore Creek to the western Town boundary near Dowd Junction. In many areas development, landscaping, fill slopes, and roads, located in close proximity to the stream, have caused the degradation or loss of natural riparian buffer zones. Natural riparian buffers provide a variety of beneficial water quality, hydrologic and habitat functions such as filtration of pollutants from urban runoff, flood attenuation, alluvial aquifer recharge, enhancement of baseflows, shading to reduce water temperature, and food chain support for aquatic and terrestrial organisms. Other studies of streams similar to Gore Creek have found that loss of the riparian vegetative buffer is a primary stressor associated with macroinvertebrate impairment (EPA, 2006).
• **Impacts of impervious cover and urban runoff** – Impervious cover on the landscape has been well documented as a useful indicator of impacts on aquatic ecosystems. Impervious surfaces include roads, paved parking lots, buildings, and sidewalks where water from precipitation cannot infiltrate to the ground. Runoff from these areas is conveyed directly to the stream via stormwater drainage channels, pipes, and sheet flows. During runoff events, pollutants are quickly washed off the impervious surfaces and rapidly delivered to the stream. Previous studies have identified a strong relationship between the impervious cover and negative impacts to water quality and biological health, particularly when the impervious areas are within riparian buffers and in close proximity to the stream (Cuffney et al., 2010; Coles, et al., 2012; Washburn, et al., 2010). Through the Town of Vail, the impervious cover, as a percentage of the area within the alluvial aquifer (groundwater that is directly connected to the stream) boundary, ranges from 12% to 35% in east Vail and up to 45% in the Vail Village area between Ford Park and Forest Road.

• **Pollutants associated with land use activities and urban runoff** – The adverse effects of pollutants in urban runoff on water quality and aquatic health are well documented (EPA, 1999). Residential, commercial, and light industrial land use activities including runoff from construction sites in Vail, generate a variety of urban runoff contaminants that are toxic to aquatic macroinvertebrates. These contaminants include sediment, pesticides, fertilizers and other lawn chemicals, de-icers, trace metals, petroleum products, and other organic materials. The toxic effects of many of these pollutants have been extensively studied and are known with reasonable accuracy, and the combined cumulative effects of multiple stressors are likely synergistic.

An important consideration for development of corrective actions is that the key stressors summarized above occur together in many areas along Gore Creek through Vail. Macroinvertebrate metrics, however, indicate substantial biological degradation at the Big Horn Park, East Vail, and Ford Park sites, which are minimally affected by land uses that are likely to generate substantial sediment, trace metals, and other pollutants associated with stormwater runoff from construction sites and commercial and light industrial land uses associated with higher percentages of impermeable land cover. It is therefore more likely that key stressors affecting these areas are related to landscape maintenance activities (pesticides, fertilizers and lawn care chemicals) de-icer,s and potentially hydrocarbons, combined with the loss of riparian buffer. Restoration of riparian buffer functions in East Vail would likely serve to mitigate some of the impacts from landscape maintenance activities. However, the biological impacts of I-70 runoff are not well known. More study to determine the impact of de-icers and hydrocarbons and effective mitigation strategies is recommended.
Corrective Actions

Information gleaned from data analysis and field surveys was used to develop detailed descriptions of existing conditions that could affect water quality and stream health along Gore Creek. Two categories of corrective actions were identified to address the key stressors. Site-specific corrective actions involve on-the-ground improvements, such as streambank stabilization or riparian buffer rehabilitation, while programmatic corrective actions are to be implemented through public policy, regulatory, and education programs. Corrective actions are summarized below and detailed in the WQIP report (Table 4.1) and corresponding reach characterization aerial photo maps.

- Riparian buffer restoration and protection – there are many areas along Gore Creek where natural riparian vegetation has been removed and/or replaced with urban landscaping and structural modifications such as riprap, constructed stream banks, patios, lawns and/or other landscaping features. Strategies to address these impacts, and protect areas where riparian buffer functions have not been significantly impacted are listed below.
  - Regulatory measures to protect areas where riparian buffer conditions are good, and restore areas on Town of Vail property and private property that have been degraded.
  - Education and outreach programs to inform governmental agencies, homeowners, property managers, and landscape design and maintenance companies about the importance of buffer protection and restoration.
  - Site-specific projects to improve and restore riparian buffer areas at many locations have been identified. Additional work will be required to prioritize, design and implement site-specific projects. Voluntary and incentive programs will be needed to encourage protection and restoration of riparian buffer areas on private lands.
Managing impacts associated with impervious cover and urban runoff – the hydrologic and water quality impacts associated with impervious cover are well documented.

- Regulatory strategies for addressing impervious cover and urban runoff include development of stormwater infrastructure design standards that incorporate low impact development (LID) and green infrastructure (GI) practices, and more stringent construction stormwater permitting requirements for development activities that are close to streams.

- Education and outreach programs are needed to inform local governmental agency staff, developers, and property owners about regulatory requirements and new approaches to selection of appropriate stormwater infrastructure and construction best management practices (BMPs).

- 25 site-specific stormwater infrastructure improvement projects were identified, but additional information is needed to further evaluate, prioritize, and develop specifications for these projects. More detailed information regarding the existing stormwater infrastructure system is needed to determine potential contaminant sources and to identify the most effective and highest priority BMPs (i.e., drainage improvements, source treatment measures, and/or outlet controls).

- The Town of Vail already has a program in place for systematic inspection and maintenance of stormwater infrastructure including street and parking lot sweeping and periodic cleaning of water quality vaults. Work is currently underway to review, better document, and further refine the Town’s inspection and maintenance programs.

- Monitoring programs – Additional stormwater monitoring is needed to better understand stormwater impacts on Gore Creek and to provide baseline data for evaluation of the effectiveness of stormwater infrastructure improvements.
• Measures to reduce and control pollutants associated with land use activities and urban runoff including pesticides, fertilizers, illegal dumping, and de-icers are summarized below.
  o Regulatory measures – Adopt a formal Town of Vail Integrated Pest Management Policy (IPM) that provides guidelines for application and management of pesticides and lawn care chemicals. New regulations are needed to reduce or restrict/ban the use of pesticides with known toxicity to aquatic life in all areas that are close to Gore Creek and its tributaries. More aggressive enforcement of existing State and local regulations may be required to further discourage illegal dumping.
  o Education and outreach programs targeting local governmental agencies, homeowners, property managers, landscape design and maintenance companies, pesticide applicators, and others are needed to inform and educate people about the toxic effects of pesticides, the Town of Vail IPM Policy, selection of appropriate products, and BMPs for their use and application. In addition, all citizens should be encouraged to report illegal dumping. Construction contractors and cleaning companies and their employers need to be informed about proper disposal of waste products and the penalties for illegal dumping.
Prioritization of Corrective Actions

The corrective actions summarized above and detailed in the Gore Creek WQIP involve programmatic management strategies including regulatory measures, educational programs, maintenance programs, and site-specific projects to improve and restore riparian buffer zones and improve stormwater infrastructure. The programmatic and site-specific actions, however, are interrelated because effective implementation of site-specific projects depends upon the concurrent implementation of many of the policy and regulatory guidelines. The programmatic management strategies, including the policy, regulatory, and educational programs listed above, should therefore be considered very high priorities because they provide the framework for more systematic and efficient implementation of site-specific water quality improvement projects.

Implementation of all of the corrective actions summarized above will require substantial time and resources. It will therefore be desirable to develop an adaptive management system for ongoing assessment and prioritization of corrective actions over time as additional information becomes available. This approach will facilitate the early implementation of corrective actions that are most beneficial to stream health and most cost effective. Chapter 6 of the WQIP provides additional details regarding possible approaches and criteria for prioritization of water quality improvement projects.

Monitoring to fill data gaps and measure results

As management programs and projects are implemented, there will be a continuing need for water quality and biological monitoring to build on previously collected data, fill data gaps, track water chemistry and biological trends, and assess the effectiveness of water quality improvement measures. These monitoring needs should be addressed through the coordinated efforts of stakeholders under existing ongoing monitoring programs and studies. Monitoring recommendations are further discussed in Chapter 5 of the WQIP.
Management strategies for program implementation and funding

Successful achievement of the water quality and stream health improvements in Gore Creek will require a long-term commitment of resources to program coordination and management. This could occur through existing local agencies and organization or through the establishment of new institutional arrangements. Either option will require a continuing source of dependable revenue. Program implementation through existing agencies and organizations would require that various entities assume responsibility and commit resources to program implementation. This approach would require extensive cooperation and coordination between agencies, which could be achieved through intergovernmental agreements (IGAs) and public/private partnerships. Establishment of a new agency for program management (e.g. a stormwater utility) could occur through an existing entity such as the Town of Vail or the ERWSD, or through the creation of a new agency such as a water activity enterprise, a water and drainage authority, or an urban drainage and flood control regional service authority. These options are described in Chapter 5 of the WQIP.

There are many potential sources of funding for stormwater projects, educational programs, watershed management and riparian restoration projects. Most of these funding sources however are temporary or based on individual projects and do not provide the stable source of revenue needed to meet long-term requirements for overall program management, implementation of projects, inspection and maintenance, monitoring, etc. Stakeholders must therefore consider potential long-term funding options such as taxes (e.g. real estate transfer tax), impact fees (from new development or redevelopment projects), special assessments, service charges, cost-sharing agreements, and other options.
Conclusions and Recommendations

The WQIP provides a thorough assessment of available information concerning water quality and biological conditions in Gore Creek from the eastern Town of Vail boundary to the confluence of the Eagle River. This assessment identified the key stressors that are the most likely causes of MMI scores below the State established thresholds for healthy macroinvertebrate communities. Water quality improvement measures, including regulatory, education, voluntary and incentive programs along with site-specific projects, have been identified for areas above Red Sandstone Creek. The WQIP also provides preliminary recommendations for prioritization of programmatic and site-specific water quality improvement measures based upon field observations, data analysis and professional judgment of the study team.

The WQIP does not, however, provide cookbook level details for implementation of the programmatic and site specific water quality improvement measures that will be needed to protect and improve stream health in Gore Creek. Previous studies of Gore Creek over the last 25 years have identified many of the same stressors that were found in this investigation, and some of the WQIP programmatic recommendations for water quality improvement measures have been previously suggested. Several of these recommended water quality improvement measures have been implemented or are in the process of being implemented. The WQIP builds on these previous studies by providing a focused compilation of the information needed to thoroughly understand the known aquatic health stressors, and based upon this information it identifies the programs and site specific projects needed to improve aquatic health in Gore Creek. It also suggests management strategies and identifies entities that could assume responsibility for WQIP implementation.
With the State’s adoption of the Aquatic Life Use Attainment Policy (Policy 10-1) and the addition of Gore Creek to the 303(d) List of impaired water bodies, there is regulatory impetus, public support, and political will to move forward aggressively with water quality improvement programs and measures. The Town of Vail has already started to implement regulatory and education programs to protect and restore riparian buffer areas and to limit and better control the use of pesticides. Next steps should include the following:

- Use the guideline and recommendations in Chapter 6 to develop an action plan that identify and further prioritize the site specific projects and regulatory actions identified in the plan with emphasis on the East Vail area;
- Continue to coordinate and fund planning and implementation efforts through the URG and the ERWC;
- Clarify and formalize the management framework needed for effective and coordinated WQIP funding and implementation;
- Continue efforts to formalize and adopt the policy and regulatory programs needed to guide and implement site specific projects and actions such as improved management of the use of pesticides and lawn care chemicals;
- Opportunities for water quality improvements associated with new development and redevelopment should be considered high priority in order to avoid increasing the need for additional corrective actions in the future;
- Continue and refine monitoring programs and implement new data collection efforts where needed to learn more about potential biological stressors and to assess the effectiveness of programmatic and site specific water quality improvement measures;
- Consider additional studies to further investigate and understands the impacts of stressors such as chemical deicers and pesticides;
- Do not delay implementation of necessary water quality improvement measures pending additional studies;
- Consider using the upper reach of Gore Creek from the eastern town boundary to Bighorn Park as a focus area for testing the effectiveness of WQIP programs and measures; and
- Refine strategies and actions in response to the results of the actions listed above based upon adaptive management principles.

Biological impacts associated with the combined stressors identified in the WQIP have evolved over a period of many years and it may therefore take several years before significant and continuing improvements can be observed. The WQIP could possibly be adapted to meet the requirements of the State and EPA for a Category 4b demonstration plan, which, if approved, could result in the removal of Gore Creek from the State’s 303(d) List of impaired water bodies prior to fully achieving the State’s biological use attainment thresholds.