SOUTHWEST CLIMATE CHANGE INITIATIVE

Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin: Summary

December 2-3, 2009
Gunnison, Colorado

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Appendices

Executive Summary

The Nature Conservancy (TNC) convened a two-day workshop entitled *Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin* on December 2-3, 2009 in Gunnison, Colorado. The goal of the workshop was to identify management strategies that will help native plants, animals and ecosystems adapt to a changing climate and lay the groundwork for their implementation in the Gunnison Basin. Fifty-seven representatives of 20 state and federal agencies, local governments, academic institutions, and non-governmental organizations participated.

The objectives of the workshop were to:

1. Provide background information on climate change as it applies to the Gunnison Basin.
2. Introduce a framework for landscape-scale climate change adaptation planning for use at this workshop and as a tool that can be used in other landscapes.
3. Assess the impacts of climate change on a set of high-priority species, ecosystems and natural processes selected by workshop organizers and participants.
4. Identify strategic actions that will reduce climate change impacts.
5. Identify opportunities for ongoing learning, collaboration, and implementation of on-the-ground climate change adaptation projects in the Gunnison Basin.

Over the course of two days, managers, scientists and conservation practitioners identified adaptation strategies under two climate change scenarios – one moderate, and one more extreme – for three conservation features: Gunnison Sage-grouse, Gunnison headwaters, and alpine wetlands ecosystem.

Key outcomes of the workshop were:

1. A shared understanding of the known current and potential future effects of climate change, through development of conceptual models, on Gunnison Sage-grouse, Gunnison headwaters, and alpine wetlands.
2. Set of strategic actions that can be implemented to promote resilience and realignment of Gunnison Sage-grouse, Gunnison headwaters and alpine wetlands in the face of climate change.
3. A list of opportunities to implement the identified strategic actions successfully.
4. A list of research and monitoring needs for climate adaptation in the Gunnison Basin for the Gunnison Sage-grouse, Gunnison headwaters, and alpine wetlands.
5. Recognition among participants of the urgent need to take action to prepare for a changing climate.
6. A list of recommended next steps to be taken by natural resource managers of the Gunnison Basin.

Each breakout group selected several important strategic actions for the three conservation features, and discussed opportunities for implementation. These features and actions were:

- Gunnison Sage-grouse:
    - Retain water in most vulnerable sage-grouse brood-rearing habitats (hay meadows, seeps, and springs).

- Improve/restore nesting and wintering sage-grouse habitats.
- Zoning laws and other policy options to protect habitat and maintain land uses.

- Gunnison headwaters:
  - Manage water resources for groundwater recharge and base flow maintenance.
  - Improve forest, fire and watershed health through forest and shrubland management.
  - Reduce erosion potential through reseeding and restoration.
- Alpine wetlands:
  - Augment and maintain water flows to alpine wetlands.
  - Minimize negative influences of grazing and human disturbances.
  - Reduce dust-on-snow events.

At the end of the workshop, participants concluded that the strategic actions need further refinement to reduce the impacts to the conservation features, particularly for the extreme climate change scenario. The ecological changes that could occur under these scenarios likely require more extensive and intensive management intervention than the suite of strategies identified at the workshop. Participants expressed the need for continued collaboration across jurisdictional boundaries to plan for species and ecosystem adaptation to climate change in the Gunnison Basin. Recommended next steps are outlined below.

Short-term recommendations:

- Convene a small group of key stakeholders, including federal and state land management agencies, county, scientists, and non-governmental organizations, to continue the climate adaptation dialogue and determine strategies for working together.
- Conduct further analyses of climate change and its ecological effects in the Gunnison Basin, e.g., further interpretation of the moderate and extreme climate scenarios.
- Refine the identified strategic actions, especially for the more extreme scenario.
- Implement "no-regrets" strategic actions for the three conservation features.
- Develop a communications plan related to these activities, emphasizing public outreach and education.

Long-term recommendations:

- Conduct climate vulnerability assessment of species and ecosystems of the Basin.
- Assess climate vulnerability at a state level and conduct workshops in other landscapes.
- Develop a comprehensive climate change adaptation strategy for the Gunnison Basin.
- Encourage research to better understand the biological responses to climate change to assist land managers in making land management decisions.

The *Gunnison Basin Climate Change Adaptation Workshop* was the second in a series of four workshops organized by the Southwest Climate Change Initiative (SWCCI), a project of TNC and collaborators from the Wildlife Conservation Society, USDA Forest Service, University of Arizona and University of Washington. The goal of the SWCCI is to provide information and tools for climate change adaptation planning and implementation to conservation practitioners in Arizona, Colorado, New Mexico and Utah. For SWCCI products, including the Gunnison Basin workshop presentations and participant notebook materials, see: http://www.nmconservation.org/projects/new_mexico_climate_change.

Introduction

The Nature Conservancy (TNC) in Colorado, working with the USDA Forest Service, TNC-New Mexico, University of Arizona, and Wildlife Conservation Society, convened a two-day workshop entitled *Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin* on December 2-3, 2009 at Western State College in Gunnison, Colorado (See Appendix 1 for the agenda). Fifty-seven representatives of 20 state and federal agencies, local governments and non-governmental organizations participated (See Appendix 2 for list of participants).

This workshop was the second of a series of four workshops organized by the Southwest Climate Change Initiative (SWCCI), a collaborative effort (with the above-listed partners) to provide information and tools for climate change adaptation planning and implementation for conservation practitioners in the Four Corners states: Arizona, Colorado, New Mexico and Utah.

Workshop Goal and Objectives

The workshop goal was to identify management strategies that will help native plants, animals and ecosystems adapt to a changing climate and lay the groundwork for strategy implementation.

The objectives of the workshop were to:

1. Provide background information on climate change as it applies to the Gunnison Basin.
2. Introduce a framework for landscape-scale climate change adaptation planning for use at this workshop and as a tool that can be used in other landscapes.
3. Assess the impacts of climate change on a set of high-priority species, ecosystems and natural processes selected by workshop organizers and participants.
4. Identify strategic actions that will reduce climate change impacts.
5. Identify opportunities for ongoing learning, collaboration, and implementation of on-the-ground climate change adaptation projects in the Gunnison Basin.

Why the Gunnison Basin?

We selected the Gunnison Basin landscape for a pilot case study workshop in Colorado for a variety of reasons. First, the SWCCI recently completed a rapid regional climate change assessment that indicated that the Gunnison Basin has both a high climate change exposure and a large number of species vulnerable to climate change when compared to other regions in the state. The Gunnison Basin is known for its high biodiversity values, including high-quality sagebrush shrublands, aspen forests, extensive alpine tundra, and species of concern including the Colorado cutthroat trout, Skiff milkvetch, boreal toad, and Gunnison Sage-grouse. Analyses of past climate impacts indicate significant increases in mean annual temperature over the last 50 years (1.6 °F or 0.9 °C) (Ray et al. 2008). Climate models project Colorado will warm by 2.5 °F (1.4°C) by 2025, and 4° F (2.2°C) by 2050 (Ray et al. 2008). The Gunnison Basin lies within the larger Colorado River Basin, the epicenter of warming and drying in the Western United States (Saunders et al. 2008). Since the 1970s, the basin has warmed more, by some measures, than any other region in the contiguous United States (Saunders et al. 2008). This warming is already having an effect on ecosystems and wildlife species, as documented by Drs. Ian Billick and David Inouye of the Rocky Mountain Biological Laboratory in their presentation entitled *Overview of the Terrestrial Ecological Consequences of Climate Change in the Southwest and the Gunnison Basin*.

Another reason for selecting the Gunnison Basin was to build upon the excellent long-term research by scientists at the Rocky Mountain Biological Laboratory (RMBL). RMBL studies indicate ecological changes in the region that are likely to be related to climate change. For example, marmots are emerging from hibernation approximately one month earlier than historically, one bumblebee species has moved up 2,000 feet in elevation since the 1970s, snowmelt is earlier, and frequency of frost damage to plants is increasing with earlier flowering (Inouye et al. 2000, Inouye 2008, and Steltzer et al. 2009).

The workshop also provided an opportunity to build on the research and monitoring conducted by Colorado Division of Wildlife (CDOW), Western State College (WSC), and others. The organizers wanted to build on the strong presence and engagement of public land management agencies, including the US Forest Service (USFS), National Park Service (NPS), and Bureau of Land Management (BLM), and a tradition of collaboration across land ownership boundaries, e.g., Gunnison Sage-grouse Working Group and Committee.

Finally, the Conservancy wished to build on its investments in the Gunnison area – for example, Mexican Cut, the Conservancy's first preserve in Colorado, currently managed by the RMBL. TNC also holds 15 conservation easements in the basin, largely focused on protecting the Gunnison Sage-grouse and its sagebrush shrubland habitat. In the early 2000s, TNC led a conservation planning exercise with BLM, CDOW, NPS, WSC, NRCS, and others to prioritize conservation efforts, resulting in the Gunnison Basin Measures of Conservation Success Report (TNC 2008).

Workshop Outcomes

Over the course of two days, participants worked through an interactive process to identify adaptation strategies under two climate change scenarios developed by Senior Scientist Linda Mearns of the National Center for Atmospheric Research and Research Scientist Joe Barsugli of University of Colorado's Western Water Assessment. Workshop outcomes include:

1. Development of ecological descriptions and long-term management objectives for three conservation features, the Gunnison Sage-grouse, Gunnison headwaters, and alpine wetlands.

2. Review and interpretation of two climate change scenarios – moderate and extreme. Shared acknowledgement of uncertainties associated with projections, but recognition of the need to move forward.

3. Shared understanding of the known current and potential future effects of climate change, through development of conceptual models, for Gunnison Sage-grouse, Gunnison headwaters, and alpine wetlands. Conceptual models illustrate the climate, ecological, physical, and social factors that affect conservation features.

4. Identification of management intervention points (places in the system that we can influence through management and conservation actions) using conceptual models to help managers document the assumptions behind specific management actions for reducing negative impacts of climate change.

5. Identification of practical adaptation strategic actions that can be implemented by managers to promote resiliency and realignment of the Gunnison Sage-grouse, Gunnison headwaters, and alpine wetlands in the face of two climate scenarios. Many of the conservation strategies that are already being implemented in the Gunnison Basin can be used to prepare for climate change. However, the scale, sequencing, priority and cost of these strategies will very likely need to be adjusted if management objectives are to be met under a changing climate.

6. Evaluation of opportunities to implement strategic climate adaptation actions.

7. Statement of research and monitoring needs for informing climate adaptation strategies in the Gunnison Basin.

8. Recognition that more work is needed to identify "no-regrets" strategic actions to reduce the impacts predicted for more extreme climate change scenarios. The ecological changes that could occur under these scenarios will require more in-depth climate analyses and more intensive and extensive management intervention – or perhaps even wholesale changes in management goals.

9. Recognition that cross-jurisdictional collaboration is needed to refine workshop products and implement the actions.

10. Recognition that effective climate change adaptation will require a great deal of communication and collaboration among stakeholders and policy makers.

See http://www.nmconservation.org/projects/new_mexico_climate_change for the Gunnison Basin Climate Workshop presentations and participant notebook materials.

Background Information for Development of Adaptation Strategies

Introduction

Both **Tim Sullivan**, Acting Director, TNC-CO, and **Pat Magee**, Thornton Chair in Biology, Western State College, welcomed the participants to the meeting.

Patrick McCarthy of The Nature Conservancy in New Mexico (TNC-NM) and Director of the Southwest Climate Change Initiative (SWCCI) gave a presentation on the SWCCI. Key points:

- We can no longer assume climate stability and persistent ecosystems in carrying out our conservation work. Climate change is already causing change both subtle (e.g., changes in timing of migrations or leaf-out) and dramatic (e.g., widespread forest dieback) shifts in ecological systems.
- Even if we completely eliminated greenhouse gas emissions, the Earth's climate would continue to warm for hundreds of years (Solomon et al. 2009). Concerted action will be required to conserve species and ecosystems that are affected by a rapidly changing climate.
- TNC's analysis of climate change in the Southwest, begun in 2007, found that the climate of the Southwest has been warming for decades, and it is already affecting native plants, animals and habitats. We concluded that, though there is uncertainty about how climate change will affect ecosystems in the future, now is the time to take action to reduce the damage.
- TNC joined the University of Arizona, Wildlife Conservation Society and US Forest Service in forming the SWCCI, whose goal is to provide climate adaptation information and tools to conservation practitioners. The Initiative's objectives are to:

    1. Help identify needs and priorities for climate adaptation by preparing a regional assessment of climate change exposure.
    2. Provide a forum for conservationists to identify science-based and practical adaptation strategies in a series of landscape workshops, one in each of the Four Corners states.
    3. Draw upon the four workshops for data, tools and lessons that can be applied to other landscapes in the southwestern US that may be adversely affected by climate change.

Gregg Garfin of the University of Arizona (UA) was the overall facilitator of the two-day workshop. Dr. Garfin is an expert in Southwest climatology and is the UA's Deputy Director for Science Translation and Outreach at the Institute of the Environment.

In his introductory session, Garfin provided the rationale for the workshop and gave participants a chance to share their current thinking and concerns about climate change. Garfin asked participants to break out into small groups to identify barriers and uncertainties regarding climate change (Box 1). Participant responses were diverse but consistent with the concerns natural resource managers are expressing throughout the United States (US Government Accountability Office 2007). Key points:

- We need to get from the continental level to the landscape level to identify strategies to address impacts.

- The rate at which emissions will rise – and thus, the extent to which the climate will change – is uncertain because of uncertainty about the future of global and national energy policy and the global economy.
- The statistics of the past are not going to be a good guide to the future: this is termed "non-stationarity." One of the goals is to think about uncertainty in constructive ways and get beyond the paralysis that it can induce.
- Preliminary lessons learned from other landscape adaptation workshops: take an adaptive management approach, learning as you go; managers need to lead the development of adaptation strategies; work in partnerships; science-management collaboration; involve the public; and confront uncertainty.
- Managers can begin to address climate change now by protecting key ecosystem features and processes, reducing anthropogenic stressors, and increasing collaboration and coordination across the Gunnison landscape.

Box 1. Opening session break-out groups responses to two questions:

What is your greatest barrier or uncertainty that you face in moving forward on climate change?

- Uncertainty about direction, magnitude, and timing of climate change
- Political will and action, human inertia, change is slow
- Issue still abstract to policy makers at highest levels
- How to get managers to change way they do things
- Need more and better information
- How to find common ground given naysayers
- Mismatch of spatial scale of climate information to management
- Having enough capacity and resources to respond and adapt to climate change
- How to effectively incorporate into everyday duties

Do you think you can do anything about it?

- Provide incentives for climate change adaptation and monitoring.
- Identify no-regrets strategies.
- Form interdisciplinary groups to generate recommendations and carry them out.
- Communication
- Important to have a dialogue to figure out what to do
- Form interdisciplinary groups, workshops like this.

Presentations: Climate Change in the Gunnison Basin

Following this session, a series of introductory presentations were given by experts on the evidence for climate change and its ecological effects in and around the Gunnison Basin. These presentations provided background information for participants to apply during the adaptation planning exercise. Copies of these presentations can be downloaded from http://nmconservation.org/projects/new_mexico_climate_change/ or at ConserveOnline[1].

Linda Mearns, Director of the Weather and Climate Impacts Assessment Science Program and Senior Scientist at the National Center for Atmospheric Research (NCAR), Boulder, Colorado, gave an overview of regional climate change impacts—*The Known, the Unknown, and the Uncertain*. Key points:

- Concentrations of atmospheric greenhouse gases are increasing at alarmingly rapid rates. The average temperature of the planet is about 0.75°C (1.3°F) warmer

[1] This free public Web-based conservation library requires users to create a user name and password.

than it was in 1860, based upon dozens of high-quality long records. Eleven of the last 12 years are among the 12 warmest since 1850.

- Most of the observed increase in global temperatures since the mid-20th century is very likely (90% probability) due to the observed increases in greenhouse gas concentrations. Discernible results of human influences include ocean warming, increase in continental-average temperatures, greater temperature extremes and changing wind patterns (IPCC 2007).
- Sources of uncertainty:
    - Future trajectory of greenhouse gas emissions is explored by multiple scenarios of future world development that include factors such as population growth, adoption of technological innovations to mitigate greenhouse gas emissions, and global economics. Thus, these projections are uncertain by nature.
    - How the climate system will respond to increasing greenhouse gases (explored through climate models).
    - Spatial scale at which models are run.
    - Physical processes that we don't know about or can't quantify and catastrophic extremes. There are uncertainties we can't readily quantify, e.g., projections of temperature change are probably under-estimates because we have incomplete knowledge of physical processes and catastrophic extreme events (e.g., collapse of the Greenland ice sheets).
- Making decisions in the face of uncertainty:
    - Quantification of uncertainty is important because models will continue to get better, but uncertainties are not going away anytime soon. Scientific progress does not always translate to more certainty.
    - We need to make decisions under conditions of uncertainty. Many resource managers need this information so that they can plan and act.
- Observed emissions are higher than the most fossil fuel intensive projection (A1FI) used in the IPCC Fourth Assessment Report (Solomon et al. 2007).The climate system is very complicated, but computer-based Global Climate Model (GCM) generated projections match observed temperature change on all continents. Warming will increase if greenhouse gases increase. If greenhouse gases were kept fixed at current levels, a committed 0.6°C (1°F) of further warming are expected by 2100. 2°C (3.5°F) change is a global indicator or level at which a lot of systems will be in trouble.
- Selected scenarios from the Special Report on Emissions Scenarios: A1B: business as usual greenhouse gas emissions, no increase in globalization of sustainable practices; B1: lower rate of emissions, in a green world with a commitment to sustainability and assumes low increase in population; A2: close to business as usual emissions, with assumptions of no greenhouse gas mitigation and large increase in population.
- North American projections (end of 21st century, assuming A1B scenario) are based on estimates from 21 GCMs. The IPCC report chapter on regional climate projections concluded that precipitation in the Southwest will decline. There is much uncertainty regarding precipitation in this region. There is much variability in how global climate models project precipitation.

- What resolution do we need for adaptation purposes? How can we balance the need for high resolution vs. the need to develop multiple approaches to projection? Global models are at 200 km spatial resolution and regional models are 10 km resolution. Dr. Mearns leads the North America Regional Climate Change Assessment Program (NARCCAP) which is developing high-resolution (50 km) models for impacts and adaptation assessments: www.narccap.ucar.edu.
- Do we need to reduce uncertainty to make decisions about climate change? No, it is better to make decisions that are robust and flexible that can be adjusted as we learn more about climate change in the future.
- Dr. Mearns developed and presented two climate scenarios for the purposes of this workshop. See climate scenarios section below for details.

Ian Billick, Executive Director, Rocky Mountain Biological Laboratory (RMBL) gave an *Overview of the Terrestrial Ecological Consequences of Climate Change in the Southwest and the Gunnison Basin*. Dr. Billick provided an overview of the Lab, which is the destination of one of the largest migrations of scientists every year. Key points:

- Scientists at the RMBL have conducted long-term studies documenting how the biology has been changing over time (over 1,300 peer-reviewed scientific papers since the founding of the lab). About 10% are directly relevant to climate change. A summary of key studies is provided below.
- Selected results from a warming experiment study on the effects on species:
    - Decrease in showy wildflowers, increase in shrubs; mechanism is soil moisture (Harte and Shaw 1995).
    - Flowering time will advance up to 11 days for every two weeks of earlier snowmelt or for every increase in average spring temperature/growing season temperature; flowering time of some species not effected and late-flowering species less sensitive (Dunne et al. 2003).
    - Investment in reproductive effort depends upon species (Lambrecht et al. 2007).
    - Plants in warmed plots had more damage and were attacked by more species (Roy et al. 2004).
    - Warming had no effect on aphids (Adler et al. 2007).
- Other studies:
    - Lodgepole pine increases productivity in response to warmer temperatures and earlier snowmelt; Engelmann spruce insensitive to changes in temperature and snowmelt (Kueppers and Harte 2005);
    - Subalpine fir responds to drought in different ways at different sites (Valentovich 2006).
    - Long-term data indicate mayfly emergence is driven by peak flow and water temperature; experiments indicate temperature is a driving factor. If relationship between flow and temperature changes, there will be impacts on population densities and distributions (Harper and Peckarsky 2006).
    - There has been an increase over the past 30 years in some low-elevation bumble bee (*Bombus*) species and a decrease in high-elevation bee species. Other *Bombus* and *Psithyrus* spp. show no changes (Miller 2007).

    - Mosquito species moving up in elevation will affect disease distribution (anecdotal obs.).
- General conclusions: 1) making site- and species-specific predictions and decisions will be tough; 2) increasing variability in correlations of abiotic factors will be a problem; and 3) long-term responses may be very different from short-term responses.
- For the future, we need: 1) to maintain investment in sustained, place-based research; 2) to bring management of field data into modern age of communication; and 3) better tools, models, and long-term studies and data.

David Inouye, Professor and Director, CONS Program, Department of Biology, University of Maryland and Researcher at Rocky Mountain Biological Laboratory continued Dr. Billick's presentation describing the *Ecological Consequences of Climate Change in the Southwest and the Gunnison Basin*; with further examples from the research at RBML and beyond. Key points:

- Higher elevations in the Rocky Mountains have experienced three times the average warming of the globe.
- Observed trends in snowmelt in the West: more precipitation is falling as rain, runoff is arriving earlier by 1-4 weeks, and major dust events are having an impact on timing of snowmelt (Stewart et al. 2004, Steltzer et al. 2009, and Rhoades et al. 2010).
- Observed changes in flora and fauna:
    - Normally low-elevation Douglas fir is moving up.
    - Bumble bee species moved up 2,000 ft since the 1970s.
    - One-third of pika colonies in Nevada and Utah have disappeared in the last century.
- Previously synchronized events between plants and animals are changing relative to each other, e.g., pollination. Plants and animals respond in different ways to warming in Gothic. Examples of changes in animal phenology (See Inouye et al. 2000):
    - White-tailed ptarmigan turning white before there is snow on the ground.
    - Yellow-bellied marmots are emerging from hibernation about a month earlier than they used to, and are more susceptible to predation.
    - Some animals that did not inhabit RMBL in the past have moved in, such as Wyoming ground squirrels and foxes.
    - American robins are arriving 3-4 weeks earlier.
- Decreased snowpack, warmer springs, earlier snow melt, and the beginning of growing season is becoming earlier, but date of last frost (early to mid-June) has been stable, resulting in increased frost damage and lower seed production, leading to a decline in native wildflowers and butterflies (Inouye 2008).
- Observed increases in wildfire frequency, longer duration, and longer wildfire season (Westerling et al. 2006) and pine bark beetle epidemic are rooted in warmer and drier temperatures.
- Conclusions: 1) climate is changing; 2) snowmelt dates are getting earlier; 2) flowering is starting earlier; 3) frequency of frost damage is increasing; 4) plant demography is being affected; 5) pollinators may be affected. Climate change is

also likely to affect ecological services, such as clean water. Long-term monitoring is needed.

- Good resource: Eviner Lab at University of California at Davis has an interdisciplinary project looking at impacts of climate change on alpine and subalpine ecosystems of the Sierra Nevada Mountains, California.

Joe Barsugli, Research Scientist at the Cooperative Institute for Research in the Environmental Sciences (CIRES) at the University of Colorado, Boulder, gave a presentation entitled *Overview of Past and Potential Future Hydrologic Trends in the Gunnison Basin.* Key points:

- The average precipitation in Colorado is 16 inches, but only 3 inches end up in the rivers/streams and 2 of those inches leave the state. In Gunnison, most precipitation falls in the summer; in the upper watershed, most falls as snow in winter.
- Hard to detect statistically significant trends in precipitation in Colorado, for a number of reasons having to do with natural climate variability.
- For Cochetopa Creek (weather station with one of the longest records in the state), maximum temperatures have increased since 1947 -- larger than expected based on global and regional climate models (3°F). This warming is part of a much broader trend across the western US, roughly half of which is attributed to human causes.
- No big trends in Gunnison River stream flow over past 60 years. But over the last 30 years –there has been a trend towards earlier snowmelt and stream flow (*Colorado River Water Availability Study*-CWCB). Tomichi Creek (at Sargents) climate station records show low flows in drought years.
- 112 downscaled precipitation and temperature projections for the Gunnison River basin (from B1, A1B and A2 emissions scenarios) were used to develop a hydrology model that generates 112 runoff projections (from Levi Brekke, Bureau of Reclamation) indicating earlier runoff, lower soil moisture with severe declines in summer and fall, and less snow accumulation.
- *Colorado River Water Availability Study* preliminary results: 19% and 26% reduction in average annual runoff volume by 2040 and 2070. Eight and 13 day shift earlier in peak runoff by 2040 and 2070. This will lead to 35% reduction in available flow. Total amount and pattern of availability both change. Rule of thumb for Colorado River Basin: 5-9% reduction in runoff for every 1°C (1.8° F) warming and a 20% increase in runoff for every 10% increase in precipitation.
- Uncertainties for 2050 model: summer monsoon, Pacific Ocean variability and drought (El Niño/La Niña), magnitude of hydrologic response to warming, Land Cover feedbacks on regional climate and hydrology, dust and flooding potential.
- See below for Gunnison Basin hydrologic scenarios developed by Dr. Barsugli.

Introduction to Adaptation Planning

Molly Cross, Climate Change Ecologist and Adaptation Specialist with the Wildlife Conservation Society (WCS), provided an overview of climate change adaptation concepts and approaches, including a new adaptation planning framework in her presentation, *Place-based Climate Change Planning: Overcoming the Paralysis of Uncertainty*. Key points:

● General principles of adaptation and approaches to reframing management goals such as the "5Rs+1" (Box 2) are useful at a conceptual level, but more specific solutions are needed by managers working at landscape and site levels; the lack of specific direction is causing *uncertainty paralysis*, preventing managers from taking action in the near term.

● The Wildlife Conservation Society, the Center for Large Landscape Conservation, and the National Center for Ecological Analysis and Synthesis (WCS-NCEAS) convened a working group of scientists and managers from multiple institutions and agencies to develop an adaptation planning framework designed to translate general recommendations on climate change adaptation strategies into practical, specific actions for a given landscape, set of species, or ecosystems using a transparent and participatory process (Cross et al. *in prep.*). This framework was modified slightly for the purposes of this workshop, to include components of TNC's conservation action planning methodology for addressing climate change (TNC 2009a).

Box 2. General concepts for thinking about climate change adaptation and natural resource management.

The "5-Rs + 1" Framework (adapted from Millar et al., 2007):

- Resistance – hold back the tide
- Resilience – decrease stressors
- Response – conserve for all extremes
- Realign – conserve for new reality
- Reduce – mitigate greenhouse gases
- Triage – prioritize action

Question: Will promoting resistance and resilience be feasible in light of the magnitude of projected changes?

General Principles of Adaptation (adapted from Glick et al. 2009):

- Reduce non-climate stressors
- Manage for ecological function and protection of biodiversity
- Establish buffer zones and connectivity
- Implement proactive strategies
- Increase monitoring

Challenges: How to deal with complexity and uncertainty?

The WCS-led adaptation framework has been applied at the Jemez Mountains climate adaptation workshop held in Los Alamos, New Mexico (Enquist et al. 2009) and at a workshop organized by WCS and the U.S. Fish and Wildlife Service on adaptation planning for grizzly bears and wolverine in the Northern U.S. Rockies (contact mcross@wcs.org for details). The TNC climate framework has been applied to 20 sites across the globe at a workshop held in Utah in September 2009. (See The Nature Conservancy's Climate Adaptation workspace on ConserveOnline for more information).

Implementation of the Adaptation Planning Framework

The climate change adaptation framework is designed for collaborative application in a given landscape by a multidisciplinary group of managers, conservation practitioners and scientists, and includes the following steps:

1. Select feature targeted for conservation (e.g., species, ecological processes, or ecosystems) and specify an explicit, measurable management objective for that feature.
2. Build a conceptual model that illustrates the climatic, physical, ecological, and socio-economic drivers that affect the selected feature.
3. Assess impacts of plausible future climate scenarios:
    a. Use the conceptual model to assess climate change impacts (i.e., develop hypotheses of change) by examining how specific changes in climate variables might directly or indirectly influence the selected feature, for each scenario of future climate conditions being considered.
    b. Consider how human responses to climate change (e.g., solar and wind power development, geothermal exploration, construction of dams for increased water storage, etc.) may influence the selected feature.
    c. Assess the likely impact of climate change relative to other known impacts or threats, and identify which climate-induced impacts are most critical to address to achieve the stated management objective.
4. Identify potential strategic actions in light of climate change:
    a. Identify intervention points—those places in the system that we can influence through management and conservation actions.
    b. Brainstorm potential strategic actions that can be taken at those intervention points to achieve the stated objective under each climate scenario.
    c. Determine whether the management objective or the selection of the feature needs to be revisited: Does climate change fundamentally change the landscape? Do the management objectives for that feature need to change? Will the feature even be found in the same location in the future? Does our view of the landscape and boundaries need to change?
5. Evaluate feasibility of potential strategic actions and prioritize according to factors such as: cost; social and political feasibility; potential for positive effects or risk of unintended negative consequences for other features or objectives; and robustness to uncertainty in future climate.
6. Develop action plan outlining priority strategic actions to be implemented.
7. Implement action plan.
8. Monitor and evaluate action effectiveness and progress toward objectives—adjust or reevaluate actions if needed to address system changes or ineffective actions.

For the purposes of this workshop, breakout groups focused on completing the first five steps of the *planning phase* (left-hand side of Figure1). Workshop facilitators divided the participants into three groups, each with a different conservation feature: 1) Gunnison-sage grouse; 2) Gunnison headwaters; and 3) alpine wetlands. In order to test the framework for one species, one ecosystem, and one ecological process, and to make the workshop most useful to participants, features were selected through a participant survey before the workshop.

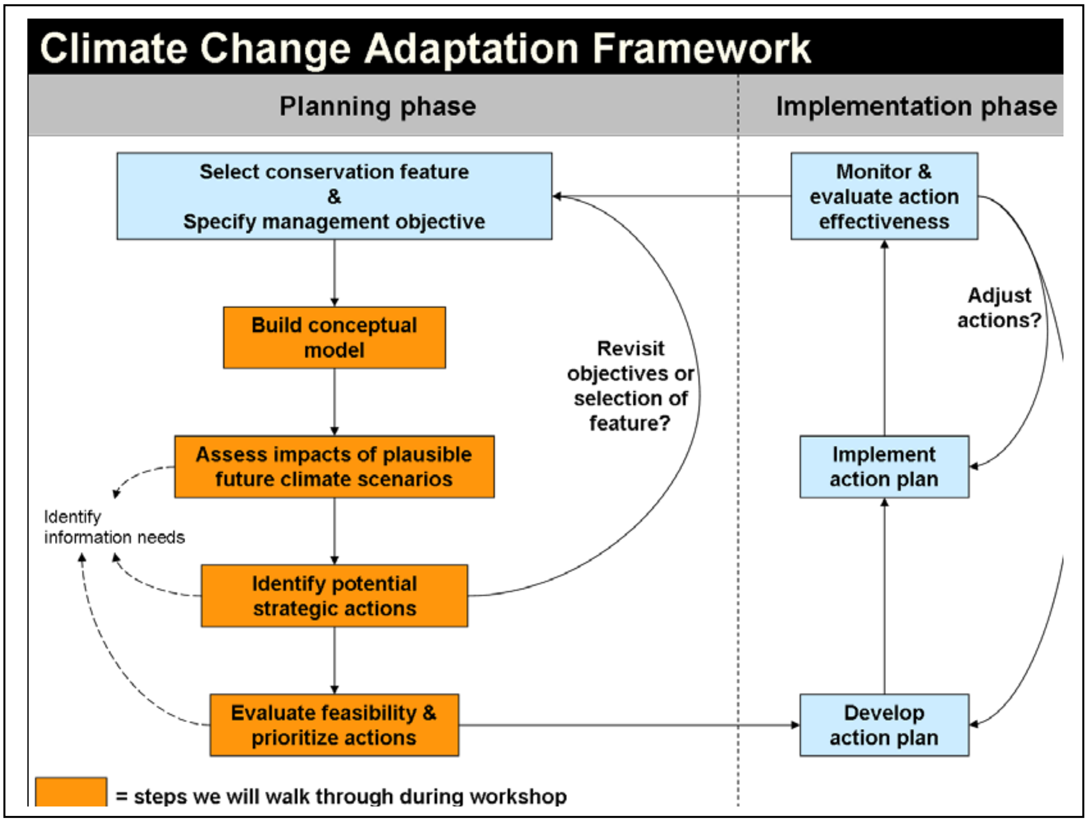

Figure 1. An iterative climate change adaptation framework for natural resource management and conservation (adapted from Cross et al. *in prep*. and TNC 2009a). The left side represents the adaptation planning phase; the right side represents the implementation phase.

Climate Scenarios for the Gunnison Basin

To guide the workshop discussions of the impacts of climate change and potential adaptation strategies, Linda Mearns (NCAR), developed two climate change scenarios in collaboration with Joe Barsugli (CU), who developed two scenarios of hydrological change. Scenarios for the development of adaptation strategies at this workshop are for 2040-2060. The scenarios are based on the IPCC SRES Emissions Scenario-A2 (medium-high emissions). The hydrologic scenarios are consistent with the climate change scenarios. Hydrologic scenario 1 (moderate change) is developed from the average of the modeled hydrologic projections. Scenario 2 (extreme change) is developed from an individual simulation that has seasonal temperature and precipitation changes that are similar to the climate change scenario. The two climate scenarios are summarized below.

1. **Scenario #1: Moderate change:** Increased annual temperatures (2+°C), no substantial change in annual precipitation, but increased cool season precipitation and decreased warm season precipitation.

Season	Precip %	Temp °C	Temp °F
Annual	~0.0	+2.0-3.0	+3.6-5.4
Winter	+15.0	+2.0	+3.6
Spring	-12.0	+2.5	+4.5
Summer	-15.0	+3.0	+5.4
Fall	+4.0	+2.5	+4.5

Hydrologic implications

Parameter	Impacts
Streamflow Amount	5-10% decrease
Snowpack Accumulation and Melt	Later fall accumulation, earlier spring melt, high elevation midwinter accumulation may be similar to present
Streamflow Timing	Earlier by 7 days
Soil Moisture	Significantly less during summer

- **Stream flow Amount:** Annual natural stream flow will decrease under a scenario of increased temperature, even if precipitation remains the same. The shift of precipitation from summer to winter somewhat counteracts the drying tendency somewhat leading to a moderate decrease (5-10%) in annual flows.
- **Snowpack Accumulation and Melt:** Warming temperatures lead to a later accumulation of snow in the fall, and an earlier snowmelt in the spring. However, because of the increased precipitation in winter, and the generally cold, high-elevation nature of the Upper Gunnison Basin, the mid-winter snowpack may be similar to the present.
- **Stream flow Timing:** Snowmelt-driven stream flow will occur earlier in the spring, by about 7 days on average.
- **Soil Moisture:** The earlier melt along with decreased summer precipitation and increased summer temperatures results in significantly lower amounts of water stored in the soils during summer.

2. **Scenario #2: Extreme change:** Increased annual temperatures (3+°C), ~10% decrease in annual precipitation, with greater decreases in warm season precipitation

Season	Precip %	Temp °C	Temp °F
Annual	-10.0	+3.0	+5.4
Winter	~0.0	+3.0	+5.4
Spring	-15.0	+3.0	+5.4
Summer	-20.0	+4.0	+7.0
Fall	-10.0	+3.0	+5.4

Hydrologic Implications

Parameter	Impacts
Streamflow Amount	20-25% decrease
Snowpack Accumulation and Melt	Later fall accumulation, earlier spring melt, potential for substantial early melt and decreased yield if high dust deposition
Streamflow Timing	Earlier by 14+ days
Soil Moisture	Extremely low in summer and fall

- **Stream flow Amount:** Decrease in precipitation and increase in temperature both act to reduce annual stream flow totals. Projected stream flow decreases are in the range of 20-25%.
- **Snowpack Accumulation and Melt:** Warming temperatures lead to a later accumulation of snow in the fall, and an earlier snowmelt in the spring. Because this likely represents a hot/dry scenario for much of the West, the potential exists for more frequent dust deposition events, which also may lead to an earlier melt and to reduced water yield from the snowpack.
- **Stream flow Timing:** Snowmelt-driven stream flow will peak about two or more weeks earlier in the spring.
- **Soil Moisture:** The much earlier melt, along with decreased summer precipitation and increased summer temperatures, results in extremely low amounts of water stored in the soils during summer and fall.

See the References section below for information sources and the Workshop Participant Notebook materials for more details at the following link (see downloads section): http://nmconservation.org/projects/new_mexico_climate_change/).

Climate Change Adaptation Strategies for Gunnison Sage-grouse

The Gunnison Sage-grouse group, facilitated by Terri Schulz and Carrie Enquist, consisted of 18 participants representing local, state and federal agencies, non-governmental organizations, and Western State University, with expertise in grouse ecology and management.

Defining the Conservation Feature

The breakout group discussed whether the conservation feature should include the sagebrush system as well as Gunnison Sage-grouse. The group decided not to focus on the system except as habitat for the grouse. The group also agreed to focus on the Gunnison population, and to include the Crawford population (to the west) because of connectivity issues.

Management Objective

The group discussed appropriate management objectives for grouse. Two entities coordinate local management for grouse: the Working Group and Strategic Committee. A range-wide conservation plan for Gunnison Sage-grouse has specific population goals. The group decided to use these population goals as the management objective. The group also discussed the importance of habitat quality and connectivity between populations. The group agreed that important factors to help meet this objective are to increase recruitment and decrease chick mortality. The management objective is to:

Increase and maintain the Gunnison population of grouse to greater than 3,500 individuals. The management objective for the Crawford population is greater than 200 individuals.

Conceptual Model and Impacts Assessment

The group created a conceptual model that diagrams the factors that affect Gunnison Sage-grouse population size and habitat condition (See Figure 2). These factors include direct and indirect ecological, social, and land use drivers. The management currently being conducted for Gunnison Sage-grouse is focused on restoration of critical habitat characteristics. The group discussed existing impacts to grouse survival and habitat quality. Many of these impacts involved habitat degradation and destruction from land uses that impact the groundwater table or structure of sagebrush systems. Another suite of issues revolves around mortality, especially chick survival.

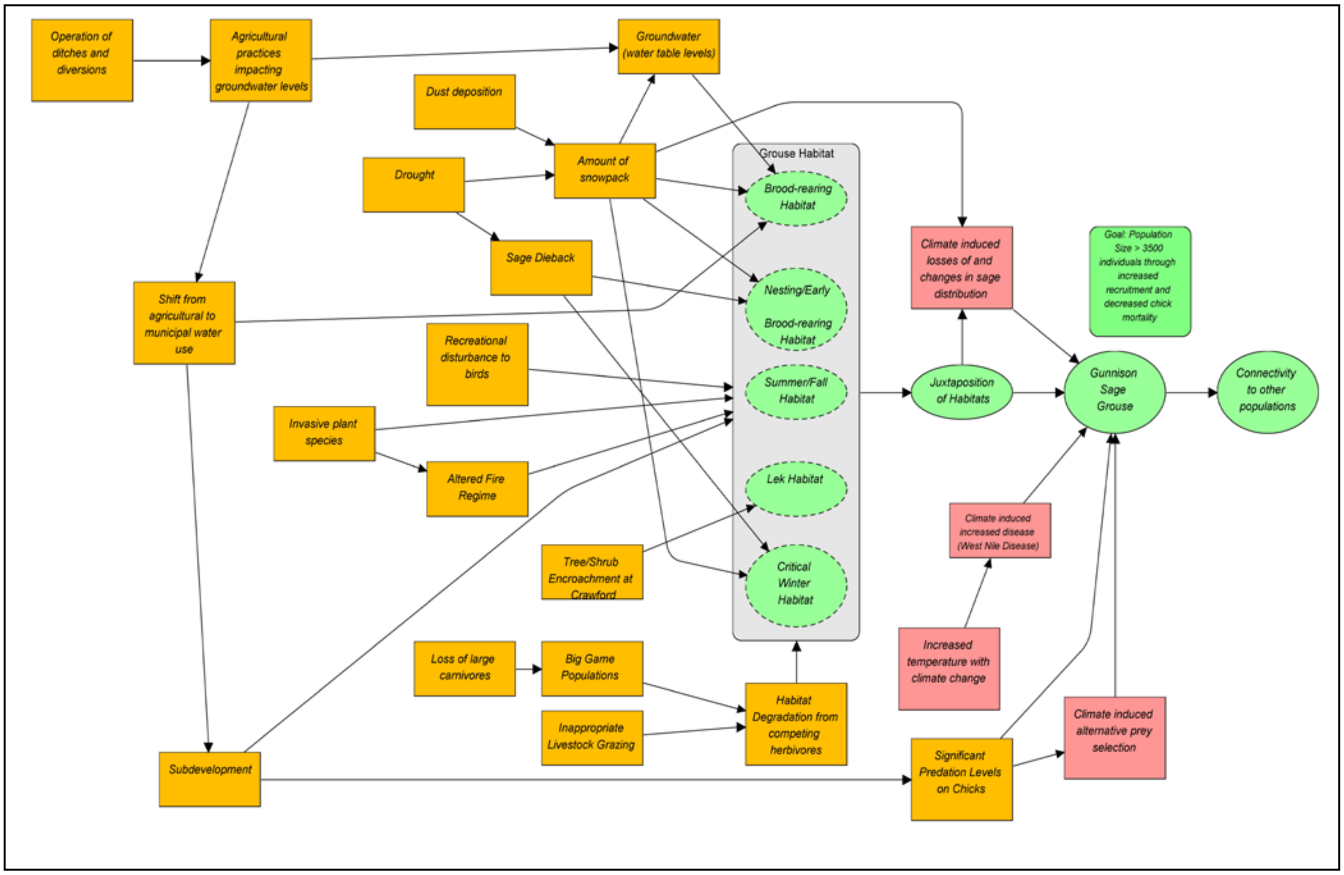

Figure 2. Gunnison Sage-grouse conceptual model.

The group then looked at the factors and assessed the potential impacts likely under the climate change scenarios (See Appendix 3). Under Climate Scenario #1, a few new factors are potentially an issue with climate change. Although not much of a concern presently, the group thought that diseases such as West Nile Virus, spread by temperature-sensitive mosquito populations, may become a significant mortality issue with a warmer climate. The group also thought that climate change might increase the frequency and severity of droughts, as well as impact snowpack, which could lead to sagebrush dieback and/or changes in the distribution of sage. In addition, the group thought that invasive species such as cheatgrass will increase significantly, lowering habitat quality and increasing fire frequency. This might be the biggest impact to the sagebrush and therefore the grouse. Since the grouse is dependent upon sagebrush with specific characteristics for nesting and wintering, these changes could result in possible shifts in distribution to higher elevation sites and/or reduced grouse population size.

Under Climate Scenario 2, the impacts were more severe, such as shrinkage or significant loss of all grouse habitats, but otherwise no new impacts were identified. In particular, the group focused on the brood-rearing and nesting habitat that might see the most severe impacts with the drying of springs and potential land use shifts with less water available for agriculture. The group discussed the potential indirect impact of climate change on the ranching community. If the frequency and severity of drought increases, the stocking rate for livestock may decrease to the point where ranches are no longer viable. If this happens, water previously used for agriculture might be re-directed to municipal use leading to drying of hay meadows and the loss of brood rearing habitat. Subsequently, conversion of agriculture lands to sub-development could lead to severe degradation or permanent habitat destruction.

Management Intervention Points and Adaptation Strategies

The group then identified intervention points in the conceptual model where management actions could be taken to lessen the climate-induced negative impacts and provide progress toward the management objective (See Appendix 4). The group listed potential adaptation strategies in a brain-storming session. Many of these management actions focused on brood-rearing habitat specifically at retaining more water in these areas through the management of snowpack, groundwater and agricultural practices. Other actions worked to improve habitat quality overall such as invasive species, wildlife, and livestock management. The group also discussed managing the habitat as a whole to determine priority actions across land ownerships. With the exceptions of emergency or heroic actions such as artificial irrigation in brood rearing habitats, assisted migration (translocation) of populations to higher elevations, and planting drought tolerant species or ecotypes from lower elevations, the group distinguished few differing actions needed under Climate Scenario #1 vs. #2. The discussion was that the urgency of action may be greater and therefore, the need to put the priority actions in place is greater with Scenario #2. The group also acknowledged that management of some satellite grouse populations may need to receive less attention given their higher potential to not be viable and instead focus on the core population under this more extreme scenario.

Priority Adaptation Strategies

After a long list of potential management actions was developed, the group voted on the top three adaptation strategies (see Table 1). Below are the three that received the most votes and were shared with the larger workshop group in the subsequent report-back session:

1. <u>Maintain and restore seeps and springs</u>: Retain water in hay meadows, seeps and springs. This might be accomplished by tying water to the land in the highest priority brood rearing habitat using conservation easements, improving irrigation practices and efficiency, or maintaining high quality and restoring degraded seeps and springs. The group also wondered whether a water right could be designated for grouse.

2. <u>Improve nesting and winter habitat</u>: Restore the mountain shrub communities, expanding perennial grasses and forbs, and prevent cheatgrass expansion.

3. <u>Policy options</u>: Zoning and other policy options to protect private grouse habitat including transfer of development rights and subdivision planning; Manage grouse habitat as a whole to ensure all habitats are available in high quality and right places.

Table 1. Priority strategic actions identified by participants for reducing climate change impacts on the Gunnison Sage-grouse for two climate scenarios.

Observed & Projected Climate Change Impact (Hypotheses of Change)	**Intervention Point**	**Scenario #1 Strategic Action (Planning Horizon: 10-15 yrs)** ***(Note: these also apply to S2)***
Brood rearing habitats: fewer mesic sites, lower quality, more erosion; may shift to higher elevation; located further from nesting; chick survival diminished (S1 & S2)	Snowpack and groundwater management Agriculture practices (esp. hay meadows) Public land management and policy	**Retain H_2O in most vulnerable brood rearing habitats (hay meadows, seeps, springs)** • Permanently tie water to land via easements (esp. senior water rights & those for grouse) • Improve irrigation practices (efficient use of water, in addition to conservation) • Restore seeps, springs; remove headcuts, gullies; raise H2O table
Nesting habitats: loss due to increased fire frequency (cheatgrass) & sage dieback; decreased quality (less forbs &perennial grasses); reduced recruitment & decreased carrying capacity of habitat itself (S1 & S2)	Public land management Grazing management Invasives management	**Improve/restore nesting and wintering habitats:** • Improve/re-establish leeward-mtn shrub habitats (snowberry, serviceberry) via fencing, planting • Maintain & expand perennial grass and forb cover • Abate/prevent cheatgrass encroachment
Human responses to climate change: Reduction of agricultural use of water shifting to municipal use leading to drying of hay meadows leading to permanent loss of brood rearing habitat; conversion of agricultural lands to developed may increase (S1 & S2)	Public land management policy Agriculture practices	**Zoning laws and other policy options to protect habitat and maintain land uses:** • Transfer of development rights; • Subdivision planning to protect all habitats • Manage grouse habitat as a whole to ensure all habitats are available in high quality and right places

Discussion and Next Steps

In the recent past, several groups have been collaboratively working on Gunnison Sage Grouse in the Gunnison Basin. In order to implement these or other draft adaptation strategies, these collaborative groups need to participate in the refinement of the strategies and creation of an implementation plan. While no radical new strategies were identified for grouse, the workshop group did reach consensus that work is not occurring fast enough in light of climate change. Break-out group participants were encouraged, however, that many of the projects they are currently working on have the potential to be re-tooled and/or re-framed to address some of the issues related to climate change. These projects include BLM mapping of cheatgrass invasion and other vulnerable, priority habitats and the receipt of funding to conduct habitat restoration in certain areas, such as Dry Creek/Dolores.

Climate Change Adaptation Strategies for the Gunnison Headwaters

Facilitated by Gregg Garfin and David Gori, the Gunnison headwaters breakout group included 24 workshop participants with varied experience in forest, watershed, wildlife, water management, hydrology and climatology.

Defining the Conservation Feature

The Gunnison headwaters conservation feature includes the upper Gunnison River and its tributaries down to those that flow into the Blue Mesa reservoir. The group defined the Gunnison headwaters conservation features as follows: *the cold-water snowmelt-driven stream system that supports the Colorado River cutthroat trout, boreal toad, Black Swift, and the Gunnison Sage-grouse.* Key attributes include base flow, frequency of bankfull discharge and size and timing of peak flow. Other important attributes include water quality, quantity, temperature, and nutrient exchange.

John Sanderson (TNC) suggested that the group make explicit linkages between species and components of the flow regime, such as the influence of peak flow timing on dispersal and germination of cottonwoods. The group supported elaboration of the conservation feature to this level of detail, but acknowledged that the two-day workshop length did not allow sufficient time to accomplish this.

Management Objective

The group identified maintenance of the following as desired outcomes:

- High water quality
- A flow regime that provides for the needs of aquatic and riparian species
- Key components of the flow regime (e.g., characteristic summer base flow) in order to maintain species of interest, and
- Diurnal temperature fluctuations

The following management objective, the group agreed, would encompass the aforementioned outcomes:

Maintain summer base flow, frequency of bankfull discharge, and the size and timing of peak flow sufficient to maintain viable aquatic and riparian communities and viable populations of species of interest.

Conceptual Model and Impacts Assessment

Participants modified the conceptual model developed by the water/hydrologic regime group at the April 2009 SWCCI Jemez Mountains Climate Change Adaptation Workshop (See Figure 3). The model shows the many climatic, ecological, social, and economic drivers, identified by the group, that affect Gunnison headwaters surface hydrologic function. Drivers unique to the Gunnison headwaters conceptual model include recreational development, ski areas and snowmaking, trans-basin water diversions, municipal, industrial, residential and recreational water use, and mining. In addition the group explicitly identified a number of species as conservation features to be considered in impacts assessment. These include the following:

- Leopard frog

- Bald eagle
- Gunnison Sage-grouse
- Coldwater fish species
- Boreal toad
- Cutthroat trout
- Wet meadows
- Willow thickets
- Seasonal wetlands
- Woody riparian vegetation
- Black swift
- Thin-leaf alder (affected by a canker that thrives when summer temperatures are warmer than average)

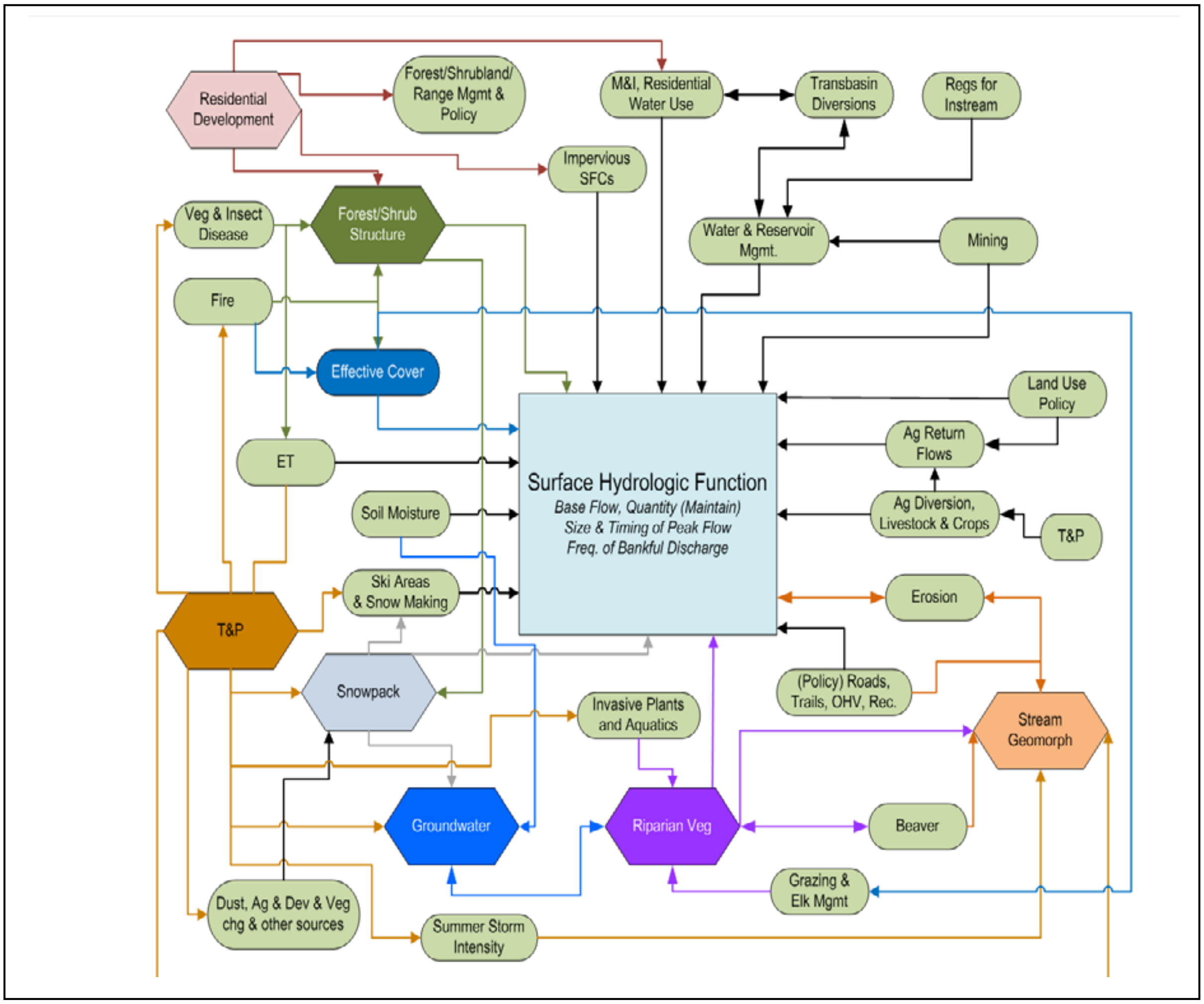

Figure 3. Gunnison headwaters conceptual model (T=temperature, P=precipitation, ET=evapo-transpiration).

The group discussed the potential directions of change in the drivers under the moderate and extreme climate change scenarios, carefully considering alternative lines of reasoning. They identified a number of climate change impacts and proposed hypotheses of change, whereby direct and indirect effects of changes in temperature and precipitation result in cascading ecosystem impacts and management challenges (See Appendix 5). The group also estimated the likelihood of impacts, given the two climate change scenarios. The major lines of reasoning focused on changes to snow hydrology, precipitation variability, and evapo-transpiration and their impacts on runoff, base flows, groundwater recharge, flood regimes, and erosion – with cascading effects on vegetation and habitat. Other important lines of reasoning emphasized changes to ecosystem vegetation disturbance regimes, with cascading impacts on effective vegetation cover (defined as herbaceous cover that protects against excessive erosion) and erosion, and the effects of enhanced dust deposition on snowmelt and runoff characteristics.

Management Intervention Points and Adaptation Strategies

The group identified 14 intervention points for climate change adaptation, as follows:

1. Riparian management
2. Fire management
3. Forest management
4. Grazing management
5. Fire management
6. Reservoir management
7. Municipal and industrial water use policy
8. Residential development policy
9. Invasive species management
10. Agricultural water use policy
11. Road system management
12. Ski area management
13. Fisheries management
14. Snowpack management

The group then devised several strategies that addressed the overall need for coping with less water and more variable water in the Gunnison Basin under moderate and extreme climate change scenarios.

Adaptation Strategies for Climate Scenario #1—"Moderate Change"

The group identified a diverse mix of adaptation strategies (See Appendix 6). These included well known riparian and forest ecosystem management practices, such as forest thinning, regeneration cuts and grazing management, but also legal strategies, such as leasing of water rights to maintain base flows, and infrastructure improvements, such as installation of larger culverts, enhanced road drainage measures, and hardened stream crossings. Innovative ideas included encouraging recruitment and growth of young trees that may be better adapted to warmer climates. Somewhat more controversial were suggestions to construct new wetland complexes, in order to improve groundwater recharge and retain base flows during the summer months. More intensive reservoir management and more aggressive management of agricultural diversions were proposed, but there was no consensus on these strategies. Some participants questioned the feasibility and effectiveness of these strategies, citing legal and institutional constraints.

Adaptation Strategies for Climate Scenario #2—"Extreme Change"
The group considered more novel approaches for addressing extreme climate changes, noting that extreme temperature increases may lead to substantial declines in snowmelt-driven runoff and soil moisture, as well as increased evapo-transpiration. An additional factor that was perceived as virtually certain in the extreme change scenario is increased dust deposition on snowpack, which would lead to faster snowmelt and early peak runoff and cascading riparian ecological impacts. Novel approaches to maintain as much base flow and groundwater recharge as possible included introducing vegetation species from lower elevations or more southern latitudes, triage of species and even whole drainages for management intervention, and construction of new reservoirs (See Appendix 6).

Some participants suggested trans-basin water diversions or development of new dams for strategic storage and release of water to maintain flows and riparian habitat. There was a lack of consensus, however, regarding the efficacy of investments in new water infrastructure. Enhanced use of retention basins and capture of municipal runoff were also suggested as measures to combat decreased recharge and base flows. The idea of triage for species habitat conservation, because of the inevitable conversion of perennial streams to intermittent ones, was accepted, though not enthusiastically, as a strategy that may be necessary in a much warmer and drier Gunnison River Basin. Enhanced potential for ecosystem-altering disturbances, such as large fires and insect outbreaks leading to massive forest mortality, was the only abrupt change explicitly considered by the group.

Priority Adaptation Strategies
The highest priority selected by breakout group participants for adaptation in the Gunnison Basin headwaters is the management of water resources to maintain groundwater recharge and base flow, especially during the summer months (see Table 2 for details).

The second adaptation priority selected by the breakout group involves improving forest, fire, and watershed health through forest and shrubland management and by maintaining effective cover. Strategies include mechanical treatment, such as thinning and regeneration cuts, in addition to population management to diversify age structure and encourage regeneration of younger cohorts.

The emphasis on vegetation management originated from a sense that there would be fewer obstacles to implementing vegetation management than from changing water management and infrastructure. Moreover, the group anticipated that the benefits of vegetation management would accrue to many systems and species within the Gunnison River Basin.

Participants noted that characteristics of the annual hydrograph could be maintained through watershed management approaches. Cost sharing would be necessary among, at least, water users, grazing associations, the Colorado Water Conservation Board, the Gunnison Water Conservation District, the Bureau of Reclamation, and land management agencies. In order to implement these strategies with confidence, research is needed to reduce uncertainties in future climate changes (e.g., the shifting timing of precipitation), and to analyze the effectiveness of existing treatments and mechanisms for maintaining groundwater recharge and base flow.

The third highest adaptation priority also uses forest and shrubland management as an intervention point, but this time with the goal of reducing erosion from anticipated high intensity storms. Treatments include reseeding, improved post-disturbance restoration and, in anticipation of extreme change, introduction of species adapted to drought and higher temperatures.

The most significant barriers to implementing these three priority strategies, according to the breakout group, are land management regulations including roadless areas rules and NEPA. Improved water management strategies are also highly constrained by regulations and the prior-appropriations water rights system.

Table 2. Priority strategic actions identified by participants for reducing climate change impacts on the Gunnison headwaters for two climate scenarios.

Observed & Projected Climate Change Impact (Hypotheses of Change)	Intervention Point	Scenario #1 Strategic Action (Planning Horizon: 10-15 yr)	Scenario #2 Strategic Action (Planning Horizon: 10-15 yr)
Increased temperatures and their direct and indirect effects (e.g., on runoff) will lead to decreased groundwater and base flows. Lower base flows lead to reduced recharge during flood events and increased water temperatures. The indirect consequences of these hydrologic changes include decreased riparian vegetation cover, decreased availability of aquatic habitat, changes in macro-invertebrate species composition, and impacts due to increased algae and nutrients (S1 & S2) Increased temperatures and their direct and indirect effects (e.g., on evapo-transpiration and snow hydrology, respectively) will reduce soil moisture and groundwater recharge. Consequently, there will be changes in upland vegetation, shifts from perennial to intermittent streams, a loss of seeps and springs, and loss of	Water Management	**1st Priority Strategic Action.** Increase odds of retaining robust base flows through more intensive legal, water, ecosystem and agricultural management strategies. Appropriate and/or lease water rights. Use more intensive reservoir management to ensure summer flows. Manage for new base flow conditions. Increase recharge by constructing wetland complexes, improved maintenance of irrigation infrastructure to retain existing wetlands. More intensive use of irrigation strategies (valley floor, recharge). Reintroduce beavers. Enhanced, improved, and more intensive use of reservoir management strategies.	Manage for new base flow conditions; construct wetland complexes, maintain irrigation infrastructure to maintain existing wetlands and increase recharge. More intensive use of irrigation strategies (valley floor, recharge). Reintroduce beavers. Capture runoff from municipal sources in retention basins. Construct new reservoirs, keeping evaporative loss and potential downstream effects in mind. Potentially consider species-management triage, because of the loss of perennial streams. Adjust management objectives. Triage may also include prioritization of drainages within the watershed.

Observed & Projected Climate Change Impact (Hypotheses of Change)	Intervention Point	Scenario #1 Strategic Action (Planning Horizon: 10-15 yr)	Scenario #2 Strategic Action (Planning Horizon: 10-15 yr)
riparian and vegetation cover (S1- S2)			
Temperature increases and enhanced drought may lead to increased disturbance, such as fire, insect outbreaks and disease. Consequences include: change or loss of forest/shrubland cover, which will initially increase water yields and the potential for increased erosion and sedimentation (S1 & S2)	Forest/ Shrubland Management (Effective Cover)	**2nd Priority Strategic Action.** Maintain forest health and fire resistance through diverse vegetation management strategies, such as thinning, regeneration cuts, and taking out the overstory instead of thinning from below. What constitutes appropriate management include changes, such as shifting strategies to encourage young trees that have adapted to the warmer climate. Increase diversity in patch composition and age structure across the landscape. Increase younger cohorts.	Same actions as for S1, but also use thinning or regeneration cuts to encourage regeneration of younger cohorts. Bring in outside stock to augment regeneration. Move seed zones.
Increased variability in summer monsoon precipitation could lead to more frequent dry summers, but also occasional higher-intensity summer storms. The high intensity storms could increase localized flooding erosion in uplands and floodplains (S1 & S2)	Forest/ Shrubland Management (Effective Cover)	**3rd Priority Strategic Action.** Decrease erosion potential by reseeding and restoration, which can be used following disturbances and for vulnerable exposed soil surfaces (near roads, or after fire). For S1, use traditional species mix for reseeding and restoration.	Same actions as for S1, but experiment with species from other elevations or latitudes and/or introduce drought tolerant species.

Discussion and Next Steps

Participants recommended a mix of climate change resistance strategies, including storage and strategic release of water to maintain summer base flow, and resilience strategies, including enhancement of off-channel and bank storage, as well as enhancement of infiltration to increase groundwater storage. The latter strategy is particularly appropriate to address extreme climate change. Discussions about impacts and strategic responses generated many research questions, which chiefly pertained to: 1) more precise understanding of the hydrological impacts of climate change – such as relationships between climate, snowpack, sublimation, and groundwater recharge; 2) the multi-directional interactions between hydrologic and vegetation change; and 3) attribution of the relative contributions of direct human-caused disturbances (e.g., recreation, grazing) and indirect human-caused climate changes on dust deposition. For example, in order to improve the ability to address climate change concerns through risk management strategies, participants require information on the relationships between projected climate changes (e.g., increased temperature, greater precipitation variability) and vegetation changes, including succession, forest structure, canopy cover, and effective cover. Participants recommended further research on evolutionary adaptation of vegetation to climate change and effective management strategies to promote adaptation through natural selection. Participants also noted the need to assess projected changes to stream hydrographs in comparison with species' life history needs in order to better understand the effects of altered hydrology on riparian and aquatic species.

The group noted that implementation of the recommended strategies will require understanding of and buy-in to the moderate and extreme climate change scenarios developed by the workshop's climate experts; more in-depth discussion, followed by revision and confirmation, of the group's conclusions and recommendations; and dedicated efforts to raise funds and to rally managers around a shared program of work.

Climate Change Adaptation Strategies for the Alpine Wetlands

The alpine ecosystem group, facilitated by Molly Cross and Greg Hayward, consisted of 15 participants with expertise in natural resource management, ecology, hydrology, and/or climate science representing state and federal agencies, non-governmental organizations, and academic institutions.

Defining the Conservation Feature
The alpine ecosystem participants began their discussions by clarifying what aspects of the large and complex alpine system to concentrate on during the breakout session. Participants brainstormed a list of elements (species, ecological processes, community types) within the alpine ecosystem that they are currently tasked with managing; that are rare, threatened or endangered; or that they suspect or know are particular vulnerable to climate change:

- Pika
- Birds
- Forage for domestic livestock and wildlife
- Fens and wet meadows
- Willows
- Biological soil crusts
- Dry tundra
- Tree-line and forest transitions
- Wild ungulates: bighorn sheep and goats
- Permafrost and maintenance of talus
- Snow deposition and retention
- Plant-insect interactions
- Pollinators
- Avalanches
- Recreation opportunities
- Rare plants
- Snowbank plant and animal communities
- Headwater creeks and streams
- Alpine lakes and cirques
- Shifts in grass/forb composition
- Marmots
- Predators
- Overall soil health and status
- Nutrient cycling
- Whole ecosystem integrity/fragmentation
- Pond communities
- Permanent snowfields

The group then used the following criteria to hone in on the particular feature that would become the center of the conceptual modeling and adaptation strategy development steps in the adaptation framework: knowledge within the assembled group, level of management concern, likely existence of options for management, and things that are threatened by climate change connected to multiple features, and relatively common in the Gunnison Basin. While there were several candidate features that would have made for interesting discussions (e.g., snow depth and retention, wild ungulates, ecosystem integrity, pika, and plant-animal interactions), the group ultimately selected ***Alpine Wetlands*** (including wet meadows, riparian, willow communities, fens, and temporary ponds).

Management Objective

Participants discussed a number of factors that might be incorporated into management objectives for alpine wetlands, including maintaining sufficient soil moisture to sustain native hydrophilic plants, cover of willows, proper functioning condition, riparian cover, connectivity, and the diversity, representation and extent of alpine wetlands across the region of interest.

The final management objective (and sub-objectives) that the group decided to focus on when discussing management interventions was to:

Maintain current proportional representation of all alpine wetland community types and (75%) of the current spatial extent of dominant types by:

- *Maintaining hydrology and sediment regime in target wetlands to retain soil moisture and the current plant community;*
- *Retaining species currently associated with wetlands; and*
- *Maintaining ecosystem function.*

While the group inserted a tentative target goal for the spatial extent of dominant alpine wetland types (75% of the current extent), that number was somewhat arbitrary. It was selected to indicate that while some amount of wetland loss was inevitable, the objective would be to retain a large percent of existing wetlands in light of climate change. The exact percentage is something that would need to be considered in more detail, and would be influenced by the general magnitude of climate change impacts that are expected under any given future climate scenario.

Conceptual Model and Impacts Assessment

Working as a group, participants built a graphical conceptual model of important direct and indirect physical, ecological, climatic, social and economic drivers affecting the hydrology, soils, vegetation and resident and transient organisms within alpine wetlands (Figure 4). The group then used the conceptual model to guide their discussions of observed and predicted impacts of Climate Scenario #1 on alpine wetlands (See Appendix 7). The group did not have time during the workshop to consider how the consequences of Climate Scenario #2 might be similar or different from those under Climate Scenario #1.

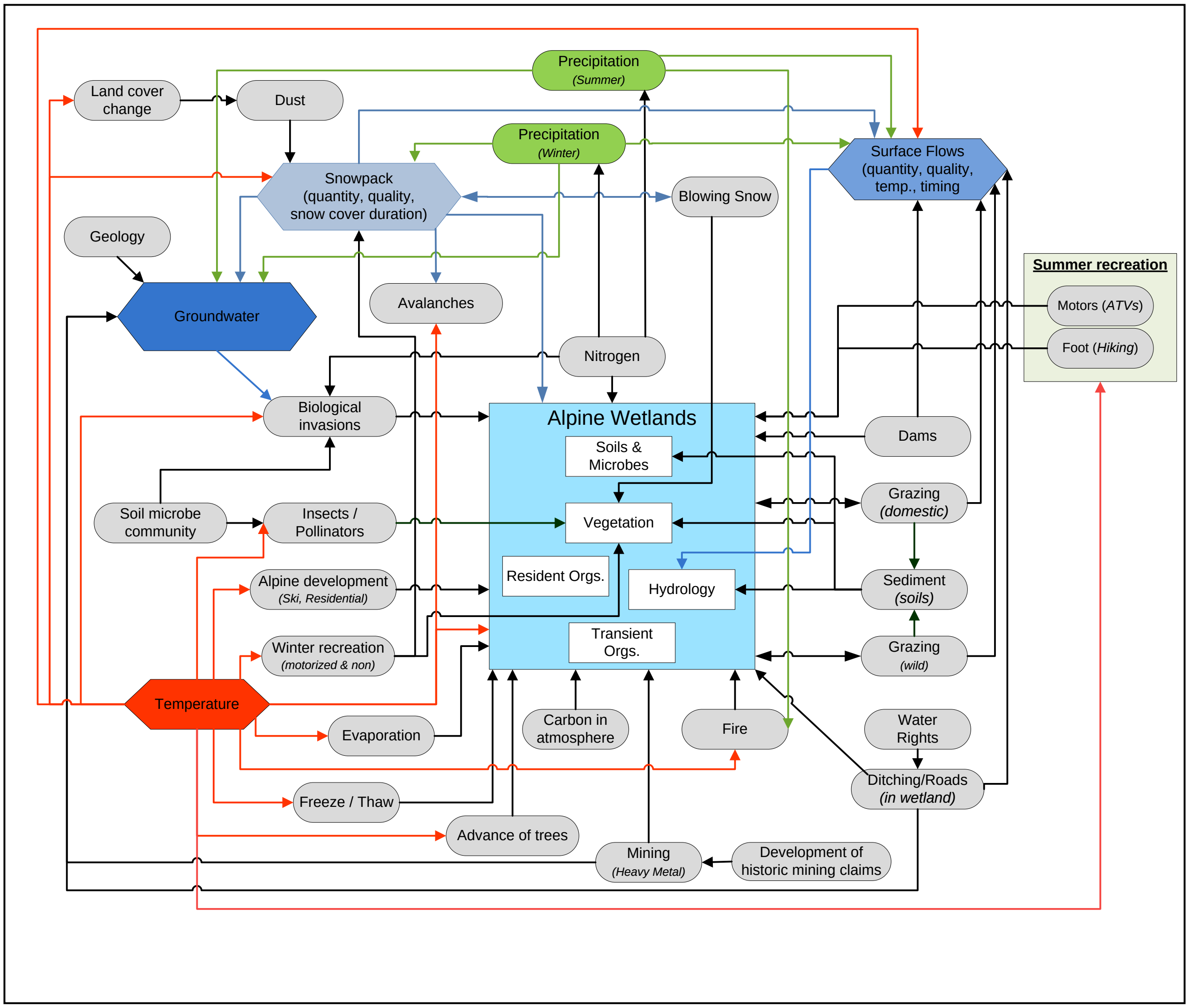

Figure 4. Alpine Wetlands conceptual model.

Details of the breadth of participants' discussions on how climate change scenario #1 might potentially affect the hydrology, soils, microbes, vegetation and resident and transient organisms in alpine wetlands are described in detail in Appendix 7. Changes to alpine wetland hydrology were of particular concerns since wet soil conditions are essential to the maintenance of native alpine wetland plant and animal communities. Overall, participants anticipate a longer period of drying during the warm season, due to earlier snowmelt, decreased summer precipitation, and increased evaporation. These changes would serve to decrease both groundwater and surface water inputs to alpine wetlands, resulting in drier soil conditions and a decrease in the aerial extent of wet areas. Drier soils would likely affect plant community composition by favoring grasses over forbs, and could decrease anaerobic processes, potentially leading to irreversible changes to plant community composition and negative impacts on peat-rich wetlands such as fens.

Several types of disturbances of importance to alpine wetlands may be affected by Climate Scenario #1. With warmer temperatures in the spring and summer when snow in alpine areas is melting, there is a possibility of more frequent spring floods and channelization or down-cutting events at higher elevations where there are generally not considered an issue. This could lead to increased sediment loads to alpine wetlands, which can alter plant community composition and may increase avalanche risk. While it is not clear how likely it is that alpine areas will encounter these kinds of flood and sedimentation events in the future, it is something that would be of concern to alpine wetlands if they did begin to occur. Other disturbances that may be affected by climate change include summer recreation, wildfire, and invasive species.

While it was unclear exactly how Climate Scenario #1 might impact dust-on-snow events, participants pointed out that dust deposition has the potential to change the alpine environment dramatically through rapid and significant losses in snowpack, even before climate change begins to have a noticeable effect on snow deposition and retention. The combined effect of climate change and dust deposition on snowpack could have an even greater impact on the timing of snowmelt; therefore it was highlighted as a critical issue for further research, and for consideration during discussions of strategic actions *(see next section)*.

Management Intervention Points and Adaptation Strategies
When identifying potential adaptation strategies that would help managers achieve the goal of maintaining current proportional representation of all alpine wetland community types and (75 %) of the current spatial extent of dominant wetland types, participants considered actions at several intervention points within the broader conceptual model, including management of: snowpack, wildlife and domestic grazers, ground and surface hydrology, precipitation, summer and winter recreation, vegetation, and the development of mining claims (See Appendix 8).

Since participants only had time to consider the anticipated impacts associated with Climate Scenario #1, the group also restricted their discussion of strategic adaptation actions to those that might be relevant or necessary under that scenario. Strategic adaptation actions generally related to one of several strategies. The first was to augment and maintain the amount of water reaching alpine wetlands so as to sustain current hydrologic regimes. This in turn relates to the second strategy of maintaining native hydrophilic alpine wetland plant communities. Since these species and communities rely on having sufficiently wet soil conditions to maintain a competitive advantage over drier-loving species, actions aimed at maintaining the hydrological regime were also considered necessary for maintaining native alpine wetland plants. Actions aimed at minimizing the negative influences of human activities, as well as wild and domestic grazers, were also considered important strategies. And while participants recognized that the strategy of addressing the negative impacts of dust deposition on alpine snowpack would not necessarily involved actions that could be implemented by Gunnison Basin managers, the fact that snow-on-dust events could be exacerbated by climate change scenario #1 warranted consideration of these kinds of actions.

Priority Adaptation Strategies
While participants in the alpine wetland breakout group did not have time to vote on their top priority strategic adaptation actions, several actions that were identified as being of

relatively high importance can be roughly grouped into three important strategies: augmenting and maintaining water flows to alpine wetlands, maintaining native alpine wetland vegetation, and minimizing dust-on-snow events (Table 3).

Table 3. Important strategic actions identified by participants for reducing climate change impacts on Alpine Wetlands for Climate Change Scenario #1.

Observed & Projected Climate Change Impact (Hypotheses of Change)	**Intervention Point**	**Scenario #1 Strategic Action (Planning Horizon: 10-15 yrs)** ***(Note: we only considered Scenario #1)***
Alpine wetland hydrology: Decreases in ground and surface water flows resulting from longer dry period during the growing season due to earlier snowmelt, decreased summer precipitation, and increased evaporation due to warmer temperatures.	Snowpack management Groundwater and surface water flow management	**Augment and maintain water flows to alpine wetlands:** • Strategically install snow fences to maximize snow deposition and retention. • Restoration of past disturbances to hydrology (e.g., drainage engineering of roads, trails, culverts, ditches, etc.) **Minimize negative influences of grazing and human disturbances:** • See actions listed below for minimizing the negative influences of grazing and human disturbances on hydrology.
Native alpine vegetation: Changes in native alpine wetland plant species communities due to increased summer dry period exacerbated by wild and domestic grazing and human disturbances	Groundwater and surface water flow management Human recreation management Management of historic mining claims Wild and domestic grazing management	**Maintain alpine wetland hydrology:** • See actions listed above for augmenting and maintaining water that reaches alpine wetlands. **Minimize negative influences of grazing and human disturbances:** • Increase the size and enforcement of buffer zones around alpine wetlands – restrict recreation, grazing, development, and hydrological disturbances. • Manage summer and winter recreation (e.g., ATVs, snowmobile, skiing, hiking) to reduce impacts on alpine wetlands. • Land acquisition to retire historic mining claims. • Manage domestic grazing to reduce impacts on wetlands (e.g., through grazing permits, fencing, herding practices). • Manage wildlife grazing to reduce impacts on wetlands (e.g., using sheep herders, increasing hunting pressure).
Winter dust deposition: Already considered to have a negative impact on alpine snowpack by leading to rapid and early snowmelt, the combined effects of warmer climate and dust events could have an even greater negative impact on snowmelt timing and quantity. While more research is needed, there is a potential for climate change to increase dust deposition if source areas become drier.	Research / monitoring / exploring intervention opportunities	**Reduce dust-on-snow events:** • Conduct more research on how significant of a problem snow-on-dust events are likely to be across the region. • Identify the most significant sources of dust (both currently and in the future as climate and land use activities in other areas change). • Work with Western Governors Association, DOI, Dept. of Transportation and other state and federal agencies to identify strategies for reducing blowing dust.

Discussion and Next Steps
The alpine breakout group did not have time to discuss how the impacts and management responses for alpine wetlands might differ under Climate Scenario #2. Future discussions about alpine wetlands should focus on alternate scenarios to identify those management actions that are appropriate under multiple future scenarios, and therefore relatively robust to uncertainty in knowing exactly how climate may change and ecological systems may respond. There were also many aspects of alpine ecosystems that we were unable to cover during the two-day workshop, e.g., the importance of fens in carbon sequestration (see “Defining the conservation feature” section above). In fact, our discussion was purposefully limited to a single, important, component of these systems. We found that doing so appeared to be the only way to begin moving toward a conceptual model of sufficient specificity to guide development of adaptation actions. It would be interesting to explore the consequences of the two selected climate change scenarios on other alpine features in order to get a more inclusive picture of how climate change may affect alpine ecosystems.

While many of the actions discussed are equally relevant under current conditions as they are in light of climate change, the fact that roughly 85-90% of all alpine areas in the Gunnison Basin occur within Wilderness Areas (primarily USFS, and some BLM) will likely complicate the ability of managers to implement many actions. The current management framework for Wilderness Areas is highly restrictive, with the primary goal being to maintain natural processes and allowing natural change. Therefore, many of the strategic adaptation actions identified by participants are likely not going to be allowed under the current Wilderness Act. If there is a strong enough motivation or interest in trying to implement some of those actions, it may require a revision of the Wilderness Act.

Opportunities for Strategic Action Implementation

Discussion and Synthesis of Breakout Group Sessions
The three breakout groups re-convened in the plenary to present/review their management objectives and priority strategic actions. A short summary of the priority actions for each of the three groups is below. (Note: since the alpine wetlands breakout group did not have time to narrow their list down to two top priority actions, the two selected for a subsequent discussion of opportunities for implementation were unsystematically selected from the list of strategic actions identified in Table 3 in the *Climate Change Adaptation Strategies for the Alpine Wetlands* section above.)

Facilitator Gregg Garfin reviewed the combined list of priority adaptation strategies created by the three breakout groups. He directed small groups of participants to evaluate top priority actions considering barriers and key uncertainties, e.g., cost, social, political, regulatory, lack of knowledge, and opportunities for implementation (See Table 4).

Strategic Actions
Barriers and opportunities were developed by small breakout groups during the plenary session for the following strategic actions (see Table 4):

1. Gunnison Sage-grouse:
    a. Retain water in most vulnerable Gunnison Sage-grouse brood-rearing habitats
    b. Improve/restore nesting/wintering habitats for sage-grouse
2. Gunnison headwaters:
    a. Manage upland vegetation for effective groundwater recharge and base flow maintenance for Gunnison headwaters
    b. Construct and/or restore wetland complexes for Gunnison headwaters
3. Alpine wetlands:
    a. Build snow fences to augment water inputs for the alpine wetlands
    b. Increase buffer zones around alpine wetlands.

Table 4. Opportunities for Strategic Action Implementation.

Actions	Barriers (cost, politics, social, cultural, uncertainty)	Opportunities (funding sources, policy, action)	Who Needs to be Involved (to make this successful)
Retain water in most vulnerable brood-rearing sage-grouse habitats	• High cost (~$2 million over 15 yrs) • Political, social (e.g., visual) • Confident it will work, but will need more monitoring • Capacity – having the number of people necessary on the ground	• Positive ecological consequences for other aspects of the system • If it works to protect grouse, politicians will support it • Working together with other agencies, and garnering public support	• Politicians to lobby for resources • NRCS, USFS, CDOW, USFWS, BLM, NPS, counties, HCCA, Black Canyon Audubon, TNC, livestock industry, landowners
Improve/restore nesting and wintering habitats for sage-grouse	• Finding ways to accomplish projects (e.g., staff capacity) • Big game management conflicts • Need to know more about where treatments would be most successful (look at data, research, etc.) • Ability to control cheatgrass expansion (how that will affect fire and ecosystem change, what are the major vectors of invasion)	• Increase noxious weed rank of cheatgrass to channel more resources ($) for control • Opportunities to collaborate to control cheatgrass (e.g., ATV users, vehicle washing) • Bring groups together to educate on cheatgrass • Look for opportunities to manage big game (move populations or control numbers) to keep them out of important grouse areas • Work with non-profits to provide capacity to implement activities	• Everyone (ATV users, hunters, landowners, stock-growers, developers, state, federal agencies, county and local governments)
Manage upland vegetation for groundwater recharge and base flow maintenance for headwaters	• Analyzing existing mechanisms and prioritizing placement of treatments and sharing data. • Roadless area rules and NEPA regulations • Uncertainty = what level of climatic change will be experienced and how will it play out? (e.g., shifting	• Gunnison basin "plumbing" is conducive to this approach. If you can store water in mid-elevation areas, you can spread out run-off (and perhaps maintain the hydrograph shape). • Improved hydrology would benefit many other species/systems. • Many groups stand to gain –	• Water end users, grazing associations, CO water conservation board, Gunnison water conservation district, BOR, land management agencies.

Actions	Barriers (cost, politics, social, cultural, uncertainty)	Opportunities (funding sources, policy, action)	Who Needs to be Involved (to make this successful)
	timing of precipitation)	while they may need to share in the cost	
Construct &/or restore wetland complexes for headwaters	• Costs could be high • Water rights • New definitions of jurisdictional wetlands	• Consider more natural fixes, e.g., reintroducing beavers • Focus on rehabilitating rather than creating new • Maintain properly managed agricultural uses (e.g., hay meadows) • Remove channelizations (e.g., railroad grades and roads) • High-end fisherman developments – use as opportunities to improve wetlands • Funding for private landowners to protect wetlands • County can redefine wetlands • Underground reservoirs with Styrofoam panels.	• Landowners, water users, NRCS, county planners, USFS, BLM, CWCB, USFWS partners program, CDOW, other agencies
Build snow fences to augment water inputs for alpine wetlands	• Wilderness regulations (limited access and manipulation) • Uncertainties (lack of knowledge about how big, how many, where) • Lack of knowledge about wetland distribution and types • Funding (low cost of fencing, but where will $$ come from) • NEPA (the ability to justify the installation of a proactive activity)	• Stratify the alpine to find areas outside wilderness (possibly private land) where to test out snow fences and observe/monitor how they work, magnitude of effect, and how they impact other aspects of the system.	• 14-er group, trail groups (Colorado trail groups) might help provide support for the idea of snow fences.
Increase buffer zones around alpine wetlands	• Historic uses on the land (mining claims, property claims, roads) • Costs = regulatory • Lack of knowledge among visitors to the alpine	• Educate visitors about the importance of the alpine • Incorporate into travel plans and management • Incorporate climate change into forest planning • Amendments to existing management plans • Changing from “guidelines” to something more stringent • Incorporate into grazing management permits	* USFS, CDOW, BLM, private landowners, permit holders, user groups (recreation = motorized, hiking, etc.), HCCA, wool growers

Several common barriers that could hinder participants' ability to implement strategies across the three break-out groups included: lack of funding, lack of knowledge and uncertainty, lack of capacity, and regulations (e.g., wilderness, roadless rules and NEPA). In spite of these sizeable and very real hurdles, participants identified opportunities to help overcome them to implement the strategic actions. Consistent themes included: political support, opportunities to work collaboratively, development of programs to monitor the effectiveness of strategies (e.g., of snow fences), increased public education and outreach, incorporating climate change into forest planning amendments and travel plans, working together to identify funding to support projects, and the development of a multi-jurisdictional climate change plan for the Gunnison Basin.

While time did not allow discussion regarding intervention points (places in the system that we can influence through management and conservation actions, e.g., grazing management or invasive species management) in the plenary session, there were several common intervention points across the three breakout groups. For example, water management (groundwater and surface flow) was a common intervention point for the three conservation features: sage-grouse, headwaters, and alpine wetlands. Thus water management could be a significant opportunity to help accomplish multiple strategic actions.

Monitoring and Research Needs

Following the discussion about opportunities for implementing the strategies, Dave Gori, Director of Science, TNC-NM, reviewed the monitoring and research needs identified by each breakout group related to understanding climate changes, ecological responses, and adaptation strategies. This spawned a discussion of other research needs, summarized below. This list of monitoring and research needs can be used by academic and agency research programs to help catalyze ongoing and emergent research priorities.

Gunnison Sage-grouse

1. Can water rights be purchased for the express purpose of maintaining habitat for grouse?
2. Does less summer precipitation mean less thunderstorms and lightning?
3. Interaction of livestock/ranching viability—what is the future of ranching in the Gunnison Basin and how does it affect grouse/wildlife habitat?
4. Will sagebrush be lost without snowpack, especially at low elevation?
5. What is driving the lack of recruitment (and mortality) in grouse populations?
6. Can we manage hay meadows differently (e.g., use less water)?
7. What is the relationship/species interaction between grouse and prairie dogs?
8. How critical is the mountain shrub community for nesting now and in the future?
9. Will the grouse move up the basin with or without assistance as vegetation shifts?
10. Need to further flesh out the interactions between fire and cheatgrass in the basin.
11. Need to know more about West Nile virus ecology, control, and potential infection in birds.

Gunnison Headwaters

1. What is the relationship between climate change, snowpack, sublimation and groundwater recharge?
2. We predict that evapo-transpiration will increase with temperature increase; we also predict that evapo-transpiration will decrease with change in vegetation composition/structure—need to determine how this balances out locally and affects soil moisture.
3. How will vegetation changes affect elk populations, their distribution and herbivory impacts?
4. How will shifts in forest structure/cover caused by disturbance events affect snowpack, runoff and water yield?
5. What is the relationship between forest canopy cover and snowpack accumulation, sublimation (may have many years of data on this)?
6. What is the relative contribution of roads, recreation, grazing and CC effects on herbaceous cover and dust deposition on snowpack?
7. How will the predicted changes in transpiration and precipitation affect the effective cover across vegetation types? Need better monitoring of effective cover.
8. How will succession and vegetation change with climate change?
9. Are young cohorts adapting evolutionarily to climate change and what are the interactions with management to encourage that adaptation. How do we manage to promote adaptation by natural selection?
10. What is the effect of earlier peak flows on riparian and aquatic species? Use stream flow projections to model hydrograph under different climate change scenarios; compare with species' life history needs, environmental cues important in life cycle, etc.

Alpine Wetlands

1. What is the threshold for the phase change from wetland to non-wetland systems?
2. What is the effect of rain-on-snow events (overland flow, floods in alpine, sediment flow)?
3. What would happen to snow accumulation in spring (timing of snow melt, flooding, etc.) relative to different climate change scenarios?
4. What are the baseline conditions and current extent of wetlands?
5. What is the feasibility of creating a wilderness study area focused on climate change, human use (e.g., trails), and adaptation?
6. What size buffers are needed to protect ground and surface water in alpine wetlands?
7. What are the critical invasive species and how do we effectively manage them.
8. What are consequences of fire and how do you conduct prescribed burns within timberline zone?
9. What is the impact of dust-on-snow events in wetlands? Where does the dust come from now and into the future, quantity and how does it affect water quantity and timing of snowmelt? What is the impact on avalanche frequency?
10. What is the impact of domestic sheep and elk grazing on wetland plant communities?

Additional Research Needs

Several participants brought up the need for more background on how the climate scenarios were developed, e.g., what global models were selected and why, how were they downscaled, to feel more confident in using the scenarios. The agencies need to come to consensus on what climate models, scenarios, and other climate data will be used for future planning. They suggested that it would be helpful to use climate change projections to assess probable ecological effects, including vegetation and species range shifts. Ron Neilson (USFS-Pacific Northwest) has developed dynamic vegetation models for the United States at 10km resolution. These provide a starting point for determining how habitats will shift and how far and how fast species will move across the landscape. The participants also suggest analyses of species and habitat data for other locales (e.g., lower elevations) to make predictions of future distribution. Other recommendations included: Draw upon research insights and observations provided by David Inouye and others. Consider historical reconstructions of vegetation, fire regimes, stream flows and compare to paleo-climate to provide further insights. Several participants suggested consulting with workshop participant and climate adaptation specialist Linda Joyce of the USFS-Rocky Mountain Research Station for further information.

Panel Discussion: Implementing Recommendations from the Workshop

Near the end of the second day during the plenary session, agency representatives were asked by David Gann, TNC, to respond to the question: How do you see going back to your agency and taking those recommendations into strategies for implementation? What can you take home? Panelists included Tom Schreiner (Colorado Division of Wildlife), Taryn Hutchins-Cabibi (CWCB), Greg Hayward (USFS), Dustin Perkins (NPS), and Russell Japuntich (BLM).

Tom Schreiner, *CDOW*

- Part of the value of this workshop was not only the outcomes generated, but in the process of facilitating dialogue among agency representatives, learning about and developing experience with the framework for landscape-scale climate change adaptation planning as presented by Mollie Cross of WCS, and in making decisions as a group within that framework.
- For CDOW, the next steps will be to have an internal dialogue among staff about the value of this experience and what our future role will be relative to this project. Included in that assessment will be questions of what specific information do we need, what can we offer this group, and what are the management recommendations from this pilot project that are different from what we're already doing?
- It will be important to continue to flesh out the details of specific actions that could potentially be taken in the Gunnison Basin relative to climate change. As an example, during the workshop the Alpine wetlands breakout group only

assessed the moderate change in climate scenario and did not assess recommendations for how to deal with a significant change in climate.

- It will be important to continue the dialogue started at the December workshop. A suggestion for keeping folks in the loop on future developments of the project might include an on-line Gunnison Basin Climate Change Working Group or e-mail communication network to keep this process moving forward.

Taryn Hutchins-Cabibi, *CWCB*

- CWCB is charged with implementing components of the Governor's climate change action plan from 2007. As part of this plan, CWCB is working to complete a comprehensive statewide climate change vulnerability and impacts assessment examining water resources and related sectors (i.e., ecosystems, tourism and recreation, public health, energy, agriculture). A continued dialogue is important so we can coordinate and leverage efforts, Once CWCB completes the climate change vulnerability and impacts assessment, they will be better informed of the State's vulnerabilities and can begin to discuss how to approach the development an adaptation strategies that would reduce climate change related vulnerability.
- CWCB works with CDOW and the summit climate team to provide technical resources.
- CWCB is the lead agency for statewide drought planning efforts and is in the process of revising the Colorado Drought Response and Mitigation Plan. This effort will for the first time incorporate climate change impacts on drought monitoring, mitigation and vulnerability.
- This workshop has provided insight to climate change adaptation issues that CWCB can incorporate into ongoing projects.

Greg Hayward, *USFS*

- It will be important to take the momentum from this meeting and do something with it.
- USFS has a strategic framework for climate change that provides motivation for on the ground staff to begin addressing climate change. Speaks to strategic direction for adaptation, mitigation, education, policy changes and sustainable operations. Fine upper-level framework, but it is the Gunnison National Forest and the districts that will make things happen.
- Real actions on the ground are going to be the outcome of collaborative planning that will provide the political momentum to make adaptation happen.
- We need the prompting that this workshop has provided to get moving.
- It is difficult for agencies to look very far into the future. Policy constraints are a barrier.
- In closing, the collaborative part of this meeting builds momentum for action.

Dustin Perkins, *NPS*

- The NPS has budgeted $10 million in FY10 for climate change adaptation work which is a major new initiative under Secretary Salazar.
- NPS is about preservation and climate change is forcing staffers to confront the possibility that some elements of the country's natural heritage will disappear.
- Inertia in a big federal agency like NPS. But many employees are eager to act.

- The multi-agency group meetings are vital to us.
- There is movement to develop an interagency approach across the Department of Interior.

Russell Japuntich, *BLM*

- BLM has incentive to address climate change within planning documents because of litigation.
- The Resource Management Plan is coming up next year and the BLM will need to understand how climate change is affecting the environment. BLM needs local information in order to address the issue in a meaningful way.
- BLM has yet to be funded for climate change adaptation (only $13,000 this year?), but there should be much more funding in years to come.
- Our next step as an office is looking for baseline data meaningful at the field office scale.

Recommended Next Steps

After the panel discussion near the end of the workshop, participants provided a number of recommendations regarding follow-up to the workshop. Comments by participants are outlined below.

1. Continue climate adaptation dialogue and collaboration in Gunnison Basin:
    a. Recommend a working group of multiple agencies convene to determine how best to follow-up and then take back to leadership.
    b. USFS Chief stated need to address climate change in landscape action plans; this workshop has provided a starting place to focus on. Agency management plans have base data, but climate change component is missing. The interest is there and we need to continue collaboration.
    c. Instead of waiting for action from above, we have an opportunity to show the way and develop management adaptation experiments.
    d. Opportunity to become a pilot and/or collaborate with other agencies, e.g., the Department of Interior's Landscape Conservation Cooperatives (e.g., Northern Rockies; Southern Rockies) and existing efforts, e.g., CWCB work on water resources vulnerability report, updates to the Colorado climate report.
    e. Information is changing rapidly. Consider new ways of meeting and getting together to synthesize new information.
2. Conduct further analysis:
    a. Need further interpretation of the two climate change scenarios.
    b. Increase understanding of the ecological effects of the climate change scenarios on the three conservation features.
    c. Need a rigorous vulnerability assessment of the Gunnison Basin, with documentation of anticipated climate change and effects on species,

habitats and ecological function (e.g. this is what it will look like in 100 years, a no action alternative).

   d. Consider post-doc program at NOAA for researchers to work with resource managers and university faculty to work on a climate project with natural resource managers. Funded by Bureau of Reclamation.

3. Refine adaptation strategies:
   a. Strategies developed here are preliminary and need refinement; develop no-regrets strategies.
   b. Alpine group needs to develop strategies for the more extreme Climate Scenario #2 with more drastic impacts to the wetlands.
   c. Consider developing a comprehensive adaptation plan.
4. Implement recommended strategic actions:
   a. Articulate/define climate change implementation projects.
   b. Can bring climate change into grazing management process; there are many things where we can begin to juxtapose with other objectives.
5. Improve the workshop planning process:
   a. Add feedback mechanism for managers in the framework, what aspects you find useful, that you would feel comfortable with; if not what could you use to help you in your everyday work.
   b. Need to better address uncertainties-what would you need to consider if you are making a decision? Recommend engaging social scientists to help with making decisions with uncertainties.
6. Assess climate vulnerability at a state level and apply workshop lessons to other landscapes:
   a. Need to look at climate vulnerabilities on species and ecosystems across the state (and statewide adaptation strategy).
   b. Apply what we learned from this pilot project to other areas.
   c. Synthesize workshop process and results and share with others.
   d. Need clear idea of what each region could look like that people could use, local issues, and what is common across all areas.
7. Develop a communications plan:
   a. Need to get more support from public; share information about workshop with local community, e.g., press releases.
   b. To build support for climate change, we need to communicate, outreach and education efforts.
   c. Develop a summary of workshop, with findings and scenarios.
   d. Need actual stories to bring home.

Participants concluded that the strategic actions need further refinement in order to reduce the impacts to the conservation features, particularly for the extreme climate change scenarios. The ecological changes that could occur under these scenarios likely require management intervention that is more extensive and intensive than the suite of strategies identified during the workshop. Participants expressed the need for continued collaboration across jurisdictional boundaries to plan for species and ecosystem adaptation to climate change in the Gunnison Basin. Recommended next steps are outlined below.

Short-term recommendations:

- Convene a small group of key stakeholders, including federal and state land management agencies, county, scientists, and non-governmental organizations, to continue the dialogue and determine strategies for working together.
- Conduct further analyses of climate change and its ecological effects in the Gunnison Basin, e.g., further interpretation of the moderate and extreme climate change scenarios developed for the workshop.
- Refine the strategic actions identified at the workshop, especially for the more extreme scenario.
- Implement "no-regrets" strategic actions for the three conservation features.
- Develop a communications plan related to these activities with an emphasis on public outreach and education.

Long-term recommendations:

- Conduct climate vulnerability assessment of species and ecosystems of the Basin.
- Assess climate vulnerability at a state level and conduct workshops in other landscapes.
- Develop a comprehensive climate change adaptation strategy for the Gunnison Basin.
- Encourage research to better understand the biological responses to climate change to assist land managers in making land management decisions.

Closing Remarks

Tim Sullivan, Acting State Director for The Nature Conservancy in Colorado, reminded the group of the purposes of the workshop: to test an adaptation planning process for helping species and ecosystems adapt to a changing climate and to lay groundwork for taking action. He was impressed with how well the groups worked together over the two days, and expressed hope that the tools, information and methods that participants were introduced to at the workshop would prove to be helpful. Climate change adaptation needs to infiltrate all aspects of our management and conservation work—we need to use climate change as the veil we look through.

Sullivan urged the group to capitalize on the momentum of the workshop and continue work together to help species and ecosystems of the Gunnison Basin survive in the face of a changing climate. The Gunnison Basin, with its expansive science base and existing collaboration efforts (e.g., Gunnison Sage-grouse committee) is an ideal site for addressing climate change in a coordinated manner across a large landscape in Colorado.

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Post-Workshop Update

Participant George Sibley published an article about the workshop in the Gunnison Country Times newspaper (Sibley 2009).

The Conservancy convened a small group of land managers from the Gunnison Basin in February 2010 to discuss how best to continue the climate change adaptation dialogue initiated at the workshop, identify desired outcomes and priorities, and explore opportunities for working together. The workshop was a good first step, but the stakeholders need to determine what is feasible and fundable. This initial group of land managers (BLM, USFS, Gunnison County, TNC, and NPS) will be expanded to include other interested stakeholders in the coming months. The group identified the following next steps:

1. TNC will prepare a brief proposal for follow-up to the workshop based on the discussion and circulate it to the group and other interested parties.

2. TNC will organize opportunities for key agency representatives to review, document and confirm the two climate change scenarios (moderate and extreme) developed by Linda Mearns and Joe Barsugli for the December 2009 Gunnison Basin climate change adaptation workshop.

3. Collaborate to refine, document, and fund and implement the "no-regrets" strategies that the workshop produced. Look closely at the strategic actions identified for the

three conservation features at the workshop and determine whether there is a subset of those that the agencies could work on immediately.

4. Collaborate to develop criteria for a "checklist" that agencies would run current plans and activities through to document the work they are already doing (or planning to do) that contributes to climate change adaptation and is consistent with the strategies developed at the December 2009 workshop.

A working group that includes the Conservancy, the Colorado Natural Heritage Program, Colorado Division of Wildlife, Colorado Department of Natural Resources, and Colorado Water Conservation Board, has developed a draft scope of work for a Climate Vulnerability Assessment for Colorado to help the State and partners to re-evaluate conservation priorities for species and habitats under a changing climate and to provide information that can be used for the upcoming revision of the State Wildlife Action Plan and other planning/protection efforts. The Conservancy is also planning a small workshop to document methods, lessons learned, and recommendations for conducting climate change vulnerability assessments at regional, state and landscape scales.

The Southwest Climate Change Initiative is planning the third and fourth climate change adaptation workshops in Arizona and Utah in 2010, and then will produce a summary report (with lessons learned) on all four workshops in late summer 2010.

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Appendices
Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin
December 2-3, 2009

1. **Final Agenda**
2. **Participant List**
3. **Gunnison Sage-grouse Climate Change Impacts**
4. **Gunnison Sage-grouse Adaptation Strategies**
5. **Gunnison Headwaters Climate Change Impacts**
6. **Gunnison Headwaters Adaptation Strategies**
7. **Alpine Wetlands Climate Change Impacts**
8. **Alpine Wetlands Adaptation Strategies**

Appendix 1. Final Agenda

SOUTHWEST CLIMATE CHANGE INITIATIVE (SWCCI)

CLIMATE CHANGE ADAPTATION WORKSHOP FOR NATURAL RESOURCE MANAGERS IN THE GUNNISON BASIN

December 2-3, 2009
Aspinall-Wilson Center, Western State College, Gunnison, Colorado

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WORKSHOP GOAL:
Identify management strategies that will help native plants, animals and ecosystems adapt to a changing climate and lay the groundwork for their implementation.

WORKSHOP OBJECTIVES:
1. Provide background information on climate change as it applies to the Gunnison Basin.
2. Introduce a framework for landscape-scale climate change adaptation for use at this workshop and as a tool that can be used in other landscapes.
3. Assess the impacts of climate change on a set of high-priority species, ecosystems and natural processes selected by workshop organizers and participants.
4. Identify management strategic actions that will reduce climate change impacts.
5. Identify opportunities for ongoing learning, collaboration, and implementation of on-the-ground climate change adaptation projects in the Gunnison Basin.

DESIRED OUTCOMES:
1. Shared understanding of the known current and potential future effects of climate change, through development of conceptual models, for Gunnison sage-grouse, alpine ecosystem and Gunnison headwaters.
2. Set of strategic actions to promote conservation resilience and realignment of Gunnison sage-grouse, alpine ecosystem, and Gunnison headwaters in the face of climate change.
3. Set of opportunities to facilitate successful implementation of strategic actions.
4. Statement of research and monitoring needs for climate adaptation in the Gunnison Basin.
5. Commitment among participants to take action and recommended next steps to be taken by natural resource managers of the Gunnison Basin.

DECEMBER 2, 2009: 8:30 AM -11:45 PM

8:30- 8:40 Welcome
- Tim Sullivan, *State Director, The Nature Conservancy, CO*
- Pat Magee, *Thornton Chair of Biology, Western State College*

8:40-8:50 Southwest Climate Change Initiative (SWCCI) Overview
- Patrick McCarthy, *Director, SWCCI, The Nature Conservancy, NM*

8:50-9:10 Statement of the Problem and Rationale for Workshop
- Gregg Garfin, *Director of Science Translation and Outreach, University of Arizona (Workshop Facilitator)*

9:10-9:40 Overview of Regional Climate Change Impacts: the Known, the Unknown, and the Uncertain

- Linda Mearns, Senior *Scientist, National Center for Atmospheric Research*

9:40-10:15 Overview of Terrestrial Ecological Consequences of Climate Change in the Southwest and the Gunnison Basin Landscape

- Ian Billick, *Director, Rocky Mountain Biological Laboratory*
- David Inouye, *Professor, University of Maryland and RMBL*

BREAK: 10:15 - 10:30 AM

10:30-11:00 Overview of Past and Potential Future Trends in River/Stream Flows in Western Colorado and the Gunnison Basin

- Joe Barsugli, *Western Water Assessment, University of Colorado*

11:00-11:30 Overview of Conservation Adaptation Planning

- Molly Cross, *Climate Scientist & Adaptation Specialist, Wildlife Conservation Society*

11:30-11:45 Implementing a Framework for Adaptation Planning: Future Climate Scenarios, Goals & Logistics for Remainder of the Workshop

- Gregg Garfin & Molly Cross

LUNCH: 11:45 – 12:45 PM (PROVIDED)

<u>12:45 - 4:30 PM, W/ BREAK FROM 3:00 – 3:15 PM</u>

12:45-4:30 Break-out groups assemble in separate rooms; introductions

- Grouse Facilitators: Terri Schulz and Carrie Enquist
- Alpine Ecosystem Facilitators: Molly Cross and Greg Hayward
- Hydrologic Regime Facilitators: Gregg Garfin and Dave Gori

<u>Objectives for the three groups include:</u>

- *Identify/refine management objectives*
- *Develop a conceptual model*
- *Assess impacts of two future climate change scenarios*
- *Complete Table 1: Climate Change Impacts (in participant packet)*

DAY ONE ADJOURN: 4:30 PM

HAPPY HOUR: 4:30 PM (AT THE ASPINALL-WILSON CENTER)

<u>DECEMBER 3, 2009, 8:30 AM -11:30 AM W/ BREAK FROM 10:15 – 10:30 AM</u>

8:30-11:30 Re-assemble into three break-out groups and designated rooms

<u>Objectives for three groups include:</u>

- *Identify strategic actions by building on the work of the previous day*
- *Complete Table 2: Identification of Strategic Actions (in participant packet)*
- *Review management objectives*
- *Begin to evaluate level of urgency/priority and identify opportunities for implementation*
- *List research and monitoring needs*

LUNCH: 11:30 – 12:30 PM (PROVIDED)

<u>12:30 – 4:30 PM</u>

12:30-1:30 Break-out Groups Re-assemble in Large Room and Report Back (Gregg)

- All three groups present/review their priority strategic actions
- Facilitated summary and synthesis

1:30-2:30 Opportunities for Strategic Action Implementation: Evaluate top priority actions considering barriers and key uncertainties, e.g., cost, social, political, regulatory, lack of knowledge, and opportunities for implementation

- Facilitators: Gregg Garfin and Patrick McCarthy

<u>Outcomes:</u>

- *Barriers to implementing strategic actions*
- *Opportunities for overcoming barriers to implement the actions*
- *If time is available, include lead agency and timeline*

BREAK: 2:30 – 2:45 PM

2:45-3:10 Monitoring & Future Research Priorities: Facilitated Discussion
Facilitator: Dave Gori, *Director of Science, TNC-NM*

<u>Outcomes:</u>

- *The three groups share research and monitoring needs identified in the breakout sessions.*
- *Participants identify other research and monitoring information that would improve their ability to respond to climate change.*

3:10-4:10 Panel/Group Discussion: Potential Next Steps for Implementing Workshop Recommendations (Moderator: Dave Gann, *The Nature Conservancy*)

- Tom Schreiner, Colorado Division of Wildlife
- Dustin Perkins, National Park Service
- Taryn Hutchins-Cabibi, Colorado Water Conservation Board
- Greg Hayward, US Forest Service
- Russell Japuntich-Bureau of Land Management

4:10-4:20 Workshop Summary, Outcomes and Next Steps: Patrick McCarthy

4:20-4:30 Closing Remarks: Tim Sullivan

PLEASE COMPLETE EVALUATION FORM!! THANK YOU!!

WORKSHOP ADJOURNS: 4:30 PM

Appendix 2. Gunnison Climate Change Adaptation Workshop Participant List

Organization	Last Name	First Name	Target Group	E-mail Address
BLM	Breibart	Andrew	Headwaters	Andrew_Breibart@blm.gov
BLM	Japuntich	Russell	Grouse	russell_japuntich@blm.gov
BLM	Kinateder	David	Grouse	david_kinateder@blm.gov
CDOW	Brauch	Dan	Headwaters	dbrauch@state.co.us
CDOW	Graf	David	Headwaters	david.graf@state.co.us
CDOW	Jones	Paul	Headwaters	Paul.Jones@state.co.us
CDOW	Schreiner	Tom	Alpine	Tom.Schreiner@state.co.us
CDOW	Seglund	Amy	Alpine	Amy.Seglund@state.co.us
CDOW	Seward	Nathan	Grouse	Nathan.Seward@state.co.us
CDOW	Wenum	J.	Grouse	J.Wenum@state.co.us
CU-WWA	Barsugli	Joe	Headwaters	Joseph.Barsugli@noaa.gov
CNHP	Rondeau	Renee	Alpine	rjr@lamar.colostate.edu
CWCB	Hutchins-Cabibi	Taryn	Headwaters	Taryn.Hutchins-Cabibi@state.co.us
GCO	Cochran	James	Grouse	JCochran@gunnisoncounty.org
HCCA	Glazer	Steve	Headwaters	steve@hccaonline.org
HCCA	Navy	Sue	Grouse	suenavy@gmail.com
MSI	Nydick	Koren	Alpine	NYDICK_K@fortlewis.edu
NCAR	Mearns	Linda	Alpine	lindam@ucar.edu
NPS	Bockus	Danguole	Grouse	Danguole_Bockus@nps.gov
NPS	Childers	Theresa	Grouse	Theresa_Childers@nps.gov
NPS	Malick	Matt	Headwaters	Matt_Malick@nps.gov
NPS	Perkins	Dustin	Headwaters	Dustin_W_Perkins@nps.gov
NPS	Stahlnecker	Ken	Grouse	Ken_Stahlnecker@nps.gov
NRCS	Scott	John	Headwaters	john.scott@co.usda.gov
RMBL	Billick	Ian	Alpine	ibillick@gmail.com
RMBL/UM	Inouye	David	Alpine	inouye@umd.edu
TNC	Bergeron	Adam	Headwaters	abergeron@tnc.org
TNC	Enquist	Carrie	Grouse	cenquist@tnc.org
TNC	Gann	Dave	Alpine	dgann@tnc.org
TNC	Gori	Dave	Headwaters	dgori@tnc.org
TNC	McCarthy	Patrick	Headwaters	pmccarthy@tnc.org
TNC	Millard	Katie	Grouse	kmillard@tnc.org
TNC	Neely	Betsy	Alpine	bneely@tnc.org
TNC	Pague	Chris	Grouse	cpague@tnc.org
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TNC	Schulz	Terri	Grouse	tschulz@tnc.org
TNC	Smith	Ed	Alpine	esmith@tnc.org
TNC	Sullivan	Tim	Headwaters	tim_sullivan@tnc.org
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UGRWCD	Sibley	George	Headwaters	george@gard-sibley.org
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Appendix 2. Gunnison Climate Change Adaptation Workshop Participant List

USFS	Etzenhouser	Matt	Headwaters	metzenhouser@fs.fed.us
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USFS	Howe	Carol	Headwaters	chowe@fs.fed.us
USFS	Johnston	Barry	Grouse	bcjohnston@fs.fed.us
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USFS	Vasquez	Matt	Grouse	mgvasquez@fs.fed.us
USFS	Worrall	Jim	Headwaters	jworrall@fs.fed.us
USFS-RMRS	Joyce	Linda	Alpine	ljoyce@fs.fed.us
USFWS	Reinkensmeyer	Dan	Grouse	Dan_reinkensmeyer@fws.gov
WCS	Cross	Molly	Alpine	mcross@wcs.org
WSC	Bartleson	Bruce	Headwaters	brucebartleson@msn.com
WSC	Magee	Pat	Grouse	pmagee@western.edu

* workshop organizers are highlighted in gray

KEY	
BLM	Bureau of Land Management
CDOW	Colorado Division of Wildlife
CNHP	Colorado Natural Heritage Program
CU	University of Colorado
CWCB	Colorado Water Conservation Board
GCO	Gunnison County
HCCA	High Country Citizens Alliance
MSI	Mountain Studies Institute
NCAR	National Center for Atmospheric Research
NPS	National Park Service
RMBL	Rocky Mountain Biological Lab
TNC	The Nature Conservancy
UA	University of Arizona
UGRWCD	Upper Gunn. River Conservancy District
UM	University of Maryland
USFS	US Forest Service
USFS-RMRS	USFS Rocky Mtn Research Station
USFWS	US Fish and Wildlife Service
WCS	Wildlife Conservation Society
WSC	Western State College

Appendix 3. Gunnison Sage-grouse Climate Change Impacts (Hypotheses of Change): Gunnison Climate Change Adaptation Workshop

Key Climate-Influenced Drivers/Effects (e.g., Physical, Ecological, Social, Economic)	Observed & Projected Climate Change Impact[1] (i.e., Hypotheses of Change)	Likelihood[2]/Severity[3] of Climate Change Impact		Comments, Notes, Sources
		Scenario #1: Moderate Change	Scenario #2: Extreme Change	
Drought & hydrological impacts (additive): reduced snowpack, earlier peaked hydrograph, decreased groundwater/H2O availability, less water in ditches, diversions	**Brooding rearing habitats**: fewer mesic sites, lower quality, more erosion; may shift to higher elevation; located further from nesting; chick survival diminished (S1 & S2)	Very likely/high	Virtually Certain/Very high	
	Nesting habitats: loss due to increased fire frequency (cheat grass) & sage dieback; decreased quality (less forbs &perennial grasses); reduced recruitment & decreased carrying capacity of habitat itself (S1 & S2)	Very likely/high	Virtually Certain/Very high	
	Shrinkage or significant loss of all grouse habitats (S2)		Uncertain/Very high	Higher elevation leks may become more important in the future
Invasive plant species (esp. cheat grass)	Lowers quality of all habitats, increased fire frequency (S1 & S2)	Very likely	Virtually Certain/Very high	All habitats affected
Disease (West Nile Virus)	Increased mosquito populations as vector for West Nile infection in birds (S1&S2)	Uncertain/high	Uncertain/very high	High severity esp. in non-Gunnison pops (lower elevations)
Livestock Grazing	Increased competition for limited forage (S1 & S2)	Likely short-term/high	Likely short-term/high	Influences stocking rates; how will this affect ranching given climate change?
Wildlife grazing & browsing (elk, deer)	High population levels negatively affect brooding, nesting, winter habitats; changes quality of leks; some areas may be more accessible and vulnerable (S1&S2)	Very likely/high	Very likely/high	Uncertain about the number of elk (related to carrying capacity, pop. management); lag effects
Fire	Increased frequency in all habitats (S1)	Uncertain	Uncertain	Distinct from cheat grass-induced fire;

Key Climate-Influenced Drivers/Effects	Observed & Projected Climate Change Impact[1]	Likelihood[2]/Severity[3] of Climate Change Impact		Comments, Notes, Sources
				lightening effects?
Human effects/responses to climate change (agriculture, renewable energy development, residential development)	Reduction of agricultural use of water shifting to municipal use leading to drying of hay meadows leading to permanent loss of brood rearing habitat; conversion of agricultural lands to developed lands increase (S1 & S2)	Likely/high	Virtually certain/very high	Water rights issues

[1] Indicate Scenario (see description in heading) the impact applies to: "S1" = Scenario #1 only, "S2" = Scenario #2 only, or "S1+S2" = both.
[2]Likelihood of Impact: Virtually Certain, Very Likely, Likely, and Uncertain (see "Definitions" document in packet).
[3]Severity of Impact: Very High, High, Medium, Low (estimates based on expert knowledge).

Appendix 4. Gunnison Sage-grouse Strategic Actions to Address Climate Change Impacts for Scenarios #1 and #2: Gunnison Climate Workshop

Management Objective: *By 2050, maintain and protect range-wide population of 3,500-5,000 individuals in Gunnison population and 200-300 in Crawford population while maintaining habitat connectivity between populations to promote gene flow.*

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 10-15 yrs)	Scenario #2 Strategic Action (Planning Horizon: 10-15 years)	Level of Urgency / Priority	Opportunities to Implement
Brood rearing habitats: fewer mesic sites, lower quality, more erosion; may shift to higher elevation; located further from nesting; chick survival diminished (S1 & S2)	Snowpack & groundwater management Agriculture practices (esp. hay meadows) Wildlife management Public land management & policy	(1) **Retain H_2O in most vulnerable brood rearing habitats (hay meadows, seeps, springs)** • **Permanently tie water to land via easements** (esp. senior water rights & those for grouse) • **Improve irrigation practices** (efficient use of water, in addition to conservation) • **Retain water in ecological system; Restore seeps, springs; remove headcuts, gullies; raise H2O table,** • Restoration activities that view grouse habitat as a whole on both public & private lands; provide incentives; Manage grouse habitat as a whole to ensure all habitats are available in high quality and right places • Re-zoning laws in priority areas; transfer of dev rights; sub-dev planning • Use key elements of ESA, Farm Bill, Wetlands Protection Act and other federal programs to generate financial and logistical support for achieving short term and long	• Artificial irrigation focused on brood rearing habitat • Assisted migration (translocation) to higher elevations and to maintain gene flow • Give up on some satellite populations; focus on Gunnison (lacks consensus)	High (1) top priority for action	• BLM has started to prioritize habitats; initiated restoration • Need ways to prioritize across landownership; Establish collaborative initiative that designates priority habitat; possible areas at least 25K acres/lek, ACECs/ congressional designation (could bring more $) • North Rim Strategy Group focused on Crawford pop & beyond (elk movement study & many other aspects ongoing to guide landscape level mgmt) • Dry Creek/ Dolores PJ removal; grouse habitat restoration funding received

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 10-15 yrs)	Scenario #2 Strategic Action (Planning Horizon: 10-15 years)	Level of Urgency / Priority	Opportunities to Implement
		term conservation goals as identified in the rangewide conservation plan. • Captive breeding program from source to sink pops			
Nesting habitats: loss due to increased fire frequency (e.g., cheat grass) & sage dieback; decreased habitat quality (less forbs &perennial grasses); reduced recruitment & decreased carrying capacity of habitat itself (S1 & S2)	Public land management Grazing management Invasive species management	(2) **Improve/restore nesting & wintering habitats:** • Improve/re-establish leeward-mountain shrub habitats (snowberry, serviceberry) via snow fencing (artificial and live), and planting (need to be doing 50 fold what is being currently conducted) • Maintain & expand perennial grass and forb cover (need to be doing 10 fold what is being currently conducted) • Abate/prevent cheat grass encroachment		High: Mountain shrub restoration (2) top priority for action	Mountain shrub restoration: may be biggest bang for the buck?
Human responses to climate change: Reduction of agricultural use of water shifting to municipal use leading to drying of hay meadows leading to permanent loss of brood rearing habitat; conversion of agricultural lands to developed may increase	Public land management & policy Agriculture practices	**3) Zoning laws & other policy options to protect habitat and maintain land uses:** • Transfer of development rights; • Subdivision planning to protect all habitats • Manage grouse habitat as a whole to ensure all habitats are available in high quality and right places		High (3) top priority for action	

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 10-15 yrs)	Scenario #2 Strategic Action (Planning Horizon: 10-15 years)	Level of Urgency / Priority	Opportunities to Implement
(S1 & S2)					
Shrinkage or significant loss of all grouse habitats; more sage dieback (e.g., habitat could resemble those in Saguache currently) (S2)	Vegetation management Wildlife management Recreation management		• Plant/seed more drought tolerant yet similar species (broader phenotypic plasticity) from lower elevations and other similar habitats; • Maintain opportunity to move birds and/or • Ensure connectivity to potential higher elevation sites (e.g., valley of Taylor Reservoir)		Use NRCS vegetation models/descriptions from lower elevation sites to map possible future distributions for use as visualization tool and planting guide
Invasive species encroachment lowers quality of all habitats, increased fire frequency (S1 & S2)	Invasive species management Fire management	Control cheat grass expansion: • Prevent disturbance along roadsides, corridors, and other sites via mgmt; • Avoid contaminated seed mixes (if possible); • Remove seed potentially brought in by heavy equipment; • Spraying as appropriate • Increase communication & coordination between mgmt agencies Control other invasive species with			BLM is mapping expansion and invaded sites County Weed Board involvement

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 10-15 yrs)	Scenario #2 Strategic Action (Planning Horizon: 10-15 years)	Level of Urgency / Priority	Opportunities to Implement
		potential to significantly degrade grouse habitat Suppress fires in invaded areas			
Increased mosquito populations as vector for West Nile infection in birds (S1&S2)	Pest control	Spray insecticide specific to mosquito-infested areas			Unsure of effectiveness of and need for this strategy.
Livestock grazing: Increased competition for limited forage (S1 & S2)	Public & private land management	"Grass banking" including public land allotments; pooled allotments; seasonal movements to other grazing sites (co-ops to haul?); incentives for ranchers to build & maintain grouse-friendly fence (& for improved range mgmt)			
Wildlife grazing: Negatively affects brooding, nesting, winter habitats; changes quality of leks (S1&S2)	Wildlife management	Manage wildlife herd numbers based on winter range carrying capacity and impact on grouse habitat (e.g., issue more tags for deer & elk; change distribution of hunters during season (more late season tags?); change distribution of animals across winter range; issue more female tags)			

[1]See list of Definitions in participants' packet.

Appendix 5. Gunnison Headwaters Climate Change Impacts (Hypotheses of Change): Gunnison Climate Change Adaptation Workshop

Key Climate-Influenced Drivers/Effects (e.g., Physical, Ecological, Social, Economic)	Observed & Projected Climate Change Impact[1] (i.e., Hypotheses of Change)	Likelihood[2]/Severity[3] of Climate Change Impact	
		Scenario #1: Moderate Change	**Scenario #2: Extreme Change**
Increased temperature and its relation to snow hydrology and runoff	Increased temperatures will lead to a shorter snowpack accumulation season, and earlier snowmelt. This, in turn, will lead to: earlier, flashier, and potentially increased flooding; a shorter flood hydrograph recession limb; less riparian inundation; less bank storage, and lower base flows (S1 & S2)	Likely	Virtually certain
Increased temperature and its relation to baseflows	Increased temperatures and their direct and indirect effects (e.g., on runoff) will lead to decreased groundwater and decreased base flows. Lower base flows lead to reduced recharge during flood events and increased water temperatures. The indirect consequences of these hydrologic changes include decreased riparian vegetation cover, decreased availability of aquatic habitat, changes in macroinvertebrate species composition, and impacts due to increased algae and nutrients (S1 & S2)	Very likely	Virtually certain
Increased variability of summer precipitation and its relation to runoff	Increased variability in summer monsoon precipitation could lead to more frequent dry summers, but also occasional higher-intensity summer storms. The high intensity storms could increase localized flooding erosion in both uplands and floodplains.	Uncertain	Uncertain
Increased temperature and its relation to snow hydrology and groundwater recharge	Increased temperatures and their direct and indirect effects (e.g., on evapo-transpiration and snow hydrology, respectively) will reduce soil moisture and groundwater recharge. Consequently, there will be changes in upland vegetation, shifts from perennial to intermittent streams, a loss of seeps and springs, and loss of riparian and vegetation cover (S1 & S2)	Likely	Very Likely
Disturbance-related changes and their relations to forest anb shrubland structure and effective cover	Temperature increases and enhanced drought may lead to increased disturbance, such as fire, insect outbreaks and disease. Consequences include: change or loss of forest/shrubland cover, which will initially increase water yields and the potential for increased erosion and sedimentation (S1 & S2)	Very Likely	Virtually certain
Dust deposition on snow	Increased dust deposition on snow, due to drying regionally and locally, loss of vegetative cover, road building, recreation, and grazing, will accelerate snowmelt and lead to even earlier peak flows. Consequently,	Likely but not every year	Virtually certain

Key Climate-Influenced Drivers/Effects (e.g., Physical, Ecological, Social, Economic)	Observed & Projected Climate Change Impact[1] (i.e., Hypotheses of Change)	Likelihood[2]/Severity[3] of Climate Change Impact	
		Scenario #1: Moderate Change	Scenario #2: Extreme Change
	hydrographs will be characterized by a steep receding limb (S1 & S2)		

[1]Indicate Scenario (see description in heading) the impact applies to: "S1" = Scenario #1 only, "S2" = Scenario #2 only, or "S1+S2" = both.
[2]Likelihood of Impact: Virtually Certain, Very Likely, Likely, and Uncertain (see "Definitions" document in packet).
[3]Severity of Impact: Very High, High, Medium, Low (estimates based on expert knowledge).

Appendix 6. Gunnison Headwaters Strategic Actions to Address Climate Change Impacts for Scenarios #1 and #2: Gunnison Climate Workshop

Management Objective: *Maintain summer base flow, frequency of bankfull discharge, and the size and timing of peak flow sufficient to maintain viable aquatic and riparian communities and viable populations of species of interest.*

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 10-15 yr)	Scenario #2 Strategic Action (Planning Horizon: 10-15 yr)
Increased temperatures will lead to a shorter snowpack accumulation season, and earlier snowmelt. This, in turn, will lead to: earlier, flashier, and potentially increased flooding; a shorter flood hydrograph recession limb; less riparian inundation; less bank storage, and lower base flows (S1 & S2)	Snowpack management (Effective Cover)	Increase snow retention by managing forest cover to decrease sublimation and the rate of snow melt. Design management for local conditions (vegetation species, aspect, elevation, exposure).	Same actions as for S1, but, in addition, construct snow fences to enhance snow retention.
Same as above	Water management	Enhanced, improved, and more intensive use of reservoir management strategies.	Construct new reservoirs, keeping evaporative loss and potential downstream effects in mind.
Same as above	Water management	Enhanced emphasis on use of wetland management strategies. Construct wetland complexes; maintain irrigation infrastructure to maintain existing wetlands and increase recharge; use more intensive irrigation strategies (valley floor, recharge); reintroduce beavers.	Same actions as for S1
Increased temperatures and their direct and indirect effects (e.g., on runoff) will lead to decreased groundwater and decreased base flows. Lower base flows lead to reduced recharge during flood events and increased water temperatures. The indirect consequences of these hydrologic changes include decreased riparian vegetation cover, decreased availability of aquatic habitat, changes in macroinvertebrate species composition, and impacts due to increased	Water management	Increase odds of retaining robust base flows through more intensive legal, water, ecosystem and agricultural management strategies. Appropriate and/or lease water rights. Use more intensive reservoir management to ensure summer flows. Manage for new base flow conditions. Increase recharge by constructing wetland complexes, improved maintenance of irrigation infrastructure to retain	Manage for new base flow conditions; construct wetland complexes, maintain irrigation infrastructure to maintain existing wetlands and increase recharge. More intensive use of irrigation strategies (valley floor, recharge). Reintroduce beavers. Capture runoff from municipal sources in retention basins.

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 10-15 yr)	Scenario #2 Strategic Action (Planning Horizon: 10-15 yr)
algae and nutrients (S1 & S2)		existing wetlands. More intensive use of irrigation strategies (valley floor, recharge). Reintroduce beavers.	
Same as above	Forest and shrubland management	Enhance infiltration and soil moisture retention through enhanced forest and shrub cover management techniques.	Experiment with introducing species from lower elevations, and/or southern latitudes.
Same as above	Road management	Install catchment structures to detain road runoff. Use better road design to reduce rapid runoff.	Construct more retention and wetland structures.
Increased temperatures and their direct and indirect effects (e.g., on evapo-transpiration and snow hydrology, respectively) will reduce soil moisture and groundwater recharge. Consequently, there will be changes in upland vegetation, shifts from perennial to intermittent streams, a loss of seeps and springs, and loss of riparian and vegetation cover (S1 & S2)	Similar snowpack and water management strategies as those used to address base flow issues	See above	Potentially consider species-management triage, because of the loss of perennial streams. Adjust management objectives. Triage may also include prioritization of drainages within the watershed.
Temperature increases and enhanced drought may lead to increased disturbance, such as fire, insect outbreaks and disease. Consequences include: change or loss of forest/shrubland cover, which will initially increase water yields and the potential for increased erosion and sedimentation (S1 & S2)	Forest and shrubland management	Maintain forest health and fire resistance through diverse vegetation management strategies, such as thinning, regeneration cuts, taking out the overstory instead of thinning from below. What constitutes appropriate management include changes, such as shifting strategies to encourage young trees that have adapted to the warmer climate. Increase diversity in patch composition and age structure across the landscape. Increase younger cohorts.	Same actions as for S1,but also use thinning or regeneration cuts to encourage regeneration of younger cohorts. Bring in outside stock to augment regeneration. Move seed zones.

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 10-15 yr)	Scenario #2 Strategic Action (Planning Horizon: 10-15 yr)
Increased variability in summer monsoon precipitation could lead to more frequent dry summers, but also occasional higher-intensity summer storms. The high intensity storms could increase localized flooding erosion in both uplands and floodplains (S1 & S2).	Forest management (Effective Cover)	Decrease erosion potential by reseeding and restoration, which can be used following disturbances and for vulnerable exposed soil surfaces (near roads, or after fire). For S1, use traditional species mix for reseeding and restoration.	Same actions as for S1, but experiment with species from other elevations or latitudes and/or introduce drought tolerant species.
Same as above	Grazing management (Effective Cover)	Decrease erosion potential by making adjustments to duration and intensity of livestock grazing and exposure to grazing by elk herds – based on available forage.	Same actions as forS1
Same as above	Riparian Management	Decrease erosion potential by creation of riparian buffers, fencing, willow plantings, retention dams.	Same actions as for S1
Same as above	Road management	Decrease erosion potential by installing larger culverts, using hardened stream crossings, enhancing road drainage,enhanced use of drainage BMPs, and improved dust management. Road closures may be necessary.	Invest more resources in road management. Improved dust management and foad closures will be necessary.

[1]See list of Definitions in participants' packet.

Appendix 7. Alpine Wetlands Climate Change Impacts (Hypotheses of Change): Gunnison Climate Change Adaptation Workshop

Key Climate-Influenced Drivers/Effects (e.g., Physical, Ecological, Social, Economic)	Observed & Projected Climate Change Impact[1] (i.e., Hypotheses of Change) NOTE: WE ONLY CONSIDERED SCENARIO #1
Wetland soils/vegetation	Warmer soils lead to drier and less saturated soils and a decrease in anaerobic processes, which changes plant community composition and decreases overall wetland area. (Potentially irreversible change)
Wetland vegetation	Drier soils lead to increases in grasses, decreases in forbs, loss of mosses.
Wetland vegetation	Alpine vegetation limited by temperature may increase in productivity as it gets warmer, but increased CO_2 may reduce forage quality, leading to unknown impacts on grazers (both wild and domestic)
Sedimentation	Possibility of increased spring flood events and channelization/down-cutting at higher elevations where we don't normally see those events, potentially leading to increased sediment loads and changes to the plant community, as well as increased avalanche risk *[note: not sure if this is as relevant in alpine vs. lower elevation]*
Wetland hydrology	Longer dry period during the growing season due to earlier snowmelt, decreased summer precipitation, and increased evaporation due to warmer temperatures [through decreases in both groundwater and surface water flows] *[relates then to soil moisture and vegetation changes above]*
Wetland hydrology	Warmer temperatures and dry conditions (including shrinking aerial extent of wet areas) leads to higher nutrient and heavy metal concentrations, lower dissolved oxygen. Greater fluctuations of water temperature. Instability in the chemistry of the aquatic system (e.g., decreased buffering capacity).
Biological invasions	Warmer temperatures may lead to increased invasion by both native and non-native plants.
Wetland plant-insect interactions	Changes in plant composition and the potential for disruption in relative phenologies could change plant-insect-fauna interactions (e.g., pollinators, song birds)
Wetland resident organisms	Drier and warmer conditions and altered water quality may lead to changes in aquatic communities (e.g., insects, inverts, amphibians), changes in species composition.

Key Climate-Influenced Drivers/Effects	Observed & Projected Climate Change Impact[1]
Wetland non-resident organisms	Decreases in birds and other transients, possible increases in other/new transients.
Wetland soils/carbon cycle	Early melt, warmer temperatures lead to decreased soil moisture, which increases decomposition (esp. in fens) and releases more carbon to atmosphere (and creates feedbacks to the climate system)
Fire	While fire is not currently an issue in alpine ecosystems, as conditions get warmer and drier the risk for fire in high elevation areas may increase. Even if fires don't start in the alpine, those areas may experience increased fire "spillover" from subalpine areas that likely will experience increased fire risk.
Recreation	Summer recreation activity in alpine areas may increase as neighboring areas get warmer and drier (and more uncomfortable).
Dust-on-snow events	Already considered an important negative influence on alpine snowpack (dust leads to rapid and early snowmelt), the combined effects of warmer climate and dust events could have an even greater impact. While there is still a lot to learn about what factors lead to dust deposition in Gunnison-area alpine areas, if source areas become more dry as climate changes, dust deposition could increase in the future.

[1] Indicate Scenario (see description in heading) the impact applies to: "S1" = Scenario #1 only, "S2" = Scenario #2 only, or "S1+S2" = both.

Appendix 8. Alpine Wetlands Strategic Actions to Address Climate Change Impacts for Scenarios #1 and #2: Gunnison Climate Workshop

Management Objective: *Maintain current proportional representation of all alpine wetland community types and (75 %) of current spatial extent of dominant types: •Maintain hydrology and sediment regime in target wetlands to retain current plant community; •Retain species currently associated with wetlands; •Minimize human induced direct sedimentation.*

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	**Intervention Point[1]**	**Scenario #1 Strategic Action (Planning Horizon: 2040-2060)** **NOTE: WE ONLY CONSIDERED SCENARIO #1**
Decreased snowpack	Snowpack management	• Install snow fences • Consider cloud seeding (probably will require policy changes in wilderness)
Changes in wetland plant species diversity due to increased summer dry period exacerbated by wild and domestic grazing and human recreation	Wildlife and range management	• Manage elk herds w/ sheepherders, increased hunting pressure and other methods (e.g., can we control where wildlife go by using things like salt licks to move wildlife to non-wetland areas?) to reduce impacts on wetlands. • Manage domestic grazing in alpine (e.g., through fencing, herding restrictions, grazing permitting, altering the timing, duration and intensity of grazing) to reduce impacts of grazing on the wetlands.
Decreases in ground and surface water flows	Ground and surface water flows	• Keep or restore natural hydrology (e.g., remediate roads, improved engineering, improved culverts, require hydro restoration with mining claim or other development) • Increase buffer (prohibiting trails, timber sales, camping, stocking areas) around wetland areas (using a geomorphological approach where possible). Make buffers more visual/apparent, and make information more widely available to public, developers, managers. • Identify wetlands that have gone beyond restoration that could be used to water development, and those that are high priority for conservation to put higher level of protection.
Decreases in surface flows	Summer recreation	• Divert trails/roads from wetlands – prioritize based on rare wetland types and/or magnitude of impact due to climate change.
Negative changes to water chemistry	Hydrology	• Divert water towards wetlands (e.g., create channels, artificial or real beaver dams) and sustain existing flows (e.g., through snow fences) to maintain threshold level of water volume as wetlands get smaller (to avoid concentrating nutrients and heavy metals).

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 2040-2060) NOTE: WE ONLY CONSIDERED SCENARIO #1
Decreased precipitation in the summer	Precipitation	• Fog catchers to trap fog moisture.
Exacerbation of climate impacts on vegetation due to human recreation (which is already a problem and may increase as things get warmer and drier in surrounding areas)	Summer recreation	• Create wilderness "climate change study areas" for research on adaptation, and to limit human impact.
Reduced spatial extent of wetland plant communities and resulting fragmentation	Vegetation management	• Rehabilitation/reclamation/restoration efforts in areas that we see being degraded and/or fragmented – isolate an area, prohibit human use, re-establish water flow (e.g., through beaver activity, channeling, re-routing of flows, etc.), and rehabilitate vegetation.
Increased biological invasions due to warmer and drier conditions	Weed management	• Early detection and rapid response program for the alpine. Need research to develop strategies for how to focus limited capacity and to better understand weeds and their impacts. *[note: it is currently very difficult to get permission to manage weeds with chemicals in wilderness areas]*
Fragmentation of alpine plant habitats	Development of historic mining claims	• Land acquisition to retire alpine mining claims. • Prioritization of where the most critical places are to target the acquisition of land and mining rights.
Unavoidable loss of wetlands		• Look for opportunities to mitigate losses (e.g., augment the health/abundance of wetlands in subalpine zone, water rights trading), especially in areas where geomorphology or other reasons might lead to augmentation of wetlands.
Tree encroachment into wetlands	Vegetation management	• Maintain treeless characteristics of areas (e.g., by removing tree seedlings, prescribed burning, and exploring other techniques) *[note: probably not currently possible in wilderness*

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Scenario #1 Strategic Action (Planning Horizon: 2040-2060) NOTE: WE ONLY CONSIDERED SCENARIO #1
		areas]
Warmer temps. moving alpine areas up-slope	Vegetation management	• Fence tundra areas where recruitment might occur in the future; consider assisted migration of wetland species, in appropriate situations/locations.
Increased sedimentation	Range / vegetation management	• Maintain plant cover outside of the wetland areas. Trap moving sediments through plantings, natural material fencing. Possibly remove trapped material.
Negative impacts of winter recreation on wetland condition	Winter recreation	• Limit snowmobile and skier access to wetland areas. *[research = can winter recreation be used to influence hydrology in a positive way??]*
Decreased groundwater inputs to wetlands	Winter recreation / ski areas	• Limit snowmaking
Dust on snow	Research / monitoring / exploring intervention opportunities	• Clarify how much of an impact is it creating on willows/wetlands? Where is the dust coming from (both now and in the future)? What are strategies to reduce dust in those areas? • Send appeal to DOI, WGA, (plus other state and fed agencies) to investigate management actions to reduce blowing dust. • Will there be water rights conflicts with downstream users??
All impacts	Monitoring	• Monitor wetland condition and extent to feedback into determining when and where interventions are needed.

[1]See list of Definitions in participants' packet.