DRAFT Appendices
Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin
February 8, 2010

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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)

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

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

Objectives for the three groups include:

- *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)

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

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

Objectives for three groups include:

- *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)

12:30 – 4:30 PM

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

Outcomes:

- *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*

Outcomes:

- *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
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HCCA	Navy	Sue	Grouse	suenavy@gmail.com
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Appendix 2. Gunnison Climate Change Adaptation Workshop Participant List

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* 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 effect 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; lightening effects?

Key Climate-Influenced Drivers/Effects	Observed & Projected Climate Change Impact[1]	Likelihood[2]/Severity[3] of Climate Change Impact		Comments, Notes, Sources
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 (S1 & S2)	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
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 potential to significantly degrade grouse habitat			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
		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 evapotranspiration 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.