Johnson Environmental Consulting, LLC

EcoMetrics, LLC

A Comprehensive Assessment of Wetland Condition in Cucumber Gulch Preserve, Breckenridge, Colorado.

Report Submitted to the Town of Breckenridge, CO

by
Mark Beardsley, M.S.
Brad Johnson, Ph.D., P.W.S.

10/31/11

Contents

Background 3
Study Area 6
Study Design 7
Methods and Results 10
    Existing information 10
    Extent of wetlands 10
    Wetlands Functional Assessment 16
    Assessment Framework 16
    Catalog of Stressors Affecting Cucumber Gulch Preserve 17
    Evaluation and Rating of State Variables 19
    Evaluation of CGP Landscape Variables 20
    Peak 7 Side Slopes 23
    Upper Cucumber Gulch 33
    Lower Cucumber Gulch 50
Discussion 57
    The State of Wetlands Habitat in Cucumber Gulch Preserve 57
    Management implications 58
        Sediment 60
        Water 61
        Beavers 61
Monitoring Objectives 63
Appendix 1: List of reports 67
Appendix 2: Summarized analysis of past water quality data 70
Appendix 3: Wetlands delineation data sheets 77
Appendix 4: FACWet - List of identified stressors 78
Appendix 5: Photos 86

Background

Cucumber Gulch is located in a northeast trending glacial valley set in the mountains of the Ten-mile Range in Summit County, Colorado (Fig. 1). The site is perched above the Town of Breckenridge ("Town") and below the Peak 7 and 8 areas of the Breckenridge ski resort (Fig. 2)[1]. The gulch bottom and side slopes hold an extensive and variously interconnected complex of wetlands. The steep upper portion of the gulch gradually gives way to a lower-gradient, wider bottomland that supports wetland from one side to the other. Near its bottom, the morainal trough bends to the north and narrows, becoming steeper until it meets the Blue River valley. The change in valley morphology impedes surface outflow causing water to back up and spread across the wide bottom.

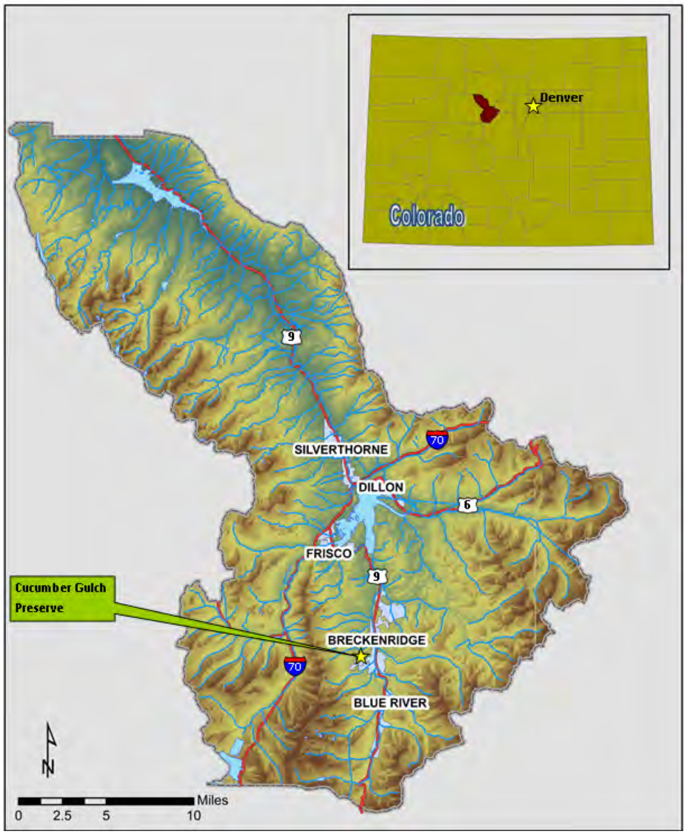


Fig. 1. Shade relief map of Summit County, CO showing the location of the Town of Breckenridge's Cucumber Gulch Preserve in reference to major roads and towns. The inset map shows the county's location within Colorado.

Owing to the significance of its wetlands and aquatic habitats, Cucumber Gulch was designated an Aquatic Resource of National Importance by the U.S. Environmental Protection Agency. The Town, who owns most of the land within the gulch, manages the area as a natural preserve called the Cucumber Gulch Preserve, CGP or "the Preserve" for short (Fig. 3). The preserve's primary management goal, as articulated by the Town of Breckenridge, is to "*maintain the existing high level of biological diversity*". This goal necessarily focuses management on the preservation of natural wetland functioning which by and large supports the desired biological diversity.

---

[1] Note, Cucumber Creek is a separate water body. The confluence of Cucumber Gulch and Cucumber Creek is down-gradient and outside of the study area.

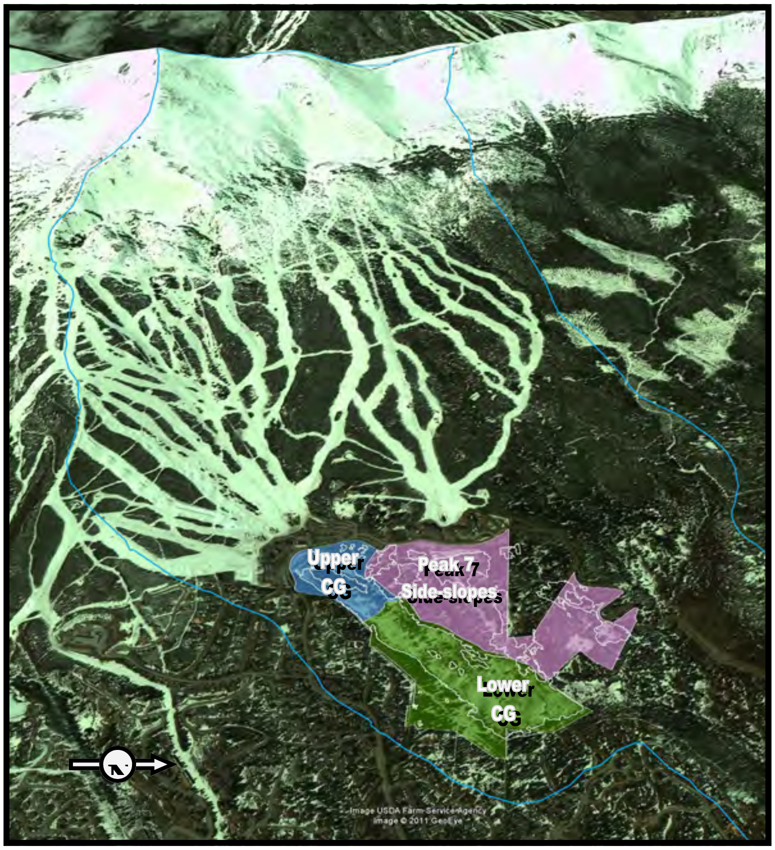


Fig. 2. A Google Earth terrain model showing the Cucumber Creek 12-digit Hydrologic Unit Code watershed (blue line). Shaded polygons identify three assessment units within Cucumber Gulch Preserve. Note that Cucumber Gulch, proper, is fed by the Peak 8 portion of this watershed which is identified by the left group of ski runs that terminate at the Peak 8 base.

Widespread land use change in the Cucumber Gulch watershed makes successful management and preservation of wetland functioning a challenging endeavor. In such a dynamic environment, an adaptive approach is essential to meeting management goals. Thus, an ongoing picture of system health is important for allowing the Town to respond to the often unforeseen impacts of ecological stress that arise from concentrated human activity. To track key parameters of wetland health, the Town of Breckenridge along with Vail Resorts has commissioned planning efforts and monitoring programs, ambitious in both their scope and intensity. Beginning around 1997, a host of investigations have considered essentially every aspect of the natural system, and continuous seasonal monitoring of hydrology, vegetation, wildlife and water quality has occurred since at least 2001.

In 2011 the Town contracted EcoMetrics, LLC and Johnson Environmental Consulting, LLC to develop a synthetic evaluation of CGP's functional condition, or health, based on existing monitoring information and our own site-level survey. An additional goal of the project was to complete a comprehensive mapping of wetland boundaries within CGP. The focus of the functional assessment was to develop a holistic evaluation of wetland health and to use the information to guide future monitoring efforts. Our approach is prescriptive in that we focus first on investigating the signs and symptoms of ecological stress to identify the causes of impairment, or “stressors”. Such an approach was adopted to inform the Town about aspects of the Preserve management program which have been successful, while at the same time identifying aspects that may warrant change based on wetland degradation. Stressors may arise within the preserve, directly as a result of management practices, or they can originate outside of the Preserve in the wetland’s contributing watershed. Our investigation considers both potential sources of ecological stress.

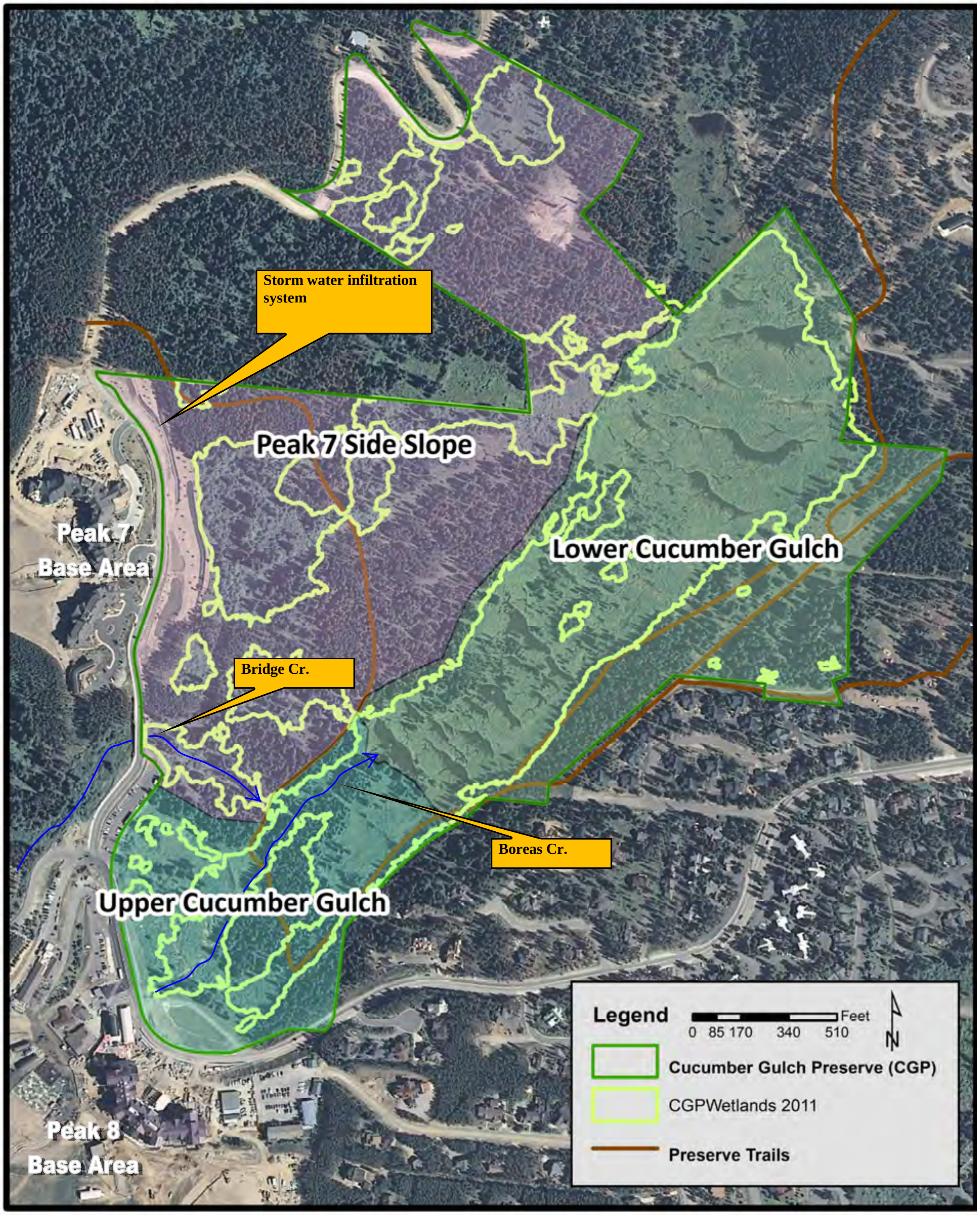


Fig. 3. Aerial image (2009 NAIP) of the Cucumber Gulch Preserve with the three assessment units shaded. Wetland boundaries delineated in 2011 are included for general reference. The Peak 7 base area development is at the left edge of the image above center, while the Peak 8 one is at the lower left corner.

A primary goal of this study is to provide the Town with a catalog of the stressors affecting the preserve, and an assessment of their relative severity and extent. Secondly we note which wetland components are affected by a given stressor, providing evidence of their relative impacts. This information is critical to the successful management of CGP and prioritization of limited management resources, since minimizing ecological stress is an implicit goal of preserve management and the key to effectively maintaining its habitat value.

Our aim in this report is to make the study results readily accessible to the Town and applicable for setting future management objectives, prioritizing improvement or restoration efforts, designing a more efficient and targeted monitoring program, and as a context for understanding the impacts of existing or proposed development projects.

Study Area

The study area includes lands owned by the Town of Breckenridge within CGP (Fig. 3). To increase the resolution of the evaluation, we divided the area into three individual units, based on their location in the watershed (Figs. 2-3). The main valley bottom was divided into two parts: Upper and Lower Cucumber Gulch (Upper CG and Lower CG, respectively). This division is based primarily on the supporting water source in conjunction with longitudinal valley position and predominate surrounding land use. Drainage from the Peak 8 Watershed supplies water to both units of Cucumber Gulch, but in Lower CG, groundwater discharge in the form of numerous springs and seeps plays a larger role in supporting wetland hydrology. The Preserve also includes the northwest side of the Cucumber Gulch valley, generally below Peak 7, which we term the Peak 7 Side Slope ("Peak 7 SS"). Local groundwater discharge feeds most of the wetlands on the side slope; however, a small channel that we call Bridge Creek also supplies the area, as does recharged groundwater and surface water effluent coming from an engineered water distribution system below the Peak 7 Base area.

The Peak 7 SS is characterized as a mosaic of variously interconnected "slope" wetlands (that is, groundwater-supported wetlands in the hydrogeomorphic classification[2]) interspersed with patches of subalpine spruce-fir forest. Where surface connections are lacking, these wetlands tend to be hydrologically linked by subsurface flow. Water exported from the Peak 7 SS wetlands travels down the valley side and into Cucumber Gulch as shallow groundwater and within very small channels. Apparently, the Peak 7 SS section is where the greatest concentration of fen wetlands occurs, but this statement is based on general principles and field observations, since no organic soil or fen mapping is available. Springs and several small old beaver dams maintain limited areas of aquatic pond habitat within the Peak 7 SS.

---

[2] Brinson, M. M. (1993). A Hydrogeomorphic Classification for Wetlands." Technical report WRP-DE-4, U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.

The Upper and Lower CG areas are very old beaver complexes characterized by a high density of ponds interconnected by a system of small distributary channels. Long occupation by beaver has created a terraced configuration in this valley. Upper CG acts as the headwaters of the gulch system and, while predominately supported by surface water from Boreas Creek, the unit contains a number of small seeps and springs. Seeps and springs are particularly important in the southern arm of Upper CG which appears to be almost entirely groundwater supported. The wetlands in the northern arm (including recently dewatered ones) are (or were) supported by a riverine beaver pond complex. Lower CG receives water from both Upper CG and the Peak 7 SS wetlands, in addition to springs that emerge within it. The area is characterized as an extensive beaver pond complex; but in addition to the channels and ponds, there are areas of groundwater-supported wetlands including fens that are fed by tributary shallow groundwater or deep springs. The relative importance of groundwater sources (compared to surface water drainage) appears to increase going from top to bottom through Lower CG.

Cucumber Gulch Preserve has been intensively studied for the past 15 years by hydrologists, ecologists and water chemists, among others, and there is an abundance of information available to the Town in the form of investigative, engineering and monitoring reports. Appendix 1 is a comprehensive list of all the reports supplied to us by the Town for review in this study. The goal of our study is not to describe the detailed characteristics of various habitats, soils, hydrology, water quality, flora, or wildlife except insofar as they are pertinent to the description of stressors or their effects. Such topics are well covered in the sources cited in Appendix 1.

Study Design

Our aim was to synthetically describe the functional condition of CGP focusing on identification and description of ecological stressors and their actions. The Functional Assessment of Colorado Wetlands (FACWet)[3] framework was used to structure our investigation and contextualize the wealth of existing information. Our study adopted a meta-analytical approach, using previous studies to inform a targeted investigation of ecological stressors. This information was then used to guide field-based functional assessment and stressor identification. The Town's information and data archive on the Preserve comprised our reference pool.

With the background of existing studies to guide us, multiple reconnaissance trips were undertaken to familiarize ourselves with the site. This initial process allowed us to focus our data collection efforts on specific parameters that were known or suspected to be problematic or otherwise important, and to eliminate redundancy among the various environmental monitoring efforts on-going in CGP. Specific data-collection methods are described in the relevant portions of the Methods and Results section.

---

[3] Johnson, B., M. Beardsley, and J. Doran. The Functional Assessment of Colorado Wetlands (FACWet) Method: User Manual Version 2.0. Colorado Department of Transportation Research Report.

A delineation and mapping of CGP wetlands was completed following the procedures detailed in the *2010 Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys and Region*. Beyond the obvious habitat mapping information yielded by this task, it also ensured that every wetland area was visited in the field and examined in detail.

Study findings are structured according to FACWet which considers nine wetland "state variables", or ecological forcing factors, that exert primary control over the functioning of wetlands (Table 1).

Attribute	Variable Number	State Variable Name
Buffer & Landscape Context	**V1**	**Habitat Connectivity - Neighboring Wetland Habitat Loss**
	V2	**Habitat Connectivity - Migration/Dispersal Barriers**
	V3	**Buffer Capacity**
Hydrology	**V4**	**Water Source**
	V5	**Water Distribution**
	V6	**Water Outflow**
Abiotic & Biotic Habitat	**V7**	**Geomorphology**
	V8	**Chemical Environment**
	V9	**Vegetation Structure and Complexity**

Table 1. The state variables or ecological forcing factors considered during a FACWet analysis.

FACWet provides a framework within which to systematically describe wetland impairment, creating a forensic, weight-of-evidence approach to conditional assessment. Best professional judgments on variable condition are supported with the available evidence. In the case of CGP, supporting evidence ranges from observational and circumstantial in nature, to quantitative and highly compelling.

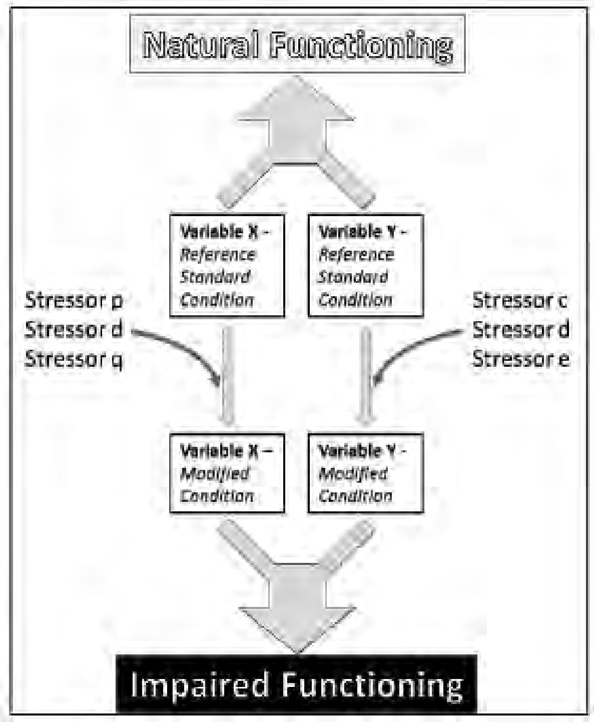


Fig. 4. Conceptual model of the FACWet approach to wetland functional assessment. State variables describe the primary factors driving wetland functioning. Variables in their native state result in functions being performed at natural levels. Human impacts, or stressors, modify state variables which consequently alter wetland function. Wetland systems are assumed to be in reference standard condition and functioning naturally unless there is some evidence of human-caused change, or stress.

According to the FACWet procedure, we assume that if no stressors are present, then the system is functioning at its natural potential (Fig. 4). Where stressors do exist, we describe their impacts to the system and report the cumulative effects in terms of departure from the reference standard or pristine condition. Ratings represent our best professional judgment based on the evidence at hand, including results from monitoring efforts over the past decade, targeted investigation, and first-hand observations. At times the available evidence is inconclusive which engenders judgments with uncertainty, but in many cases we are able to make definitive conclusions. The FACWet structure imparts transparency to evidentiary quality and the reasoning underlying all judgments.

Based on the composite effects of stressors, the degree of departure of each state variable from reference standard condition is categorically rated (Table 2). This categorization can be thought of as a concise narrative description of overall impairment. To aid with intuitive interpretation, FACWet functional ratings parallel the familiar academic grading scale as shown in Table 2.

FACWet Functional Category	Equivalent Academic Grade	Description
Reference standard	**A**	Full natural potential. No significant stressors apparent.
Highly functioning	**B**	Nearly natural potential. Stressors have minimal impact.
Functioning	**C**	Significant stressors apparent, but still functional.
Function impaired	**D**	Diminished functionality due to cumulative impact of stressors.
Non-functioning	**F**	Wetland condition unsupported or threatened.

Table 2. Grading scale used to rate condition of state variables of the wetland in FACWet.

Methods and Results

Existing information

Cucumber Gulch has been the subject of extensive scientific research for more than 15 years, and there is a wealth of data and information about the hydrology, ecology, and water chemistry available. To begin our assessment, we compiled all of the information provided by the Town in the form of study reports and water quality data sets (See Appendix 1[4].) Information we gleaned from these reports was used to help identify stressors and support our evaluation of wetland condition in the rating of specific state variables. We understand that additional relevant reports exist, but this study is necessarily limited to the findings that have been provided to us by the Town.

In addition to the reports from past studies, we were also given a raw dataset containing 23,152 water quality observations made in and around Cucumber Gulch between 1999 and 2010 by ERO, TetraTech, and Dr. Christy Carello. From this overall database, we compiled individual datasets for each of 25 water quality parameters, and organized measurements by sampling location (12 groundwater sites and 30 surface water sites) and by date to plot the trend in each parameter for each site through time. These plots were used to identify baseline values and important trends in water quality within the Preserve. As a summary of this analysis, we prepared a table that lists a general assessment, specific concerns, and recommendations for future monitoring for each of the 25 water quality parameters in Appendix 2. As with the information gathered from reports, the implications of water quality data are discussed below in the evaluation of relevant FACWet Variables. Most of the discussion about water quality results is included in the sections on Variable 8 - Wetland chemical environment.

Extent of wetlands

In July, 2011 we completed a delineation of all the wetlands on Town of Breckenridge property within the PMA (Fig. 3) according to US Army Corps of Engineers protocol[5]. The Town provided a GIS layer of the extent of wetland habitat as mapped by a previous effort, but the methodology used to delineate or map the wetlands for this source is not currently known. The past wetland map was employed as a useful guide to approximate wetland locations and boundary trends. The Preserve possesses a patchwork of wetland and upland habitats, in addition to large contiguous systems such as that of Cucumber Gulch proper. To affect the most complete mapping possible, each previously mapped wetland polygon was visited and its wetland status considered. Areas lacking previously mapped wetlands were surveyed on foot, until the existence of undiscovered wetlands was deemed unlikely.

---

[4] Report citations are included as subscript and refer to the number from the list in Appendix 1.

[5] Corps delineation protocols are found in: 1987 *Corps of Engineers Wetland Delineation Handbook* and the *2008 Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region*.

Boundaries were flagged with labeled nylon ribbon or pin flags at the extent of wetland habitat. No attempt was made to determine the jurisdictional status of any mapped wetland under current federal policy. Six points were sampled using the Corps delineation protocol. Points were sampled to: 1) familiarize ourselves with the specific characteristics of boundary condition, 2) document boundary conditions, and 3) locate the wetland boundary when it was not otherwise readily discernible. Wetland delineation data forms are included as Appendix 3.

Wetland boundaries were surveyed using a mapping-grade, Ashtech Mobile Mapper™ global positioning system (GPS) unit. Rugged terrain and often heavy canopy created difficult mapping conditions. Satellite signal was commonly weaker than that necessary to achieve the optimal sub-meter accuracy throughout the property[6]. Although accuracy could be considerably higher in favorable locations, boundaries should generally be within approximately 2 m of the mapped position. While traditional ground survey methods (such as with a theodolite) could have increased some aspects of map accuracy, others aspects would have suffered, and these methods are also cost prohibitive.

Within expansive wetland complexes of the type found in Cucumber Gulch, small tree islands are commonly imbedded within the wetland matrix. Such islands are generally accompanied by a topographical rise that may lack one or more wetland criterion (*i.e.,* wetland hydrology, hydric soils, or hydrophytic vegetation). In accordance with the goals of mapping for this project, we did not attempt to delineate these features as upland for the reason that these small patches play an integral role in the mosaic of the wetland system. The extent of unmapped "upland" tree islands is approximately 200 sq. ft. (0.005 ac) or less.

Overall, within the approximately 117 ac. Preserve, 51.9 ac. (44%) were mapped as wetland (Table 3 and Fig. 5). We believe this represents the most comprehensive and intensive mapping of the Preserve's wetland habitats completed to date. Insofar as wetland density is concerned, the Lower CG unit contains the highest concentration of wetlands, at 62% of the total unit area. Wetland habitat is the most diffuse (29% of area) in the Peak 7 SS unit where wetlands commonly take the form of distinct patches of habitat, rather than an extensive continuous surface system.

Assessment area	Wetland area in assessment unit (ac.)	Assessment unit size (ac.)	% Wetland
Upper Cucumber Gulch	8.3	18.2	46%
Lower Cucumber Gulch	28.2	45.2	62%
Peak 7 Side Slopes	15.4	53.6	29%
Totals	51.9	117	44%

Table 3. Summary tabulation of the extent of wetland habitat within each assessment unit.

---

[6] The accuracy of the Town's Trimble GPS unit was also evaluated; however, higher performance was achieved with the Ashtech unit.

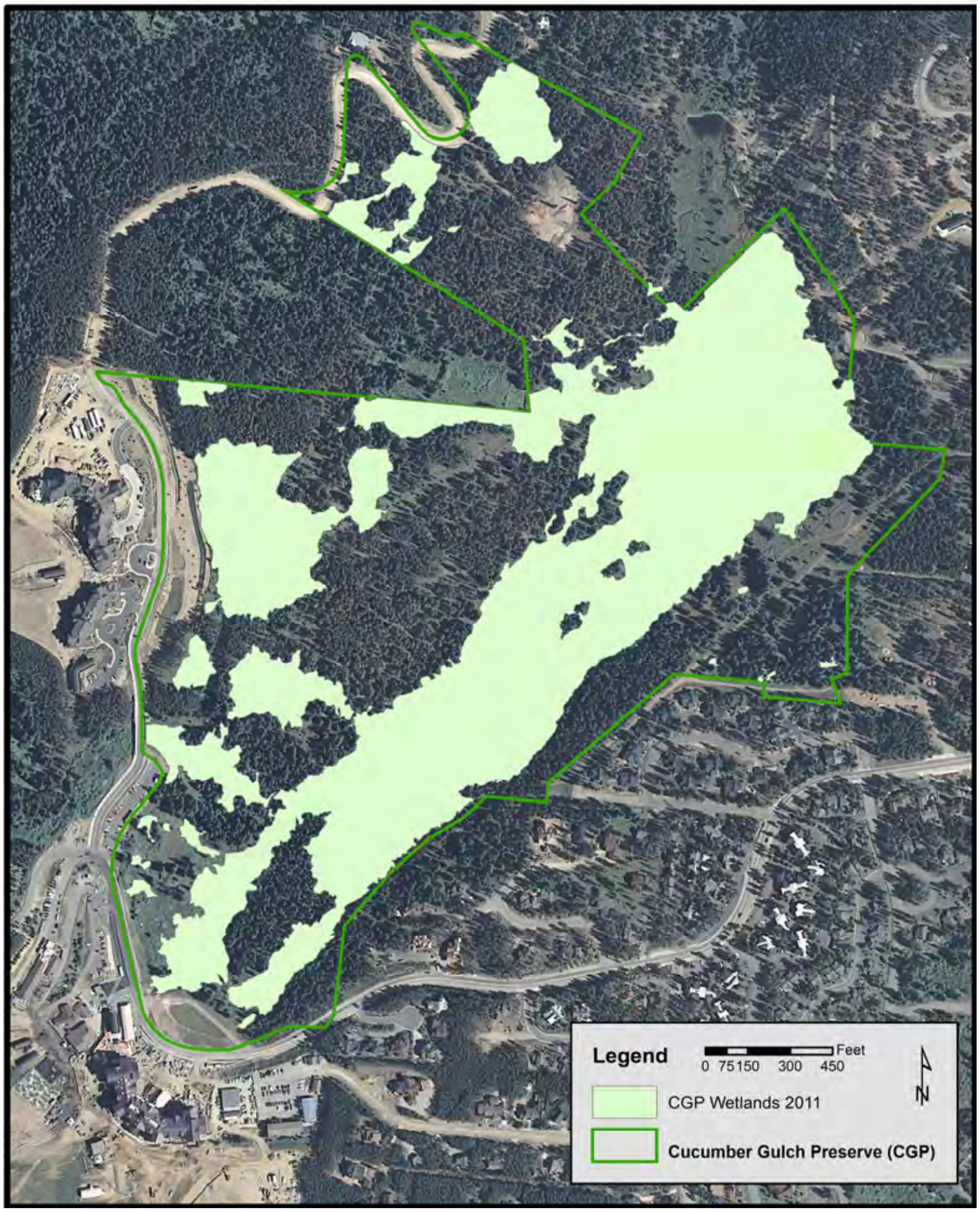


Fig. 5. Overview of the distribution of wetlands within CGP .

The source of the GIS layer, provided to us by the Town, with the previous wetland mapping data was not initially known. Later however, we learned from a 2008 report[25] by Western Ecological Resources, Inc. (WER) that the GIS map appears to be from an original wetland delineation performed by that company in 1997. The specific aims and methods of that study (*e.g.*, on-the-ground vs. aerial interpretation) are not known at the time of this writing. Moreover, upon analysis it became clear that wetland polygons in the GIS file were geographically offset or shifted from their actual positions. It appears that this resulted from a previous “projection” of the data. This shift moved wetlands on the map approximately 60 ft. to the west of their apparent actual locations. Therefore, we manually shifted the 1997 wetland boundary layer to render the greatest correspondence to high resolution geo-rectified aerial imagery and our own mapping. Although this situation creates some uncertainty in precise interpretation, a map of the original 1997 wetland delineation provides an interesting comparison to the boundaries we delineated in 2011. A map comparing these two wetland delineations is presented in Fig. 6.

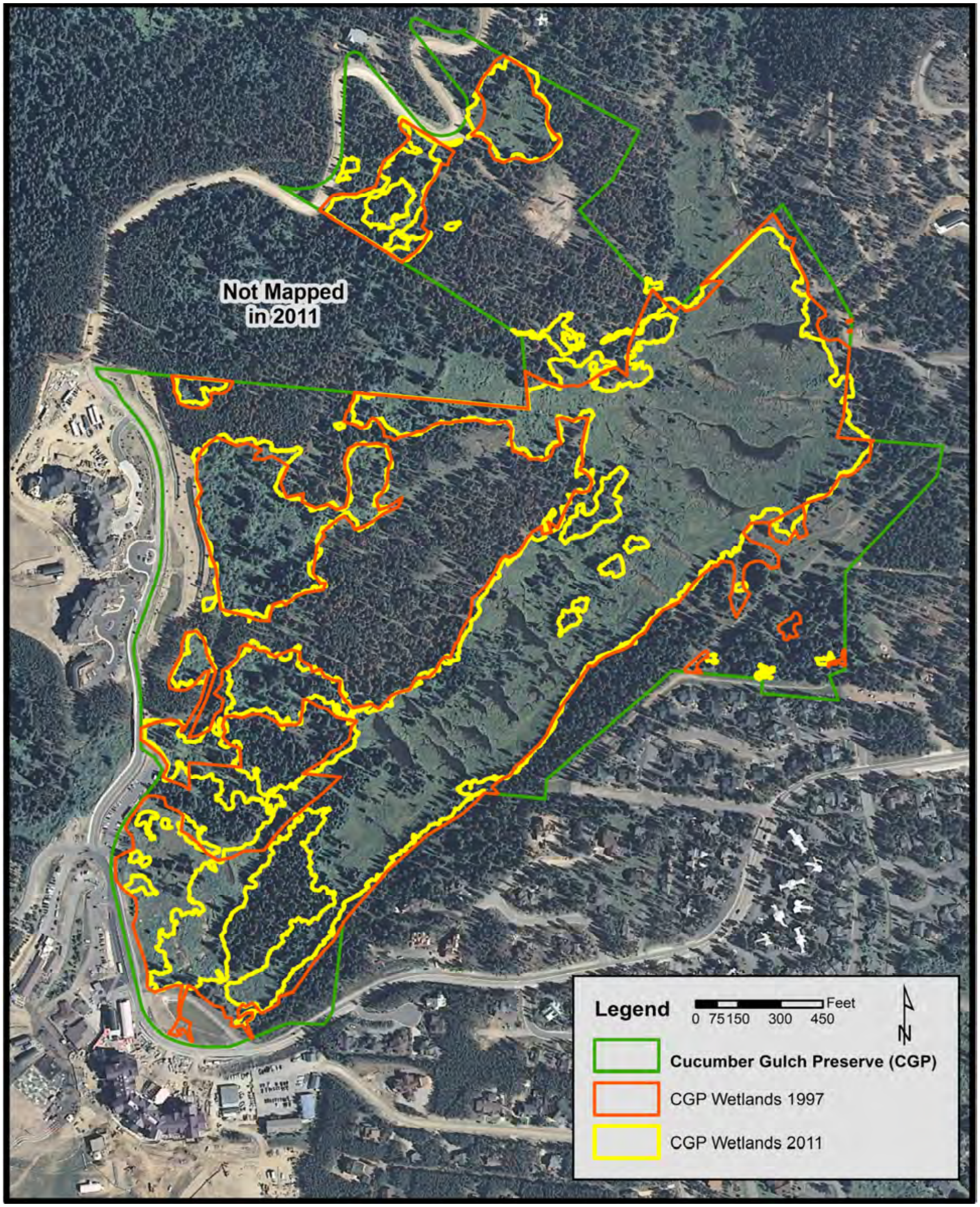


Fig. 6. Map showing the extent of wetlands in the CGP delineated as part of this 2011 study (yellow outline). Previous mapping of wetland extent from a 1997 delineation provided to us by the Town is also shown for reference (orange outline).

Given the uncertainties about the accuracy and precision of past delineation maps, we are unable to provide a precise numerical estimate for the degree of change in wetland extent from 1997 to 2011. Still, visual comparisons between past and present wetland boundaries may be made to identify broader trends in wetland coverage. In general, differences in wetland boundaries between the previous and current mapping can be attributed to: 1) technological advances between 1997 and 2011, 2) presumed differences in methodology, 3) mapping or file errors, or 4) actual physical changes in the extent of wetlands.

For the most part there is good correspondence between the two mappings, although the 2011 map has a much finer resolution than the 1997 map. The 1997 map, however, contains several obvious anomalies and omissions. For instance, in an outlying area south of the main CG wetland, we found that one small patch mapped as wetland in 1997 is actually upland (Fig. 6). We did not observe any obvious relict wetland features at this location or any obvious factor that could have led to the extirpation of the wetland; thus we conclude that the 1997 delineation of this patch is most likely an error. Similarly, the original mapping appears to have missed a large inland of upland habitat between the north and south arms of Upper CG.

In Upper CG, a comparison of the past and present wetland delineations shows an inward movement of the boundary. Based on an overwhelming amount of evidence, the change in the wetland boundary location documents a real phenomenon of wetland recession, rather than an aberration of mapping. The trend in habitat loss is corroborated by the WER 2008 study[25] which revised a portion of the wetland boundary inward based on results from a delineation that they performed in 2007, combined with quantitative monitoring data. Together the 1997, 2007 and 2011 mappings neatly describe an east and southeastward trajectory of wetland recession which spatially follows the terrain and temporally tracks adjacent development activity (Fig. 7). In other words, the wetland has been retreating down valley in step with intensifying land use in the adjacent, up-gradient Peak 8 base area development.

Consistent with the rapid ecological change that is occurring in Upper CG, indicators of wetland conditions were inconclusive in a number of locations near of the western edge of the 2011 delineation (Fig. 7). This is because soils there are either hydric or relic hydric, and because the vegetation typically consists of borderline wetland species that can persist for years on sites that have lost wetland hydrology. Indicators of wetland hydrology were also unclear and hydrologic conditions, in fact, changed markedly throughout the 2011 season in response to the unstable conditions at the head of the gulch. In delineating the wetland boundary we therefore adopted a highly conservative approach. That is, if indicators were indeterminate for an area, we included it as wetland rather than mapping it as being converted to upland. A more precise determination of these “borderline” or suspect wetland areas could be made in the future by installing soil and hydrology monitoring instruments to quantitatively describe soil chemistry and hydrologic conditions on a site-level basis.

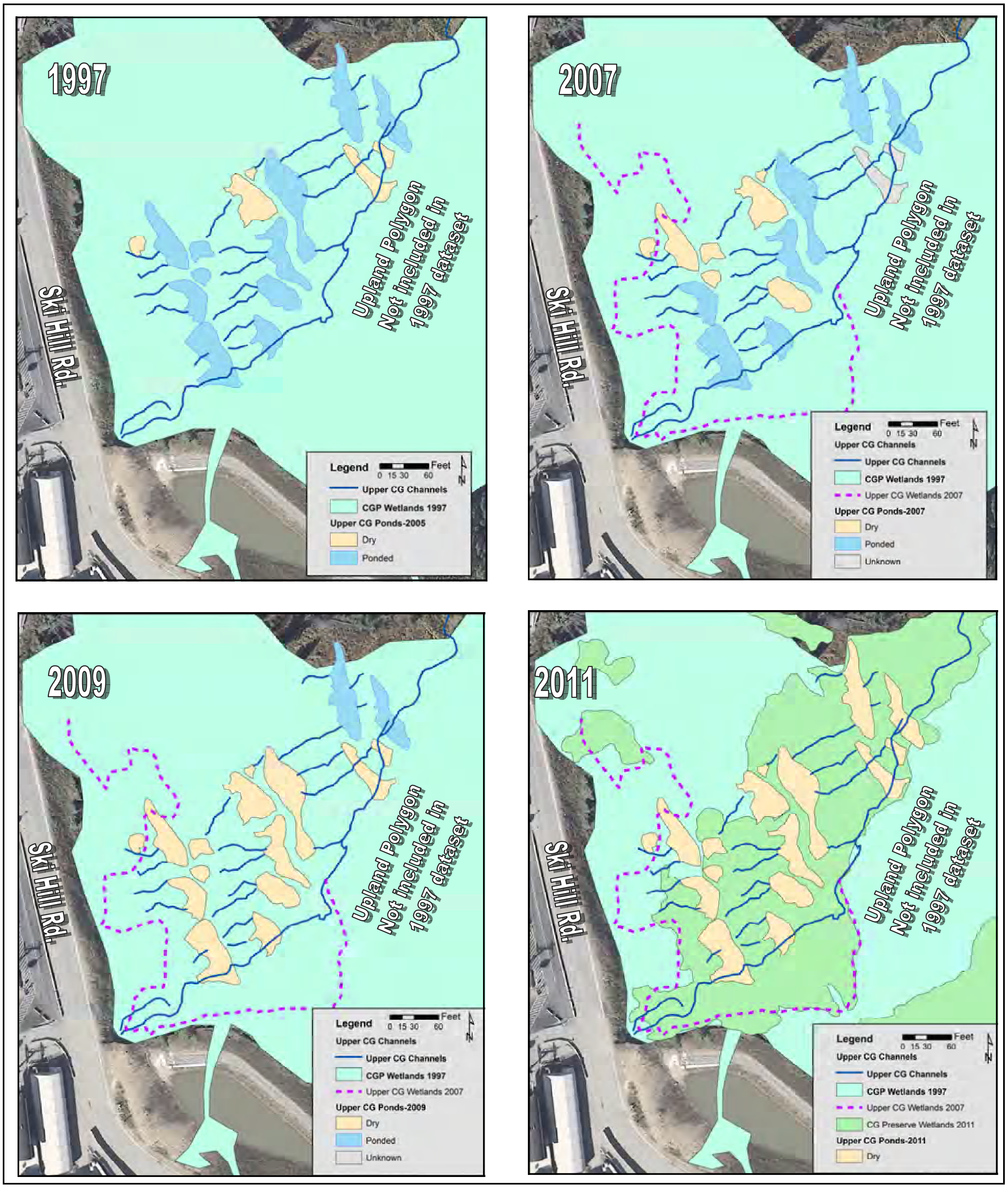


Fig. 7. Time-series illustration showing the sequential drying of beaver ponds in Upper CG along with the inward movement of the wetland boundary. The area labeled as missing 1997 data should be disregarded in terms of wetland boundary changes. We suspect that this area was mapped as upland in 1997 (WER 2008[25]), but we do not have those data. The 2007 line is shown in the lower left panel for reference, but we do not mean to imply that there was no movement of the boundary between 2007 and 2011. Wetland boundaries were not mapped in 2009.

Simple comparison of the conservative 2011 boundary with the 1997 map suggests that wetland losses incurred during this period could amount to as much as 2.5 acres. We must acknowledge that, because of the uncertainties in the original wetlands mapping, this estimate is subject to error, particularly if areas of upland had been lumped into the delineated wetland polygon in 1997 (which seems likely). Nevertheless, signs of wetland retreat at this location are very clear, and 2.5 ac. is the best estimate of the magnitude of this loss given the information available to date. A change of this magnitude (2.5 ac.) would represent the loss of nearly 5% of the total wetland area of the entire Preserve which is clearly substantial. The factors and processes causing wetland loss are discussed in the sections below on the functional assessment of the Upper CG Preserve unit.

Wetlands Functional Assessment

Assessment Framework

According to the FACWet procedure, the Area of Interest (AOI) is the area within which the search for target habitats occurs. For this study the AOI was the Town of Breckenridge property within Cucumber Gulch Preserve (Fig. 2-3). Within the AOI, target habitats (*i.e.*, wetlands) were identified during the delineation phase of the project. These wetlands are called assessment areas (AAs). In this study, we partitioned the CGP into three assessment units based on surrounding hydrology, land use, and predominant physical wetland types present. As described in the *Study Site* section above, these units are Upper and Lower Cucumber Gulch, and the Peak 7 Side Slopes. Within these units, wetlands are relatively homogenous with regard to their ecological type, the stressors present, and their effects on wetland functioning. Where differences do exist, such as at impact “hot spots”, we highlight those in descriptions and figures, but for the most part our evaluations focus on holistic system functioning within each the three units.

FACWet is a method of impact evaluation and description which considers the alterations to a wetland system that impair its ability to function in a natural or characteristic fashion. Thus, FACWet begins with a cataloging of stressors and then secondarily a relation of identified stressors to their effect on the wetland’s State Variables. The assessment portion of the report is organized into the following sections:

1) Catalog of stressors affecting the CGP.
2) Summary of FACWet variable scoring for the individual units of the CGP
3) Evaluation of landscape context of the CGP as a whole (FACWet variables 1-3).
4) Evaluation of hydrology and habitat for the Peak 7 Side Slopes (FACWet variables 4-9)
5) Evaluation of hydrology and habitat for Upper Cucumber Gulch (FACWet variables 4-9)
6) Evaluation of hydrology and habitat for Lower Cucumber Gulch (FACWet variables 4-9)

Catalog of Stressors Affecting Cucumber Gulch Preserve

Based on our reviews of past reports, data and aerial imagery, along with direct observations and site visits, we compiled a catalog of stressors that affect the condition and functioning of CGP wetlands. A list of these identified stressors is provided in Table 4. To aid with the development of future management strategies, it is useful to classify stressors according to the location of their origin; therefore, we have organized stressors into three categories based on whether they emanate from: 1) outside the AOI (exterior stressors), 2) the edge of the AOI (edge stressors), or 3) within the AOI (interior stressors). Stressors also vary in their degree of impact (severity and extent), and in the components of the wetland they affect (*i.e.*, which variables). Appendix 4 provides expanded coverage of this inventory with an assessment of the degree of impact attributed to each stressor, an indication of which state variables are affected by each stressor, and a description of the manner in which impacts are manifested. This catalog of stressors is not exhaustive and we suggest that it be updated and reorganized to take into account future observations and new perspectives.

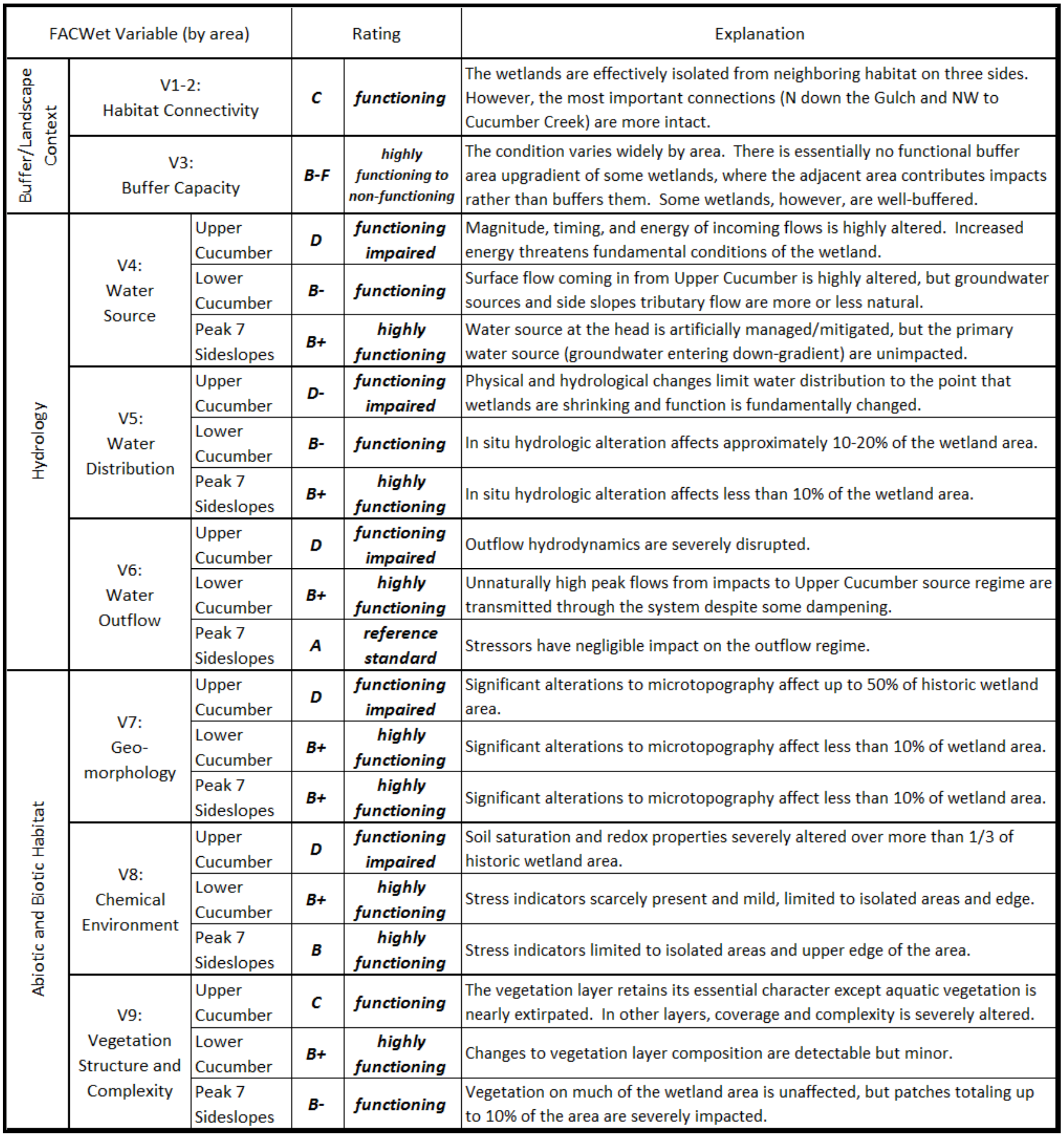
Stressor	**Description**	**Primary Location of effect**
Exterior Stressors		
1. Residential development (Shock Hill to Peak 8 Base)	Residential area (roads, infrastructure, houses, landscaping)	Along the SE flank of Cucumber Gulch within the HCE and BA
2. Peak 8 snowmaking	Water for snowmaking imported from outside the drainage	Throughout Peak 8 watershed area, mostly below tree-line
3. Peak 8 watershed forest clearing	Approx. 40% of forested area of Peak 8 watershed has been cleared.	Throughout Peak 8 watershed area below tree-line
4. Peak 8 ski area/base area drainage	Engineered drainage (roadside ditches, water bars, storm drains, culverts, pipelines, detention ponds)	Peak 8 watershed, especially at Peak 8 base area
5. Peak 8 Base area development	Commercial development	Peak 8 Base area within the drainage at the head of Cucumber Gulch
6. Bridge Creek watershed development	Forest clearing, cul-de-sac road, Old CR3 road alignment, created wetlands, service roads	Drainage area for Bridge Creek between Bergenhoff building and Peak 7 base
7. Bridge Creek channelization	Bridge Creek is artificially straightened and channelized	Bridge Creek channel upstream of Cucumber Gulch
8. Peak 7 snowmaking	water for snowmaking imported from outside the drainage	Throughout Peak 7 watershed area, mostly below tree line
9. Peak 7 watershed forest clearing	Approx. 30% of forested area within the portion of the Peak 7 watershed that feeds Cucumber Gulch has been cleared.	Throughout Peak 7 watershed area below tree line
10. Peak 7 ski area/base area drainage system	Engineered drainage (roadside ditches, water bars, storm drains, culverts, pipelines)	Peak 7 watershed, especially at Peak 8 base area
11. Peak 7 Base area development	Commercial development	Peak 8 Base area within the drainage at the head of Cucumber Gulch
12. Cloud seeding	Cloud seeding generators in use to attempt to increase winter snowfall	Regional

Edge Stressors		
13. Ski Hill Road (P8 base to P7 base) and retaining wall	Major paved road constructed primarily of fill, openings limited to few culverts and one bridge span, hillside below is steep or retaining wall	Along the up-gradient edge of Cucumber Gulch and Peak 7 Side Slopes
14. Stables lot	Paved road parking area with steep retaining wall, storm drain	Up-gradient edge of Cucumber Gulch and Peak 7 Side Slopes
15. Adjacent septic systems	Residential septics adjacent to Preserve	Near Nordic Center
16. Peak 8 Base drainage/detention pond	Dammed impoundment collects flow from base area surface runoff	Up-gradient edge of Upper Cucumber Gulch, below P8 base area
17. Admin drainage/detention pond	Riprap channel and small detention pond collects runoff from parking areas	Below P8 base area below ski area administration buildings
18. Glenwild drainage/detention pond	Riprap channel and two small detention ponds collect runoff from road	Below Glenwild subdivision, edge of Upper Cucumber
19. Peak 7 Base drainage distribution system	System of interconnected detention ponds and infiltration trenches	Below Peak 7 base area at head of Peak 7 Side Slopes area
20. County Road 3 (P7 Base to north boundary of Preserve)	Dirt/gravel improved road	Along the up-gradient edge of Peak 7 Side Slopes, north of Peak 7 base area
21. Historic gullies/deposition	Remnant gullies and deposition fans of large material	Lower north edge of P7 Side Slopes into edge of Lower Cucumber
22. Historic mine shafts and tailings	Remnant mine tailings	Lowest NE edge of Lower Cucumber near Shock Hill
Interior Stressors		
23. Beaver loss	Documented decline in beaver population within the preserve	Beaver activity lost from Upper Cucumber, declined in Lower
24. Sedimentation	Excess sediment deposition	Major sediment deposition fans along channels and in beaver ponds
25. Channel incision	Formation of incised channels from excess scour, active head cuts	Boreas Creek in Upper Cucumber, possible locations in Lower Cucumber
26. Gondola (cleared line and lift)	Forest cleared lift line and operational gondola	Across Lower Cucumber and through Peak 7 side Slopes area
27. Nordic center trails	Maintained nordic center ski trails	Throughout the preserve
28. Foot/bike trails	Maintained and unmaintained foot and bike trails	Within Peak 7 Side Slopes, Upper CG, and Lower CG edge
29. Weeds	Documented weed infestations (multiple species)	Concentrated along fringe of the preserve and the cleared gondola line, but present throughout
30. Elevated salt/ion, nutrient, concentrations	Reported increased salt/ion and nutrient concentrations	Most detention ponds, head of Upper Cucumber, head of Peak 7 Side Slopes

Table 4: Table of stressors identified during the CGP wetland assessment.

Evaluation and Rating of State Variables

The rating of state variables is the core of FACWet assessment. A summary of our ratings for the wetlands in Cucumber Gulch Preserve is given in Table 5 including the functional category and its corresponding academic letter-grade equivalent.



FACWet Variable (by area)			Rating		Explanation
Buffer/Landscape Context	V1-2: Habitat Connectivity		***C***	***functioning***	The wetlands are effectively isolated from neighboring habitat on three sides. However, the most important connections (N down the Gulch and NW to Cucumber Creek) are more intact.
	V3: Buffer Capacity		***B-F***	***highly functioning to non-functioning***	The condition varies widely by area. There is essentially no functional buffer area upgradient of some wetlands, where the adjacent area contributes impacts rather than buffers them. Some wetlands, however, are well-buffered.
Hydrology	V4: Water Source	Upper Cucumber	***D***	***functioning impaired***	Magnitude, timing, and energy of incoming flows is highly altered. Increased energy threatens fundamental conditions of the wetland.
		Lower Cucumber	***B-***	***functioning***	Surface flow coming in from Upper Cucumber is highly altered, but groundwater sources and side slopes tributary flow are more or less natural.
		Peak 7 Sideslopes	***B+***	***highly functioning***	Water source at the head is artificially managed/mitigated, but the primary water source (groundwater entering down-gradient) are unimpacted.
	V5: Water Distribution	Upper Cucumber	***D-***	***functioning impaired***	Physical and hydrological changes limit water distribution to the point that wetlands are shrinking and function is fundamentally changed.
		Lower Cucumber	***B-***	***functioning***	In situ hydrologic alteration affects approximately 10-20% of the wetland area.
		Peak 7 Sideslopes	***B+***	***highly functioning***	In situ hydrologic alteration affects less than 10% of the wetland area.
	V6: Water Outflow	Upper Cucumber	***D***	***functioning impaired***	Outflow hydrodynamics are severely disrupted.
		Lower Cucumber	***B+***	***highly functioning***	Unnaturally high peak flows from impacts to Upper Cucumber source regime are transmitted through the system despite some dampening.
		Peak 7 Sideslopes	***A***	***reference standard***	Stressors have negligible impact on the outflow regime.
Abiotic and Biotic Habitat	V7: Geo-morphology	Upper Cucumber	***D***	***functioning impaired***	Significant alterations to microtopography affect up to 50% of historic wetland area.
		Lower Cucumber	***B+***	***highly functioning***	Significant alterations to microtopography affect less than 10% of wetland area.
		Peak 7 Sideslopes	***B+***	***highly functioning***	Significant alterations to microtopography affect less than 10% of wetland area.
	V8: Chemical Environment	Upper Cucumber	***D***	***functioning impaired***	Soil saturation and redox properties severely altered over more than 1/3 of historic wetland area.
		Lower Cucumber	***B+***	***highly functioning***	Stress indicators scarcely present and mild, limited to isolated areas and edge.
		Peak 7 Sideslopes	***B***	***highly functioning***	Stress indicators limited to isolated areas and upper edge of the area.
	V9: Vegetation Structure and Complexity	Upper Cucumber	***C***	***functioning***	The vegetation layer retains its essential character except aquatic vegetation is nearly extirpated. In other layers, coverage and complexity is severely altered.
		Lower Cucumber	***B+***	***highly functioning***	Changes to vegetation layer composition are detectable but minor.
		Peak 7 Sideslopes	***B-***	***functioning***	Vegetation on much of the wetland area is unaffected, but patches totaling up to 10% of the area are severely impacted.

Table 5. FACWet state variable ratings and summary explanations for the assessment areas of CGP.

In essence, these ratings are intended to provide a very concise narrative description of the condition of each variable. The rationale behind each rating and a discussion of the stressors causing impairment are provided in subsequent sections of this report.

Evaluation of CGP Landscape Variables

Three variables characterize the condition of the landscape surrounding the AA. They consider the landscape setting, first, in terms of its effect on the ability of the AA habitat to freely exchange materials and energy with surrounding wetland and riparian habitats; and second, in the way in which the immediate surroundings of the AA help to maintain or impair its ability to perform characteristic natural functions.

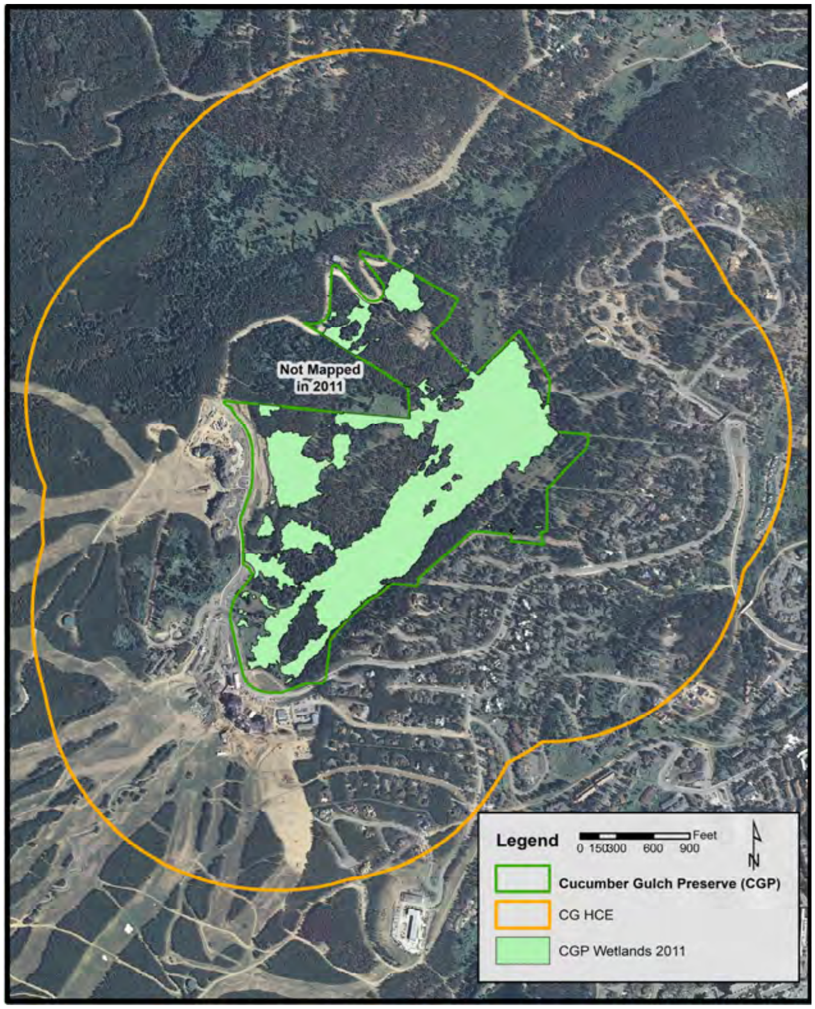


Fig. 8. The Habitat Connectivity Envelope (HCE) around Cucumber Gulch Preserve is identified as the area surrounding it within the orange boundary. Substantial migration and dispersal barriers exist along much of the perimeter of the Preserve. Additionally, development has led to known, but un-quantified, loss of wetland habitat within the HCE. Important connections to neighboring wetlands north (Cucumber Gulch) and northwest (Cucumber Creek) are still intact, however.

V1-2. Habitat Connectivity

Habitat Connectivity considers how links between the AA and its neighboring riparian or wetland habitat have been disrupted, or alternatively how fragmented the habitat has become. We assessed habitat connectivity in CGP by combining the first two FACWet Variables (V1 – Neighboring Wetlands Loss and V2 - Migration/Dispersal Barriers) to make a composite score. When considering migration/dispersal barriers, it is important to take into account the impact to the movement of all types of biota including microorganisms, plants and small animals (including aquatic) in addition to terrestrial macrofauna.

According to the FACWet method, the Habitat Connectivity Envelope (HCE) (Fig. 8) is set 500-meters out from the boundary of the area being assessed, and it is evaluated according to the degree to which the historical habitat wetland/riparian habitat connections have been lost due to habitat destruction or constructed barriers. The Breckenridge ski area, base area, residential development, and roads fill nearly the entire width of the HCE in its up-gradient portion. Given the nature of these land use changes, we assume that this development involved some loss of historic neighboring wetland, but the amount is uncertain and we did not attempt to further quantify such losses. Roads, retaining walls, culverts, and development also pose moderately impermeable barriers to most wildlife between the AA and any remaining wetland habitats that neighbor CGP to the south (towards Peak 8) or east (towards town). Ski Hill Road and the Peak 7 Base area form less severe barriers between the AA and remaining wetland areas on the Peak 7 portion of the ski area to the west.

While most habitat connections to the east, south, and west are disrupted or lost, the largest and most important connections (the downstream continuity of Cucumber Gulch going north) are still viable. And even though there is a culverted road and some development between CGP and the riparian wetlands of the Cucumber Creek drainage, the connection to this area is still largely intact. We must also consider the fact that the wetlands of Cucumber Gulch Preserve are themselves a large interconnected network. The gondola line, Nordic ski trails, and summer biking/hiking trails (and the human visitation that these bring), together with any potential wetlands loss are the only stressors within the AA that cause habitat fragmentation. These within-AA stressors are notable but relatively permeable barriers, so fragmentation within CGP is still minimal. Considering the degree of apparent wetland loss and impacts to habitat connectivity, as offset by the remaining linkages, we rate this variable in the ***functioning (C)*** category; that is, there are significant stressors, but functional connectivity is still largely present.

V3. Buffer Capacity

Variable 3, Buffer Capacity, is concerned with the condition of the area immediately surrounding the wetland. Many stressors originate outside of the wetlands, and the buffer stands between the AA and potential sources of stress, diminishing (or exacerbating) their impacts. An unimpacted and, therefore, functioning buffer holds intrinsic value as quality habitat, but it also has the capacity to attenuate deleterious effects of external land uses on the AA's condition. On the other hand, a poorly functioning buffer may itself negatively impact the condition of the AA by contributing toxic compounds, urban runoff, sediment and other substances that diminish wetland functioning.

In FACWet, the buffer area is defined as a 250 meter wide belt surrounding the perimeter of the AA (Fig. 9). The variable is a measure of the capacity of that area to mitigate deleterious effects of surrounding land use change. In evaluating the condition of the buffer area, the severity, extent and especially the proximity of land use changes to the AA is taken into account.

Some portions of the buffer area around Cucumber Gulch Preserve are severely impacted. In particular, along the west and southwest edge, at the Peak 7 and 8 developments, there is effectively no buffer between development and the Preserve wetlands. Ski Hill Road now runs adjacent to CGP wetland boundaries along its up-gradient edges to the south and west (Photo 1). The Peak 7 and 8 base areas, stables lot and cement retention walls, and all the constructed detention ponds and trenches make up the rest of the inner circle of the buffer area on these sides (Photos 2-3, 11-12, and 14-15).

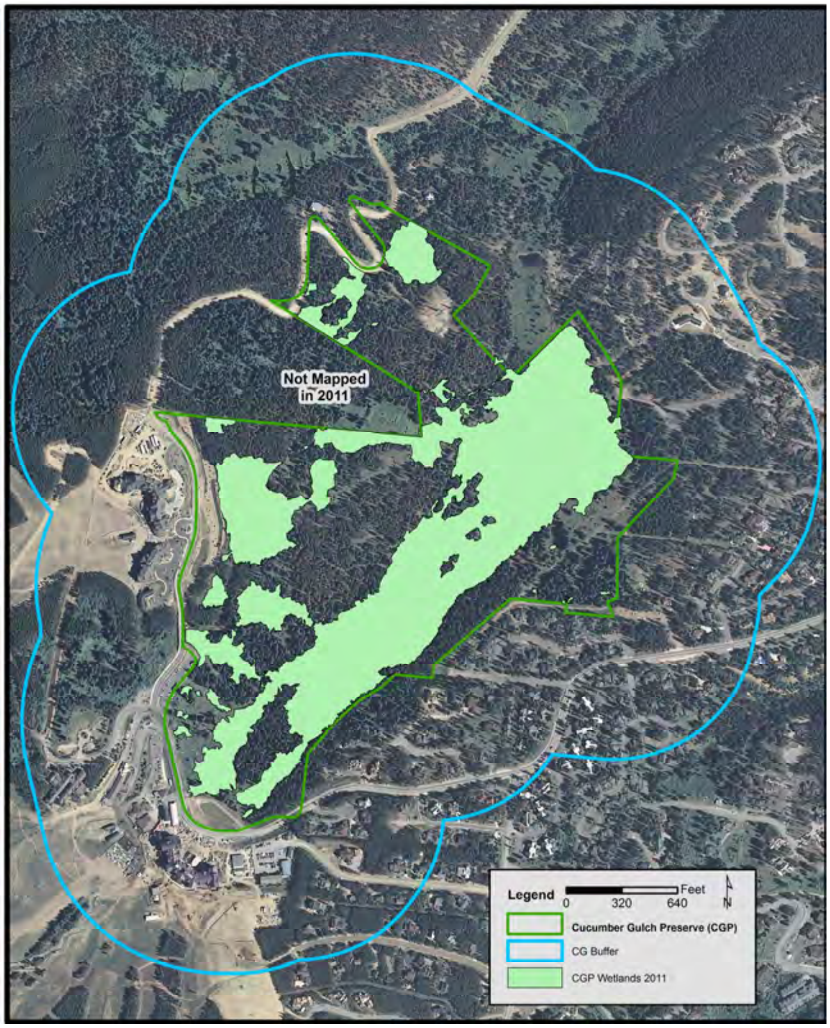


Fig. 9. Buffer area around CGP is the area between the Preserve boundary and the blue line. Much of the buffer area has undergone land use change, particularly up-gradient from the AA, so buffering capacity is often extremely limited.

None of these features (except perhaps the detention pond systems) perform a buffering function for wetlands, and instead they constitute stressors that contribute negative impacts to the AA such as road runoff, sediment, and human disturbance. The detention pond systems apparently function to reduce some impacts such as sediment, but at the same time these structures exacerbate other issues by potentially concentrating dissolved solutes and toxins, for example.

Along the eastern edge, the residential development from Shock Hill to Peak 8 is a moderate stressor on the buffer capacity for most of the width of the buffer area. High levels of human disturbance, impervious surfaces, and lack of native vegetation limit buffering capacity in this area. However, because it is located mostly down-gradient of the AA and because a strip of native upland vegetation is still in place, we surmise that this land use has a relatively small effect on the Preserve wetlands. The only remaining portion of the buffer area that is relatively undisturbed is on the north boundary of CGP.

Given the geographic distribution of impacts within the buffer area of CGP from severe to minimal, buffer capacity varies significantly from place to place. Because of the prevalence of high-intensity land uses along most of the up-gradient perimeter of Upper CG, buffer capacity for this area is rated ***non-functional (F)***. Buffer impacts around Peak 7 are equally severe but less extensive. Only about half of the CGP perimeter along the Peak 7 Side Slopes is severely impacted (along the Peak 7 Base Area) while the rest of the Peak 7 SS has only minor impacts to buffer capacity (north of the base area). Overall, buffer capacity for this area warrants a rating at the lower end of ***functioning (C-) to functioning impaired (D)***. The buffer area around the Lower CG, on the other hand, is rated as ***highly functioning (B)***. Impacts to the buffer area around Lower CG are limited to the moderate stress from residential development on the eastern edge, while the rest of the perimeter is essentially unimpacted.

Peak 7 Side Slopes

Introduction and Summary

The Peak 7 Side Slopes area contains a network of typically steep, groundwater-fed slope wetlands (Fig. 10). In general, these wetlands are in highly functioning or even reference standard condition. The state variables driving hydrology and habitat have few severe stressors. Except for the gondola line clear cut, the interior of the Peak 7 SS is subject to only minor direct negative influences. Likewise, human activity outside the area appears to have little impact on the hydrology and habitat within the wetlands since they are typically fed by a deep groundwater source. Most of the major stressors observed are edge stressors that impact landscape variables. Table 6 depicts the relative magnitude of impact that stressors have on each state variable for the wetlands in the Peak 7 SS unit.

Variable 4 – Water Source

Unlike Cucumber Gulch, proper, the wetlands on the Peak 7 Side Slope area are not part of a major drainage way. Rather, the water source for the wetlands in this area is generally groundwater emanating from a multitude of seeps and springs. Despite the dominance of groundwater as the water source for wetlands, two surface sources were identified: Bridge Creek (a small perennial channel that emerges from the area between Peak 7 and 8; Photo 7) and a new small channel that drains the north end of the Peak 7 storm water infiltration trenches (Photo 5).

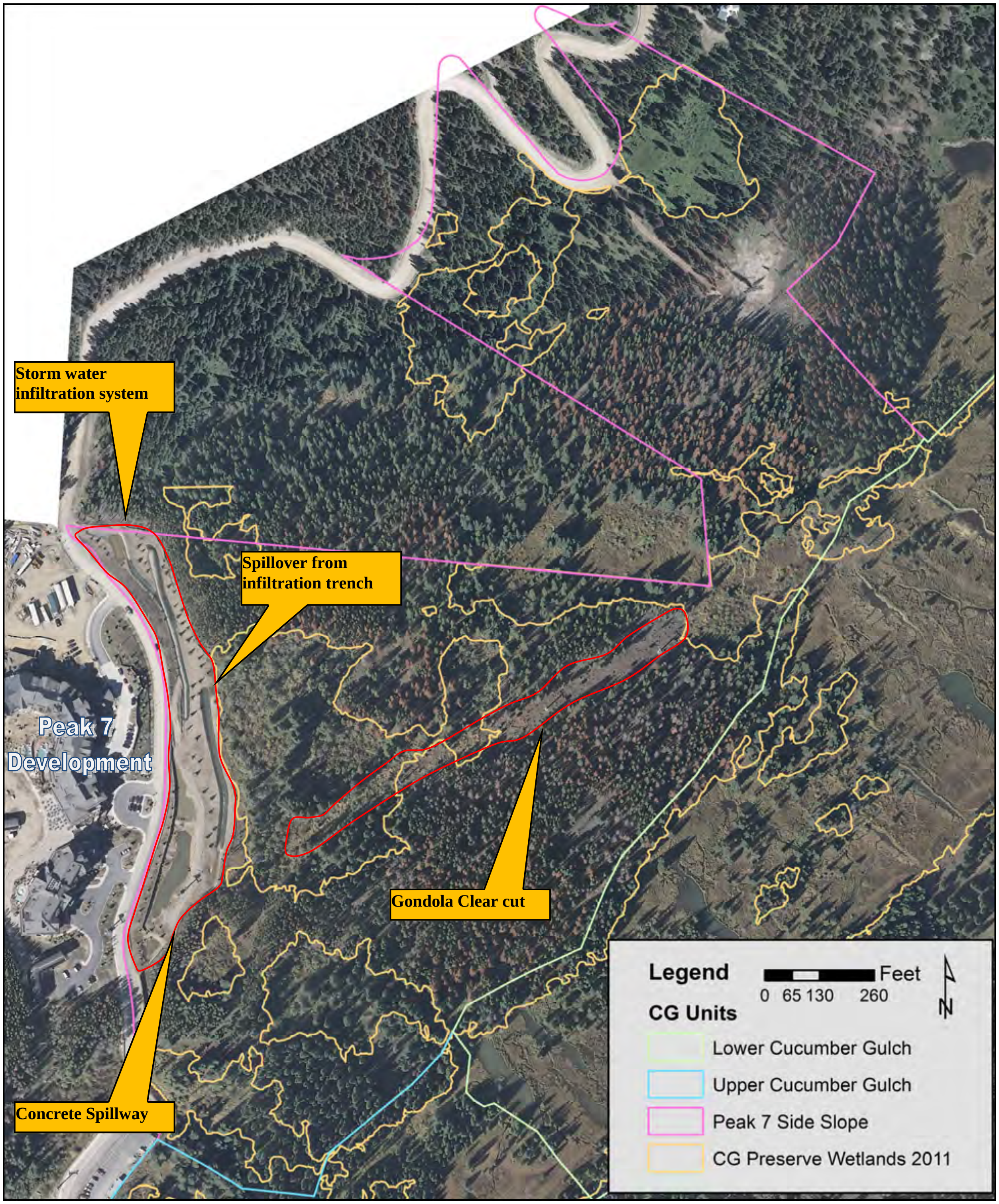


Fig. 10. Peak 7 Side Slope assessment unit.

Peak 7 Sideslopes

stressors and potential impact on wetland state variables

			Buffer/landscape		Hydrology			Abiotic and biotic habitat		
		Stressor	1-2. Habitat connectivity	3. Buffer capacity	4. Water source	5. Water distribution	6. Water outflow	7. Geomorphology	8. Chemical environment	9. Vegetation structure and complexity
external stressors	1	Residential development (Shock Hill to Peak 8 Base)								
	2	Peak 8 snowmaking								
	3	Peak 8 watershed forest clearing								
	4	Peak 8 ski area/base area drainage								
	5	Peak 8 Base area development	▒	▒						
	6	Bridge Creek watershed development	░	░						
	7	Bridge Creek channelization	░	░						
	8	Peak 7 snowmaking			░					
	9	Peak 7 watershed forest clearing	▒	▒	░					
	10	Peak 7 ski area/base area drainage system	█	█	░	▒				
	11	Peak 7 Base area development	██	██	░	▒			▓	░
	12	Cloud seeding			░					
edge stressors	13	Ski Hill Road (P8 base to P7 base) and retaining wall	██	██	░	▒			▒	░
	14	Stables lot	▓	▓	░	▒			▒	░
	15	Adjacent septic systems								
	16	P8 Base drainage/detention pond								
	17	Admin drainage/detention pond								
	18	Glenwild drainage/detention pond								
	19	P7 Base drainage re-distribution system	█	█	█	▒			▓	▓
	20	County Road 3 (P7 Base to north boundary)	▓	▓	▒	▒			░	░
	21	Historic gullys/deposition						░		░
	22	Historic mine shafts and tailings								
internal stressors	23	Beaver loss				░		░		
	24	Sedimentation				░		░	░	░
	25	Channel incision								
	26	Gondola (cleared line and lift)	▒			▒		░	▓	█
	27	Nordic center trails	▒	▒				░		▓
	28	Foot/bike trails	░					░		
	29	Weeds								▒
	30	Elevated salt/ion, or nutrient concentrations							▒	

Table 6. Stressor/variable matrix for Peak 7 Side Slope. Darkness of shading indicates the approximate relative degree of impact.

We found no evidence of major disruption of the groundwater system feeding the Peak 7 Side Slope wetlands. According to hydrogeologist Dr. Ken Kolm (pers. comm.), the primary source of water to this area is a system of springs that follow fault lines delivering groundwater to the system from deep aquifer sources. Our observations corroborate this assertion. Thus we conclude that the primary water source for this area is intact and functioning in accordance with natural conditions. Secondary surface water sources in this unit, on the other hand, have been affected or, in fact, created by stressors.

The contributing area to Bridge Creek includes roads, drainage infrastructure, and forest clearing. The channel form and alignment has been modified to accommodate the switchbacks on old Ski Hill Road. Despite these alterations, the essential qualities of this water source appear to be more or less intact, or at least their effects were not readily detectable within the unit.

To the north of Bridge Creek, Ski Hill Road, the Peak 7 Base area, and its storm water infiltration system (Photos 2, 4-7, and 11) are potentially important stressors to the water source for wetlands in the unit. In general, impervious surfaces decrease infiltration rates and concentrate surface storm runoff, and apparently building foundations within the Peak 7 base area interrupt shallow groundwater flow. But it is our understanding that the Peak 7 infiltration system was designed to mitigate these impacts by collecting storm runoff from the development and using it to recharge groundwater in a series of infiltration trenches. If this system is working optimally, net water input to the wetlands should not differ appreciably from historical, natural levels. Our analysis does not consider the effectiveness of these mitigation treatments, but rather focuses on whether there are detectable impacts that can be linked to the structures.

During our evaluation we saw little indication that the amount, timing, or energetic qualities of the water source have been negatively affected by the galleries or up-gradient development. Numerous springs exist directly below the galleries, and none appeared to be impacted. In a 2010 report, GL&A[12] state that "*groundwater levels down-gradient of the Peak 7 base area lodges have increased on average approximately 2 to 3 feet beginning in 2007 as a result of the redistribution of stormwater and underdrain discharge to the retention ponds and infiltration swales.*" A groundwater rise of this magnitude would constitute a major impact to wetlands if it were expressed at the land's surface. In fact, raising the water table this amount at the surface would totally inundate the wetlands there. At the time of this evaluation no notable surface effects are evident, thus we suspect that GL&A's finding is in reference to some of their deep-screened wells that monitor water tables that do not directly affect wetlands. We found no evidence to suggest that shallow groundwater elevations are significantly changed, at least in the depth ranges that are relevant to wetland hydrology. In the area directly below the infiltration system, field observations indicate that the water table is at or very near the land surface (which is the natural, historical condition). Even a modest rise or fall in the water table would dramatically change surface conditions, and these changes have not been observed.

At the south end of the gallery system there is a patch of wetland that appears to be drying as a result of water source disruption. The drying seems to be associated with the operation of a concrete spillway (Photo 4). Prior to reconfiguration of the gallery system (which was apparently done in 2009 or 2010), the collected water used to spill over the sill. With the reconfiguration, surface water now flows north (into the distance in Photo 4) and spills out the end of the trench (Photo 5). The north spillway is discussed below. While the drying was fairly apparent, the implications are uncertain. Clearly, with the new gallery configuration, the area below the concrete sill is receiving less water than it had been when the spillway was active. On the other hand, considering the wetland mapping, there is a very tight correspondence between the 1997 and 2011 wetland boundaries (Fig. 6), except where we mapped a lobe of wetland extending toward the spillway that is not present on the 1997 map. Thus, it seems plausible, if not probable, that while the drainage structure was active, wetland developed in this area. Then when it was abandoned, the newly created wetland began to recede, which is what we observed.

At the north end of the trench, surface water was seen flowing from the trench into the wetland throughout the summer. Temporary measures have been implemented at the end of this trench to dissipate the surface water and prevent channelization (Photo 5). These measures appear to have been effective during 2011 and so far the flows have not physically cut an identifiable channel. Nonetheless, the trench outlet has introduced a novel water source to the wetland below it. The source is surface water which is a shift from the natural condition which would have been wholly groundwater, and it is particularly concentrated in a narrow band at the top of the site. Further into the wetland, the surface flow dissipates and is lost in the complex microtopography. While negative effects were not observed in 2011, we caution that the system was newly implemented and impacts could develop in the future.

Overall, the water source variable for the Peak 7 Side Slopes area is rated in the ***highly functioning (B+)*** category.

Variable 5 – Water Distribution

The water distribution variable evaluates alteration to the spatial distribution of surface and groundwater, both vertically and laterally within the assessment area. The wetland hydrograph is a quantification of water's distributional characteristics. Alterations to water distributions generally result from alteration of the water source, its outflow from the system (both of which are exterior or edge stressors), or from geomorphic modifications in the interior of the unit.

There are several stressors identified on the edge or within the Peak 7 Side Slopes unit that impact water distribution within the wetlands, but with few exceptions the overall effect appears to be minimal. Given the pattern of groundwater source, the extent of impacts to water distribution from edge stressors (Ski Hill Road, Peak 7 Base, and the drainage redistribution system) tends to be limited to the upper portion of the wetland areas in the vicinity of developments and infrastructure. At the south end of the unit, dispersed flow through the bridge at Bridge Creek appears to be limiting the impact of Ski Hill Road fill to the wetlands at that locale (Photo 7). In the GL&A (2010) report[12], the one shallow monitoring well in this area (PS-7) does not indicate a significant alteration to hydrology.

In a 2009 report, ERO[3] cautioned about potential wetlands impacts downstream of the new bridge. These findings were based on a reported groundwater level decline of 2 feet between May and October 2009 at the ERO-GW5 monitoring point. According to the report, this would have been "*the largest seasonal decline measured in a Cucumber Gulch well during seven years of sampling*," and dewatering of this magnitude would surely be a serious threat to wetland function. To follow up on this potential threat, we visited the site in May 2011, and found the ERO-GW5 well at that site to be functioning improperly. We also installed a new automatic data-logging shallow groundwater well at this site (Photo 8) which has been collecting water table data daily since June 15, 2011. The results (Fig. 11) show a consistent water table within 0.2 ft of the ground surface throughout the season, which is consistent with the GL&A results described above that show no significant impacts at this location. We conclude that the reported water table decline in 2009 can be attributed to error or malfunction.

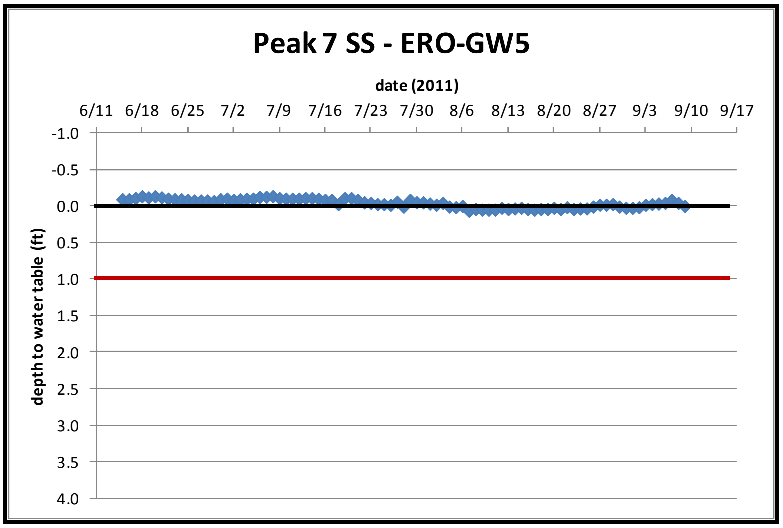


Fig. 11. Hydrograph from the shallow groundwater well at site ERO-GW5 in the Peak 7 Side Slope near the Bridge Creek Bridge and the Stables Lot. The black line is ground surface. Blue diamonds are readings of water table elevation. The red line shows a depth of one ft below ground surface. The water table at this site remained within 0.2 ft of ground surface for the 2011 season. That is, it was perpetually saturated.

Hydrographs from wells in the upper wetland areas adjacent to the Peak 7 base area (PS-8 through PS-14) also do not show any trends indicative of impact (GL&A$_{12}$). However, since the datasets in these reports go back only to 2007, they are not conclusive about changes that occurred prior to this date. Nevertheless, the lack of evidence for an on-going trend in the hydrograph and the lack of apparently drying wetland area are consistent with the idea that water distributional characteristics are generally intact here.

Below the infiltration galleries, water distribution is somewhat impacted by the water source alterations discussed above. During snowmelt, the surface flow emanating from the north end of the south trench could be followed most of the way to the valley bottom. The installation of straw waddles appears to have checked the channel formation and dispersed flow for the time being (Photo 5), however, the wetland still has an augmented hydrograph, even if only in the immediate vicinity of the surface course. North of the Peak 7 base area, the intensity of stressors drops off considerably and may be limited to the impacts from County Road 3 which traverses its upper edge. Given the overall extent of the wetlands here, impacts from this road are probably insignificant.

The one interior stressor of note within the Peak 7 SS is the gondola line. The gondola line is a swath of cleared forest canopy that cuts diagonally through the unit from top to bottom (Fig. 10 and Photo 9). Clearing the canopy here resulted in a loss of shading which causes increased ground temperatures and drying. During our delineations of this area, signs of temperature and drought stress were apparent on wetland plants. It would seem to follow that clearing of trees for the gondola line has, therefore, resulted in a localized decline in water table elevation.

Overall, water distribution in the Peak 7 SS wetlands is ***highly functioning (B+)***; however the areas under the cleared gondola line and along the new surface flow coming from the trenches may be impacted to a greater degree.

Variable 6 – Water Outflow

Alteration of the water source of Bridge Creek and wetlands below the infiltration galleries, is interpreted to augment wetland hydrology. Thus it normally follows that outflow would be similarly affected. In the case of the Peak 7 Side Slope wetlands, the complex groundwater system appears to readily absorb the extra water, and no evidence of outflow alteration was observed, consequently this variable is rated at ***reference standard (A)***.

Variable 7 – Geomorphology

The Peak 7 drainage distribution system is a major recent direct geomorphological alteration; however, it is not clear if it actually altered any wetland area. Further geomorphological stressors within the Peak 7 SS area are few and fairly mild. In addition to a developed foot/bike trail, several Nordic ski trails, and gondola tower bases, we also found evidence of some very old road grades and some historic gullies (mostly north of the gondola line) of unknown origin that impact wetlands at few locations. Wetland areas at the western edge of the unit are also subject to incoming sediment and traction sand, with new deposition plumes observed extending up to 30 meters into the wetlands off of CR-3 road drainage ditches (Photo 10). Given the minimal impact of these stressors and their limited extent, geomorphology within the Peak 7 Side Slopes area is rated as ***highly functioning (B+)***.

Variable 8 – Water and Soil Chemical Environment

Because there has been so much effort towards quantifying the chemical environment within Cucumber Gulch over the past 10 years, we have a great deal of quantitative data to draw upon for assessing chemical environment. Our assessment of this variable, therefore, is based partially on first principles and reasoned cause-effect impacts of stressors, and also on quantitative records of water chemistry parameters (Appendix 2 contains a summary of our analysis of the existing water quality database). Combining these two lines of evidence, we rated each of the chemical environment sub-variables, and combined these to generate an overall rating for the variable. These results are summarized in Table 7.

sub-var. by area		grade rating	observed stressors (indirect indicators of impact)	parameters (direct indicators of impact)
nutrients	UC	B	adjacent landscaping, fertilizer use	slight increase [salts] in upper dried area
	LC	A	adjacent landscaping, fertilizer use	none
	P7	B	adjacent landscaping, fertilizer use algae within source water (infiltration trenches)	[P] and [salts]spikes following P7 base construction
sed./turbidity	UC	C	occasional turbidity within P8 detention pond while spilling, channel instability	sediment deposition plumes, pond-filling
	LC	B	none	sediment deposition plumes, pond-filling
	P7	B	Consistently observed turbidity of surface source water (detention ponds/trenches)	sediment deposition plumes
toxicity	UC	A	adjacent development within buffer	no significant pH or metal toxicity measured
	LC	A	adjacent development within buffer	no significant pH or metal toxicity measured
	P7	A	adjacent development within buffer	no significant pH or metal toxicity measured
temperature	UC	B+	artificial ponds, impervious surface runoff	high water temperatures in detention ponds
	LC	A	none	none
	P7	B-	gondola clearing, ponds/trenches with shallow surface area, impervious surface runoff	temperature stress secondary to canopy clearing, high water temperatures in detention ponds
soil chemistry	UC	D	recent drying of past wetland soils (water distribution), sediment deposition	none
	LC	A	sediment deposition	none
	P7	A	mildly changed surface flows (distribution) impacts saturation	none
OVERALL RATING	**UC**	***D***	***impaired functioning***	*widespread alteration of soil chemistry redox potential due to unnatural drying, sedimentation*
	LC	***B+***	***highly functioning***	*sedimentation, limited extent*
	P7	***B***	***highly functioning***	*suspected temperature stress, nutrient enrichment*

Table 7. Ratings for the sub-variables of chemical environment were made by evaluating both observed stressors and measured parameters. Ratings and indicators are summarized here.

Overall, the chemical environment within the Peak 7 SS is minimally impacted and ***highly functioning (B)***. As seen in Table 5, stressors are minimal in severity and extent for all sub-variables, and each is rated in the ***highly functioning (B)*** category except for toxicity and soil chemistry which are rated as ***reference standard (A)***. Slightly elevated potassium and salt levels at some sites coincident with Peak 7 Base area construction along with observed algae in the infiltration pond effluent were the only observed stressors related to nutrients. We assume that these stressors are minor and temporary, likely being a product of fertilizer from landscaping and revegetation in the developments. The detention ponds and trenches that are part of the Peak 7 base area drainage redistribution system were consistently turbid throughout the season (Photo 11). In addition to the turbid water source, the sediment deposition plumes observed off of CR 3 (see the previous geomorphology section) were also taken as an indirect observation of sediment pollution at this location. The extent of these impacts, however, is minimal compared to the expanse of the wetlands. No significant signs of toxicity stress were observed in the field or in the water quality database. Temperature stress is the most significant impact to wetland chemical environment here, as witnessed by the high temperatures of source water in the detention ponds and trenches as well as observed temperature stress in plants under the recently-cleared gondola line. Finally, soil chemistry is probably only minimally impacted from slight changes to saturation related to water distribution.

Variable 9 – Vegetation Structure and Complexity

The most significant direct impacts to wetland vegetation in Cucumber Gulch are seen in the Peak 7 SS unit. The Gondola Path passes through the largest wetland areas in the unit, and in 2006 the tree canopy layer was completely removed. Construction also caused significant ground disturbance which affected all the other vegetation strata (shrub and herb) requiring extensive revegetation efforts which were apparently effective at establishing a new base herbaceous layer within the cleared line (see Carello's reports 2007-2010[2-5]). In addition to these direct impacts to vegetation structure and complexity, the gondola line also introduces some long-term secondary impacts to vegetation including temperature stress and increased evaporative loss due to the loss of shading layers, introduction of weeds and exotic species, increased ground disturbance and a dramatic change in light regime.

The other recent direct disturbances to wetland vegetation include the construction of the Peak 7 storm drainage infiltration system, clearing for Nordic ski trails (both of which affect all vegetation layers), and bike/foot trails (which impacts the herbaceous and shrub layers). Historically, old road grades north of the gondola and the gully/deposition areas at the lower north end may have impacted wetland vegetation at a few locations.

Weed surveys indicate several locations adjacent to or within the wetland system where weed issues were present. Within wetlands, "*Canada thistle and dandelions are flourishing in the deforested area under the gondola*" according to Carello 2010[2]. Adjacent to the wetland at its head, she reports that field pennycress, alfalfa, yellow sweet clover, oxeye daisy, dandelions, and Canada thistle are present, and in some cases encroaching to within the wetlands (Photo 12). Despite these issues, vegetation structure and complexity for the Peak 7 Side Slopes wetlands is otherwise largely intact and supporting characteristic vegetation. The variable is rated at the lower end of the ***highly functioning (B-)*** category.

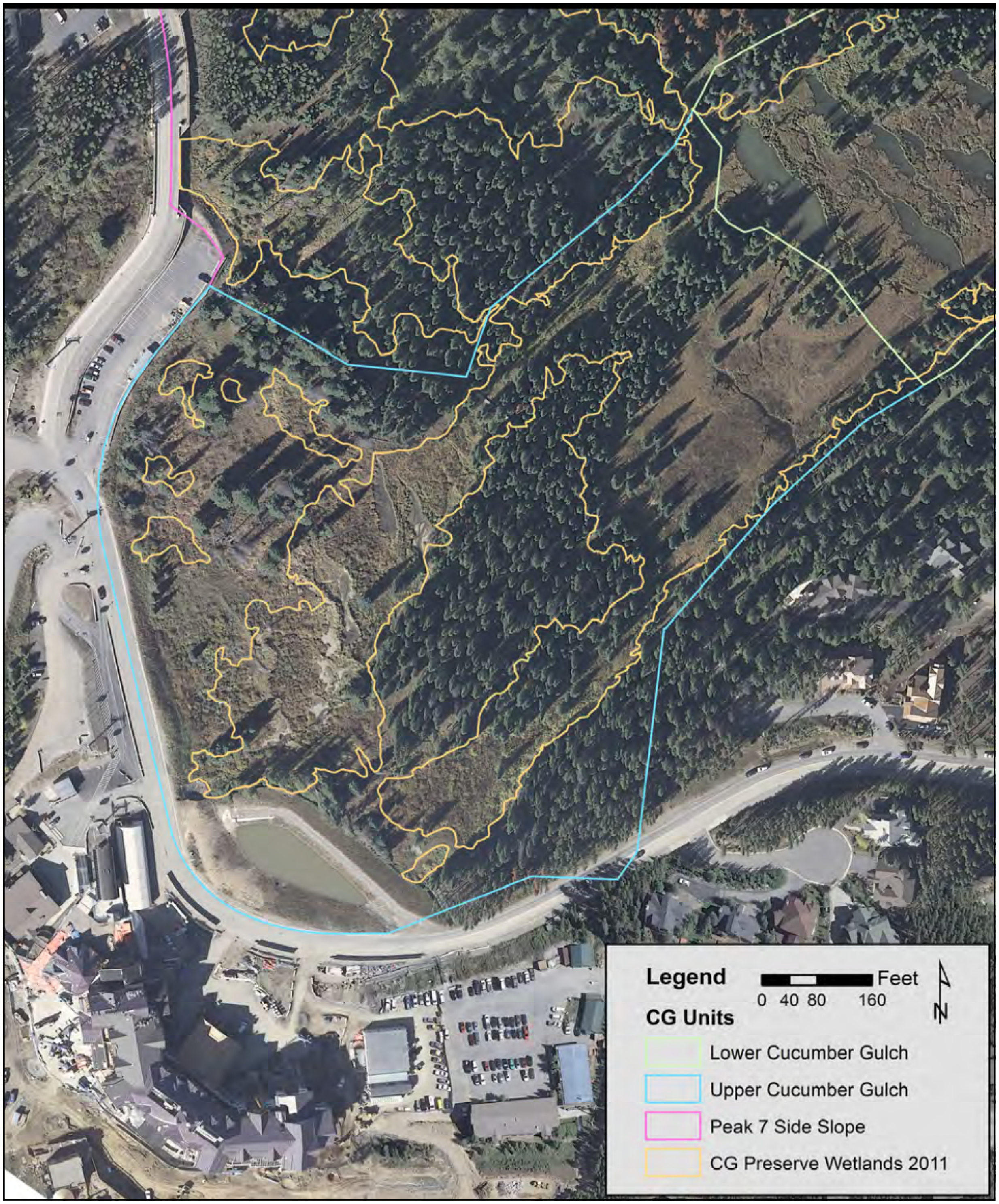


Fig. 12. Upper Cucumber Gulch is comprised of two wetland arms which come together in the lower portion of the unit. The north arm contains Boreas Creek which transports the majority of the runoff from the Peak 8 watershed and is a highly impacted, surface water system that was formerly maintained by beaver. The south arm is primarily a groundwater, spring-sourced slope wetland with fewer impacts.

Upper Cucumber Gulch

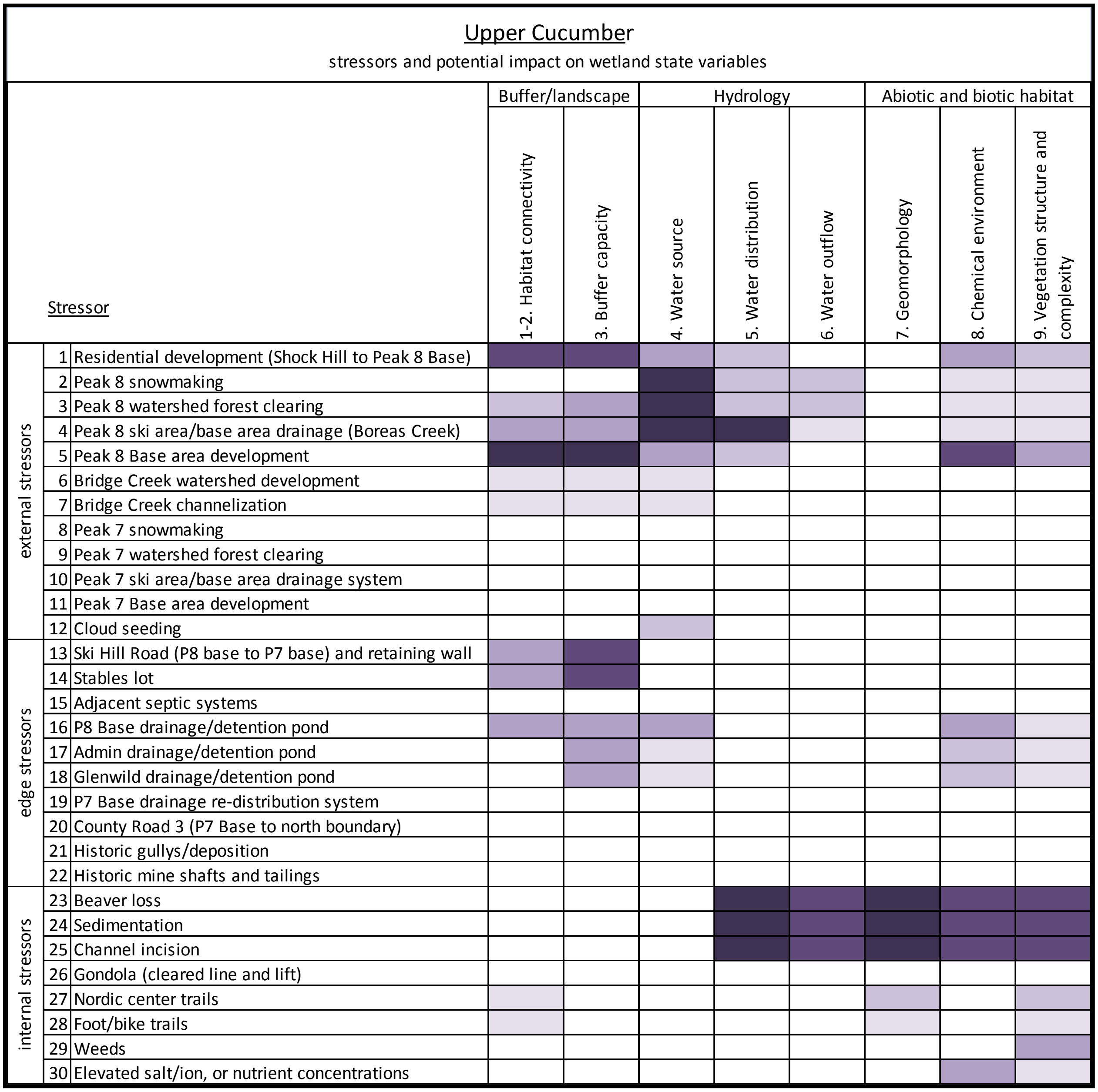
Introduction and Summary

Upper Cucumber Gulch is comprised of two wetland arms which conflux in the lower portion of the unit (Figs. 2-3, and 12). The Upper CG unit ends at the start of the interior pond system, at the up-valley shoreline of the beaver pond known as the “reset pond”. The southern arm is groundwater fed, and is in generally good functional condition, with minor stressors such as trails, urban water inputs, and adjacent disturbance. Below the pinch-point in the wetland (to the NE), the wetland width expands abruptly, stressors diminish, and the wetland appears to be in near reference standard condition.

The north arm, on the other hand, begins as a riverine system. It is fed by Boreas Creek which drains the Peak 8 watershed. This area is experiencing an on-going, rapid ecological shift from a beaver-maintained, terraced pond system, to a cascading single thread channel system. Geomorphological trends include channel incision, sediment mobilization, transport, down-gradient deposition, and dewatering of outlying areas. In our assessment we consider systemic changes such as these to be significant impacts since the management goal for the preserve is to maintain the habitat characteristics of the site which, in the case of Upper CG, has historically been beaver pond complex. Consequently, our assessment takes the former ponded configuration of the area to be the reference standard, or benchmark of comparison. The reference gives context to ecological description and variable rating by providing a standard from which the level of departure can be measured. Regardless of the reference standard used, our analyses can be viewed as an interpretation of the recent and on-going processes that are occurring in the north arm of Upper CG. Table 8 depicts the relative magnitude of impact that stressors have on each state variable for the wetlands in the Upper CG unit.

Variable 4 – Water Source

The water source for the north arm of Upper CG has been highly altered from its natural state and the stressors underlying the changes result from both watershed-scale land use changes, as well as local site modifications. It is clear from a number of lines of evidence that human activities within the Peak 8 watershed directly impact the quantity, timing, and energetic characteristics of water flow into Cucumber Gulch and are thus seen as significant stressors to the wetland system (Photo 13). To our knowledge, there has been little quantitative characterization of the cumulative effects of land use changes, development and infrastructure on the Upper Cucumber Gulch water source. Consequently, most of the discussion below is based on our interpretation of the situation from first principles and direct observation.



Upper Cucumber

stressors and potential impact on wetland state variables

		Stressor	Buffer/landscape		Hydrology			Abiotic and biotic habitat		
			1-2. Habitat connectivity	3. Buffer capacity	4. Water source	5. Water distribution	6. Water outflow	7. Geomorphology	8. Chemical environment	9. Vegetation structure and complexity
external stressors	1	Residential development (Shock Hill to Peak 8 Base)	▇	▇	▓	▒			▓	▒
	2	Peak 8 snowmaking			█	▒	▒		░	░
	3	Peak 8 watershed forest clearing	▒	▓	█	▒	▒		░	░
	4	Peak 8 ski area/base area drainage (Boreas Creek)	▓	▓	█	█	░		░	░
	5	Peak 8 Base area development	█	█	▓	▒			▇	▓
	6	Bridge Creek watershed development	░	░	░					
	7	Bridge Creek channelization	░	░	░					
	8	Peak 7 snowmaking								
	9	Peak 7 watershed forest clearing								
	10	Peak 7 ski area/base area drainage system								
	11	Peak 7 Base area development								
	12	Cloud seeding			▒					
edge stressors	13	Ski Hill Road (P8 base to P7 base) and retaining wall	▓	▇						
	14	Stables lot	▓	▇						
	15	Adjacent septic systems								
	16	P8 Base drainage/detention pond	▓	▓	▓				▓	░
	17	Admin drainage/detention pond		▓	░				▒	░
	18	Glenwild drainage/detention pond		▓	░				▒	░
	19	P7 Base drainage re-distribution system								
	20	County Road 3 (P7 Base to north boundary)								
	21	Historic gullys/deposition								
	22	Historic mine shafts and tailings								
internal stressors	23	Beaver loss				█	▇	█	▇	▇
	24	Sedimentation				█	▇	█	▇	▇
	25	Channel incision				█	▇	█	▇	▇
	26	Gondola (cleared line and lift)								
	27	Nordic center trails	░					▒		▒
	28	Foot/bike trails	░					░		░
	29	Weeds								▓
	30	Elevated salt/ion, or nutrient concentrations							▓	░

Table 8. Stressor/variable matrix for Upper CG. Darkness of shading indicates the estimated relative degree of impact.

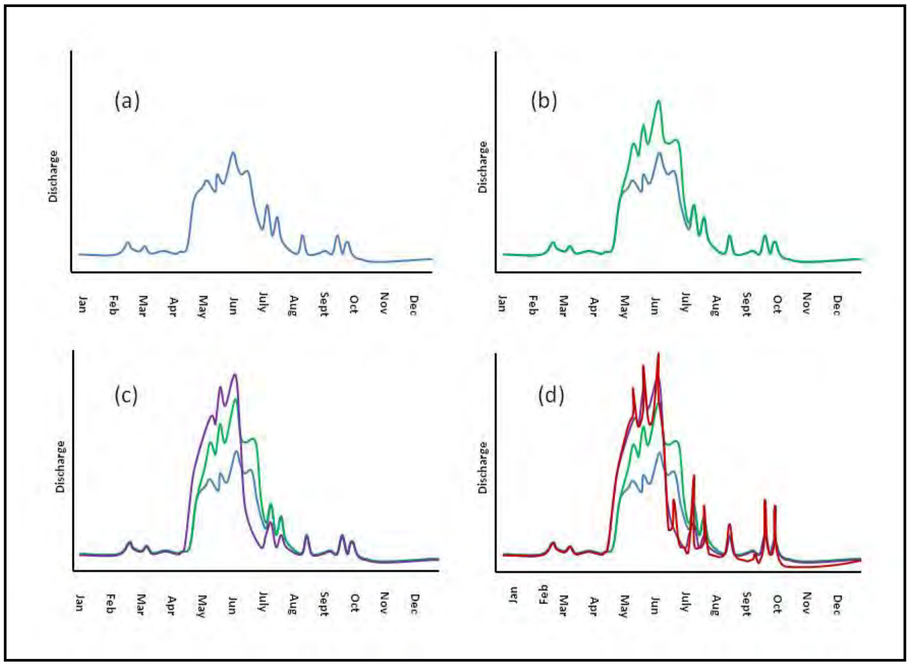


Fig. 13. Diagrammatic representation of inferred hydrograph shifts to the water source for Upper CG using a hypothetical hydrograph to show expected impacts of stressors. (a) A natural hydrograph would have the bulk of water entering the system during the snowmelt period, with more acute peaks from rainstorms and spates. (b) Augmentation from snowmaking would increase the discharge to the site during the snowmelt period. The area between the curves is the volume of water added to the system. (c) The effects of forest clearing on snowmelt would be to compress the same amount of volume released from snowmelt to a shorter, and probably earlier, portion of the season. (d) Decreased infiltration and surface runoff from impervious surfaces would make the hydrograph flashier. The difference between the blue and red curves represents the cumulative impacts from these sources. Actual hydrographs and changes have not been measured quantitatively.

Snowmaking began on Peak 8 in about 1997 and is now applied over a large percentage of the watershed area below tree line. An unknown, but substantial, amount of water is brought into the watershed during the fall and winter and applied to the slopes as artificial snow. When this bolstered snow pack melts, it constitutes a direct augmentation of the amount of water that flows into the gulch. The timing of augmented flows from snowmaking are coincident with the snowmelt period (typically May-June, though it varies by season) which is when the magnitude of inflows to the Gulch are greatest and when there is the greatest probability of spike flows and floods. By increasing the magnitude of flows at this critical time, the stressor also directly increases energy of incoming water. The net result on the hydrograph is that it is shifted upwards during the early-season snowmelt period (Fig. 13 a-b).

Forest clearing is another watershed-level stressor that is generally known to impact the timing and energy of flows. Approximately 40% of the below-tree line portion of the Peak 8 watershed has been cleared. Because snow melts more rapidly on cleared areas, forest clearing has the effect of releasing water from the snowpack over a shorter period of time which effectively increases the magnitude of discharge during the snowmelt period (and its energy) while decreasing flows later in the season (since less of the snowpack lingers in forested areas). The result is augmented flows early in the season with greater peaks and higher energy in the form of stream power, with relatively depleted flows later in the season when the system has limited water supply (although note that with snow making augmentation, it is unclear if water inflow to the gulch is ever depleted relative to natural conditions). The result of forest clearing is that the hydrograph is shifted upwards during the snowmelt period, and downwards later in the season (Fig. 13 a-c).

A third watershed-level stressor involves the cumulative impacts of changes to drainage patterns within the watershed. The flow of water from snowmelt or rain through the watershed system has been highly altered by roads, ditches, water bars, fill, compaction, infrastructure, impermeable surfaces, forest clearing, drains, diversions, culverts, and pipelines. There is reduced infiltration, sheet flow and small rivulet activation, as flows are captured and moved along water bars, ditches and pipelines. The net effect of this artificial drainage pattern is presumably a more rapid and efficient transfer of water through and out of the upper watershed, which results in a flashier hydrograph, where the peaks and valleys are both more extreme (Fig. 13 a-d). That is, more water is introduced to Upper Cucumber Gulch in pulses that cause higher magnitude but shorter duration peaks. Such flashy peak flows would significantly increase stream power at critical times.

Turning attention from the watershed to the edge of the Preserve, Ski Hill Road, the Peak 8 base area and the water collection and distribution system that support these stand as potential stressors to water source. A water collection system captures flows from the watershed above the development and routes it underneath Ski Hill Road in a single 48 in. culvert, to emerge in Cucumber Gulch as Boreas Creek (Photo 14). Concentrating watershed discharge in this manner greatly increases its energy, and moreover focuses it at a single locale, thereby greatly elevating its sediment transport, erosion and scour capability.

The road and development have also brought acres of impervious surfaces (roofs, paved lots, roads) within the wetland buffer area which again decrease infiltration in favor of rapid surface runoff. Without adequate storm-water control, these factors would be expected to exacerbate the flashiness of the water source hydrograph. It appears that most of this runoff is successfully captured in a large holding pond located below Ski Hill Road (Photo 15). The degree to which this pond offsets the impacts of the Peak 8 base area on the hydrograph of Cucumber Gulch's water source is not known; however, any wetland degradation we observed did not appear to be associated with the detention pond.

Upper Cucumber Gulch receives an overwhelming amount of its source water from the Peak 8 Watershed flowing through the Peak 8 base area development. The cumulative impacts of these stressors, or alterations to this system, indicate a water source that is highly impaired. The source is clearly augmented in a way that creates greater inflow during the snowmelt period and elevates the potential for disproportionately high peak flows. Given these alterations to magnitude and timing of inflow, combined with the concentration of inflows to one culvert, we conclude that incoming stream power and the potential for erosion and scour must be greatly increased, and evidence for this is seen in the eroding and down-cutting Boreas Creek channel (see below for further discussion). Based upon these qualitative observations of stressors, our assessment is that the water source to Upper CG is in the ***functioning impaired (D)*** category. It is important to note that this score is heavily weighted by the conditions seen in the north arm. The water source in the south arm approaches reference standard condition, with stressors limited to augmentation by surface flow from a few minor urban drainages and some impervious surfaces. Further study could be aimed at actually quantifying the degree to which water source has been altered by gauging flows at the various inlet points and other means.

Variable 5 – Water Distribution

Water distribution in the northern branch of Upper Cucumber Gulch has been severely affected by the altered characteristics of the water source, its resultant effects on geomorphology, and secondarily by the abandonment of the area by beavers (Photos 16-17). The fact that dramatic changes to distribution have occurred and appear ongoing is demonstrated by the mapped shift in the wetland boundary (described earlier), hydrologic monitoring data, the pattern of pond extirpation (tracked on aerial photographs; Fig. 7), and direct observation of dewatered habitat. Below, we first summarize the evidence supporting the assertion that the wetland in Upper CG has been drying. We then briefly summarize the area's previous water distributional characteristics which serve as the reference for our evaluation, and finally we discuss the stressors and mechanisms that apparently have been driving the dewatering.

Summary Evidence of Habitat Drying in Upper CG

The effects of augmented inflows, more extreme peaks, and concentration within the Boreas Creek channel are evident in the direct observation of excess scour and channel erosion that has been documented on the reach of Boreas Creek within Upper CG. In fact, the mere presence of a single-thread stream channel through this reach appears to be a recent development (Fig. 14).

Water table monitoring data quantify the chronosequence of water distribution impairment within Upper CG (Table 9). GL&A[12-19] have been monitoring water table in Upper CG at 3 deep wells (P-11, P-18R, and P-19R) and 4 shallow wells (PS-1, PS-2, PS-3, and PS-4). All of these monitoring wells are within the previous wetland boundary (their locations within delineated wetland habitat are shown in the GL&A or DG&A reports[12]), yet none of them recorded wetland hydrology by 2010. For those wells with long enough datasets, it is possible to identify the season during which the drying took place (Table 9).

Sequential aerial photograph analysis, report interpretation and contemporary mapping provide a second record of the sequence of drying (Fig. 14). We used mapping-grade GPS to outline of all the pond features we could identify in Upper CG. Using ArcMap 10, we superimposed the pond polygons on 2005, 2009 and 2010 color aerial photography to track pond extirpation.

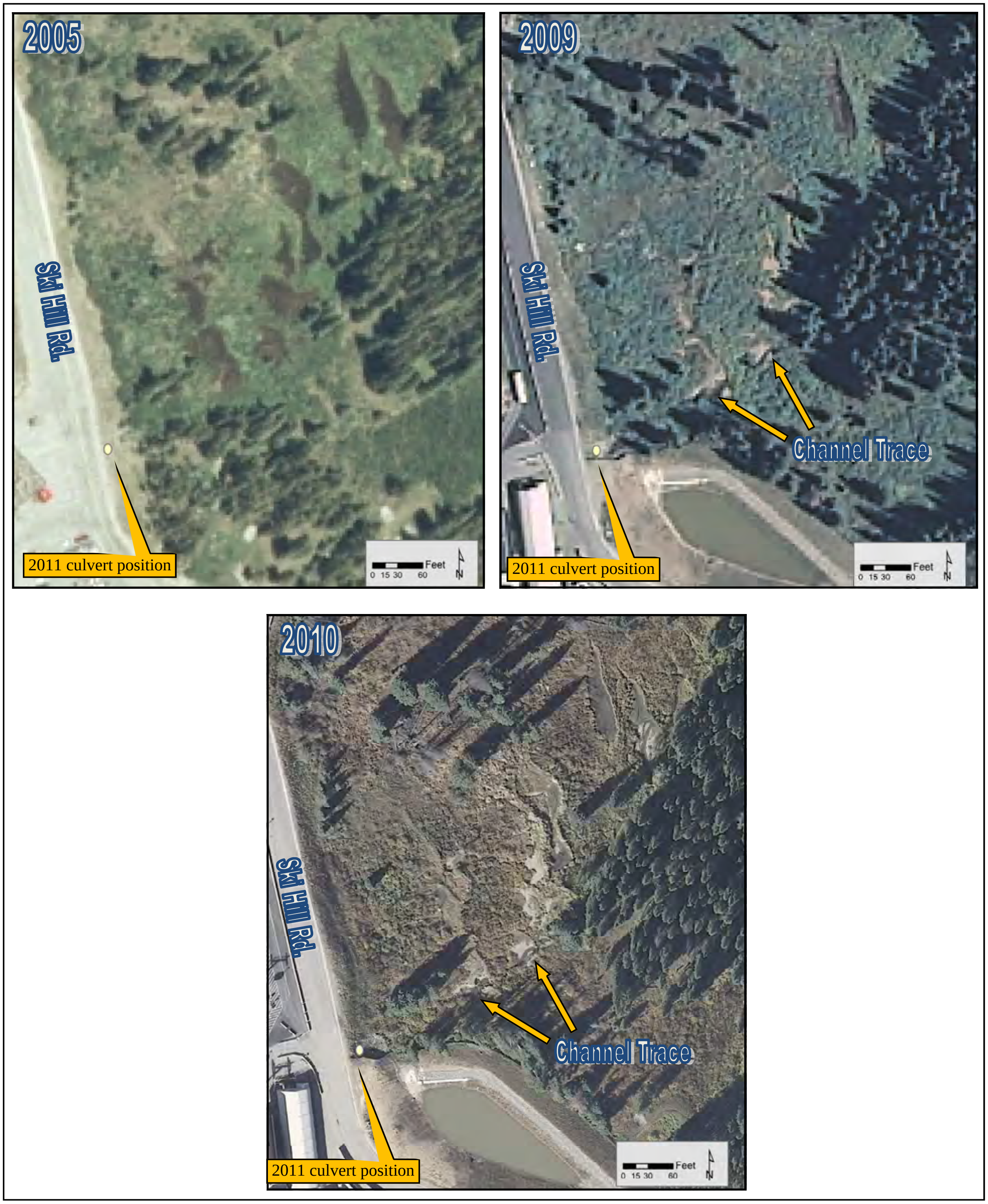


Fig. 14. Aerial photographs of the top of Upper CG in 2005, 2009 and 2010 showing the development of the Boreas Creek channel as a result of the southern breach of the upper “Spreader Pond” dam. The current position of the culvert is marked on each photograph for reference.

Well ID	Wetland hydrology present in 2010	Time of drying
P-11	NO	2007
P-18R	NO	2007
P-19R	NO	2005
PS-1	NO	2009
PS-2	NO	before 2007
PS-3	NO	before 2007
PS-4	NO	before 2007

Table 9. Summary of data from hydrographs of all the GL&A monitoring wells in Upper CG. Though all of these wells were originally placed in delineated wetlands, none of the locations now have wetland hydrology. For most of these hydrographs, historical records allowed us to identify the season during which drying took place.

We also used this mapping to place information on dam breaches and pond drying as observed by other researchers in 2007[25] into the GIS. Figure 7 is a time-series illustration of the distribution of flooded ponds in upper CG along with the applicable wetland boundary lines. In 2005, 11 of the 16 mapped ponds were flooded and the wetland was at its maximum mapped extent. In 2007, the number of flooded ponds appears to have dropped to seven. The status of two ponds towards the northwest end of the site was uncertain, but we assume that they were dry. In 2009, only 2 ponds at the bottom of the area remained flooded, and by 2010 all of the ponds were dry, as they were in 2011 during our survey. Recession of the wetland boundary parallels the pattern of pond-drying.

Supplemental water table monitoring data provides direct evidence of the recently diminished hydrology associated with drying ponds. In June 2011, we installed a shallow, data-logging groundwater well into the bed of what used to be the Spreader Pond, approximately 10 m from the Boreas Creek centerline (Fig. 15). The logger has been measuring water table depth daily since June 28, 2011.

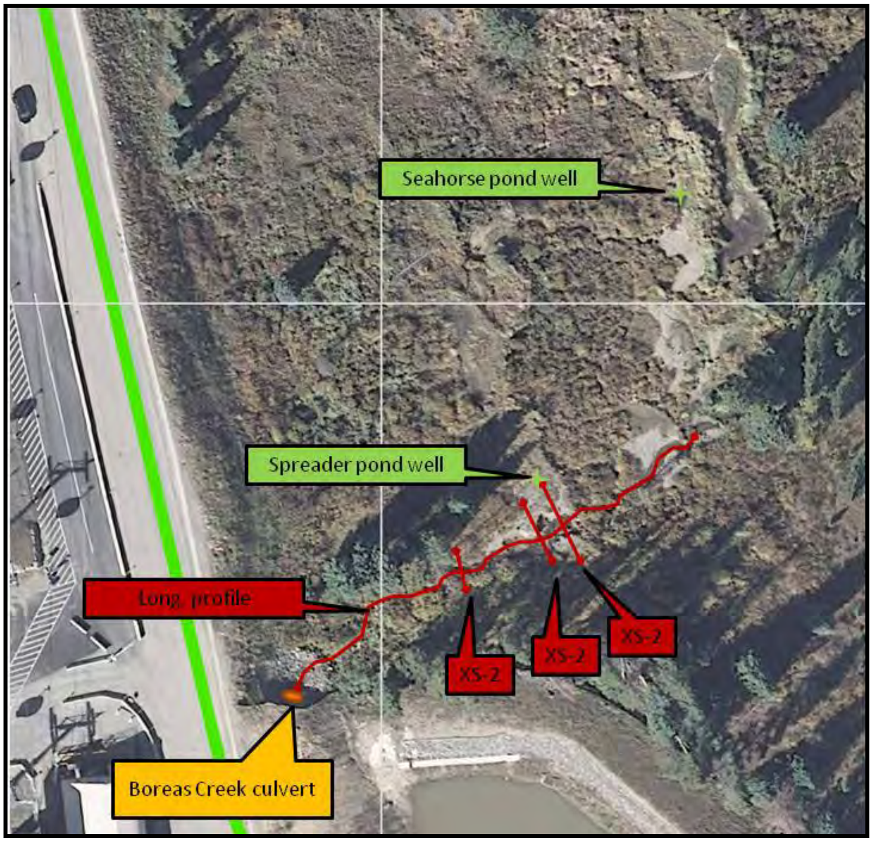


Fig. 15. Location of Boreas Creek channel surveys and supplementary well locations in Upper CG.

The results are plotted in (Fig. 16). This area, which was aquatic habitat (Photo 18) with perennial surface water as recently as 2007, now not only lacks surface water but appears to lack wetland hydrology altogether. Water table depth shallower than 1.0 ft. was measured on only four days during the 2011 season, in two peaks that followed large rainstorm events. An additional well and data-logger was placed in the bed of the "Seahorse Pond" about 40 m down-valley from the Spreader Pond (Fig. 15). This location is also within a pond that has been dewatered since 2007 (Photo 19). The water table hydrograph at this location does not show a complete conversion to upland hydrology (Fig. 17) since we recorded groundwater depth less than 1.0 ft. on 25 days. The reason for the peak in hydrology appears to be that the Seahorse Pond is located downstream from the first large sediment deposition area on Boreas Creek. During high flows, the deposition in Boreas Creek diverts water over the left bank and into the Seahorse Pond where it is impounded by a dam which is still mostly intact.

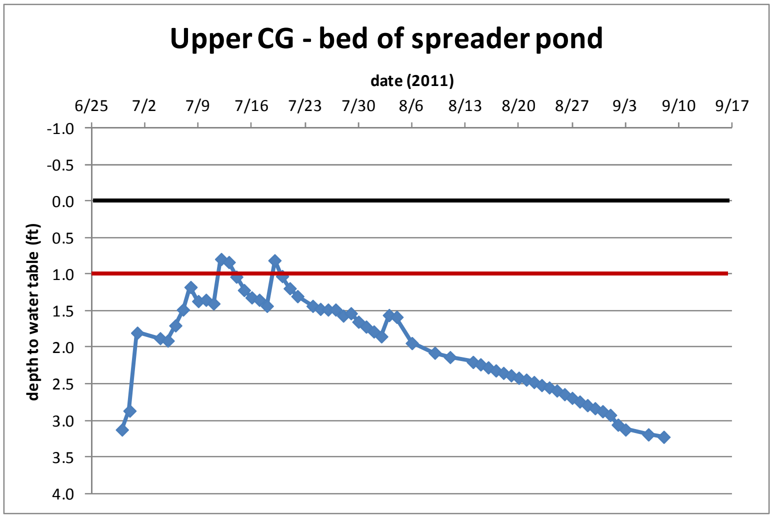


Fig. 16. Hydrograph showing water table depth in a shallow groundwater well that was placed on the bed of the recently-dried Spreader Pond in Upper CG. The black line is ground surface. Blue diamonds are readings of water table elevation. The red line shows a depth of one ft. below ground surface. The water table at this site was deeper than 1.0 ft. for all except four days of the 2011 season, indicating that wetland hydrology may no longer be present at this site.

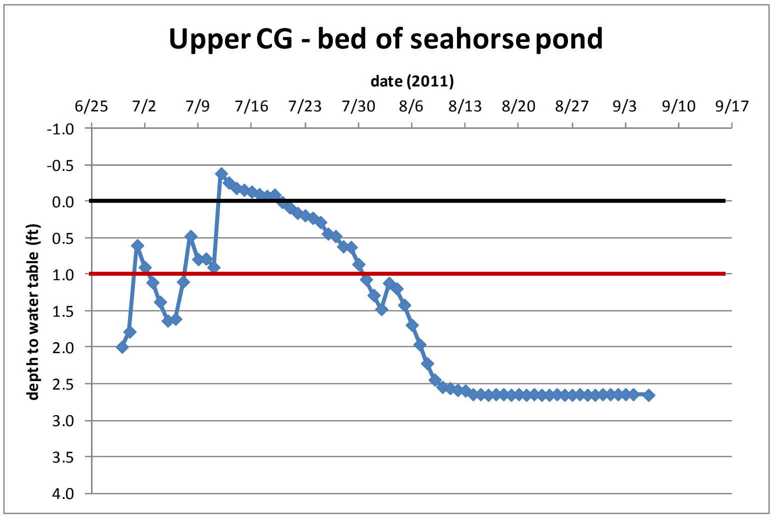


Fig. 17. Data from the well in the Seahorse Pond shows that impounded surface water was present in July. The water table was shallower than 1.0 ft for approximately 25 days this season, indicating the presence of wetland hydrology at this point.

Characteristics of the Beaver Maintained System

Evidence suggests that prior to up-gradient development, water was introduced to Upper CG via a number of small channels. For instance, relict channel traces exist up-gradient of the uppermost pond (Spreader Pond) supporting a dispersed in-flow characterization (see

Fig. 7, for example). Ponds lay behind old and substantial dams that create a series of terraces stepping down the valley. Based on observations of relic features, the ponds themselves spilled over in multiple places, spreading flows among numerous distributary channels. The terracing and dispersion of flow maintained a low-energy system that emphasized the functions of water retention and dispersion. Apparently owing to the scarcity of dam sites in the steep terrain, the same dams were continuously maintained, and most have become mineralized – essentially naturalized geomorphic features of the landscape. In fact, this type of dispersed, low-energy system is still functional throughout Lower CG, which serves as a valuable reference analog for how Upper CG used to function.

Beaver activity has been monitored in Cucumber Gulch since 2001, and a decline in beavers has been well documented. Based on monitoring data presented by Dr. Carello[2] in 2010, the mean number of active lodges within Cucumber Gulch between 2000 and 2003 was seven, but the mean dropped to three for the years 2004-2010. The same paper reports that beaver activity was present in Upper CG in 2003 and 2005, but has been absent ever since. We observed numerous unrepaired dam breaches in Upper Cucumber during our surveys and no active beaver activity. In their 2010 report[12], GL&A add that "*Beginning in 2006 beaver activity in the upper portion of Cucumber Gulch (within 500 ft of the County Road and Peak 8 Base Area) decreased significantly. As a result of the decrease in beaver activity the ponds in the upper portion of the gulch have degraded, drained, and eroded, lowering the overall groundwater levels in the upper portion of Cucumber Gulch.*" The ponded and dispersed pattern of water distribution cannot be maintained in this area without the presence of beaver.

Evaluation of Stressors and their impacts

Nearly all impacts to water distribution can be directly or indirectly tied to the abandonment of the area by beaver and the resultant failure of the dam system. Basically, this was a beaver pond system, and without beaver present to maintain dams the system is converting to a different stable form in response to the altered physical and ecological regime. The configuration that has been developing is one in which surface water is concentrated into a predominately single, high energy channel. One way to understand this change is to think of the historical ponded hydrologic regime as a “maintained” system, in the sense that its form requires constant maintenance to perpetuate. In this case, beaver provided the maintenance. With the loss of the species from the area, so too is lost the “ecosystem service” they provided (*i.e.*, maintenance of water distribution and wetland support). In this regard, the beaver themselves *were* the wetland’s water distribution system. Without them, water distributional characteristics necessarily take on another form. The systemic changes that have transpired over the last few years trace conversion of a beaver-pond system to a different form.

In a physical system that is maintained by a native biological entity, the normally distinct line between cause and effect is blurred, since there is a tight feedback between biota and the physical system, with each exerting control over the other. In the discussion below, we describe the physical changes that have occurred in the context of how beaver maintained system properties and the results of their recent departure.

First, the manner in which water is introduced to Upper Cucumber Gulch has been highly altered by the off-site geomorphic modifications of Ski Hill Road, Stables Lot, Peak 8 Base area development, and the drainage system that was constructed to support these. Together, these stressors effectively cut off the top portion of the wetland from dispersed surface water flows by virtue of the fill, retaining walls, foundations, compaction, impervious surfaces and the engineered artificial drainage that is integral to the base area development, and which focus the water source to a single point (the Boreas Creek culvert). While drainage from the ski area has been collected into Boreas Creek for decades, recent modifications to the drainage system to accommodate the new base area apparently increased drainage area to this source and improved efficiency of water transport by replacing the old, leaky culvert (Photo 20) with a new sealed one. Despite these water source modifications, when beaver were present in Upper CG, they greatly mitigated potential impacts to water distribution by shunting water northward through their upper-most dam system, a feature we call the “Spreader Pond” (Fig. 15).

The Spreader Pond system began to fail when a dam at the north end breached some time shortly before the May 2007 delineation by WER[25]. Between 2007 and 2009, the south dam was breached directly below the Boreas Creek culvert (Photo 21). We do not currently know whether this breach occurred before or after the new culvert was installed. Either way, this breach represented the final stage of the collapse of the water distribution system in Upper CG. At this point in time, Boreas Creek converted to a primarily single thread channel and began to down cut. The development of a single primary channel configuration can be seen in the comparison of 2005 and 2009 aerial photography (Fig. 14), and geomorphic changes that have occurred recently in Upper CG are more fully described in the discussion of the Geomorphology variable (below). Thus, the first component of water distribution alteration is the drainage of the pond system secondary to dam failures.

A second contributor to wetland drying is the incision of the Boreas Creek channel. To a large degree, the elevation of surface water in the channel dictates the water table level in hydrologically-dependent habitats. Thus it follows that lowering channel bed elevation would result in a deepening of adjacent water table levels, at least to a point. In July of 2011, the remaining dam structure in the vicinity of the southern breach failed (Photos 21-22). Additional down-cutting of the channel will likely cause additional local drying, and some decrease in water table elevation may occur more generally across the site, but it seems likely that those decreases will be modest. This is because, as Dr. K. Kolm suggested (pers. comm.), the water table levels in the area are probably approaching the elevation supported by the regional groundwater system. We agree with this idea in concept, but recommend continued monitoring and further study for confirmation.

Despite the assertion that future water draw-downs (beyond the significant dewatering that has already occurred) in the upper-most reach of Upper CG will probably be mild, it is critical to keep in mind that the processes currently in force may continue to advance downstream. Figure 18 provides an overview of Upper CG indicating lengths of channel throughout the unit where notable down-cutting and channel incision occurred in 2011. Habitats downstream are therefore at risk of being impacted in a manner similar to what has taken place in the upper reaches of Upper CG, including dewatering secondary to channel incision and sediment deposition. If these factors cause sufficient stress to induce further pond abandonment by beaver, more interior ponds may exhibit the same behavior as those in Upper CG in the future.

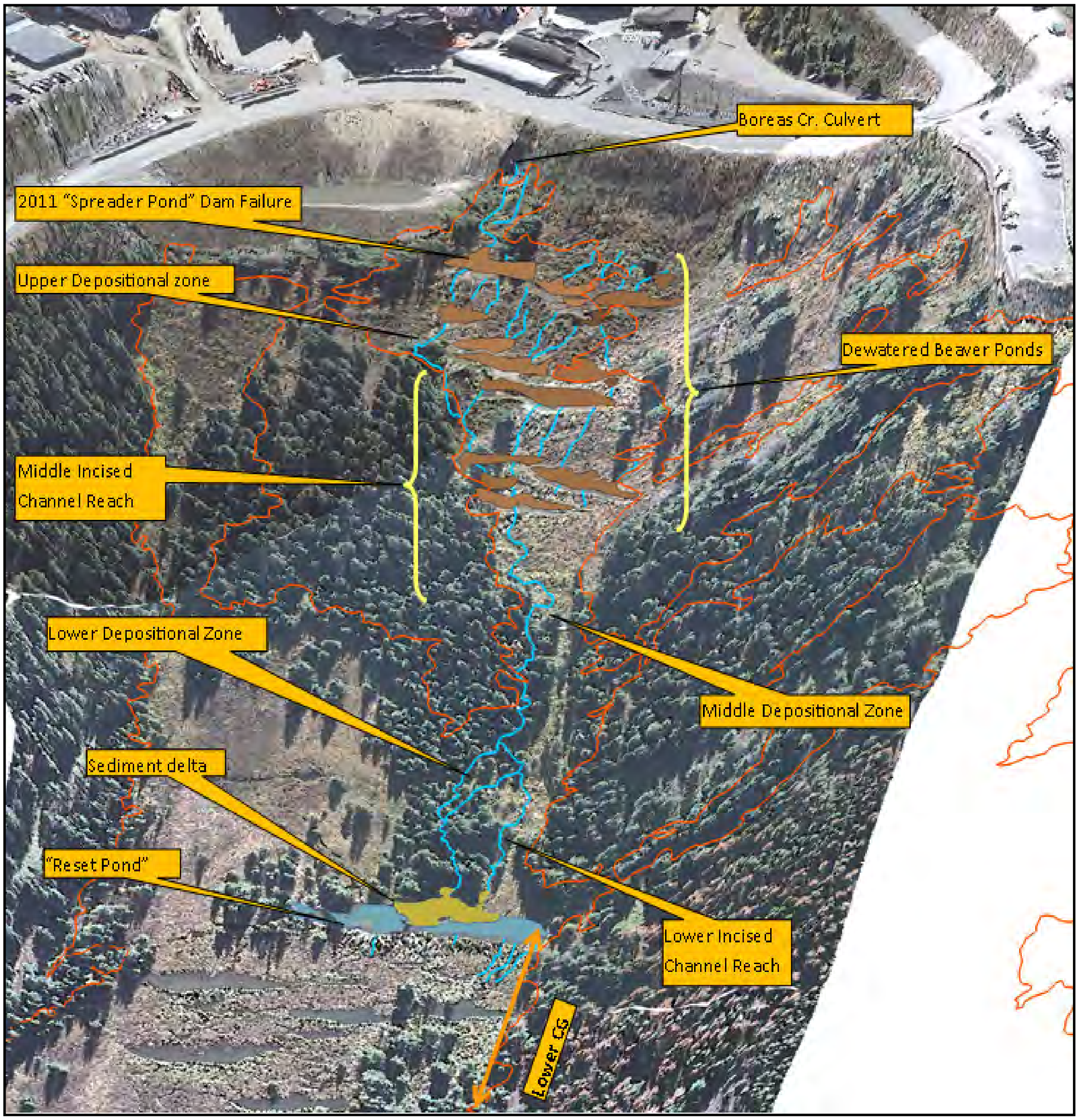


Fig. 18. An overview of the Upper CG unit showing locations where significant incision or deposition was observed in or near the Boreas Creek channel during 2011. Red lines show wetland boundaries. Note that topography in this figure had a 3:1 vertical exaggeration

Loss of the characteristic dispersed flow also changes the energetic dynamics of water flow within the aquatic system, creating flow with a much higher erosive capacity. The resulting stream instability produces large volumes of autochthonous (*i.e.*, from within the site) sediment from channel scour and erosion. Unnatural amounts of sediment affect water distribution through the physical presence of deposition. Deltas in ponds decrease the volume and depth of ponded water; on-channel areas of aggradation change the nature of channel flow; and deposition areas at all locations elevate ground or bed surfaces to make them dryer. All of these impacts are present within Upper CG (Photos 23-24). (The only exception, technically speaking, is the formation of pond deltas, since there are no longer any functional ponds in which deltas could form).

The south arm of Upper CG also shows minor signs of impairment, but these impacts are secondary to the factors impacting Boreas Creek and the beaver ponds in the north arm. In addition to springs and diffuse groundwater, the south arm is fed by several storm drainages including those that end up in the primary Peak 8 detention pond and the minor drainage/detention ponds at "Admin." and Glenwild (Photos 25 and 31). Currently, these small drainages probably have minimal impact on overall water distribution. They rarely flow except during high-runoff storms and the ponds are very low in volume. The primary Peak 8 pond, however, holds a large volume of water and was full for the entire 2010 season. Neither the source of water to this pond (beyond the obvious storm drain that feeds it) nor its pattern of outflow was investigated in detail for this report. The areas immediately down-gradient of most of the pond are not wetlands, and the fact that the pond remains full long after surface flow inputs subside suggest that it serves a retention rather than infiltration function. The effects of this large structure on the natural pattern of water distribution, if any, are not clear. Whatever its possible impacts might be, they would be minor and fairly localized in extent, since spring flow becomes the dominant water source a few hundred feet below the pond.

Given these stressors and documented impacts, our assessment for water distribution within Upper Cucumber Gulch places it in the ***functionally impaired (D-)*** category. We again caution that, as with water source, this singular rating homogenizes the range of water distribution conditions found within the unit. As the descriptions above should make clear, in some areas, particularly in the south arm, water distributional characteristics are nearly natural, while in the north arm large areas no longer possess wetland hydrology and would thus warrant a rating of ***non-functional (F)***.

Variable 6 – Water Outflow

Outflow discharge from Upper CG is artificially high and flashier due to the efficient transfer of source water to the wetland and the channel system that has developed within the site. Additionally, more of the area’s outflow is concentrated into the Boreas Creek channel owing to the lack of a functioning distributary network. Essentially, water outflow is affected by the same general suite of stressors as water source and distribution. As such, it follows that the reconfigured channel system possesses a higher capacity to export sediment and other materials to down-gradient habitats than it had when the site possessed a functioning pond system. Inflow to Upper CG is highly impaired due to these stressors, and the impacts are not much dampened or mitigated via distribution of water within the area. Consequently, the impairments are perpetuated throughout the hydrologic system and Water Outflow for Upper Cucumber is rated as ***functioning impaired (D).***

Variable 7 -- Geomorphology

Geomorphology within the north arm of Upper CG has undergone substantial change in recent years. Primary stressors include all the activities which have caused changes to the surface topography of the wetland including the channels and ponds that are part of it. In this area, the most significant impacts from stressors are manifested in the form of channel incision/erosion and sediment deposition.

In Upper CG channel instability has arisen by the inability of beaver to control inflows and successfully distribute them across the site. Channel formation and incision has likely proceeded because flows simply became too powerful for the beaver to harness, because dam maintenance ceased (the result, perhaps, of a population crash or emigration), or both. Unmitigated, high energy water inflow into the gulch has a high capacity to scour Boreas Creek and its effects are directly observed in the form of degradation (down-cutting) and incision. To better understand the channel formation dynamics occurring at Upper CG we undertook two surveys of channel morphology during the summer of 2011.

On June 2, 2011 we completed a longitudinal profile survey and several cross section surveys of the upper 300 ft. of Boreas Creek in Upper CG (Fig. 15). Cross section end point and longitudinal profile stations were monumented to allow us to repeat these surveys to document geomorphological changes to the channel over time. We resurveyed the channel on August 5, 2011 for this purpose.

Overlays of the June and August surveys show the ways in which the channel changed over the season. Considering the longitudinal profile survey shown in Fig. 19, the base level (streambed elevation) was cut one to two feet deeper along a 180 ft. segment of the surveyed reach, and five active head-cuts are apparent. At the upper portion of the reach, the data show that the creek has head-cut two feet deeper about 10-15 feet into the bed of the eroding rip-rap structure at the outlet of the Boreas Creek culvert. Near the bottom of the surveyed reach there is an active deposition area, and an aggrading bed is present. Overlays of three cross sectional surveys (Figs. 20-22) within the incising segment show the degree of bed degradation, channel enlargement, and erosion that occurred here during the two-month period. While most severe in the upper portion of the valley below the culvert, unstable eroding reaches are evident along much of the Boreas Creek channel (Fig. 18; Photo 26).

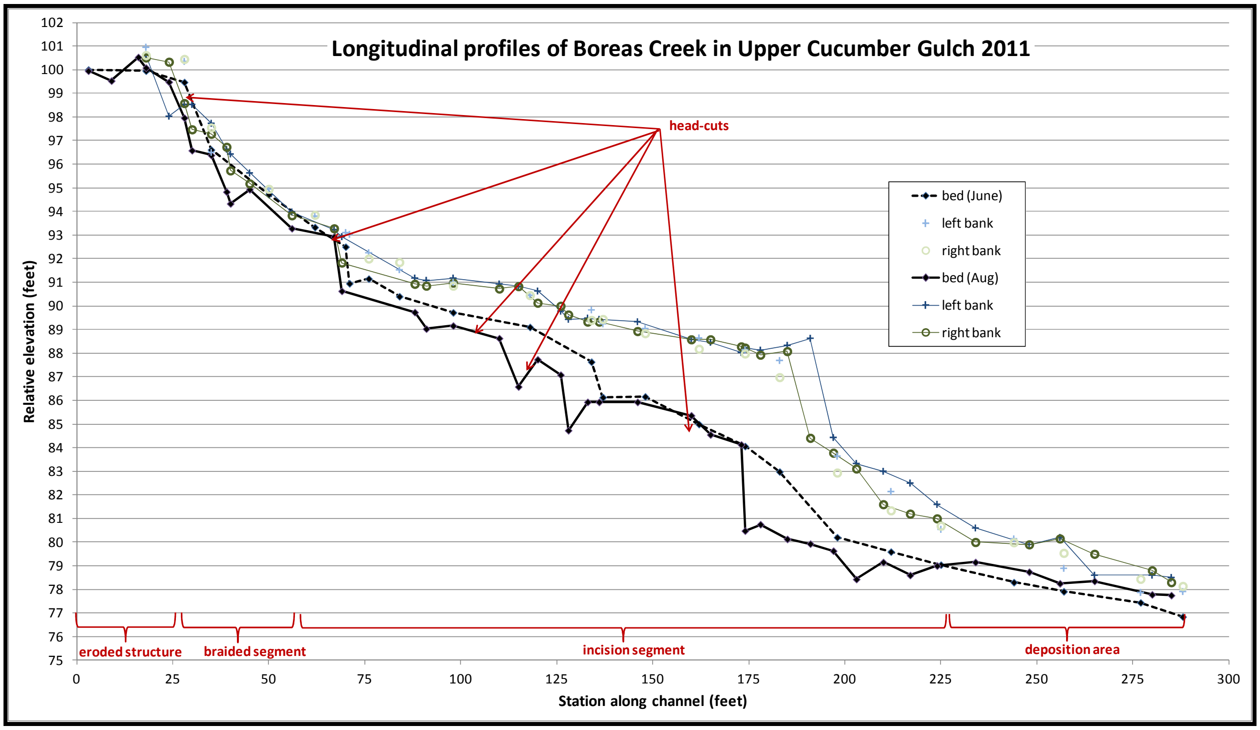


Fig. 19. Overlaid longitudinal profile surveys of the upper 300 ft. of Boreas Creek channel beginning at the Boreas Creek culvert. Surveys are from June 4 and Aug 5, 2011. The survey clearly shows areas of active incision (degradation) and deposition (aggradation).

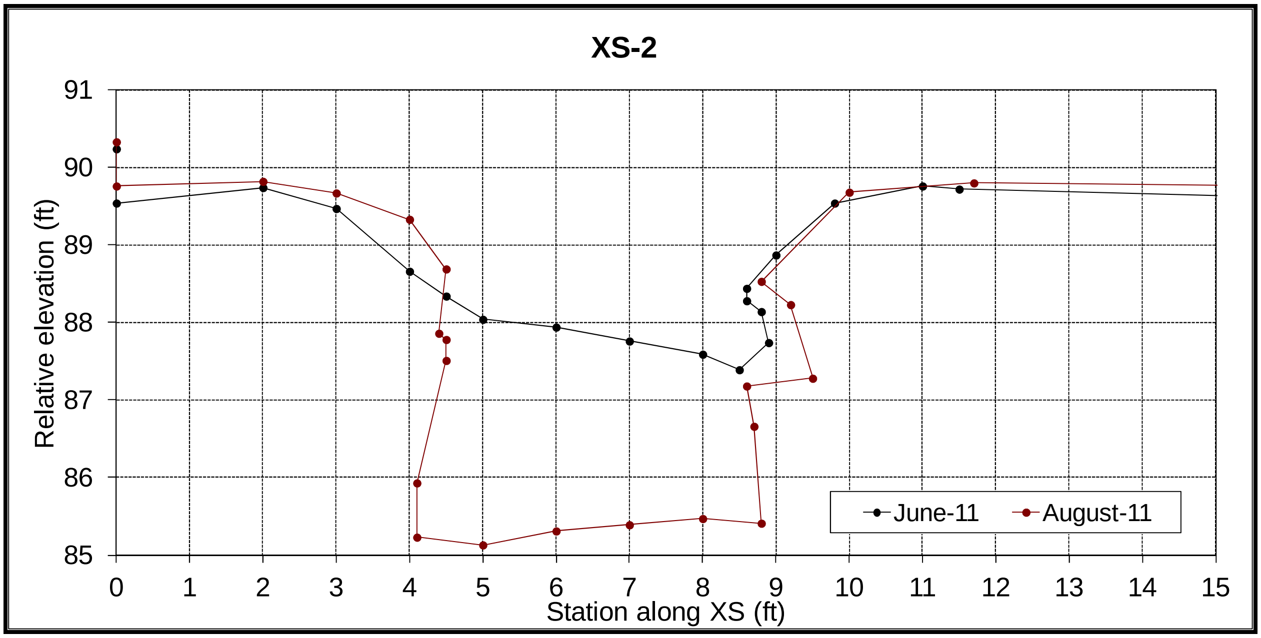


Fig. 20. Overlaid cross section surveys on XS-2 show 2.5 ft. of channel incision at this location.

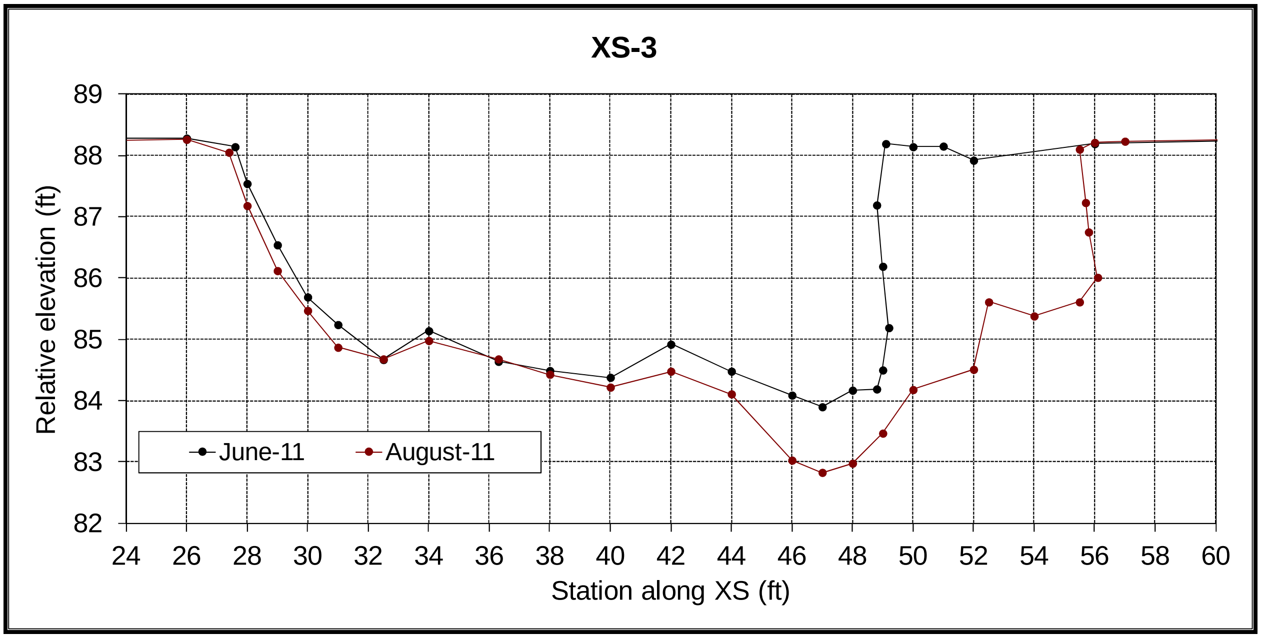


Fig. 21. Overlaid cross section surveys on XS-3, which is immediately upstream from the major head-cut show that the bed still dropped about 1 ft. at this location. Extreme bank erosion resulted in channel enlargement and generation of a large amount of sediment. This channel is fully entrenched.

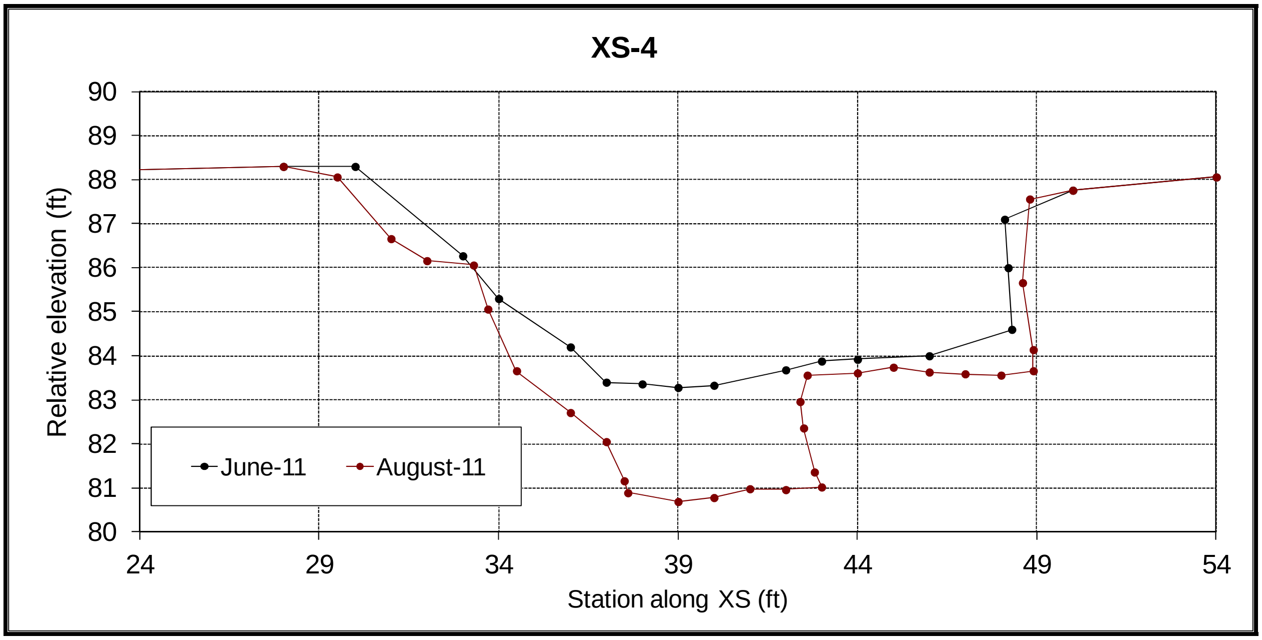


Fig. 22. Overlaid cross section surveys on XS-4 (just downstream of the major head-cut) show 2.5 ft. of channel incision at this location. Bank heights are nearly 7 feet at this location. This channel has become deeply entrenched.

Sedimentation is the other major factor effecting topography in Upper CG. Sediment sources can either be autochthonous (generated within the site), or allochthonous (introduced to the site from outside sources). At upper CG, both sources appear to be elevated relative to reference conditions. The source watershed is highly modified in ways that would likely increase sediment input (Photos 27-28). Site geomorphology has been especially altered where sediment has been accumulating in beaver ponds. The uppermost beaver ponds in Upper CG have been largely filled with sediment deposits of recent origin (Photos 29-30). Other ponds here may not be completely filled with sediment, but have reduced depth and volume.

Channel instability, including the erosion and degradation (down-cutting) of the channel caused by the derived hydraulic environment (described in previous sections) is the primary source of autochthonous sediment. While the amount of sediment generated by erosion is not precisely known, channel surveys were used to calculate the approximate amount of autochthonous sediment produced from channel instability in the upper reach of Boreas Creek. Based on this rough calculation, we estimate that approximately 2500 cubic feet (approximately 120 tons) of sediment was mobilized over the 180 ft. incising reach between June 2 and August 5, 2011.

Regardless of origin, mobilized sediment was variously transported and deposited along the Boreas Creek track. Sediment has commonly accumulated in the lower beaver ponds in the unit and has formed several large depositional features along Boreas Creek (Photo 24). These deposition fans constitute wetlands fill that creates localized areas of elevated ground surface.

In addition to the processes occurring in association with Boreas Creek, other geomorphological stressors exist in Upper CG. According to maps of past wetland delineations, the footprint of the large Peak 8 detention pond and its access road is located within historical wetlands. While this wetland filling was federally permitted, it imposed geomorphological changes severe enough that the area is no longer wetland habitat. Thus, we must consider it as a stressor to the overall wetland system.

Geomorphology is rated as ***functioning impaired (D)*** owing to the three primary sources of geomorphological change operating within Upper CG. The secondary effects of these topographic alterations are producing systemic changes in the wetland and are, along with water source alteration, the underlying factors driving the loss of wetland habitat in the northern arm.

V8 - Water and Soil Chemical Environment

As described in the Peak 7 SS section, our water chemistry analyses are summarized in Appendix 2, and the sub-variable scoring is summarized in Table 7. Our overall assessment of the water and soil chemical environment within Upper CG is that it is ***functioning impaired (D).*** This assessment is based primarily on the implied alteration of soil oxidation-reduction properties secondary to desaturation which is suspected over a large portion of the north arm of Upper CG. This observation forced a rating of ***functioning impaired (D)*** for the soil chemistry sub-variable. Desaturation is also a likely cause for the elevated salt concentrations observed in the dewatered portion of the north arm in 2009. The sedimentation sub-variable was also rated relatively poorly as ***functioning (C)***. This rating is warranted due to the consistently high turbidity in detention ponds while they were spilling and serving as source water to the wetland, and also due to the obvious signs of recent sediment deposition within ponds and along Boreas Creek Channel. Compared to soil chemistry and sedimentation, other stressors to the water and soil chemical environment – such as toxicants – appear to be minimal.

The south arm of Upper CG appears to be generally free from the impacts seen in the north arm; however, a concern that wetlands in the area could be impaired due to increased salt concentrations was brought to our attention early on. In 2010, ERO_1 reported water quality impairment in the South Arm of Upper CG based on elevated salt concentrations observed at ERO sampling site SW9. The suspected source of this potential contamination was runoff from the Glenwild storm water drainage channel. During the 2011 season, a small detention pond was constructed at the base of the channel to satisfy mitigation recommendations from that study (Photo 31).

We used a hand-held meter to measure conductivity (µS/cm) as an indicator of ionic solute concentrations to investigate the magnitude of reported salt contamination at this location and to make a positive identification of the source. The past water quality database includes 4 observations of conductivity at ERO-SW-9 (156, 67, 170, and 253 µS/cm on 10/08, 5/09, 7/09, and 10/09, respectively) which do tend to be higher than most other sampling sites within the Gulch.

When we were introduced to the site, we recognized that the primary source of water to ERO-SW-9 appeared to be a spring that emerges on the upper SE edge of the South Arm of Upper CG, about 100 meters up-gradient from SW9. On 6/14/2011, we found conductivity at SW-9 to be 239 µS/cm, and that conductivity readings gradually increased as we followed water tracks up from SW-9 to the spring source, with a value of 320 µS/cm at the spring itself. Suspecting that the natural spring is the true source of elevated ionic solutes at SW9, we continued sampling it in addition to sampling the previously suspected Glenwild channel source through July at times that the channel was flowing (Table 10).

Sampling Date	**6/14/2011**	**7/1/2011**	**7/8/2011**	**7/13/2011**	**7/19/2011**
ERO-SW9 **(reported potentially contaminated site)**	239	224	170	172	162
Glenwild channel **(reported suspected source)**	not flowing	2	4	8	2
natural spring **(alternative potential source)**	320	312	233	235	280

Table 10: Conductivity results (µS/cm, standardized for temperature) show that the source of solutes at site ERO-SW-9 is more likely a natural spring rather than runoff through the Glenwild storm water drainage.

The results suggest that the spring source of water to SW-9 is naturally high in ionic solutes (salts), that the high readings at SW9 are likely the result of natural processes, and that the Glenwild channel may not be a significant pollution point-source.

Variable 9 – Vegetation Structure and Complexity

As with other variables, stressors to vegetation are differentially dispersed across Upper CG. We did not undertake systematic vegetation sampling, but did observe evidence that vegetation in the north arm has been shifting towards a more mesic species composition. Areas especially at the top of the gulch possessed vegetation showing signs of moisture stress and often lacked hydrophytic species (Photos 16-17). Although signs of vegetation change are widespread in the area, it appears that much of the native structure and composition has been maintained to this point, apparently owing to the ability of many of the species present to persist under drier conditions for some time. Perhaps the most striking change in the area is the near complete loss of aquatic and emergent vegetation following the loss of pond habitat. Overall, we believe the vegetation succession towards a less hydric composition is a process that will be on-going in the coming years unless the hydrologic system is re-established.

Elsewhere in the unit, the greatest direct impact to wetland vegetation was within the footprint of the large detention pond which apparently caused wetlands loss. Other direct vegetation impacts include the clearing and maintenance of the Nordic ski trails and foot/bike trails, and the establishment of weeds. Weed infestations are particularly acute along the upper edge below the Peak 8 base (which is largely outside wetland boundaries), and the presence of weeds such as scentless chamomile, yellow toadflax, Canada thistle, curly dock, common dandelion, and red clover has been well-documented at this location by Dr. Carello in past monitoring reports as recently as 2010[2]. In addition to the weeds along the upper edge, we found occurrences to be very common within the area of recently dried ponds. In some locations in this vicinity, weeds and exotics make up a greater proportion of cover than do native plants. The recently dried ponds are apparently ideal locations for the establishment of weed species (Photo 32). Lower in the unit, impacts to vegetation appear to be significant but localized, stemming from the modified water source, distribution, and geomorphology variables. Given the current severity and extent of impacts to vegetation structure and complexity in Upper CG this variable is rated as ***functioning (C)***, but at high risk of further decline if the hydrologic and weed stressors are not alleviated.

Lower Cucumber Gulch

Intro and Summary

Lower Cucumber Gulch is within the core of the Cucumber Gulch Preserve (Fig. 23). Natural habitat up-gradient from this unit largely shields the area, so far. That is, the natural habitat within the Preserve that surrounds this unit is still able to buffer stressors to a very large degree. The greatest negative effects, and future threats, emanate from impacts extending down from Upper CG, factors associated with the decline in beaver activity, and to a lesser degree, stressors at the edge of the unit. Table 11 depicts the relative magnitude of impact that stressors have on each state variable for the wetlands in the Lower CG unit.

Lower Cucumber

stressors and potential impact on wetland state variables

			Buffer/landscape		Hydrology			Abiotic and biotic habitat		
		Stressor	1-2. Habitat connectivity	3. Buffer capacity	4. Water source	5. Water distribution	6. Water outflow	7. Geomorphology	8. Chemical environment	9. Vegetation structure and complexity
external stressors	1	Residential development (Shock Hill to Peak 8 Base)	▓	▓	░	░			▒	▒
	2	Peak 8 snowmaking			█	░			░	
	3	Peak 8 watershed forest clearing			█	░				
	4	Peak 8 ski area/base area drainage			▓					
	5	Peak 8 Base area development							░	
	6	Bridge Creek watershed development								
	7	Bridge Creek channelization								
	8	Peak 7 snowmaking			░					
	9	Peak 7 watershed forest clearing			░					
	10	Peak 7 ski area/base area drainage system								
	11	Peak 7 Base area development								
	12	Cloud seeding			░					
edge stressors	13	Ski Hill Road (P8 base to P7 base) and retaining wall								
	14	Stables lot								
	15	Adjacent septic systems							░	▒
	16	P8 Base drainage/detention pond								
	17	Admin drainage/detention pond								
	18	Glenwild drainage/detention pond								
	19	P7 Base drainage re-distribution system								
	20	County Road 3 (P7 Base to north boundary)								
	21	Historic gullys/deposition		░						
	22	Historic mine shafts and tailings	░	░		░		░		░
internal stressors	23	Beaver loss			▓	██	░	█		░
	24	Sedimentation			▓	▓	░	▓	▒	░
	25	Channel incision			▓	▓	░	▓		░
	26	Gondola (cleared line and lift)	░	░		░		░		
	27	Nordic center trails	░	░		░		░		▒
	28	Foot/bike trails	░	░		░		░		
	29	Weeds								░
	30	Elevated salt/ion, or nutrient concentrations								

Table 11: Stressor/variable matrix for Lower Cucumber Gulch. Darkness of shading indicates the estimated relative degree of impact.

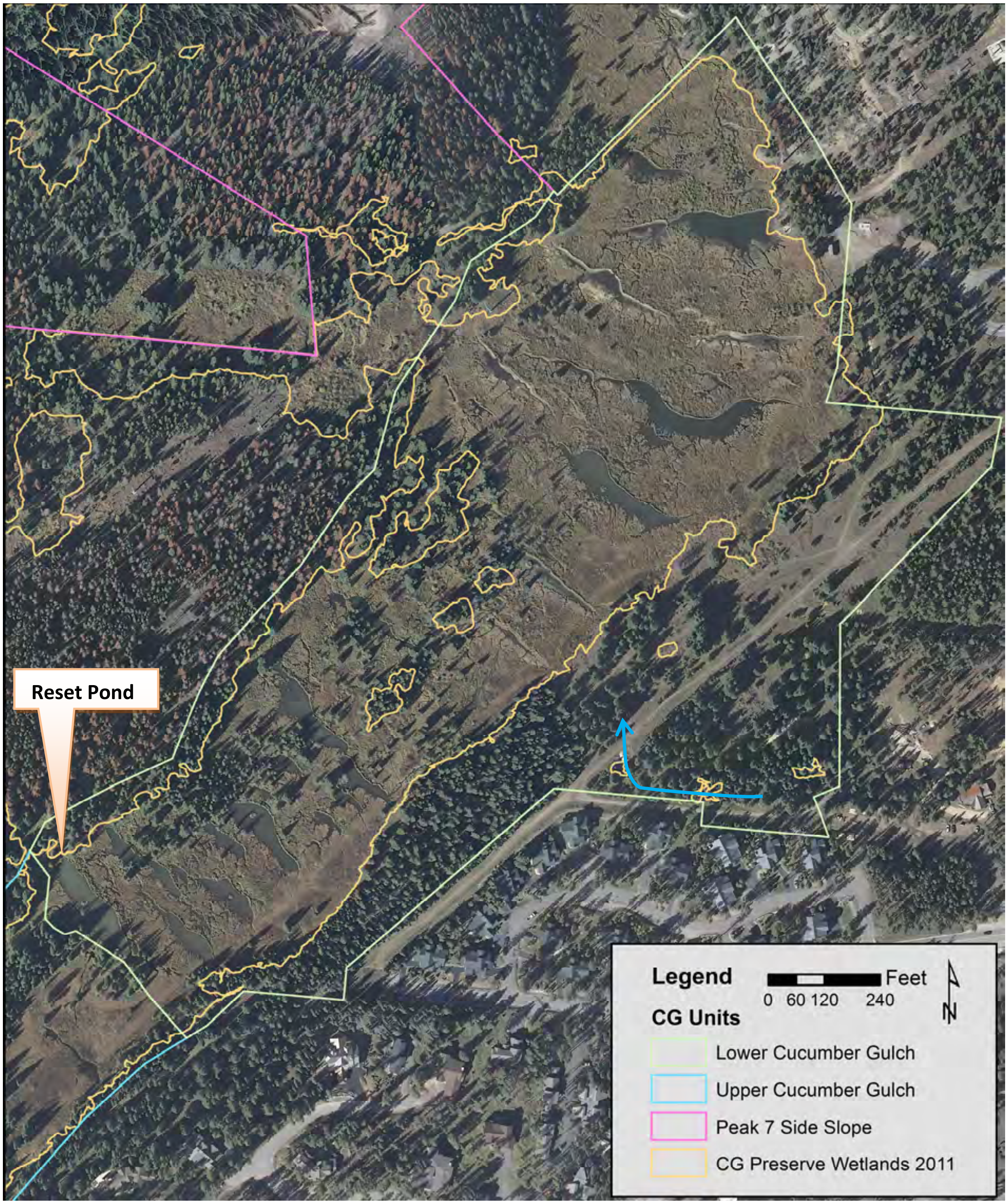


Fig. 23. A 2010 aerial image showing the Lower CG assessment unit and the extent of wetlands within. The blue arrow shows the flow path of residential runoff. The wetland nearest the arrowhead is in the vicinity of the location the suspicious water sheen that was sampled (see Water Chemistry section, below).

Variable 4 – Water Source

Some of the negative effects of Cucumber Gulch's altered water source are attenuated by Upper CG, however the impaired aspects of Upper CG's outflow define the character of inflow to Lower CG. The artificially augmented flows coming into Upper CG must flow through the area on their way down the valley, so it follows that the hydrograph at Lower CG would still be elevated at times when those augmentations occur; which again is primarily the snowmelt period. To the extent that it still can, Upper CG is helping to dampen peak flows and release water in a more even way. The slacking gradient and remnant natural habitat also act to spread flow laterally, making it less concentrated and energetic by the time it reaches the upper margin of Lower CG habitat (*e.g.*, Photo 24). In essence, Upper CG is serving as a buffer for Lower CG. There is, however, evidence that Upper CG is not wholly effective at buffering the effects of water source alteration, or that the buffering effect provided may not be sustainable.

We call the upper most pond of Lower CG the "Reset Pond", because it is the receiving body for concentrated water flows leaving the north arm of Upper CG. Currently, the Reset Pond re-establishes a natural flow network, strongly reducing the effects of augmented flow by dispersing it among many distributary channels. It also dampens the water's residual energetic properties by acting as a stilling pond. The continued existence of these beneficial properties appears almost wholly contingent on the functioning of the Reset Pond's beaver-maintained dam. Should the function of this dam become compromised, the degradation processes occurring in Upper CG would more than likely be perpetuated in Lower CG, resulting in sequential degradation of pond and wetland habitat (Figs. 7 and 14).

Despite the above concerns, we note that the Water Source of Lower CG is more diverse than what flows in from the north arm of Upper CG in that it is fed by numerous intact springs, tributary flow from side-slopes, and the less-impacted south arm. The addition of these more consistent and less-impacted sources is inferred to dilute up-gradient impacts and make the overall hydrograph less flashy than that of Upper CG, regardless of individual dam failures. Considering the net sum of all these impacts, *at present*, we rate the water source variable for Lower CG at the lower end of the ***highly functioning (B-)*** category, noting concerns for its future integrity.

Variable 5 - Water Distribution

In its present condition, water distribution in Lower CG appears to be more or less intact. Many of the distribution stressors operating in Upper CG tend to be buffered within that unit, and the scale of impacts further downstream are lessened at least for the time being. Nevertheless, Lower CG is not without notable alterations to its hydrographic properties. Due to the channelization of flows through Upper CG, Lower CG receives its water in an unnaturally concentrated manner (*i.e.* within the incised Boreas Creek channel). The degree of channelized inflow here is far less extreme here than it is at the Boreas Creek culvert feeding Upper CG. The effects of concentrated inflow on distribution are similar, but the magnitude of the stress is much lower on Lower CG than it is on Upper CG.

The most important stressor at play here would seem to the decline of the beaver population. While the GL&A (2010) report[12] relates "*Beaver activity and pond building appear to remain active in the lower reaches of Cucumber Gulch*", the question may be, "Are they ‘active’ enough?" Again we cite Dr. Carello's (2010) work[2] which documents the recent drop in active beaver lodges in Cucumber Gulch from seven to three. Beavers are very territorial, and they tend to maintain dams only within a well-defined area. As the number of beaver declines, so does the area effectively maintained. There have been signs of beaver activity within Lower CG in this 2011 season, and we did observe some recently repaired dams (Photo 33). However the number of active beaver lodges may still be relatively low given the large area of Lower CG, and the number of observed unrepaired dams outnumbered repaired ones (Photo 34).

Of particular importance here again is the Reset Pond (Photo 35). The Reset Pond is thought to function in a way similar to how the Spreader Pond of Upper CG did before it was cut through. Flows from Boreas Creek enter at the top of the Reset Pond and are dispersed by the dam among eight or more identified smaller distributary channels. The presence of beavers and their continued maintenance of this pond/dam are critical for sustaining these functions and preventing the initiation of process feedbacks that occurred at the Spreader Pond in Upper CG some years earlier.

Overall, the effects of beaver loss on wetland condition have not been manifested in Lower CG, at least not nearly to the degree that they have in Upper CG. Presently, the effects of beaver loss on water distribution in this unit may be limited to the loss of several ponds that have dam breaches which have not been maintained (Photos 36-38). That said, the events that took place in Upper CG may serve as a direct warning about the importance of beaver as a "keystone species" and "habitat engineer." While the effects of their decline are not yet widespread, the significance of their loss may best be understood as an *increasing risk* to optimal functioning of water distribution in Lower CG.

Besides beavers, several other geomorphological stressors influence water distribution within Lower CG. The primary concern is sedimentation. The amounts of sediment entering Lower CG from Boreas Creek are highly elevated. As described in detail earlier, increased amounts of allochthonous sediments (entering CGP from the Peak 8 watershed above) combined with the large amount of autochthonous sediment released from channel erosion in Upper CG amount to a dramatically increased sediment load entering into Lower CG.

The increased sediment volume from these sources is certainly substantial, but it has not been formally quantified. Evidence indicating the magnitude of sediment that is now entering Lower CG can be seen in the Reset Pond. This pond, which has existed for decades and possibly for centuries, became about one third filled, with sediment during the 2011 season (Photo 39). It is clear that sediment inputs to Lower CG are now profoundly elevated compared to natural levels. Given that the mechanisms causing this severe sediment imbalance are still active (*i.e.* increased allochthonous sediment input, increased water source power, channel instability, and erosion), ongoing sedimentation problems in Lower CG should be anticipated until these causal factors can be curtailed.

Channel instability and incision have not yet been directly observed within Lower CG, as they have within Upper CG, and no impact to water distribution from these potential stressors has yet been documented. However, with the known sediment imbalance, augmented water source, and risk of losing the distributary function that beaver-maintained dams provide, the risk for future channel instability and degradation (down-cutting) in Lower CG seems very high.

Water distribution within Lower CG is currently rated towards the lower end of ***highly functional (B-).*** This rating is based primarily on the impacts from sedimentation and degradation of pond habitat, whose effects have thus far been limited in severity and extent. We do, however, caution in the strongest of terms that multiple lines of evidence suggest that the impacts of sedimentation and upstream channel instability are just beginning to become manifest in Lower CG. Unless the sediment issue can be effectively mitigated and beaver populations maintained at a healthy level, we predict that the water distribution function in Lower CG will drop off considerably in the near future. Upper CG provides the best model available describing the probable trajectory of Lower CG habitat under the current management regime.

Variable 6 – Water Outflow

Most of the impacts to the hydrograph of incoming water are dampened and buffered within Lower Cucumber. Impacts from the loss of beavers and some channelization of flows result in slight alterations to outflow. The variable is rated toward the upper end of ***highly functioning (B+).***

Variable 7 – Geomorphology

In general, the same geomorphological stressors at play in Upper CG are also operating in Lower CG, but to a lesser degree. The problem of channel instability is not so apparent in Lower CG. Some degree of incision is indicated on a few channel segments, but unlike Upper CG (where incision is obvious and severe) we cannot be sure that the channel has been truly down-cutting except through the sediments of dried ponds; nor does it appear that the degree of incision is particularly serious anywhere at this time. Excessive sedimentation is readily apparent in a few locations, particularly as a large delta at the Reset Pond inlet (Photo 39), pond deltas in other locations (Photo 40), and sediment deposition fans along various channels. The effects of decreasing beaver activity are also observed in Lower CG, except that here we see many dams that are not yet breached or totally filled with sediment, and there are also locations where beavers are still actively filling their geomorphological role of dam maintenance.

Other additional geomorphologic stressors such as the footprints of the Nordic ski trails, foot/bike trails (Photo 41), several gondola tower bases, and remnant mining debris/tailings (Photo 42) are less significant by comparison, but still add to the overall degree of change to topography within this area of the wetland. Of these lesser impacts, the Nordic ski trails have the greatest effect on topography due to the constructed bridges, which were commonly observed to alter channel flow patterns and sediment deposition (*e.g.*, Photo 24), in addition to the influences of the imported surface materials that are used to build them.

The sum of all these impacts results in our assessment of geomorphology within Lower Cucumber to be ***highly functioning (B)***. As with the rating of water distribution, however, a caveat is in order. Presently, geomorphologic impacts are minimal; but for the reasons described earlier concerning increased sediment input, channel instability, and the effects of beaver loss, the unit is at risk for future geomorphologic impacts.

V8 - Water and Soil Chemical Environment

Based on field indicators and an analysis of the Town's water quality database (Appendix 2), we assessed the overall chemical environment within Lower CG to be towards the higher end of the ***highly functioning (B+)*** category (Table 7). The primary stressor is sediment coming from Upper CG via Boreas Creek, but for the time being at least, these impacts are largely limited to the reset pond which apparently trapping most of the incoming sediment. All other sub-variables were assessed to be functioning at the ***reference standard (A)*** level.

This high rating of water and soil chemistry was challenged in July 2011 with the report of a "suspicious sheen" on surface water draining from an area up-gradient from the Lower CG wetlands below a subdivision and near the Breckenridge Nordic Center. While technically outside the boundary of the Preserve, we investigated this water on July 23-28, 2011 as a potential point-source of contamination to Lower CG. The surface water in question appeared to be originating from the ground below a row of houses along the Baby Doe Trail west of the Nordic Center (Photo 43). The area is potentially fed by sump or septic discharge from these residences (Photo 44) or by runoff from Nordic Center machinery. Though the sheen at this site appeared to be similar to natural sheen that is common in wetlands, the Town was particularly interested in the site based on its potential anthropogenic source, so we investigated it as a potential chemical stressor.

In addition to a sheen, we found the water here to be high in algae growth which is indicative of eutrophication or nutrient enrichment (that would be consistent with discharge from a failing septic system) (Photo 44). A common contaminant which expresses in water as a sheen is petroleum which could potentially originate from a source such as an oil or gas spill, or runoff from an area where vehicles leak these fluids. We obtained several water quality samples from the site for lab analyses to test for indicators that would rule out these two possible contamination sources. The water was found to have neither significant levels of petroleum hydrocarbons nor *E. coli* bacteria. Thus, we conclude that his water source was not contaminated by petroleum or sewage, and that the observed sheen is likely caused by some other source such as a natural metabolic by-product.

Variable 9 – Vegetation Structure and Complexity

Indirect impacts to vegetation structure from altered water distribution and geomorphology are much less severe in Lower CG than they are in Upper, appearing as several dried ponds and a few sediment deposition fans. Direct impacts are limited to several Nordic ski trails (Photo 45). According to Christy Carello's reports[2-7], these trails are clipped annually for maintenance, and in addition to the direct impacts from this practice to the shrub layer, she also suggests that it may have further impacts via grazing selection. As for weeds, they report that Canada thistle and scentless chamomile near Josie's Cabin are "dangerously close to the wetland system," and perennial pepperweed has established along the Gold Digger trail. With these stressors being so limited in magnitude and extent, vegetation structure is rated near the top of the ***highly functioning (B+)*** category.

Discussion

The State of Wetlands Habitat in Cucumber Gulch Preserve

Owing primarily to its location and a long history of increasing development both surrounding the site and within its source watershed, Cucumber Gulch is no longer the pristine wetland complex it once was. The wetland system within the Preserve is subject to various ecological stressors – some of them severe – that impair its ability to function at its potential as habitat for the diversity of organisms native to the site. A large percentage the stressor-induced impacts are currently confined to edges of the Preserve, with those habitats serving as a buffer from surrounding development. This is especially true in areas that otherwise lack an effective buffer, such as below Peak 7. Such “edge effects” can also be seen within the Preserve due to interior development, most notably along the gondola clear cut. At these areas, buffering functions are now relegated to the wetlands, themselves, that exist along the edges.

Much of the Preserve is currently in an overall highly functioning condition. Importantly, however, the effects of chronic stress are becoming manifest at the head of Upper Cucumber Gulch, which is currently experiencing rapid and dramatic habitat conversion. The area which had historically maintained diverse wetland and aquatic habitats has largely shifted to mesic upland habitat associated with what is currently a single-threaded, cascading stream channel. From a wetlands perspective, much of the habitat in the north arm of Upper Cucumber Gulch is essentially ***non-functional (F)***, because it lacks required wetland characteristics. This habitat is not without other intrinsic values, but it has lost the essential qualities of the pond complex it recently was.

While we conclude that much of the Preserve is currently in very good condition, based on evaluation of a long-term and comprehensive monitoring data set and our own site survey, the available evidence strongly suggests that very real and serious threats to future natural functioning exist; that is, the "health risks" facing the wetlands are a cause for concern. The recent and rapid collapse of the pond and wetland complex in Upper Cucumber Gulch may well be viewed as “the canary in the coal mine” and a harbinger of what may soon happen to down-valley habitats. The same stressors and mechanisms that caused failure of the Upper CG system are apparently beginning to penetrate into Lower CG, which is the largest and most diverse wetland complex in the Preserve. Intensifying stress from the greatly magnified sediment load, altered hydrology, and the formation of a new (unstable) Boreas Creek channel, combined with the decline and potential loss of beaver points to a negative (or at the most optimistic, “uncertain”) prognosis unless something is done to manage the stressors penetrating into the heart of the Preserve.

The sources of stress that are causing habitat degradation in the Cucumber Gulch primarily arise from 1) by-products of high-density development adjacent to the site, 2) human-caused changes to the source watershed, and 3) a decline in the population of a keystone species, the beaver. The first and second sources of stress are very important, but they are factors that are now, realistically, beyond the scope of management. The developments and watershed impacts must be viewed as permanent fixtures on the landscape, the future of the Preserve will depend upon how well these impacts can be mitigated within and at the edge of the preserve. The origin of the third source of stress, beaver loss, is uncertain – and to some degree beside the point. The bottom line is that if the management objective for the Preserve is to maintain the essential qualities of the habitats as they existed in the recent past, direct intervention and active management will be required to mitigate the effects of these perpetual stressors. Our opinion is that given the progression of change, the likelihood of Upper CG returning to ponded habitat on its own, within a meaningful timeframe, is quite low. It is far more likely that the inward progression of habitat degradation will continue.

The health of the Peak 7 Side Slopes area, on the other hand, appears to be relatively safe, despite the presence of considerable nearby development. The security compared to Upper and Lower CG, is in large part due to the fact that it its water source appears to be largely intact, despite prevalent watershed alterations. The water source of these wetlands is generally deeply-sourced springs that appear unaffected. The stable groundwater hydrology and lack of connection to "upstream" impaired systems also means that there are few mechanisms to drive major geomorphological impacts aside from the direct actions by man (*e.g.*, deliberate filling or excavation). The typical habitat of the area is also much less dependent on beavers which, as evidenced elsewhere, introduce another source of uncertainty. The types of stressors that the Peak 7 SS is subject to tend to be those that can be more effectively managed, since they are more direct and superficially recognizable. Protection against direct impacts, like additional forest clearing within the wetland and buffer for example, may be enough to sustain an ongoing high level of function in this area.

Management implications

The cornerstone of practical ecological preservation is the knowledge of what factors or stressors are causing important negative impacts to ecological health. Once identified, stressors can be designated as practically treatable or intransient. This is what makes a stressor-based assessment method like FACWet so useful for the management of an area like the Cucumber Gulch Preserve. By identifying which stressors cause the greatest impairment to overall ecological health, the method provides managers with crucial information about how to prioritize protection and mitigation efforts. Stressors that can practicably be managed serve as viable objectives for mitigation or protection; while those that cannot be managed may be understood as artificial constraints to the system. Such imposed constraints define new boundary conditions within which the natural system must be able to survive and function. Combining our assessment of the relative importance of stressors with a general understanding about which stressors can practically or effectively be managed, helps to guide Town resources toward to where they can yield the most efficient return based on the potential for improvement.

In general, evidence suggests that management practices within the Preserve are in step with the Town's overall strategy for the area. With the notable exception of the gondola line, which bisects the largest wetland expanse and causes severe but localized alterations to the wetland, the CGP is successfully managed as an intact block of habitat. Otherwise, impacts are confined to peripheral areas adjacent to development or associated with the various trails that crisscross the Preserve. While diminishing the "pristineness" of the Preserve, and certainly disruptive to some wildlife, these multiple uses enhance the intrinsic societal value of the site, and do not appear to impair the fundamental functioning of the wetland system. Based on the findings of this study, meaningful, but relatively minor, improvements to overall habitat quality are attainable with some re-examination and refinement of current practices.

Despite the best management practices generally in force within the Preserve, it is clear that serious threats to systemic integrity exist. Acknowledging that reparation of the source of stressors originating outside of the Preserve is difficult or impossible, we necessarily have to focus management prescriptions on mitigating the impacts of this stress at or within the Preserve boundary[7]. The cumulative effects of surrounding land use have intruded into the wetlands of Upper CG and now appear to be penetrating into Lower CG. There are three fundamental issues facing the preservation of Cucumber Gulch wetlands which, when boiled down to the simplest terms, are: 1) disruption of the sediment budget, 2) altered water source and distribution, and 3) loss of beaver. The effects of all of the other stressors pale in comparison to the fundamental importance of "the big three" and, as described in the *Results* section, the causes and effects of these stressors are inter-related. Together, these factors can be understood as resulting in fundamental alteration water distributional qualities.

---

[7] For example, the exterior stressors that increase allochthonous sediment input to Upper CG are severe, but managing these at their source (the ski area that makes up the source watershed) would be difficult or impossible. The augmented sediment regime is best understood as a new boundary condition that the Town will have to deal with and manage by mitigating the impacts as best as possible at the head of the wetland. Mechanical and engineering solutions to excess sediment at the head of the wetland will likely be necessary mitigate this exterior, watershed-level impact. The severe watershed impacts to water source pose another example of an exterior source of stress that is more or less intransient, meaning that its effects will have to be creatively mitigated at the at the edge or interior of the Preserve.

From a management perspective, the Town would be best suited to direct the lion's share of their resources towards addressing these three big issues (namely water source, sedimentation, and beavers). Of course it should be important to the Town to continue best management practices regarding the minor stressors as well (such as weed control and minimizing impacts from Nordic ski trails and hike/bike trails), but these activities are of secondary importance compared to alleviating stress from the "big three."

Sediment

Based on our findings, we recommend immediate action to mitigate the impacts of increased sediment load. Not only is this factor a direct stressor to wetland function in CGP, but we believe that increased sediment loading may also be the greatest habitat factor limiting beaver populations. Relatively deep open water is an important component of beaver habitat. The faster that sediment fills a pond, the greater the effort required by beavers to elevate dams and maintain ponding. Rapid pond filling could therefore be a driving factor behind habitat abandonment. That is, at some rate of sediment input, beaver simply cannot elevate their dams fast enough to keep ahead of filling. We do not know what degree sedimentation and pond filling played in the abandonment of Upper CG; but we can say with certainty that reducing sediment loading in the system would reduce stress on beaver populations and promote their recovery.

The impacts of sedimentation are is only just beginning to be manifest in Lower Cucumber Gulch. Upper CG receives elevated allochthonous inputs from the Peak 8 watershed. Direct evidence clearly shows this. The collapse of the dam system there is now mobilizing sediments that had been retained in Upper CG, further exacerbating incoming sediment loads to Lower CG. And finally, autochthonous sediment liberated by high energy flows in the newly cut Boreas Creek channel will increase sediment loads even more. All three of these sources must be mitigated if Lower CG habitat is to be protected.

As we mentioned earlier, the ultimate source of allochthonous sediment input is the upper Peak 8 watershed which is largely out of the Town's control. Fortunately, nearly all of the harmful sediment loads enter Cucumber Gulch via Boreas Creek so inputs can be treated as a relatively straightforward point-source issue. Mitigating these impacts at the head of the Preserve could potentially be accomplished by engineering a large sediment trap on Boreas Creek to capture excess sediments before they enter the gulch. Success of this type of system will be based on a good quantitative understanding of the sediment regime as well as regular maintenance.

The way to reduce autochthonous sediment generation is to reduce the energy of incoming flows. Until recently, the upper portion of the Preserve probably did not even have a discernable creek channel. But now, the Boreas Creek channel is a well-defined steep, high energy channel that has proved to be very susceptible to erosion. Our results clearly showed that channel erosion is the source of an extreme amount of sediment input. Because of the channel slope, width/depth ratio, and degree of entrenchment, stream power (a measure of the capacity for scour and erosion) is especially high, and the channel is in the middle of a process of degradation (down-cutting) and enlargement. It would be futile to try to stabilize this channel in its present condition given the existing hydrology. The key to decreasing the rate of channel degradation (and therefore the sediment produced by it) lies in dissipating water flows and decreasing its energy. This could be done by mimicking the historic distributary nature of surface flow entrance to the Gulch that existed prior to disturbance.

Water

Flow energy reduction could come about through a number of means, but designs that integrate solutions to multiple issues would be most effective. For instance, one approach to habitat improvement might be to design a structure that mimics the function the "Spreader Pond" used to perform (prior to 2007) before it became filled with sediment and was abandoned. Spreading incoming surface flow among a number distributary channels and basically re-creating the system that existed before beaver abandonment would greatly decrease stream power, supply multiple ponds with water, and distribute the water supply across the head of the gulch. Such a structure would re-wet drained wetlands, even in the event that beaver do not return to the area. A constructed water distribution system or structure would also need to be capable of dealing with high sediment loads, unless sediment was captured prior to entering the gulch.

Reduction of flow energy would have secondary benefits towards beaver recovery. Aside from reducing erosion and sediment transport capacity, it would also lower the effort required by beaver to harness incoming flows and distribute them across the valley. As with sediment, the role that high energy water input played in beaver abandonment is not known for sure, but we can say with certainty that reducing incoming flow velocity would reduce environmental stress and improve habitat characteristics for beaver.

Beavers

Given that the goal for the Preserve is to maintain habitat to sustain *“the existing high level of biological diversity”* and that most of the habitat in the preserve that functions in this way has been created and maintained by beavers, successful management of the Preserve would seem to be intimately tied to beaver restoration and sustainability. According to our assessment, beaver occupation (or actually the lack thereof) is a primary stressor that has severe impact on several of the state variables within both Upper and Lower CG. Our findings indicate that beaver activity is a crucial component of wetland health and functioning in these units, and that the present lack of beaver activity is both a factor in the degradation of Upper CG and a threat to the continued functioning in Lower CG. Managing the Preserve habitat to promote the long-term beaver occupation should be a priority management objective, and indeed success in this arena would be a good indicator of success in managing the preserve as a whole. Because beaver habitat is inextricably linked to both sediment (the first of the "big three" stressors we identified) and hydrological regime (the second), a singular focus on the habitat suitability and ultimate long-term habitation of CGP by beavers (the third of the "big three") may be one way to approach the management of the Preserve. If, for example, 20 years from now, there are no active beaver ponds in Cucumber Gulch Preserve, then we will have probably failed to maintain the high level of biological diversity that is still mostly thriving here today. But if in 20 years we can return here to find a network of occupied beaver ponds intact, then we have probably managed to preserve most of the important functions within CGP.

Technical details regarding the maintenance and management of beaver populations in CGP would have to begin with an understanding of what factors drive population dynamics at this site. The cause for beaver decline in the area has apparently not really been studied yet, and neither have the factors which are required for beavers to remain active here. Dr. Carello has been carefully monitoring beaver population numbers in the CGP since 2003, and has effectively documented the recent decline[2], but these researchers only speculate on the causes for that decline. They suggest: "*Possibilities of the 2003-2005 decline include the following: lack of beaver lodge and dam construction material, increased predation particularly from dogs, increased encroachment of both humans and dogs in the critical habitat area, disease, changes in water flow from Peak 8 ski area activity or simply a natural fluctuation in the population*." Elsewhere in their reports, they also implicate competition with muskrats as a potential cause of the population crash. Speculations for beaver decline have also been made by other researchers. DG&A[16] state that "*the decrease in beavers and beaver ponds in this area is likely due to a lack of suitable trees for dam building and the increased traffic and noise due to construction at the Peak 7 Base Area*."

Although often displaying a preference for aspen, it difficult to understand how the lack of building materials could be limiting beaver populations given the fact that dense willow cover exists throughout the entire Cucumber Gulch Preserve, and that willow branches are the primary material (along with mud and grass) that makes up all of the beaver dams at this site. Likewise, there is no evidence that lack of food or competition for food is limiting since willows and other hydrophytic vegetation that is commonly selected by beavers for food is abundant. We are also initially skeptical about the "increased traffic and noise," "dog predation," and "human encroachment" hypotheses since beavers thrive in other areas that have far worse conditions than those seen within CGP. To us, the recent rapid filling of ponds with sediment and increased energy of augmented flows are probably more important factors in beaver emigration or population decline than any of these other factors.

We stress, however, that all of these factors are stressors and act cumulatively in beaver decline and no one factor can be singled out. Beaver have a proven ability to survive in environmentally stressful conditions, most famously by altering the environment to their favor. But at some threshold multiple stressors make habitat untenable. After a population crash, under natural circumstances we would expect beavers to come back on their own, but the level of geomorphic alteration may have progressed to the point that some portions of CGP may uninhabitable by beaver unless there is active intervention. This adds an element of urgency to the situation, as doing nothing and relying on natural recovery does not appear a viable option.

The problem of beaver decline, with all its secondary impacts, has not yet been investigated in any level of detail. Given the importance of beaver to the health and functioning of the wetland system in CGP, we highly recommend a targeted investigation into the causes of their decline in the Preserve, the potential for recovery, and practical management strategies for maintaining a healthy population here.

In short, for the continued health and functioning of the wetlands in Cucumber Gulch Preserve, we strongly recommend that the Town take direct action towards managing the three greatest ecological threats by: 1) reducing sediment, 2) dispersing incoming flows, and 3) restoring and sustaining beavers. For the reasons mentioned above, this third factor, sustaining beavers in the Preserve, may be the single most important indicator of successful management. Optimally, mitigation of the former two stressors, will lead to restoration of the third.

Monitoring Objectives

For the past decade, the Town has invested significant resources in monitoring environmental conditions within the Preserve. To date, CGP monitoring has been primarily focused on detailed measurements of long-term trends in several water quality, vegetation, wildlife, and human use parameters. This ambient program has been invaluable for developing an historical database and establishing baseline conditions. Our meta-analysis and overall assessment results suggest ways in which monitoring efforts could be made more efficient by targeting specific factors that are most important to the management of wetland health. In addition to continued ambient monitoring (at some reduced level), we recommend incorporating customized monitoring aimed at understanding the primary agents of ecological degradation and risks outlined in this study.

Now that baseline conditions are well established, the program seems to be at a point where a portion of monitoring efforts could be redirected towards specific known problems. Therefore, we suggest a more focused approach wherein each monitoring parameter that is measured is done so to inform a specific management decision or target objective. Using the latest 2010 Annual Cucumber Gulch Conservation Monitoring Report$_2$ as an outline, we provide a brief overview of the present monitoring program and how it might be adapted in the future to more efficiently serve the management needs of the Preserve.

Water Resources/Water Quality Monitoring

Through 2010, the Town has supported ongoing annual water quality monitoring based on routine field measures and lab analysis of water grab samples collected from several sampling points within CGP. Our comprehensive analysis of the Town's Cucumber Gulch water quality database (Appendix 2) contains specific recommendations for adapting the water quality monitoring approach. In general, we found that the Town's current monitoring efforts were largely redundant with the ongoing monitoring already being completed by other consultants for the ski area. We suggest that the monitoring efforts from these other sources might be adequate to meet the Town's desire to maintain an ongoing ambient data record of water quality at established points, and that future resources might be better directed toward rapid, less expensive, but more extensive surveys over the entire Preserve to scan for water-quality "hot-spots".

We strongly recommend that the Town consider redirecting its other water resource monitoring efforts towards known problems. Our assessment indicates that water quality concerns tend to be minor in the Preserve, but that the most pressing water resource issues are the source and distribution impacts within Upper CG and, to a lesser extent, in the Lower CG and Peak 7 SS areas. Specific studies aimed at quantifying the severity and extent of impacts to water source (quantity) and distribution in these areas would yield useful and practical data towards finding solutions for mitigating these stressors. Such data could be obtained by gauging inflows from various inlet points and placing shallow data-logging groundwater wells in strategic areas where groundwater hydrographs are suspected to be impacted. These data could also be useful for gaining precision in wetlands delineation and documenting progression of the hydrologic system in Upper CG. We emphasize the use of automated loggers, since the frequency at which many of the wells were read manually produces data that have severely limited value. Aside from the higher quality data, automated wells are also less expensive over the course of a long term monitoring program.

In addition to quantifying water source and distribution hydrographs, further monitoring of the geomorphologic causes of water distribution impacts would yield useful information. Specifically, we recommend that channel stability and incision be monitored along Boreas Creek to watch the progression of channel development.

Vegetation Monitoring

The town has been monitoring vegetation within CGP annually since 2001 based on a protocol and random "macro-plot" sampling strategy outlined by SAIC[11]. Over the past 10 years, annual data from these plots have been combined to describe the overall vegetation condition within CGP, and these have been useful for an overall characterization of the site and for establishing baseline condition. One aim for these studies has been to "*evaluate any changes that may occur due to climatic events and/or human impacts*[2]*.*" However, over the 10 years that this monitoring has been ongoing, there has been no statistical change in overall species richness, diversity, or evenness[2] (once the effects of changing sampling methods was accounted for), and all of the changes to cover were explained by precipitation. Given these results, we suggest that annual sampling frequency for these data may not be necessary, and that a similar level of information could be obtained by sampling these sites on a schedule of once every 3 to 5 years instead.

We also agree with the recommendations made by Carello and Galloway in 2010[1,2] for more targeted vegetation monitoring at locations where impacts are suspected. Our study identified several specific areas where present wetland degradation and vegetation impacts are suspected or predicted in the near future. Targeted vegetation monitoring at these locations would be useful for precisely identifying wetland boundaries, tracking changes to wetlands extent, and quantifying the magnitude of vegetation impacts. Related to this, these researchers also recommended mapping critical fen habitats within CGP, and we agree that this would be useful for prioritizing future monitoring efforts.

We also suggest that a more rigorous treatment of the weed issue might be helpful to management of this problem. For years, the Town's annual CGP monitoring reports have qualitatively described a problem with weeds at certain locations. Now that the problem is identified, we recommend a more quantitative approach to weed monitoring at these locations aimed at identifying which aspects of the Town's weed control efforts are successful and which are not so that adaptive management can applied to weed control.

Wildlife Monitoring

Wildlife monitoring is a critical component to the understanding and management of Cucumber Gulch Preserve since healthy wildlife populations represent an overarching goal for Preserve management and the ultimate end product of an ecologically healthy ecosystem. For this reason, we highly recommend continued wildlife monitoring. We suggest though, that the program be evaluated to make sure that the data being collected are the most useful ones to the Town from a management perspective.

Like vegetation, the Town has been funding rigorous monitoring of wildlife in CGP since 2001 with a primary focus on birds. For each of the past 10 years, annual reports give results on species counts, richness, diversity, and evenness from bird surveys. These results have certainly improved the Town's understanding about what species regularly use CGP as habitat, but the 10-year trends averaged over the entire Preserve area are difficult to interpret. For instance, none of the "*Terrestrial and Aquatic Birds Conclusions*" in the 2010 Annual Monitoring Report$_2$ draw on these results. At this point in time, now that a good baseline has been established, it may be worth evaluating the practical application of this level of data. If the level of effort put into ambient bird monitoring can be efficiently reduced without sacrificing important information, then we would suggest more targeted studies to evaluate the effects of known impacts to habitat. Recent studies evaluating the effects of the gondola on bird distributions are an excellent example of how monitoring efforts may be extended to more practical management concerns, building on the solid baseline that has already been established for these parameters. Similarly, the monitoring of other wildlife could be customized to meet specific management objectives.

Past monitoring of beaver activity in the Preserve have been invaluable in our efforts to understand he natural functioning of the CGP wetlands system as well as recent impacts. Given our recommendations for beaver habitat restoration and protection in CGP, we would advise the Town to continue beaver monitoring and to expand its efforts with studies aimed at identifying critical aspects of beaver habitat and behavior which could improve efforts at restoring this keystone species to the Preserve. Understanding what caused the recent decline in beaver populations and how to remedy these conditions is critical to the success of restoration efforts.

Monitoring Priorities

Based on these observations, we suggest the following as a list of monitoring priorities for 2012 and the future:

- Photo-documentation
    - photographs from monumented points, over time provides a great deal of information documenting ecological change with little expense.
- Fen mapping
    - map organic soils and fens to identify specific locations of this critical habitat
- Wetland hydrology
    - quantify impacts to water source
    - quantify changes to distribution by monitoring hydrographs in suspect areas
    - continue reviewing existing ongoing hydrology studies
- Geomorphology
    - quantify sediment input, transport, deposition, and erosion rates
    - monitor channel stability on Boreas Creek
    - monitor dam maintenance activity by beavers and dam breaches
- Beavers
    - targeted studies to support beaver restoration efforts
    - continued ambient monitoring to quantify the degree and locations of beaver activity
- Vegetation
    - quantify vegetation conditions at specific plots where impacts are active or suspected
- Water quality
    - continue reviewing data from existing ongoing water quality studies
    - conduct occasional broad surveys across CGP to scan for "hot spots" using simple field techniques
- Wildlife
    - continue some level of ambient wildlife monitoring
    - begin shifting efforts to more targeted studies with specific management implications

Appendix 1: List of reports

The following reports were provided to us by the Town as background information to be reviewed as part of a meta-analysis and to inform the assessment of wetland function.

1. **2010 Water Quality Issues in Cucumber Gulch, December 14, 2010 Report to Breckenridge Town Council**. By: Barbara Galloway (ERO Resources)

2. **Cucumber Gulch Annual Conservation Monitoring Report 2010, Breckenridge, Colorado, March 2011.** By: Dr. Christy Carello (Metropolitan State College of Denver and Emerald Planet), with water section by Barbara Galloway (ERO Resources)

3. **Cucumber Gulch Annual Conservation Monitoring Report 2009, Breckenridge, Colorado, March 2010.** By: Dr. Christy Carello (Metropolitan State College of Denver and Emerald Planet), Audrey Hoffa (Emerald Planet), with water section by Barbara Galloway (ERO Resources)

4. **Cucumber Gulch Annual Conservation Monitoring Report 2008, Breckenridge, Colorado, March 2009.** By: Dr. Christy Carello and Audrey Hoffa (Metropolitan State College of Denver), with water section by Barbara Galloway (ERO Resources)

5. **Cucumber Gulch *Annual Conservation Monitoring Report 2007*, Breckenridge, Colorado, May 27, 2008.** By: Dr. Christy Carello and Audrey Hoffa (ERO Resources and Metropolitan State College of Denver)

6. **Cucumber Gulch *Annual Conservation Monitoring Report 2006*, Breckenridge, Colorado, October 20, 2007.** By: Dr. Christy Carello and Audrey Hoffa (ERO Resources and Metropolitan State College of Denver)

7. **Cucumber Gulch *Annual Conservation Monitoring Report September 2004 - September 2005*, Breckenridge, Colorado, November 22, 2005.** By: Dr. Christy Carello (ERO Resources and Metropolitan State College of Denver) and assisted by Audrey Hoffa

8. **Cucumber Gulch *Annual Conservation Monitoring Report September 2003 - September 2004*, Breckenridge, Colorado, November 8, 2004.** By: Dr. Christy Carello (ERO Resources)

9. **Cucumber Gulch *2002/2003 Semi-Annual Conservation Monitoring Report, Breckenridge, Colorado*, January 31, 2003.** By: Science Applications International Corporation

10. **Cucumber Gulch *Conservation Monitoring Report*, Year 2002-2003, *Breckenridge, Colorado*, August 7, 2003.** By: Science Applications International Corporation

11. **Cucumber Gulch *Conservation Monitoring Report, Year 2001, Town of Breckenridge, Colorado, December 7, 2001*.** By: Science Applications International Corporation

12. **Semi-annual Groundwater Monitoring Report, Second Half 2010, Peaks 7 and 8 Base Area Developments, Breckenridge Ski Area, Breckenridge, Colorado.** April 4, 2011. By: Ganser, Lujan & Associates.

13. **Semi-annual Groundwater Monitoring Report, First Half 2010, Peaks 7 and 8 Base Area Developments, Breckenridge Ski Area, Breckenridge, Colorado.** August 13, 2011. By: Don Ganser & Associates.

14. **Semi-annual Groundwater Monitoring Report, Second Half 2009, Peaks 7 and 8 Base Area Developments, Breckenridge Ski Area, Breckenridge, Colorado.** February 10, 2010. By: Don Ganser & Associates.

15. **Semi-annual Groundwater Monitoring Report, First Half 2009, Peaks 7 and 8 Base Area Developments, Breckenridge Ski Area, Breckenridge, Colorado.** August 13, 2010. By: Don Ganser & Associates.

16. **Semi-annual Groundwater Monitoring Report, Second Half 2008, Peaks 7 and 8 Base Area Developments, Breckenridge Ski Area, Breckenridge, Colorado.** February 23, 2009. By: Don Ganser & Associates.

17. **Semi-annual Groundwater Monitoring Report, First Half 2008, Proposed Peaks 7 and 8 Base Area Developments, Breckenridge Ski Area, Colorado.** August 19, 2008. By: Don Ganser & Associates.

18. **Semi-annual Groundwater Monitoring Report, Second Half 2007, Proposed Peaks 7 and 8 Base Area Developments, Breckenridge Ski Area, Colorado.** January 10, 2008. By: Don Ganser & Associates.

19. **Semi-annual Groundwater Monitoring Report, First Half 2007, Proposed Peaks 7 and 8 Base Area Developments, Breckenridge Ski Area, Colorado.** August 27, 2007. By: Don Ganser & Associates.

20. **Assessment of Groundwater Impacts to Wetlands; Building 801; Peak 8 Base Area Development; Breckenridge Ski Area, Colorado.** October 31, 2007. By: Joel Sobel, PG and Donald R. Ganser, PG, (Don Ganser & Associates).

21. **Assessment of Groundwater Condition and Evaluation of Impacts; Numerical Modeling Analysis of Design Modifications; March 2007; Grand Timber Lodge South**

and North Buildings; Peak 7 Base Area Development; Breckenridge, Colorado. March 25, 2007. By: Donald R. Ganser, PG, (Don Ganser & Associates).

22. **Peak 7 Development Groundwater Review; Town of Breckenridge, Summit County, Colorado.** January 10, 2007. By: Kenneth Kolm, PhD. (Hydrologic Systems Analysis, LLC)

23. **Water Quality Testing Report, Peak 7 Breckenridge Ski Area, Breckenridge, Colorado,** March 2003; Revised April 27, 2006; Revised May 14, 2007; Revised December 14, 2007; Revised December 11, 2008; Revised December 29, 2009; Revised December 30, 2010. By: TetraTech, Inc.

24. **Water Quality Testing Report, Peak 8 Breckenridge Ski Area, Breckenridge, Colorado,** August 2007, Revised July 2008, Revised December 2008, Revised December 2009, Revised December 2010. By: TetraTech, Inc.

25. **Wetland Delineation Report. Breckenridge Ski Resort. Upper Cucumber Gulch. 2008.** By: Western Ecological Resources, Inc

Appendix 2: Summarized analysis of past water quality data

Cucumber Gulch: Summary of water quality analysis of existing data
Assessment and recommendations for future monitoring

<table>
<tr><th>Parameter</th><th>Observation</th><th>Sample Location</th><th>Explanation</th></tr>
<tr><td rowspan="6">dissolved oxygen</td><td>Consistently low</td><td>7-TT-SW3 (stagnant SW down-gradient from P7 development)</td><td>Consistently low DO (below recommended limit for fish) at this stagnant SW site. Low levels were present prior to P7 base area construction.</td></tr>
<tr><td>moderate spikes</td><td>7-TT-SW4 (stagnant SW down-gradient from P7 development)</td><td>Several spikes of low DO during 2007 season</td></tr>
<tr><td>moderate spikes</td><td>8-ERO-SW9 (stagnant SW tributary to spring and near Glenwild inlet)</td><td>Had low values near threshold for fish during 2009 season</td></tr>
<tr><td>moderate spikes</td><td>8-TT-SW4</td><td>Settling pond @ P8 parking lots. No concern</td></tr>
<tr><td colspan="3">Assessment: Occasional observations of low DO in stagnant water SW sites. Not suspected to be related to development impacts. Unclear whether DO is limiting to wildlife.</td></tr>
<tr><td colspan="3">Recommendations: No need to monitor DO at GW sites (not sure how it could be important). Continue monitoring DO at SW sites and consider including additional SW sites at locations that are significant at-risk aquatic habitats (particularly for boreal toad). Need to quantify a standard or limiting threshold for DO based on CG wildlife (particularly boreal toad).</td></tr>
<tr><td rowspan="2">pH</td><td colspan="3">Assessment: No concerns</td></tr>
<tr><td colspan="3">Recommendations: No need to continue testing pH. The level of monitoring being conducted by TetraTech is more than adequate.</td></tr>
<tr><td rowspan="3">temperature</td><td>consistently high</td><td>8-TT-SW4</td><td>This site has temp values that exceed cold water standards, but this site is a small parking lot settling pond, so we are not concerned.</td></tr>
<tr><td colspan="3">Assessment: No concerns</td></tr>
<tr><td colspan="3">Recommendations: It is reasonable to suspect that the identified impacts could affect water temperature regime. Continued monitoring is recommended at SW sites, and we also recommend expanding the number of sites to include at-risk aquatic habitat areas. However, to make use of these data, we should determine a set of standards or range of acceptable limits for temperature based on the aquatic wildlife in addition to comparing values to baseline. Additionally, temperature is automatically sampled with DO and conductivity and it is necessary for standardizing these measures, so continued monitoring is also recommended on this basis.</td></tr>
<tr><td rowspan="2">turbidity</td><td>spikes</td><td>many spikes on many SW sites</td><td>No consistent trend or pattern of turbidity spikes can be identified.</td></tr>
<tr><td colspan="3">Assessment: Most samples showed very clear water almost all the time, but some spikes of turbidity were seen. The dataset is too coarse to identify patterns or trends.</td></tr>
</table>

	Recommendations: No need to continue testing turbidity of groundwater. The results have little meaning. It may be worthwhile to continue monitoring SW turbidity. Occasional observations from a few set locations is of very little value. On the other hand, monitoring turbidity could be useful for identifying and quantifying the source of suspended sediments. To accomplish this, a new more intensive and flexible sampling scheme will be necessary.		
conductivity	increasing trend	7-TT-SW3, 7-TT-SW4, 7-TT-SW8 (SW inputs from Peak 7 construction area)	Overall values are not high, but these sites appear to show an increase that corresponds to construction at Peak 7 base area and construction of impacts to water source (culverts, drainages, detention ponds, infiltration galleries, etc.)
	increasing trend	8-ERO-SW9 (stagnant SW trib to spring and near Glenwild inlet)	Overall values not high, but the few points suggest an increase from low to moderate levels in 2009. Spring source to this site is also higher conductivity.
	mod-high spike	8-TT-SW7 (P8 admin detention pond)	Several high readings in 2008. This pond apparently rarely gets inflow except during storm events. It is supposed to be pumped out into the main P8 detention pond and not flow into the gulch.
	mod spike	6-ERO-SW5	This site likely has no upstream point sources or direct impacts (other than minimal increased runoff from snowmaking), yet its spike is higher than any other site.
	consistently very high	8-TT-SW4	This site often had very high cond. Values. It is a small settling pond for runoff from Bergenhoff parking lot. High values are likely a result of increasing conc. from evaporation (no outlet). TT stopped sampling this site.
	Assessment: The most significant concern is the apparent increase on some peak 7 source areas after construction impacts. A lesser concern is the apparent concentration of salts by P8 admin detention pond and/or (unlikely) Glenwild overflow. The magnitude of this change so far is small, however, compared with some natural sites.		
	Recommendations: Continue monitoring conductivity as very inexpensive indicator of WQ concerns. This parameter can be used to identify any salt or ionic concentration issue. We recommend increasing frequency of sampling sites and times for this parameter as the primary means of scanning for potential problems. If specific concerns are found while monitoring conductivity, then more detailed lab tests on specific substances (ions) may be warranted . More extensive monitoring of this rapid, inexpensive parameter will be useful for identifying patterns and sources of contaminants.		
hardness	increasing trend	7-TT-SW3 (SW inputs from Peak 7 construction area)	Increasing trend at this one site corresponds temporally to peak 7 construction impacts. However, other similar sites below Peak 7 construction do not show the trend
	increasing trend	8-ERO-SW9 (stagnant SW tributary to spring and near Glenwild inlet)	Overall values not high, but the few points suggest an increase from low to moderate levels in 2009. Possible (but unlikely?) influence from Glenwild overflow runoff.
	very high	8-TT-SW4	Settling pond that concentrates solutes. Same pattern as conductivity.
	Assessment: The most significant concern is the apparent increase on one Peak 7 source area after construction impacts. A lesser concern is the apparent concentration of salts by P8 admin detention pond and/or (unlikely) Glenwild overflow. The magnitude of this change so far is small, however, compared with some natural sites.		
	Recommendations: No need to continue testing hardness. Conductivity is a reasonable indicator should hardness values change significantly. TetraTech monitoring is adequate to assess Peak 7 impacts.		

zinc	consistently very high	7-ERO-GW5 (near Bridge Creek inlet)	Consistently extremely high zinc readings are very likely caused by sampling from a galvanized pipe. These data are not a valid indicator of water quality concern.
	moderate spikes	8-ERO-SW3 (wetland interior)	one spike reading exceeded TVS in 2004
	moderate spikes	8-ERO-SW1 (wetland interior)	one spike reading exceeded TVS in 2006
	low spikes	8-TT-SW5 (Boreas Creek inlet)	occasional spikes barely exceeded TVS
	Assessment: No significant concerns. The only significant standard violations were point spikes in the interior of the wetland and probably not caused by human impact.		
	Recommendations: No need to continue testing zinc. Specific tests could be ordered if of zinc contamination is suspected or if TetraTech monitoring identifies a concern.		
sodium	consistently very high	8-TT-SW4	Settling pond that concentrates solutes. Same pattern as conductivity.
	mod spikes	8-TT-SW7 (P8 admin detention pond)	Several high readings in 2008.
	increasing trend	7-TT-SW3, 7-TT-SW4, 7-TT-SW8 (SW inputs from Peak 7 construction area)	Overall values are not high, but these sites appear to show an increase that corresponds to construction at Peak 7 base area and construction of impacts to water source (culverts, drainages, detention ponds, infiltration galleries, etc.)
	high spike	8-TT-GW2 (P8 FAR parking lot)	spiked in 2009, not sure what water is being sampled here?
	increasing trend	8-TT-GW3 (up end of gulch near P8)	clear increase in 2009 following Boreas Creek blowout, down cut, and subsequent drying of the upper gulch wetlands
	Assessment: A significant concern is the increase in GW [Na] following Boreas Creek blowout that left this area in a drier condition. Another significant concern is the apparent increase on some peak 7 source areas after construction impacts. A lesser concern is the apparent concentration of salts by P8 admin detention pond and/or (unlikely) Glenwild overflow. The magnitude of this change so far is small, however, compared with some natural sites.		
	Recommendations: No need to continue testing sodium. Specific tests could be ordered if sodium contamination is suspected, if TetraTech monitoring identifies sodium pollution, or if conductivity scans identify salt concerns that we want to investigate further to identify the specific solute.		
silver	**Assessment:** No significant concerns.		
	Recommendations: No apparent need for continued silver monitoring. ERO stopped sampling after 2008.		
selenium	**Assessment:** No significant concerns.		
	Recommendations: No apparent need for continued selenium monitoring. ERO stopped sampling after 2008.		

potassium	**Assessment:** No significant concerns.		
	Recommendations: No apparent need for continued potassium monitoring. ERO stopped sampling after 2008.		
phosphorus	increasing trend	7-TT-SW3 (down from original P7 detention pond)	Significant annual spikes in P seen at this site while the original Peak 7 detention pond was in use (2007-2009). 2010 values all low following installation of new detention pond. Suspected effluent from fertilized landscaping and revegetation associated with Peak 7 base area construction.
	spikes	8-TT-SW2A (inlet drain at base of P8 ski area - above parking and construction)	Annual spikes higher than normal during 2007, 2008, 2009. Suspected effluent from fertilized reveg on lower portion of ski area
	mod spikes	8-TT-SW7 (P8 admin detention pond)	Several high readings in 2008. Additional evidence that this pond held water in 2008 that concentrated solutes by evaporation, and that in most years it normally does not function in this way.
	Assessment: There are clearly spikes of phosphorus at some locations. The magnitude of the problem is difficult to quantify, since standards for nutrients such as phosphorus and nitrogen are complicated to determine. The increase in [P] where Peak 7 base area effluent is concentrated makes us suspect that fertilizers used in landscaping this area are a likely source. Observations of algae in Peak 7 detention pond effluent in 2011 indicates that nutrient levels are still high and that the magnitude of nutrient increase and accelerated eutrophication ought to be a potential concern.		
	Recommendations: Monitoring P directly is useful for identifying the source of nutrient pollution. Continued monitoring at existing TetraTech sites is probably sufficient to assess the trend and pattern of this issue. For example, when P7 effluent (detention pond outlet water) was redirected to another part of the gulch after 2009 season, the levels in 7-TT-SW3 dropped. If the problem still exists and was just moved to a new discharge location, we would expect to see a resulting increase in [P] at 7-TT-SW4.		
nickel	**Assessment:** Very low values measured. No significant concerns.		
	Recommendations: No apparent need for continued nickel monitoring. ERO stopped sampling after 2008.		
molybdenum	**Assessment:** No significant concerns.		
	Recommendations: No apparent need for continued molybdenum monitoring. ERO stopped sampling after 2008.		
manganese	low spikes	7-TT-SW3 and 7-TT-SW1b	These sites show some spikes that approach lower TVS levels.
	low spikes	7-ERO-SW2 and 7-ERO-GW5	These sites show some spikes that approach lower TVS levels.
	increasing trend	8-TT-GW3 (up end of gulch near P8)	Increase in 2009 following Boreas Creek blowout, down cut, and subsequent drying of the upper gulch wetlands. Values still not high.
	Assessment: No significant concerns.		
	Recommendations: No need to continue testing manganese. Specific tests could be ordered if manganese contamination is suspected, if TetraTech monitoring identifies sodium pollution, or if conductivity scans identify salt concerns that we want to investigate further to identify the specific solute.		

magnesium	increasing trend	7-TT-SW3 (SW inputs from Peak 7 construction area)	Overall values are not high, but these sites appear to show an increase that corresponds to construction at Peak 7 base area and construction of impacts to water source (culverts, drainages, detention ponds, infiltration galleries, etc.)
	consistently mod-high	8-ERO-SW9 (stagnant SW trib to spring and near Glenwild)	Overall values not high, but the few points suggest higher levels than other sampling sites. May be due to fact that the water source for this site is a spring.
	consistently high	8-TT-SW4	Settling pond that concentrates solutes.
	single high spike	7-ERO-SW7 and 8-ERO-1	2004, a spike from one observation only. This is possibly a runoff following mag chloride application (see chloride), but it was not detected on any of the other sites where we would expect to have seen it.
	increasing trend	8-TT-GW3 (up end of gulch near P8)	Increase in 2009 following Boreas Creek blowout, down cut, and subsequent drying of the upper gulch wetlands. Values still not high.
	Assessment: A significant concern is the increase in GW [Mg] following the Boreas Creek blowout that left this area in a drier condition. This is evidence of a secondary effect of channelization of Boreas Creek (from multiple dammed channels to one thread). I.e. When this area dried after the blowout, existing solutes became concentrated (2009). Monitoring through 2010 shows these gradually decreasing, and the same pattern is seen for other ions. Another significant concern is the apparent increase on some peak 7 source areas after construction impacts. A lesser concern is the apparent concentration of salts by P8 admin detention pond and/or Glenwild overflow. The magnitude of all of these impacts so far has been small.		
	Recommendations: No need to continue testing magnesium. Specific tests could be ordered if magnesium contamination is suspected, if TetraTech monitoring identifies sodium pollution, or if conductivity scans identify salt concerns that we want to investigate further to identify the specific solute. Monitoring existing TetraTech sites is sufficient for evaluating the concerns already identified (above).		
lead	**Assessment:** Very low values measured. No significant concerns.		
	Recommendations: No apparent need for continued lead monitoring.		
copper	consistently high	many sites	Many SW sites at all locations have copper levels that are above TVS SW criteria throughout the time duration of the study. Nothing has been mentioned about concerns for copper pollution in previous reports, so we suspect that it is not considered a problem. At this point, high baseline values for copper lead us to the tentative conclusion that relatively high copper may be natural for this site.
	Assessment: Relatively high background levels of copper are present, but no significant human-caused impacts are suspected.		
	Recommendations: Continued monitoring of copper at TetraTech sites is more than sufficient to continue testing the assumption that high copper is natural and not increasing.		
chromium	**Assessment:** Very low values measured. No significant concerns.		
	Recommendations: No apparent need for continued chromium monitoring. ERO stopped sampling after 2008.		
cadmium	**Assessment**: No significant concerns.		
	Recommendations: No apparent need for continued cadmium monitoring. ERO stopped sampling after 2008.		

calcium	increasing trend	7-TT-SW3 (SW inputs from Peak 7 construction area)	Overall values are not high, but these sites appear to show an increase that corresponds to construction at Peak 7 base area. May be decreasing again through 2010
	increasing trend	8-ERO-SW9 (stagnant SW trib to spring and near Glenwild inlet)	Overall values not high, but the few points suggest higher levels than other sampling sites. May be due to fact that the water source for this site is a spring.
	consistently high	8-TT-SW4	Settling pond that concentrates solutes. Same pattern as conductivity.
	high spike	8-TT-GW2 (P8 FAR parking lot)	Spiked in 2009, not sure what water is being sampled here?
	consistently mod-high	8-ERO-GW5 (Near Bridge Creek and Stables Lot)	Possible impact of runoff from stables lot
	increasing trend	7-TT-GW2 (P8 FAR parking lot)	Overall values are not high, but this site appears to show an increase that corresponds to construction at Peak 7 base area.
	increasing trend	8-TT-GW3 (up end of gulch near P8)	Increase in 2009 following Boreas Creek blowout, down cut, and subsequent drying of the upper gulch wetlands. Values still not high.
	Assessment: A significant concern is the increase in GW concentrations following Boreas Creek blowout (see discussion of magnesium). Also similar to Mg, there is an apparent increase on some peak 7 source areas after construction impacts. Peak 8 admin detention pond is not a source of high chloride to 8-ERO-SW9. The magnitude of chloride pollution appears to be minimal so far.		
	Recommendations: Continued monitoring at TetraTech sites is sufficient to address the identified concerns. Specific tests could be ordered if calcium contamination is suspected, if TetraTech monitoring identifies sodium pollution, or if conductivity scans identify salt concerns that we want to investigate further to identify the specific solute.		
ammonia	low spikes	7-ERO-GW1 7-ERO-GW2 (upper P7 area)	These sites show some spikes that approach lower TVS levels. Unknown source. No concerns.
	Assessment: No significant concerns.		
	Recommendations: No apparent need for continued ammonia monitoring.		

chloride	increasing trend	7-TT-SW3 (SW inputs from Peak 7 construction area)	Overall values are not high, but these sites appear to show an increase that corresponds to construction at Peak 7
	consistently mod-high	8-ERO-SW9 (stagnant SW tributary to spring and near Glenwild inlet)	Overall values not high, but the few points suggest higher levels than other sampling sites. May be due to fact that the water source for this site is a spring.
	single high spike	7-ERO-SW7 and 8-ERO-1	2004, one observation spike, possibly a runoff following mag chloride application (see magnesium), but most sites did not detect it.
	consistently high	8-TT-SW4	Settling pond that concentrates solutes.
	increasing trend	8-TT-GW3 (up end of gulch near P8)	Increase in 2009 following Boreas Creek blowout, down cut, and subsequent drying of the upper gulch wetlands. Values still not high. Tend to be decreasing through 2010
	single mod spike	8-TT-SW7 (P8 admin detention pond)	single spike in 2008, then consistently very low
	increasing trend	7-TT-SW8 (P7 base detention pond)	slight increase in 2010
	spike	8-TT-GW2 (up end of gulch near P8)	Spiked in 2009, not sure what water is being sampled here?
	Assessment: A significant concern is the increase in GW concentrations following Boreas Creek blowout (see discussion of magnesium). Also similar to Mg, there is an apparent increase on some peak 7 source areas after construction impacts. P8 admin detention pond is not a source of high chloride to 8-ERO-SW9. The magnitude of chloride pollution appears to be minimal so far.		
	Recommendations: Continued monitoring at TetraTech sites is sufficient to address the identified concerns. Specific tests could be ordered if magnesium contamination is suspected, if TetraTech monitoring identifies sodium pollution, or if conductivity scans identify salt concerns that we want to investigate further to identify the specific solute.		
Nitrate	**Assessment:** Values are all extremely low compared to standards. No concerns		
	Recommendations: No need to continue monitoring nitrate.		
total petroleum hydrocarbons	Increasing trend	7-TT-SW3 (standing water site below P7 base)	annual spikes at this site are continually increasing from 2007-2009
	Assessment: Possible trend of increasing annual spike magnitude below P7 following construction. Likely related to summertime construction vehicles or runoff from new road. All values from ERO sites were continuously low.		
	Recommendation: Continue monitoring TetraTech sites to scan for contamination events.		

Appendix 3: Wetlands delineation data sheets

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: CG (CUCUMBER GULCH) City/County: Summit Sampling Date: A1
Applicant/Owner: TOWN OF BRECKRIDGE State: CO Sampling Point: 7/13/11
Investigator(s): BJ, MB, AH, JD Section, Township, Range: SEC 36 T6S, R78W
Landform (hillslope, terrace, etc.): Valley SIDE Local relief (concave, convex, none): SLOPING Slope (%): ~4
Subregion (LRR): ROCKY MT. RANGE & FO LONG ~~Lat~~: 408414 LAT ~~Long~~: 4370720 Datum: UTM NAD 83
Soil Map Unit Name: UNMAPPED NWI classification: UPLAND FOREST
Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)
Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ____
Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____ No X	Is the Sampled Area within a Wetland?	Yes ____ No X
Hydric Soil Present?	Yes ____ No X		
Wetland Hydrology Present?	Yes ____ No X		

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: 1X3 m)	Absolute % Cover	Dominant Species?	Indicator Status
1. ~~Ex~~ Pic eng (Picea engelmanni	40	Y	FACU
2.			
3.			
4.			
	40	= Total Cover	
Sapling/Shrub Stratum (Plot size: ____)			
1.			
2.			
3.			
4.			
5.			
		= Total Cover	
Herb Stratum (Plot size: 1x3)			
1. Mert ciliata (Metensia ciliata)	45		FACW
2. Epi Ang (EPILOBIUM angustif	10		FACU
3. TAR off (TARAXACUM officinale)	2		FACU
4. Car aqu (Carex aquatilis)	3		OBL
5. Erigeron peri (Erigeron perigrinus)	1		FACW
6. Arnica (latifolia)	1		FACU
7. Achillea millefolium	2		FACU
8. Vaccinium scoparium	2		FACU
9.			
10.			
11.			
	66	= Total Cover	
Woody Vine Stratum (Plot size: ____)			
1.			
2.			
		= Total Cover	
% Bare Ground in Herb Stratum 34			

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC:	1	(A)
Total Number of Dominant Species Across All Strata:	2	(B)
Percent of Dominant Species That Are OBL, FACW, or FAC:	50	(A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	3	x 1 = 3
FACW species	46	x 2 = 92
FAC species	0	x 3 = 0
FACU species	56	x 4 = 224
UPL species	0	x 5 = 0
Column Totals:	105 (A)	319 (B)

Prevalence Index = B/A = 319/105 3.01

Hydrophytic Vegetation Indicators:

NO 1 - Rapid Test for Hydrophytic Vegetation
NO 2 - Dominance Test is >50%
NO 3 - Prevalence Index is ≤3.0[1]
__ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
__ 5 - Wetland Non-Vascular Plants[1]
__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ____ No X

Remarks:

SOIL

Sampling Point: ____________

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-7	10YR2/2	100					O	O
7-10	10YR3/3	100					SCL	w/ gravel/cob
10-14	10YR3/3		10YR4/6	9%			SCL	w/ gravel Cob
≥14								Cobble
								Soils ARE Damp

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- __ Histosol (A1)
- __ Histic Epipedon (A2)
- __ Black Histic (A3)
- __ Hydrogen Sulfide (A4)
- __ Depleted Below Dark Surface (A11)
- __ Thick Dark Surface (A12)
- __ Sandy Mucky Mineral (S1)
- __ Sandy Gleyed Matrix (S4)
- __ Sandy Redox (S5)
- __ Stripped Matrix (S6)
- __ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- __ Loamy Gleyed Matrix (F2)
- __ Depleted Matrix (F3)
- __ Redox Dark Surface (F6)
- __ Depleted Dark Surface (F7)
- __ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- __ 2 cm Muck (A10)
- __ Red Parent Material (TF2)
- __ Very Shallow Dark Surface (TF12)
- __ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______________________

Depth (inches): ______________________

Hydric Soil Present? Yes _____ No X

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- __ Surface Water (A1)
- __ High Water Table (A2)
- __ Saturation (A3)
- __ Water Marks (B1)
- __ Sediment Deposits (B2)
- __ Drift Deposits (B3)
- __ Algal Mat or Crust (B4)
- __ Iron Deposits (B5)
- __ Surface Soil Cracks (B6)
- __ Inundation Visible on Aerial Imagery (B7)
- __ Sparsely Vegetated Concave Surface (B8)
- __ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- __ Salt Crust (B11)
- __ Aquatic Invertebrates (B13)
- __ Hydrogen Sulfide Odor (C1)
- → __ Oxidized Rhizospheres along Living Roots (C3)
- __ Presence of Reduced Iron (C4)
- __ Recent Iron Reduction in Tilled Soils (C6)
- __ Stunted or Stressed Plants (D1) (**LRR A**)
- __ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- __ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- __ Drainage Patterns (B10)
- __ Dry-Season Water Table (C2)
- __ Saturation Visible on Aerial Imagery (C9)
- __ Geomorphic Position (D2)
- __ Shallow Aquitard (D3)
- __ FAC-Neutral Test (D5)
- __ Raised Ant Mounds (D6) (**LRR A**)
- __ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes _____ No _____ Depth (inches): ___________

Water Table Present? Yes _____ No _____ Depth (inches): ___________

Saturation Present? (includes capillary fringe) Yes _____ No _____ Depth (inches): ___________

Wetland Hydrology Present? Yes _____ No ✓

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: CUCUMBER GULCH City/County: BreckenRidge, Summit Sampling Date: 7/13/11

Applicant/Owner: TOWN OF BRECKENRIDGE State: CO Sampling Point: A2

Investigator(s): A. Herb / M. Beardsley Section, Township, Range: SEC 36 T6S R78W

Landform (hillslope, terrace, etc.): Valley SIDE Local relief (concave, convex, none): Concave Slope (%): 3

Subregion (LRR): ROCKY MTN RANGE & FO. Lat: 4371435 Long: 409013 Datum: UTM NAD 83

Soil Map Unit Name: NOT MAPPED NWI classification: UPLAND MEADOW

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ✓ (If no, explain in Remarks.) m

Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes ______ No ✓

Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ✓ No ✓

Hydric Soil Present? Yes ✓ No ✓

Wetland Hydrology Present? Yes ✓ No ______

Is the Sampled Area within a Wetland? Yes ______ [✓ No]

Remarks: wetter than normal for mid-July?
Lack of indicators in soil and borderline veg → No wetland

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: 1×3m)	Absolute % Cover	Dominant Species?	Indicator Status
1. Pinus contorta	5	✓	FACU
2.			
3.			
4.			
	5 = Total Cover		
Sapling/Shrub Stratum (Plot size: 1×3m)			
1. Salix drummondiana	20	✓	OBL
2. Dasiphora fruticosa	35	✓	FACW
3.			
4.			
5.			
	55 = Total Cover		
Herb Stratum (Plot size: 1×3m)			
1. Calamagrostis canadensis	60	✓	OBL
2. Epilobium angustifolia	20	✓	FACU
3. Potentilla pulcherrima	7		
4. Bistorta bistortoides	1		
5. Achillea millefolium	1		
6. Poa palustris	1		
7. Elymus trachycaulus	1		
8.			
9.			
10.			
11.			
	91 = Total Cover 45/18		
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
	______ = Total Cover		

% Bare Ground in Herb Stratum ______

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 60 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- __ 1 - Rapid Test for Hydrophytic Vegetation
- __ 2 - Dominance Test is >50%
- __ 3 - Prevalence Index is ≤3.0[1]
- __ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- __ 5 - Wetland Non-Vascular Plants[1]
- __ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ______

Remarks: Swale w/ diverse mix of shrubs + Mostly Caca

SOIL

Sampling Point: A2

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-16"	10yr 2/1	100	N/A	→			Silty Clay loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- __ Histosol (A1)
- __ Histic Epipedon (A2)
- __ Black Histic (A3)
- __ Hydrogen Sulfide (A4)
- __ Depleted Below Dark Surface (A11)
- __ Thick Dark Surface (A12)
- __ Sandy Mucky Mineral (S1)
- __ Sandy Gleyed Matrix (S4)
- __ Sandy Redox (S5)
- __ Stripped Matrix (S6)
- __ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- __ Loamy Gleyed Matrix (F2)
- __ Depleted Matrix (F3)
- __ Redox Dark Surface (F6)
- __ Depleted Dark Surface (F7)
- __ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- __ 2 cm Muck (A10)
- __ Red Parent Material (TF2)
- __ Very Shallow Dark Surface (TF12)
- __ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes ___ No ✓

Remarks:

loose / friable - no indicators
very dark soil

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- __ Surface Water (A1)
- ✓ High Water Table (A2)
- ✓ Saturation (A3)
- __ Water Marks (B1)
- __ Sediment Deposits (B2)
- __ Drift Deposits (B3)
- __ Algal Mat or Crust (B4)
- __ Iron Deposits (B5)
- __ Surface Soil Cracks (B6)
- __ Inundation Visible on Aerial Imagery (B7)
- __ Sparsely Vegetated Concave Surface (B8)
- __ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- __ Salt Crust (B11)
- __ Aquatic Invertebrates (B13)
- __ Hydrogen Sulfide Odor (C1)
- __ Oxidized Rhizospheres along Living Roots (C3)
- __ Presence of Reduced Iron (C4)
- __ Recent Iron Reduction in Tilled Soils (C6)
- __ Stunted or Stressed Plants (D1) (**LRR A**)
- __ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- __ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- __ Drainage Patterns (B10)
- __ Dry-Season Water Table (C2)
- __ Saturation Visible on Aerial Imagery (C9)
- __ Geomorphic Position (D2)
- __ Shallow Aquitard (D3)
- __ FAC-Neutral Test (D5)
- __ Raised Ant Mounds (D6) (**LRR A**)
- __ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No ✓ Depth (inches): ______

Water Table Present? Yes ✓ No ___ Depth (inches): 10" (@10min)

Saturation Present? (includes capillary fringe) Yes ✓ No ___ Depth (inches): 0

Wetland Hydrology Present? Yes ✓ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

soil pit filling with water. Appears to be high g.w. discharging @ toe of slope

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: CUCUMBER GULCH City/County: BRECKENRIDGE, Summit Sampling Date: 7/13/2011
Applicant/Owner: TOWN OF BRECK State: CO Sampling Point: A3
Investigator(s): A. Herb / M. Beardsley Section, Township, Range: SEC36 T6S R78W
Landform (hillslope, terrace, etc.): Valley side (TOE) Local relief (concave, convex, none): SLOPING Slope (%): 2
Subregion (LRR): Rocky Mt. Range & Fo. Lat: 4371242 Long: 408949 Datum: UTM NAD83
Soil Map Unit Name: NOT MAPPED NWI classification: UPLAND MEADOW, open
Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ______ (If no, explain in Remarks.)
Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ______
Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ✓ No ______
Hydric Soil Present? Yes ______ No ✓
Wetland Hydrology Present? Yes ______ No ✓

Is the Sampled Area within a Wetland? **Yes** ______ **No** ✓

Remarks: veg primarily willows leans to hydrophytic, But no soil indicators and dry or questionable hydrology

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
		= Total Cover	
Sapling/Shrub Stratum (Plot size: 1×3 m)			
1. Salix wolfii	75	✓	FACW
2. Betula glandulosa	2		OBL
3.			
4.			
5.			
	77	= Total Cover	
Herb Stratum (Plot size: ______)			
1. Achillea millefolium	10	✓	FACU
2. Frageria virginiana	20	✓	FACU
3. Potentilla pulcherrima	5		FAC
4. Taraxacum officinale	2		FACU
5. Carex praegracilis	10	✓	FACW
6.			
7.			
8.			
9.			
10.			
11.			
	47	= Total Cover 24/9	
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
		= Total Cover	

% Bare Ground in Herb Stratum ______

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 2 (A)
Total Number of Dominant Species Across All Strata: 4 (B)
Percent of Dominant Species That Are OBL, FACW, or FAC: 50 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	2	x 1 = 2
FACW species	85	x 2 = 170
FAC species	5	x 3 = 15
FACU species	32	x 4 = 128
UPL species	0	x 5 = 0
Column Totals:	124 (A)	315 (B)

Prevalence Index = B/A = <3

Hydrophytic Vegetation Indicators:

- ___ 1 - Rapid Test for Hydrophytic Vegetation
- ___ 2 - Dominance Test is >50%
- ✓ 3 - Prevalence Index is ≤3.0[1]
- ___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ 5 - Wetland Non-Vascular Plants[1]
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ______

Remarks: Open willow area above main wetland area

SOIL

Sampling Point: A3

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix		Redox Features				Texture	Remarks
	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]		
0-5	10YR2/1	100					O	organic, some charcoal
5-16	10yR2/2	100					Sandy Clay Loam	Some gravel

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10)
- ☐ Red Parent Material (TF2)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? **Yes** ☐ **No** ☑

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Surface Soil Cracks (B6)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ☐ Salt Crust (B11)
- ☐ Aquatic Invertebrates (B13)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres along Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Stunted or Stressed Plants (D1) (**LRR A**)
- ☐ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ☐ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ☐ Drainage Patterns (B10)
- ☐ Dry-Season Water Table (C2)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ FAC-Neutral Test (D5)
- ☐ Raised Ant Mounds (D6) (**LRR A**)
- ☐ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ☐ No ☑ Depth (inches): ______

Water Table Present? Yes ☐ No ☑ Depth (inches): ______

Saturation Present? (includes capillary fringe) Yes ☑ No ☐ Depth (inches): 14"

Wetland Hydrology Present? **Yes** ☐ **No** ☑

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Damp throughout profile. Likely result of recent pre-cip

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: Cucumber Gulch City/County: Breckenridge, Summit Sampling Date: 7/14/11

Applicant/Owner: Town of Breckenridge State: CO Sampling Point: A4

Investigator(s): Andy Herb Section, Township, Range: Sec 36 T6S R78W

Landform (hillslope, terrace, etc.): Hill Slope Local relief (concave, convex, none): Convex Slope (%): 3-4

Subregion (LRR): Rocky Mtn Range & Fo. Lat: 4371412 Long: 408740 Datum: UTM NAD83

Soil Map Unit Name: Not Mapped NWI classification: PAL Em.

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ✓ (If no, explain in Remarks.) wet year; late snowmelt

Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes ______ No ✓

Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ✓	No ______
Hydric Soil Present?	Yes ✓	No ______
Wetland Hydrology Present?	Yes ______	No ✓

Is the Sampled Area within a Wetland? THIS SITE APPEARS to Be drying. Uncertain Hydrology Yes ✓ No ______

Remarks: Fen That appears to be somewhat compromised; evidence of both recent + historic ground disturbance; XC ski trail runs thru fen here; much of fen is very dry

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
		= Total Cover	
Sapling/Shrub Stratum (Plot size: 1×3 m)			
1. Dasiphora fruticosa	5	Y	FACW
2. Salix planifolia	2	Y	OBL
3. Lonicera involucrata	2	Y	FAC
4.			
5.			
	9	= Total Cover 5/2	
Herb Stratum (Plot size: 1×3 m)			
1. Carex aquatilis	50	Y	OBL
2. Maianthemum stellatum	10	N	
3. Taraxacum officinale	1	N	
4. Achillea millifolium	5	N	
5. Potentilla pulcherrimum	2	N	
6. Epilobium angustifolium	5	N	
7. Fragaria virginiana	2	N	
8. Calamagrostis canadensis	10	N	
9.			
10.			
11.			
	85	= Total Cover 37/15	
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
		= Total Cover	

% Bare Ground in Herb Stratum ~15

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- __ 1 - Rapid Test for Hydrophytic Vegetation
- __ 2 - Dominance Test is >50%
- __ 3 - Prevalence Index is ≤3.0[1]
- __ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- __ 5 - Wetland Non-Vascular Plants[1]
- __ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ______

Remarks: Caaq appears to be invaded by other more Mesic spp.

SOIL

Sampling Point: A4

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix		Redox Features				Texture	Remarks
	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]		
0-16+	10YR2/1	100					O	Fibric ? Some clay

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ✓ Histosol (A1)
- __ Histic Epipedon (A2)
- __ Black Histic (A3)
- __ Hydrogen Sulfide (A4)
- __ Depleted Below Dark Surface (A11)
- __ Thick Dark Surface (A12)
- __ Sandy Mucky Mineral (S1)
- __ Sandy Gleyed Matrix (S4)
- __ Sandy Redox (S5)
- __ Stripped Matrix (S6)
- __ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- __ Loamy Gleyed Matrix (F2)
- __ Depleted Matrix (F3)
- __ Redox Dark Surface (F6)
- __ Depleted Dark Surface (F7)
- __ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- __ 2 cm Muck (A10)
- __ Red Parent Material (TF2)
- __ Very Shallow Dark Surface (TF12)
- __ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ____

Depth (inches): ____

Hydric Soil Present? Yes ✓ No ____

Remarks: Appears to be fibric "O" layer

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- __ Surface Water (A1)
- __ High Water Table (A2)
- __ Saturation (A3)
- __ Water Marks (B1)
- __ Sediment Deposits (B2)
- __ Drift Deposits (B3)
- __ Algal Mat or Crust (B4)
- __ Iron Deposits (B5)
- __ Surface Soil Cracks (B6)
- __ Inundation Visible on Aerial Imagery (B7)
- __ Sparsely Vegetated Concave Surface (B8)
- __ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- __ Salt Crust (B11)
- __ Aquatic Invertebrates (B13)
- __ Hydrogen Sulfide Odor (C1)
- __ Oxidized Rhizospheres along Living Roots (C3)
- __ Presence of Reduced Iron (C4)
- __ Recent Iron Reduction in Tilled Soils (C6)
- __ Stunted or Stressed Plants (D1) (**LRR A**)
- __ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- __ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- __ Drainage Patterns (B10)
- __ Dry-Season Water Table (C2)
- __ Saturation Visible on Aerial Imagery (C9)
- __ Geomorphic Position (D2)
- __ Shallow Aquitard (D3)
- __ FAC-Neutral Test (D5)
- __ Raised Ant Mounds (D6) (**LRR A**)
- __ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ____ No ✓ Depth (inches): ____

Water Table Present? Yes ____ No ✓ Depth (inches): ____

Saturation Present? (includes capillary fringe) Yes ____ No ✓ Depth (inches): ____

Wetland Hydrology Present? Yes ____ No ✓

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks: No hydrology indicators – nearby spring of same elevation but not wet at data point

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: CG (Cucumber Gulch) City/County: Breckenridge, Summit Sampling Date: 7/13/11

Applicant/Owner: Town of Breckenridge State: CO Sampling Point: B1

Investigator(s): BJ & JD Section, Township, Range: Sec 36 T6S R78W

Landform (hillslope, terrace, etc.): Valley Side, toe Local relief (concave, convex, none): Sloping Slope (%): 3

Subregion (LRR): Rocky Mtn. Range & Fo. Lat: 4370971 Long: 408673 Datum: UTM NAD83

Soil Map Unit Name: Not Mapped NWI classification: PAC. EM.

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ✓ No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes X No ____

Hydric Soil Present? Yes X No ____

Wetland Hydrology Present? Yes X No ____

Is the Sampled Area within a Wetland? Yes X No ____

Remarks: We are awesome!

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ____)			
1. Abies lasio (Abies lasiocarpa)	10	Y	FACU
2.			
3.			
4.			
	10	= Total Cover	
Sapling/Shrub Stratum (Plot size: ____)			
1. Abi lasi (Abies lasiocarpa)	5	Y 10%	FACU
2.			
3.			
4.			
5.			
	5	= Total Cover	
Herb Stratum (Plot size: ____)			
1. Car. aqu (Carex aquatilis)	30	Y	OBL
2. Strep (Streptopus fassettii	5	N	FACW
3. Lupinus argentus	1	N	UP
4. Gaultheria humifusa	3	N	FACU
5. Caltha leptosepala	5		OBL
6. Fragaria vesca	3		FACU
7. Equi Arv. (Equisetum arvense)	1		FACW
8. Mitella pentandra	1		FACW
9. Arnica cordifolia	2		UP
10.			
11.			
	51	= Total Cover	
Woody Vine Stratum (Plot size: ____)		25	10%
1.			
2.			
		= Total Cover	

% Bare Ground in Herb Stratum ____

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 50 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	35	x 1 = 35
FACW species	7	x 2 = 14
FAC species	0	x 3 =
FACU species	21	x 4 = 84
UPL species	3	x 5 = 15
Column Totals:	66 (A)	148 (B)

Prevalence Index = B/A = 2.24

.1
66
3
198

Hydrophytic Vegetation Indicators:

N 1 - Rapid Test for Hydrophytic Vegetation

N 2 - Dominance Test is >50%

Y 3 - Prevalence Index is ≤3.0[1]

__ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

__ 5 - Wetland Non-Vascular Plants[1]

__ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes X No ____

Remarks:

SOIL

Sampling Point: B1

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix		Redox Features				Texture	Remarks
	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]		
0-1.5	10YR 4/3	70						
1.5-7	10YR 4/2	70	2.5YR4/6	30				
>7	Cobble							

[1] Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2] Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

☐ Histosol (A1)
☐ Histic Epipedon (A2)
☐ Black Histic (A3)
☐ Hydrogen Sulfide (A4)
☐ Depleted Below Dark Surface (A11)
☐ Thick Dark Surface (A12)
☐ Sandy Mucky Mineral (S1)
☐ Sandy Gleyed Matrix (S4)

☐ Sandy Redox (S5)
☐ Stripped Matrix (S6)
☐ Loamy Mucky Mineral (F1) (**except MLRA 1**)
☐ Loamy Gleyed Matrix (F2)
☒ Depleted Matrix (F3)
☐ Redox Dark Surface (F6)
☐ Depleted Dark Surface (F7)
☐ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

☐ 2 cm Muck (A10)
☐ Red Parent Material (TF2)
☐ Very Shallow Dark Surface (TF12)
☐ Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: CoBBler

Depth (inches): 7

Hydric Soil Present? Yes [✓ X] No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

☐ Surface Water (A1)
☑ High Water Table (A2)
☑ Saturation (A3)
☐ Water Marks (B1)
☐ Sediment Deposits (B2)
☐ Drift Deposits (B3)
☐ Algal Mat or Crust (B4)
☐ Iron Deposits (B5)
☐ Surface Soil Cracks (B6)
☐ Inundation Visible on Aerial Imagery (B7)
☐ Sparsely Vegetated Concave Surface (B8)

☐ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B)**
☐ Salt Crust (B11)
☐ Aquatic Invertebrates (B13)
☐ Hydrogen Sulfide Odor (C1)
☒ Oxidized Rhizospheres along Living Roots (C3)
☑ Presence of Reduced Iron (C4)
☐ Recent Iron Reduction in Tilled Soils (C6)
☐ Stunted or Stressed Plants (D1) (**LRR A**)
☐ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

☐ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B)**
☐ Drainage Patterns (B10)
☐ Dry-Season Water Table (C2)
☐ Saturation Visible on Aerial Imagery (C9)
☐ Geomorphic Position (D2)
☐ Shallow Aquitard (D3)
☐ FAC-Neutral Test (D5)
☐ Raised Ant Mounds (D6) (**LRR A**)
☐ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No [✓ X] Depth (inches): ___
Water Table Present? Yes [✓ X] No ___ Depth (inches): 9
Saturation Present? (includes capillary fringe) Yes [✓ X] No ___ Depth (inches): 5

Wetland Hydrology Present? Yes [✓] No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Appendix 4: FACWet - List of identified stressors

Exterior stressors

1. **Residential development (Shock Hill to Peak 8 Base)**
   Description: Residential area (roads, infrastructure, houses, landscaping)
   Location: along the right (SE) flank of Cucumber Gulch within the HCE and BA
   Variables with major impact:
      V1 – likely historic neighboring wetlands loss
      V2 – impediment to wildlife migration, increased human and pet interaction
      V3 – land use conversion of buffer
   Variables with minor impact:
      V4 - impervious surfaces and managed drainage decrease infiltration, increase magnitude and frequency of peak flows
      V5 - indirect impacts from changes to water source
      V6 - indirect impacts from changes to water source
      V7 – increased sedimentation source
      V8 – nutrient enrichment (landscaping, fertilizer runoff), sediment source (construction, surface erosion, traction sand), contamination source (vehicles, machinery, building materials, solute concentration (surface flows, detention and holding ponds)
      V9 –source of exotics, ornamentals, weeds
2. **Peak 8 snowmaking**
   Description: water for snowmaking imported from outside the drainage
   Location: throughout Peak 8 watershed area, mostly below tree line
   Variables with major impact:
      V4 – augmentation, increased magnitude of snowmelt peak flows
      V5 – augmented water source impacts distribution
      V6 –augmented water source impacts outflow
   Variables with minor impact:
      V2 – possible impediment to wildlife migration
3. **Peak 8 watershed forest clearing**
   Description: Approx. 40% of forested area of Peak 8 watershed has been cleared.
   Location: throughout Peak 8 watershed area below tree line
   Variables with major impact:
      V4 – augmentation, increased magnitude and frequency of peak flows from watershed, Decreased duration of snowmelt period
      V5 – indirect impacts from changes to water source
      V6 – increased water outflow during peaks, decreased during lows
   Variables with minor impact:
      V1 – possible historic neighboring wetlands loss related to clearing
      V2 – impediment to wildlife migration and dispersal
      V3 – land use conversion of buffer area
      V7 – increased sediment load from watershed
      V8 - increased sediment load from watershed
4. **Peak 8 ski area/base area drainage**

Description: engineered drainage (roadside ditches, water bars, storm drains, culverts, pipelines, detention ponds)

Location: Peak 8 watershed, especially at Peak 8 base area

Variables with major impact:

- V2 – barrier to aquatic wildlife migration
- V4 – concentration of most watershed discharge into one primary surface source (Boreas Creek culvert), increase magnitude and frequency of peak flows
- V5 – shallow groundwater and dispersed surface flows blocked, concentration of discharge into Boreas Creek culvert
- V6 – nutrient enrichment (landscaping, fertilizer runoff), sediment source (construction, surface erosion, traction sand), contamination source (vehicles, machinery, building materials, concentration (surface flows, detention and holding ponds)
- V7 – increased energy flows (scour and erosion potential)

Variables with minor impact:

- V6 – indirect impacts from changes to water source
- V8 – increased sediment source, solute concentration
- V9 – altered hydrology secondary effect on vegetation

5. **Peak 8 Base area development**

Description: commercial development

Location: Peak 8 Base area within the drainage at the head of Cucumber Gulch

Variables with major impact:

- V1 – likely historic wetland loss (fill to form base area)
- V2 – barrier to wildlife migration
- V3 – land use conversion of buffer area
- V4 – impervious surfaces and managed drainage decrease infiltration, increase magnitude and frequency of peak flows, foundation drains may disturb groundwater flow patterns
- V8 – nutrient enrichment (landscaping, fertilizer runoff), sediment source (construction, surface erosion, traction sand), contamination source (vehicles, machinery, building materials, solute concentration (surface flows, detention and holding ponds), trash/litter

Variables with minor impact:

- V5 - snow plowing and diversion of surface flows, decreased infiltration
- V9 –source of exotics, ornamentals, weeds

6. **Bridge Creek watershed development**

Description: Forest clearing, cul-de-sac road, Old CR3 road alignment, created wetlands, service roads

Location: Drainage area for Bridge Creek between Bergenhoff building and P7 base

Variables with minor impact:

- V1 – wetlands creation, possible historic wetlands loss
- V2 – wetlands/riparian connection concentrated to bridge span
- V4 – forest clearing and impermeable/compacted surfaces increase magnitude and frequency of peak flows, decrease infiltration/recharge
- V5 – concentration of surface and groundwater flows within bridge span

7. **Bridge Creek channelization**

Description: Bridge Creek is artificially straightened and channelized

Location: Bridge Creek channel upstream of Cucumber Gulch

Variables with minor impact:

- V5 – concentration of flows
- V7 - increased sediment load
- V8 - increased sediment load

8. **Peak 7 snowmaking**

   Description: water for snowmaking imported from outside the drainage

   Location: throughout Peak 7 watershed area, mostly below tree line

   Variables with major impact:

      V4 – augmentation, increased magnitude of snowmelt peak flows

      V5 - augmented water source impacts distribution

      V6 –augmented water source impacts outflow

   Variables with minor impact:

      V2 – possible impediment to wildlife migration

9. **Peak 7 watershed forest clearing**

   Description: approx. 30% of forested area within the portion of the Peak 7 watershed that feeds Cucumber Gulch has been cleared.

   Location: throughout Peak 7 watershed area below tree line

   Variables with major impact:

      V4 – augmentation, increased magnitude and frequency of peak flows from watershed, Decreased duration of snowmelt period

      V5 – indirect impacts from changes to water source

      V6 – increased water outflow during peaks, decreased during lows

   Variables with minor impact:

      V1 – possible historic neighboring wetlands loss related to clearing

      V2 – impediment to wildlife migration and dispersal

      V3 – land use conversion of buffer area

      V7 – increased sediment load from watershed

      V8 - increased sediment load from watershed

10. **Peak 7 ski area/base area drainage system**

    Description: engineered drainage (roadside ditches, water bars, storm drains, culverts, pipelines)

    Location: Peak 7 watershed, especially at Peak 8 base area

    Variables with major impact:

       V2 – barrier to aquatic wildlife migration

       V4 – concentration of watershed discharge into surface sources that feed detention pond/distribution system, increased magnitude and frequency of peak flows

       V5 – shallow groundwater and dispersed surface flows blocked, concentration of discharge into Boreas Creek culvert,

       V6 – nutrient enrichment (landscaping, fertilizer runoff), sediment source (construction, surface erosion, traction sand), contamination source (vehicles, machinery, building materials, concentration (surface flows, detention and holding ponds)

       V7 – increased energy flows (scour and erosion potential)

    Variables with minor impact:

       V6 – indirect impacts from changes to water source

       V9 – altered hydrology secondary effect on vegetation

11. **Peak 7 Base area development**

    Description: commercial development

    Location: Peak 8 Base area within the drainage at the head of Cucumber Gulch

    Variables with major impact:

       V1 – likely historic wetland loss (fill to form base area)

       V2 – barrier to wildlife migration

       V3 – land use conversion of buffer area

- V4 – impervious surfaces and managed drainage decrease infiltration, increase magnitude and frequency of peak flows, foundation drains may disturb groundwater flow patterns
- V8 – nutrient enrichment (landscaping, fertilizer runoff), sediment source (construction, surface erosion, traction sand), contamination source (vehicles, machinery, building materials, concentration (surface flows, detention and holding ponds), trash/litter

Variables with minor impact:

- V5 - snow plowing and diversion of surface flows, decreased infiltration
- V6 – indirect impacts from changes to water source
- V7 – increased energy flows (scour and erosion potential)
- V9 –source of exotics, ornamentals, weeds

12. Cloud seeding

Description: Cloud seeding generators in use to attempt to increase winter snowfall

Location: Regional

Variables with minor impact:

- V4 – augmented volume of flows during snowmelt period
- V5 – indirect impacts from changes to water source
- V6 – indirect impacts from changes to water source
- V8 – possible source for seeding nuclei (silver iodide?)

Edge stressors

13. Ski Hill Road (P8 base to P7 base) and retaining wall

Description: Major paved road constructed primarily of fill, openings limited to few culverts and one bridge span, hillside below is steep or retaining wall

Location: along the up-gradient edge of Cucumber Gulch and Peak 7 Side Slopes

Variables with major impact:

- V1 – historic neighboring wetlands loss from road fill
- V2 – barrier to wildlife migration
- V3 – land use conversion of buffer area (paved road)
- V4 – barrier to dispersed surface and shallow groundwater flow, concentration of flows to few culverts and one bridge span, impervious surfaces
- V5 – Areas below road are cut off from water source, flows concentrated into single channels, snow plowing

Variables with minor impact:

- V6 - indirect impacts from changes to water source
- V7 – increased sedimentation source
- V8 – sediment/turbidity (construction, surface erosion, traction sand), contamination source (vehicles, machinery, building materials)
- V9 – altered hydrology secondary effect on vegetation

14. Stables lot

Description: Paved road parking area with steep retaining wall, storm drain

Location: Up-gradient edge of Cucumber Gulch and Peak 7 Side Slopes

Variables with major impact:

- V1 – historic neighboring wetlands loss from fill
- V2 – barrier to wildlife migration
- V3 – land use conversion of buffer area (paved road)
- V4 – barrier to dispersed surface and shallow groundwater flow, concentration of flows via storm drain
- V5 – Areas below retaining wall are cut off from water source, snow plowing

Variables with minor impact:
  - V7 – increased sedimentation source
  - V8 –sediment/turbidity (construction, surface erosion, traction sand), contamination source (vehicles, machinery, building materials), trash/litter
  - V9 – direct alteration within footprint, drying

15. **Adjacent septic systems**

    Description: Residential septics adjacent to Preserve

    Location: Near Nordic Center

    Variables with minor impact:
    - V8 – potential source of nutrient enrichment/eutrophication if septics are not fully functioning
    - V9 – secondary impact on vegetation

16. **P8 Base drainage/detention pond**

    Description: Dammed impoundment collects flow from base area surface runoff

    Location: Up-gradient edge of Upper Cucumber Gulch, below P8 base area

    Variables with major impact:
    - V1 – suspected wetlands loss within footprint of pond
    - V4 – little evidence of infiltration/recharge, water loss to evaporation, higher flows exit via a drain and culvert
    - V5 – areas below detention pond are cut off from water source unless infiltration is successful
    - V7 – direct alteration (dam, impoundment, and access road)
    - V8 – concentration of solutes, increased summer water temperature

    Variables with minor impact:
    - V2 – barrier to wildlife migration
    - V3 – land use conversion of buffer area
    - V9 – direct alteration within footprint, drying

17. **Admin drainage/detention pond**

    Description: Riprap channel and small detention pond collects runoff from parking areas

    Location: below P8 base area below ski area administration buildings

    Variables with minor impact:
    - V4 – collection of sheet flow into a point source, managed hydrology (pumping plan)
    - V7 – direct alteration (dam, impoundment, drain, riprap channel)
    - V8 – concentration of solutes, increased summer water temperature
    - V9 – direct alteration within footprint, created wetland

18. **Glenwild drainage/detention pond**

    Description: Riprap channel and two small detention ponds collect runoff from road

    Location: below Glenwild subdivision, edge of Upper Cucumber

    Variables with minor impact:
    - V4 – collection of sheet flow into a point source
    - V7 – direct alteration (dam, impoundment, riprap channel)
    - V8 – concentration of solutes, nutrient and salt enrichment from construction (fertilizer), increased summer water temperature
    - V9 – direct alteration within footprint, created wetland at detention pond

19. **P7 Base drainage distribution system**

    Description: system of interconnected detention ponds and infiltration trenches

    Location: below Peak 7 base area at head of Peak 7 Side Slopes area

    Variables with major impact:
    - V1 – suspected wetlands loss within footprint
    - V3 – buffer area impacts

V4 –some infiltration/recharge, point discharge of inflow at low end of final trench

V5 – altered and re-engineered water distribution

V7 – direct alteration (dam, impoundment, access road, graded slopes)

V8 – nutrient enrichment (landscaping, fertilizer runoff), solute concentration (surface flows, detention and holding ponds), increased summer water temperature altered soil chemistry (direct disturbance, altered saturation), sediment source (construction, surface erosion, traction sand), contamination source (vehicles, machinery, building materials)

V9 – direct alteration within footprint, revegetation, indirect effects of altered hydrology

Variables with minor impact:

V2 – impediment to wildlife migration

V6 – possible indirect effects of altered water source and distribution

20. County Road 3 (Peak 7 Base to north boundary of Preserve)

Description: Dirt/gravel improved road

Location: along the up-gradient edge of Peak 7 Side Slopes, north of Peak 7 base area

Variables with major impact:

V3 – land use conversion of buffer area (gravel road)

V5 – altered drainage pattern (roadside ditches, culverts)

V7 – sedimentation at point sources from road

V8 – sediment/turbidity (maintenance, surface erosion, traction sand), contamination source (vehicles, machinery, building materials)

Variables with minor impact:

V1 – historic neighboring wetlands loss from road fill

V2 – barrier to wildlife migration

V4 – altered drainage pattern (roadside ditches, culverts)

V9 – altered hydrology and sedimentation secondary effect on vegetation

21. Historic gullies/deposition

Description: remnant gullies and deposition fans of large material

Location: lower north edge of Peak 7 side Slopes into edge of Lower Cucumber

Variables with minor impact:

V5 – gullies capture groundwater flow and route it on surface in channels, debris fans alter surface flows

V7 – cut gully areas, elevated debris fans

V9 – altered hydrology and sedimentation secondary effect on vegetation

22. historic mine shafts and tailings

Description: remnant mine tailings

Location: lowest NE edge of Lower Cucumber near Shock Hill

Variables with minor impact:

V5 – possible interruption of flows

V7 – tailings within wetland area

V9 – secondary effect on vegetation

<u>Interior stressors</u>

23. beaver loss

Description: Documented decline in beaver population within the preserve

Location: Beaver activity lost from Upper Cucumber, declined in Lower

Variables with major impact:

  - V5 – loss of ponds, loss of distributary channels, formation of single channel pattern, decreased infiltration/recharge
  - V6 - outflow more concentrated to single channels
  - V7 – degraded dams fail as grade control, pond loss, increased channel instability, sedimentation
  - V8 – sediment/turbidity (maintenance, surface erosion, traction sand), contamination source (vehicles, machinery, building materials)

  Variables with minor impact:
  - V1 – historic neighboring wetlands

24. **sedimentation**

    Description: excess sediment deposition

    Location: major sediment deposition fans along channels and in beaver ponds

    Variables with major impact:
    - V5 - altered/diverted surface flows
    - V7 - pond-filling, deposition fans
    - V8 - sediment/turbidity, soil chemistry
    - V9 - indirect effects on vegetation from altered hydrology and bare deposition areas
25. **channel incision**

    Description: formation of incised channels from excess scour, active head cuts

    Location: Boreas Creek in Upper Cucumber, possible locations in Lower Cucumber

    Variables with major impact:
    - V5 - gully formation, drying (lowered water table tributary to channel), incised channels contain flows without spreading, rapid transport of water through system,
    - V6 - timing and concentration of outflow is impacted
    - V7 - gully formation, channel instability (excessive erosion, enlargement), bed scour, floodplain deactivation, dam breaches, excess sediment source
    - V8 - sediment/turbidity (bed scour and channel instability generate large volumes of autochthonous sediment)
    - V9 - indirect effects on vegetation from altered hydrology and bare deposition areas
26. **gondola (cleared line and lift)**

    Description: forest cleared lift line and operational gondola

    Location: across Lower Cucumber and through Peak 7 side Slopes area

    Variables with major impact:
    - V5 - increased evaporation/drying in cleared lift line
    - V8 - increased temperatures from excess solar heating in cleared areas
    - V9 - direct impacts (tree removal), construction disturbance, revegetation/reclamation introduced species, weed occurrences increased, shift in community type

    Variables with minor impact:
    - V2 - impediment to wildlife
    - V4 - temporary irrigation for reclamation of lift line
    - V7 - lift tower bases and foundations
27. **nordic center trails**

    Description: maintained nordic center ski trails

    Location: throughout the preserve

    Variables with major impact:
    - V2 - increased human -wildlife interaction
    - V7 - cleared and compacted areas, imported surface (wood chips and/or gravel), bridges, log crossings
    - V9 - cleared areas (shrubs and trees), areas of shrub trimming
28. **foot/bike trails**

Description: maintained and unmaintained foot and bike trails

Location: within P7 Sideslopes, Upper Cucumber, and Lower Cucumber edge

Variables with minor impact:

- V2 - impediment to wildlife, increased human -wildlife interaction
- V7 - cleared and compacted areas, imported surface (wood chips and/or gravel), bridges, elevated walkways, observation decks
- V9 - cleared areas (shrubs and trees), areas of shrub trimming

29. weeds

Description: documented weed infestations (multiple species)

Location: concentrated along fringe of the preserve and the cleared gondola line, but present throughout

Variables with major impact:

- V9 - altered species composition and structure

30. elevated salt/ion, nutrient, concentrations

Description: reported increased salt/ion and nutrient concentrations

Location: most detention ponds, head of Upper Cucumber, head of P7 Sideslopes

Variables with minor impact:

- V8 - nutrient enrichment
- V9 - possible vegetation effects

Appendix 5: Photos

Photo 1. Ski Hill Road runs across the top of the Upper CG and Peak 7 SS wetland areas making it a key stressor to habitat connectivity and buffer capacity.

Photo 2. Major stressors to habitat connectivity and buffer capacity along the Peak 7 SS edge include dense commercial development, Ski Hill Road (above), and an engineered drainage/ water redistribution system (below).

Photo 3. Major stressors to habitat connectivity and buffer capacity along the Upper CG edge include the Peak 8 base area developments, Ski Hill Road, detention ponds, and an engineered drainage system.

The lower photo shows the Peak 8 detention pond with Ski Hill Road and ski area base facilities in the background. The culvert in the foreground is Boreas Creek. Nearly all of the surface runoff from the Peak 8 watershed enters Upper CG at this point. Peak 8 watershed, the primary water source for Upper CG is entirely within the ski area.

Photo 4. Part of the Peak 7 Base area drainage system, this infiltration trench carries collected storm water from south to north. Here at the south end there is a concrete spillway which apparently used to function as a level spreader before the trench was extended northwards in 2009 or 2010.

The wetlands immediately below the old spillway (to the right of the concrete in the photo) show signs of drying. This small patch of wetland may have depended on water from the spillway which was cut off following reconstruction of the extended trench.

Photo 5. The new trench at the bottom of the Peak 7 drainage system is filled at its south end, and it spills at its north end (shown here). The upper photo is a view north of the outlet. The lower two show it looking south. The middle photo shows the outlet as it looked in May. The lower photo shows it in July, after a set of waddle check dams was installed.

Photo 6. A concrete retaining wall constructed below Ski Hill Road and the Stables Lot in 2008 may influence local water distribution in addition to being a barrier to hydrologic connection and wildlife movement.

Photo 7. The realigned Ski Hill Road crosses over Bridge Creek via a bridge span rather than a culvert allowing much better hydrologic and migration connectivity between CGP and wetland habitats upstream. The bridge is high enough that everything from aquatic organisms to moose can pass through the opening.

Photo 8. A data-logging well was installed at Bridge Creek to monitor groundwater table elevation at the location of the water quality test site called ERO-GW5, which is below the Bridge of Ski Hill Road. A large decline in water table elevation was reported here in 2009 (based on manual readings from the metal well seen just to the right of ours in the photo).

However, readings from our well in 2011, and from other wells in the area throughout the study indicated a steady water table. We conclude that the previous report of drying in this region was likely erroneous.

Photo 9. A gondola crosses CGP from Shock Hill (foreground), across Lower CG (center), and back up through the otherwise forested Peak 7 SS (background). Within the Peak 7 SS unit, the clear cut lift line is recognized as a direct stressor on vegetation, and an indirect stressor to water distribution and abiotic habitat via temperature and drying effects secondary to the removal of the shading canopy and shrub clearing.

Photo 10. Sediment runoff from County Road 3 is a notable stressor on water/soil quality, geomorphology, and vegetation in the Peak 7 SS unit. Though fairly severe, the extent of this impact is quite limited.

Photo 11. Water in detention ponds was often turbid long after storm events. Most of these ponds have surface water outlets to Peak 7 SS or Upper CG wetlands. While some of the suspended sediments did settle out in ponds, outflows to CGP were regularly high in turbidity. Water quality stressors of this type tended to be limited to the wetlands at the upper edge of these units.

Photo 12. Canada thistle outbreak near the Stables lot above the southern end of the Peak 7 SS is shown.

Photo 13. The Peak 8 watershed (shaded in blue) is directly tributary to Upper Cucumber Gulch (approximate extent shaded in purple) via Boreas Creek. Waters within this catchment flow directly into Cucumber Gulch and waters outside this area flow elsewhere.

The entire Peak 8 watershed is within the Breckenridge Ski Area. Severe and extensive stressors from land use and augmentation within the watershed are the cause of critical impacts to water source and sediment supply for Upper CG wetlands.

Photo 14. Boreas Creek enters Upper CG through this new 48” culvert. Water and sediment discharge from the Peak 8 watershed are concentrated by drainage systems above to this single channel. These photos show the culvert and the rock diversion structure below it. The upper photo is from early June. The lower photo is from early August. The rock structure has eroded, an indication of high stream power associated with this channel.

Photo 15. Surface runoff from some of the Peak 8 base area flows into this retention pond which held water for the length of the 2011 season.

Photo 16. Two views of the dried portion of Upper CG in 2011. The upper photo is from June, and the lower one from September. In 2005, the area in the foreground was filled with beaver ponds. Wetland habitat has significantly receded since then.

Photo 17. Photos of several dewatered and dried beaver ponds in Upper CG.

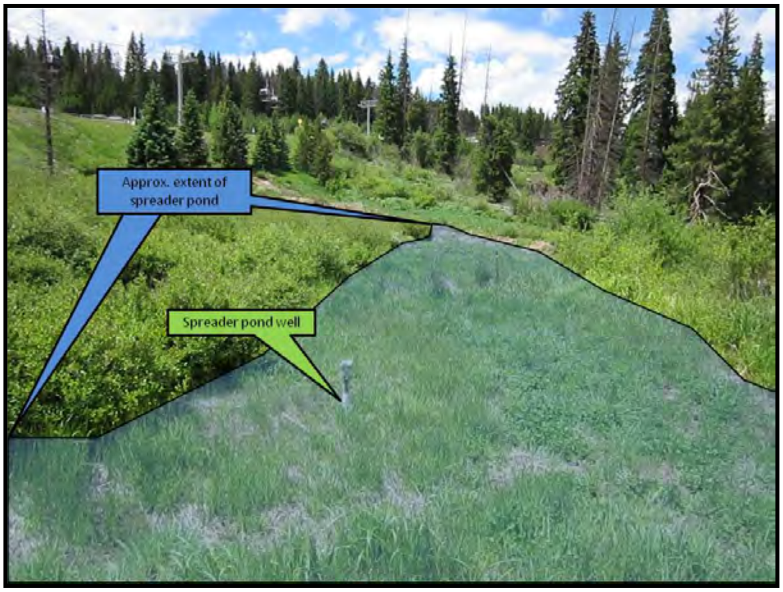


Photo 18. Obviously, the Spreader Pond is now no longer a pond. For reference, the approximate extent of the former pond is shaded in this photo. This photo also shows the location of our data-logging well on what used to be the bed of the pond. Data from this well indicates that this location may now be dried to the point that it no longer has wetland hydrology. Note that this pond had become entirely filled with sediment before its recent breach, raising the elevation of the bed.

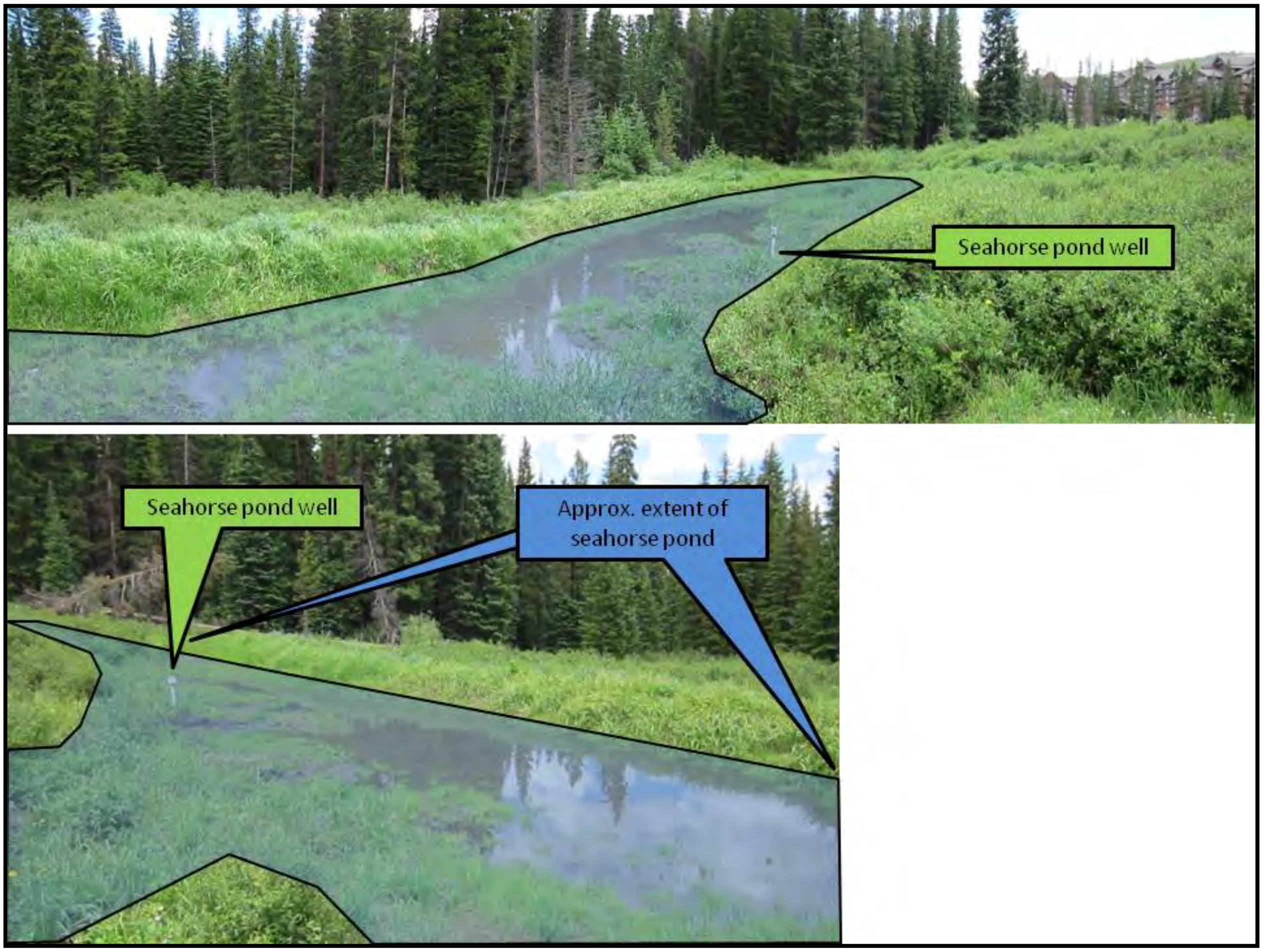


Photo 19. These two photos are of the Seahorse Pond (from alternate angles) which is about 40 m down-valley from the spreader pond. The approximate extent of the former pond is shaded. The Seahorse Pond was dry early in the 2011 season, but was partially filled for about 4 weeks in July (the photos show the pond in its partially filled condition) before it dried again. The location of the monitoring well within the bed is shown. Located off the main Boreas Creek channel, this pond has not yet become fully filled with sediment, so when overbank flows from Boreas Creek divert into the area in front of the dam (as happened in July, 2011), there is still volume (depth) for a smaller pond to form.

Photo 20. Photos from within the old Boreas Creek culvert (underneath Ski Hill Road) show that the bottom of this old pipe had completely rusted through. Some portion of Boreas Creek flows probably used to drain out of the pipe and into the ground while this old culvert was in use. A new culvert was installed recently, so any incidental spreading action of this old pipe is now no longer in play.

Photo 18. These photos show a view of the spreader pond dam taken from a point upstream (within the historic bed of the pond) in early June (upper photo) and mid-July (lower) of 2011. The dam had clearly begun to breach prior to this season, but the job was finished during July of 2011. Prior to this, the dam had functioned by impounding water and diverting much of the flow northward (left) to outlets on that side of the pond. Now, water flows directly through this area in one single, larger channel. Notice that the volume of the pond (in front of the dam) is completely filled with allochthonous sediment. In the upper photo notice the black piece of sediment fence at the bottom middle of the picture which is buried in sediment. The creek is now down-cutting through this sediment and even further down into ancient sediments that were below the level of the bottom of the pond.

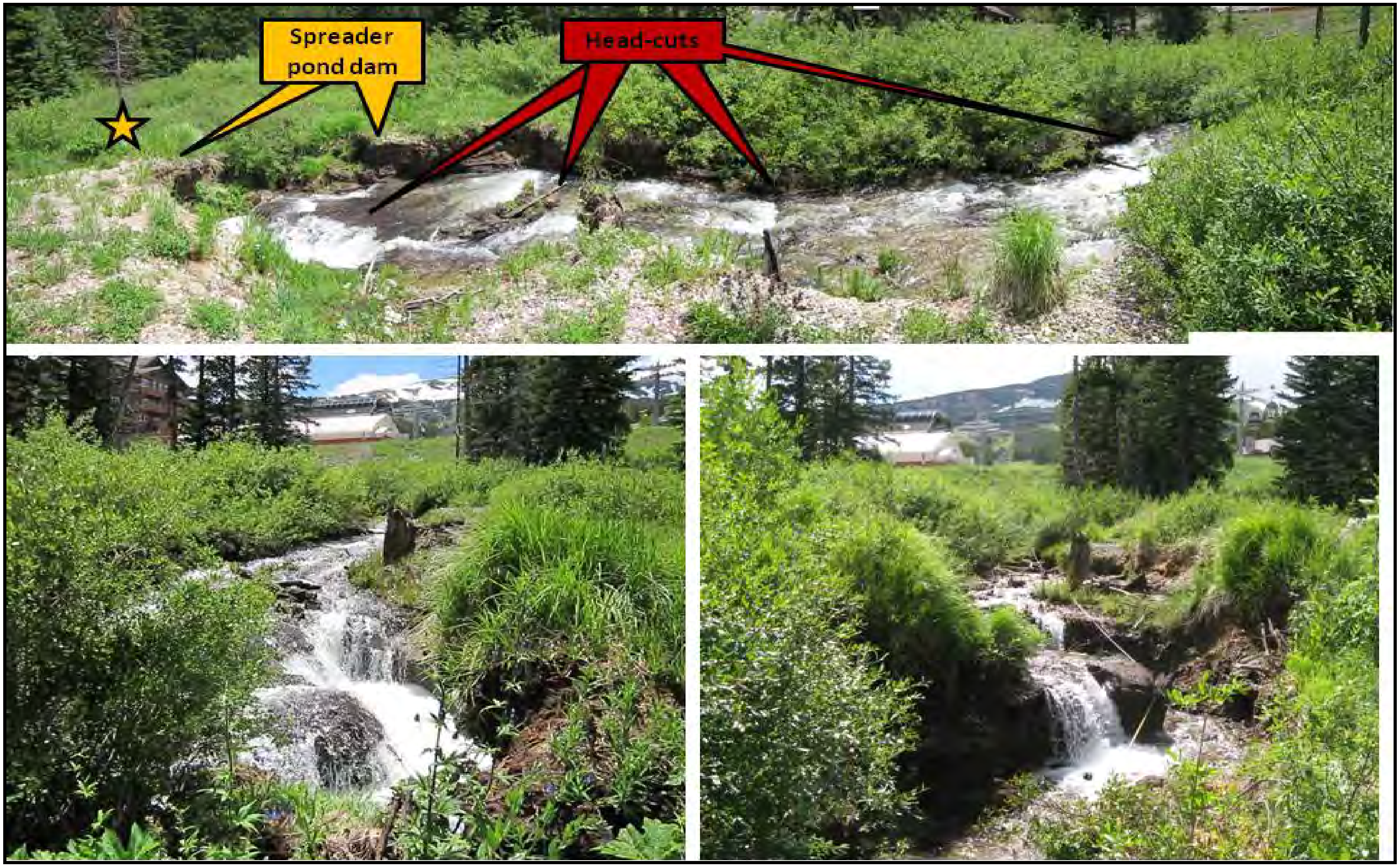


Photo 19. These photos illustrate the process of degradation (down-cutting) on Boreas Creek through the region of the old spreader pond. The upper photo (from early July, 2011) shows the channel lengthwise where it runs through what used to be the spreader pond. The location of the dam breach and several active head-cuts are shown. The lower photos are taken from just downstream of the dam breach (location marked by a star) looking upstream. The left photo was taken in early July, and the right photo in early August, 2011 showing the advancement of channel incision.

Photo 20. These photos show ponds in Upper CG that have been filled completely by sediment. The sediment that accumulated has reached the elevation of the top of the beaver dams that had previously created ponds. That is, the volume of each pond is completely filled, so they can no longer function as ponds even if water source is restored.

Photo 21. Large volumes of sediment were deposited along segments of the Boreas Creek channel in Upper CG during 2011. The logs and lumber in these photos are debris from a destroyed bridge. The logs used to span a much narrower creek channel which is now buried somewhere under this dome of deposited sediment. The channel in this area is now wide and braided. Sediment deposition of this type impacts geomorphology and water distribution.

Photo 22. In addition to the main Peak 8 detention pond, two other primary storm drainage-ways enter CGP on the south arm of Upper CG. The Admin. drainage/detention pond (upper photo) was never observed to hold water during the 2011 season.

The Glenwild detention pond (lower photo) was just constructed during July, 2011. This channel did run during rainstorm events.

Photo 23. Channel incision occurred on segments of on Boreas Creek throughout the length of Upper CG in 2011. This photo shows a segment about 600 ft. downstream of the culvert which down-cut about 1.0-1.5 ft.

Photo 24. The source watershed for Upper CG is entirely within a ski area. There are many signs which indicate that activities within the watershed have an impact on the sediment regime.

Photo 258. Additional observations on the artificially managed hydrology and sediment regime in the CGP source watershed are shown. Accelerated erosion and efficient sediment transport in the watershed have consequences in receiving areas such as CGP.

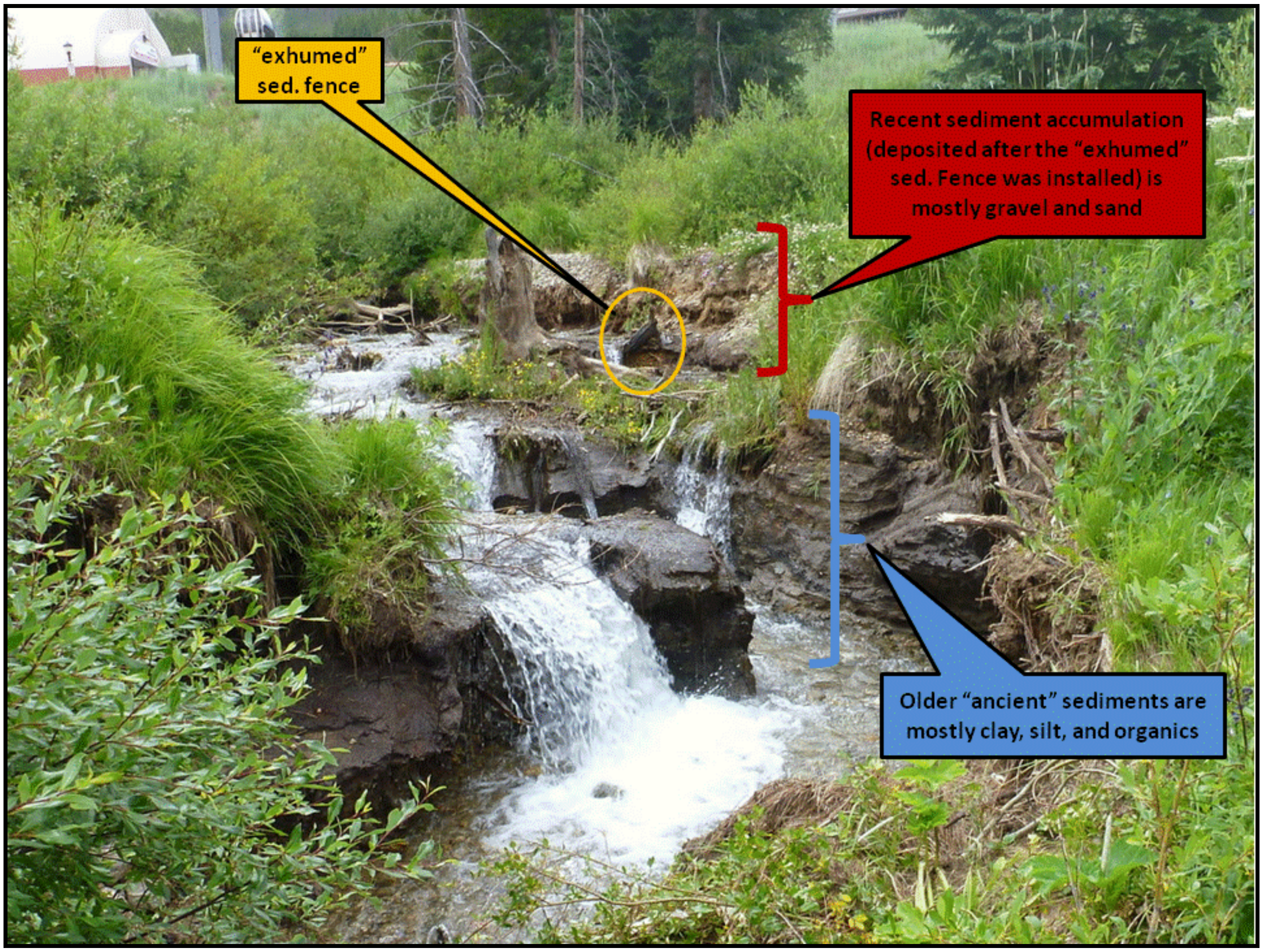


Photo 269: The down-cutting channel on Boreas Creek yields key information about the sediment profile and history of sedimentation in Upper CG. This photo is taken from just downstream of the Spreader Pond dam, looking upstream.

When the dam originally breached (*circa* 2009), the channel cut through sediments that had recently been deposited in the pond upstream of the dam. These recent sediments (bracketed in red) were obviously deposited within the past few years, since they are above the level of a sediment fence that was also "exhumed" by channel erosion. Recent sediments are up to three ft. deep and consist mainly of gravel and sand.

Near the dam (and progressing upstream) we see another deep head-cut (pouring in 2 places in this photo) that is cutting another 2.0 - 3.0 ft deeper into more ancient sediments. We infer that the older, smaller grained sediments were deposited slowly, in a natural sediment regime prior to upstream watershed impacts. The recent larger sediment deposits are occurring at an accelerated rate due to an augmented allochthonous sediment regime.

Photo 27. This photo gives a clearer view of the "exhumed" sediment fence (circled) within the enlarging Boreas Creek channel. The base of the fence and the base of the adjacent tree stump indicate the elevation of the streambed at the time the fence was installed. Since the time that fence was installed up to the time the dam broke, about three ft. of coarse sediment had filled the pond, effectively raising the ground surface by that height. Now, the creek is cutting through these sediments, and deeper, leaving the new ground surface "high and dry."

This observation provides key insight into the mechanism of pond dewatering and overall wetlands drying which essentially involves two processes: accelerated sedimentation and subsequent incision.

Photo 31. These photos show sites important to the investigation of alleged surface water contamination in the south arm of Upper CG. The lower left photo is of the ERO-SW9 sampling location, where somewhat elevated salt concentrations were reported in 2010.

The upper photo shows the Glenwild storm drainage channel and a new small detention pond which was built in 2011. In 2010, past researchers suspected that the Glenwild drainage was a source of contamination to SW9, and the detention pond was built as a mitigation measure.

Our work, however, suggests that the relatively high solute readings at SW9 are natural since the primary water source for SW9 (the spring showed in the lower right photo) has similarly high conductivity.

Photo 32. In upper CG, recently dried ponds are proving to be opportune places for weeds to become established. Here, weedy species are strongly dominant.

Photo 33. This dam breach (in Lower CG) was repaired by beavers during the 2011 season. Notice that the building materials consist of nothing larger than willow stems.

Photo 34. In addition to some repaired dams, we also observed many dams which were not being maintained by beavers including this one. Notches in the dam like this, if not repaired, concentrate flows and scouring energy which will eventually cut through the dam altogether, draining the pond. Note that the logs are debris from an upstream broken bridge that were carried here in high flows, not material placed by beavers.

Photo 28. These photos of the Reset Pond show how it functions by distributing outflow across the dam into numerous distributary channels below. If this dam fails, the distribution function will be compromised.

Photo 29. The upper photos shows some ponds in Lower CG as viewed from the gondola in September, 2011. The approximate extent of ponds is shaded as if they were filled. The pond in the lower right of the frame was dry throughout the 2011 season as its dam was breached (arrow) and not repaired by beavers. The pond in the center of the frame also had a breached and unrepaired dam (arrow), but this pond retained some impounded water as its dam breach was only partial (this is the breach shown in Photo 34). The lower photo shows the ponds as they appeared earlier in July.

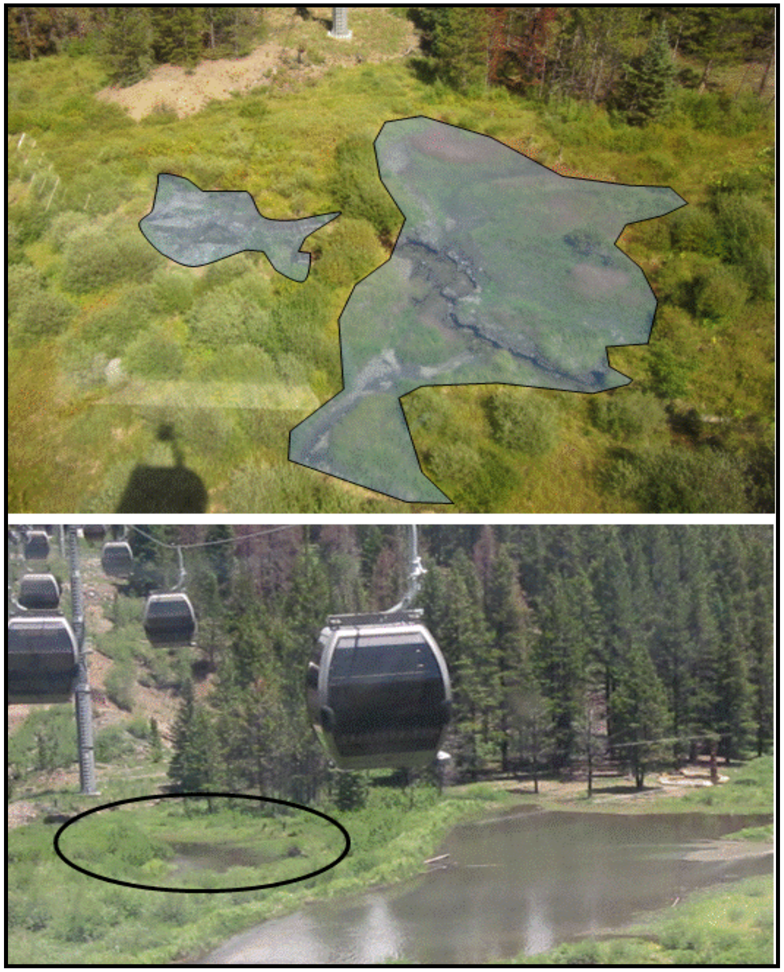


Photo 30. The upper photo (from September) shows two adjacent ponds which dried during 2011. The approximate extent of the ponds is shaded as if they were filled. One can see where a channel has cut through sediments in the old bed. The lower photo shows these ponds still full in early July, before their dams breached.

Photo 31. Two views of a new channel cutting through pond sediments and a breached dam in Lower CG are shown here. This channel is in the bed of the dried pond shown in Photo 34.

Photo 32. This photo shows the sediment delta that was deposited in the Reset Pond at the head of Lower CG during July, 2011. The delta is estimated to contain tens of thousands of cubic feet of sediment. The vegetated mound behind the biologist in the photo is a beaver lodge which used to be an island. It is now on land, which makes it more vulnerable to predation. We do not know if it is still functional as a lodge, but there is a camera trained on it (visible on the tree) that monitors beaver activity.

Photo 33. These photos show formation of a sediment delta in a large pond near the lower end of Lower CG in early July. Without more quantitative investigation, it remains unclear whether these rates of sedimentation are unnatural at this location, but the rapid formation of deltas of this size do "raise a red flag" of concern about sedimentation impacts.

Photo 34. These photos show impacts of Nordic ski trails (upper) and foot/bike trails (lower) on geomorphology and vegetation in Lower CG

Photo 35. Relic mine tailings, gullies, and deposition exist adjacent to wetland habitat near the bottom of the Lower CG unit. Generally outside the wetland area, these are minor stressors to geomorphology and vegetation.

Photo 36. Water emanating from a residential area above Lower CG near the Breckenridge Nordic Center was investigated in July due to concerns about a "curious sheen". Laboratory samples ruled out petroleum and *E. coli*, so the sheen was assumed to be a natural metabolic by-product rather than the product of a petroleum or septic contamination.

Photo 37. Algae in the water was taken as a possible indicator of eutrophication or nutrient enhancement which raised concerns about septic system failure in this residential area within the buffer of Lower CG. Laboratory tests did not indicate septic leakage, however.

Photo 38. This photo shows where a Nordic ski trail crosses the wetlands of Lower CG. The observed difference in height of willows at this location is interpreted as a very minor impact to the vegetation variable.