

Implementing a Framework for Adaptation Planning: Future Climate Scenarios, Goals & Logistics

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

2-3 December 2009 – Western State College – Gunnison, Colorado

Gregg Garfin & Molly Cross



Scenarios for Gunnison



- Moderate scenario:

- Annual temperature: +2.5 °C (+4.5 °F)
- Annual precipitation: no change

Season	Precip %	Temp °C	Temp °F
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

Scenarios for Gunnison



- Moderate scenario:

Parameter	Impacts
Runoff Amount	5-10% decrease
Snowpack Accumulation and Melt	<ul style="list-style-type: none">• later fall accumulation• earlier spring melt• high elevation midwinter accumulation: similar to present
Runoff Timing	earlier by 7 days
Soil Moisture	significantly less during summer

Scenarios for Gunnison



- More extreme scenario:
 - Annual temperature: +3.0 °C (+5.4 °F)
 - Annual precipitation: –10%

Season	Precip %	Temp °C	Temp °F
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

Scenarios for Gunnison



- More extreme scenario:

Parameter	Impacts
Runoff Amount	20-25% decrease
Snowpack Accumulation and Melt	<ul style="list-style-type: none">• later fall accumulation• earlier spring melt• substantial early melt and decreased yield if high dust deposition
Runoff Timing	earlier by 14+ days
Soil Moisture	extremely low in summer and fall

Refine Management Objectives

Develop Conceptual Model

Assess Impacts: Scenarios

Complete Table 1: Impacts

12:45-4:30 Breakout Groups Refine objectives Develop model Assess impacts	Gunnison sage-grouse ("grouse") Alpine ecosystems ("Alpine") Gunnison headwaters ("hydro")	Schulz & Enquist Cross & Hayward Garfin & Gori
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8:30-11:30

Breakout Groups

Identify Actions

Opportunities

Needs

Grouse

Alpine

Hydro

Identify Strategic Actions

Complete Table 2

Review Management Objectives

Evaluate Priority/ID Opportunities

Research & Monitoring Needs

Conservation Features – Tab 3

Gunnison Climate Change Adaptation Workshop Summary of Conservation Features

At the Gunnison Basin Climate Change Adaptation Workshop, we will apply an adaptation planning framework to develop strategic actions for three different types of conservation features (species, ecosystem, and ecological process). Based on participant input, we selected the Gunnison sage-grouse, alpine ecosystem and Gunnison headwaters to be the focus of adaptation planning exercises conducted during breakout sessions.

Criteria for selecting features to focus on at the workshop include: species, ecosystems or processes of ecological significance within the watershed; rare, imperiled or Colorado Division of Wildlife Tier I species; species of concern; availability of information; particular vulnerability to climate change; and potential for development of adaptation strategies. A short description of each of these features is below.

Gunnison sage-grouse:

The largest known population of the Gunnison sage-grouse, only known from southwestern Colorado and southeastern Utah, occurs in the Gunnison Basin. The grouse's priority habitats include montane sagebrush shrublands and riparian meadows. The Gunnison sage-grouse is ranked as critically imperiled by NatureServe/Colorado Natural Heritage Program, and is a Colorado Division of Wildlife Tier I species. Other imperiled species and/or species of concern inhabiting the sagebrush shrublands include Gunnison's prairie dog, Brewer's sparrow, Green-tailed towhee, Vesper's sparrow, Sage thrasher, Rollin's twainpod, skiff milkvetch and Gunnison milkvetch.

Gunnison headwaters:

The Gunnison headwaters include the upper watershed of the Gunnison River above the junction with Beaver Creek. Primary tributaries include East River, Ohio Creek, Taylor River, Tomichi Creek, Los Pinos Creek, and South Beaver Creek. These rivers and streams support riparian woody riparian vegetation. Associated imperiled species and/or species of concern inhabiting the headwaters include Colorado River cutthroat trout, boreal toad, Black Swift, and the Gunnison sage-grouse. The group will consider these "nested" species and ecosystems of conservation concern and the characteristics of the headwaters hydrologic regime that are important for maintaining them.

Alpine ecosystem:

The alpine ecosystem occurs above approximately 11,500 feet (timberline) and includes the highest peaks of the West Elk, Elk, Sawatch, and San Juan Mountains. Alpine habitats include dry alpine tundra, moist to wet alpine meadows, dwarf shrublands, fell-fields, talus slopes, snow and ice fields, and krummholz. These are cold wind-swept environments much of the year and receive intense ultraviolet radiation. For the purposes of this workshop, we will also include the transition zone between the alpine and subalpine zone (e.g., subalpine meadow/tree-line interface) because of potential shifts in plant and animal species. Associated imperiled species and/or species of concern include American pika, yellow-bellied marmot, Uncompahgre fritillary, Colorado tansy-aster, White-tailed Ptarmigan, Brown-capped Rosy Finch, and Rocky Mountain bighorn sheep. Wolverines were historically present.



A photograph of a Gunnison Sage Grouse perched on a branch. The bird has a yellow head, a blue body, and a tail with black and white horizontal stripes. Its wings are partially spread, showing a mix of blue and white feathers. The background is a clear blue sky.

Gunnison Sage Grouse

Room: This room

Facilitators: Terri Schulz, Carrie Enquist

Notetakers: Chris Pague, Katie Millard



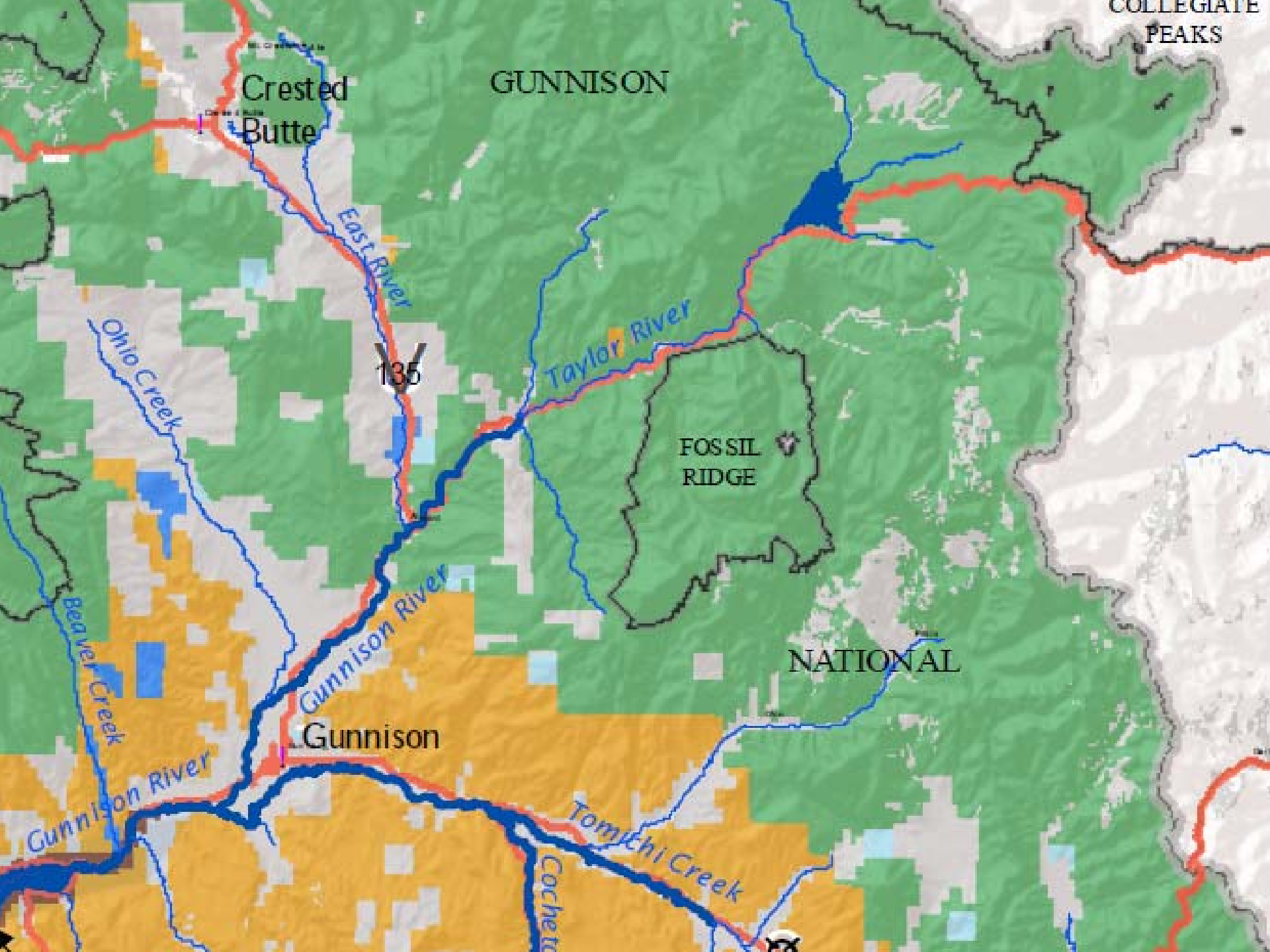
Alpine Ecosystems



Room: End of hallway

Facilitators: Molly Cross, Greg Hayward

Notetakers: Betsy Neely



COLLEGIATE PEAKS

GUNNISON

Crested Butte

East River

Taylor River

Fossil Ridge

NATIONAL

Gunnison River

Gunnison

Tomichi Creek

Cochetopa

Ohio Creek

Beaver Creek

Gunnison River

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A map of the Gunnison River watershed in Colorado. The map shows the Gunnison River flowing from the north towards the south, with several tributaries including the East River, Tomichi Creek, and Beech Creek. The town of Gunnison is marked on the river. The map also shows the Gunnison National Forest and the Collegiate Peaks. The text 'GUNNISON' is written in large letters at the top, and 'NATIONAL' is written in large letters at the bottom right. The text 'COLLEGIATE PEAKS' is written in small letters at the top right. The text 'Crested Butte' is written in small letters at the top left. The text 'Gunnison River' is written in blue letters along the river. The text 'Tomichi Creek' is written in blue letters along the creek. The text 'Beech Creek' is written in blue letters along the creek. The text 'Gunnison' is written in black letters near the town. The text 'GUNNISON' is written in black letters at the top. The text 'NATIONAL' is written in black letters at the bottom right. The text 'COLLEGIATE PEAKS' is written in black letters at the top right. The text 'Crested Butte' is written in black letters at the top left.

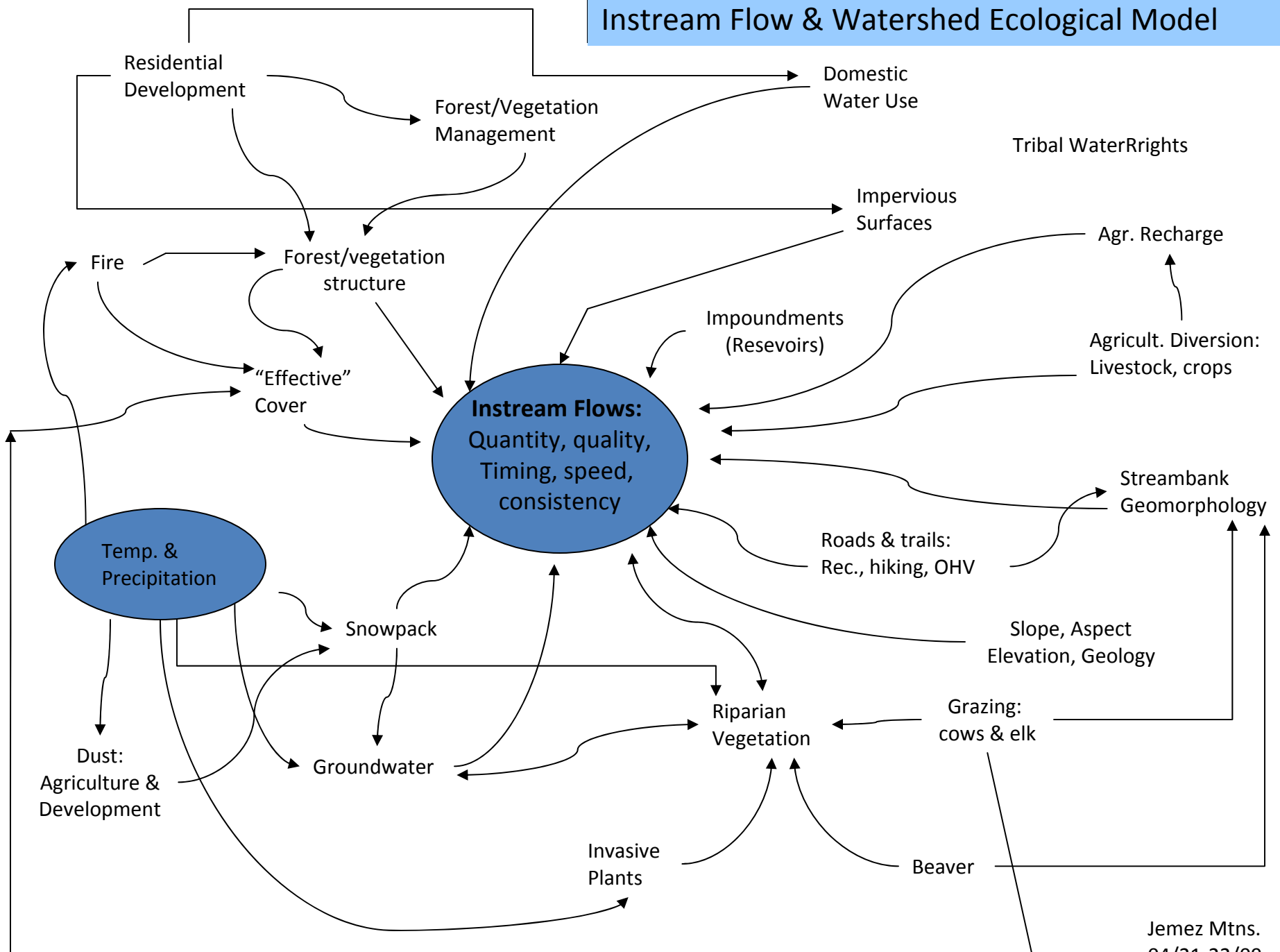
Headwaters Hydrology

Room: Across the hall

Facilitators: Gregg Garfin, Dave Gori

Notetakers: Patrick McCarthy,
John Sanderson

Instream Flow & Watershed Ecological Model



Climate Scenarios – Notebook Tab 4

Scenarios for Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin (L. O. Meama with contribution from J. Barugli)*

Time frame: 2040-2060 compared to 1980-1999

Region: Western Colorado

IPCC-SRES Emissions Scenario: A2 ("medium-high emissions")

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 to 3.0	+3.6 to 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

Scenario #2: Extreme change

Increased annual temperatures (3°C), 100% decrease in annual precipitation, with greater decrease 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	+7.2
Fall	-10.0	+3.0	+5.4

Qualitative statement regarding expected temperature change signal and elevation

Most research for mid-latitude locations indicates increasing temperature change signal with increasing elevation, such that the signal should be largest at higher elevations. However, this statement must be modified by consideration of the overall degree of warming. With very low levels of warming, this signal may not be seen. For example, in Colorado so far, trends in observed temperature, more warming is seen at middle and lower elevations. At higher elevations, temperatures are still low enough such that snow persists and a strong feedback between snowmelt and resulting lower reflectivity and increased absorption of energy at the surface (known as the snow-albedo feedback) does not develop.

Other general features of climate change

Due to increased temperatures, more precipitation will fall as rain as opposed to snow. Snow melt will start earlier in the spring, and snow will begin to accumulate later in the winter. This will have distinct implications for the timing of runoff, for example.

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Scenarios for Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin (L. O. Meama with contribution from J. Barugli)*

Scenario Framework

The framework for the two scenarios chosen was quantification of the probability distributions for temperature change and precipitation change (%) for annual and seasonal values for an area covering most of western Colorado, but with input from the other reports cited above.

Quantiles: 25th to 75th

Season	Precip %	Temp °C	Temp °F
Annual	-5.0 to +7.0	+2.0 to +2.7	+3.6 to +4.8
Winter	-5.0 to +15.0	+1.5 to +2.5	+2.7 to +4.5
Spring	-12.0 to -0.1	+1.7 to +2.5	+3.0 to +4.5
Summer	-20.0 to +6.0	+2.0 to +3.0	+3.6 to +5.4
Fall	-7.0 to +16.0	+2.0 to +2.5	+3.6 to +4.5

This refers to the values associated with the lowest and highest 25% of the statistical data distribution of model runs.

Scenario Information Sources

- Ray, A. et al., 2005. Climate Change in Colorado: A Synthesis to Support Water Resource Management and Adaptation. Boulder, CO: Western Water Assessment. <http://web.state.co.us/Home/ClimateChange/ClimateChangeinColoradoReport/>
- Climate Change and Aspects: An Assessment of Impacts and Potential Responses. http://www.sci.org/4B/PDFs/Publications/2006_CCA.pdf
- Probabilistic information generated using the CMIP3 suite of model results, based on methods used by Tebaldi, C. et al. 2004, 2005.
 - Tebaldi, C., L. O. Meama, R. Smith, D. Stieglitz, 2004. Regional probabilities of precipitation change: A Bayesian approach. *Geophys. Res. Lett.* 31: L24213. doi:10.1029/2004GL021276
 - Tebaldi, C., R. Smith, D. Stieglitz, and L. O. Meama, 2005. Quantifying uncertainty in projections of regional climate change: A Bayesian approach to the analysis of multi-model ensembles. *J. Climate* 18: 1524-1540.
- Results from Regional Climate Projections (Christensen, J.R., et al., 2007, in: *Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Solomon, S., et al., (eds.)) http://www.ipcc.ch/pdf/assessment_report/ar4/wg1/ar4_wg1_chapter1.pdf
- Preliminary results from the North American Regional Climate Change Assessment Project (NARCCAP <http://www.narccap.org/>) Regional Climate Model Simulations. The main emissions scenario considered is the A2, a medium-high scenario. Meama, L. O., et al., 2009. A regional climate change assessment program for North America. EOS, September 2009.

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Scenarios for Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin (L. O. Meama with contribution from J. Barugli)*

Hydrologic Scenarios – Notebook Tab 4

Hydrologic Scenarios for Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin (J. Barragán, in coordination with L.O. Meares)

Time frame: 2040-2060 compared to 1950-1999¶
Region: Gunnison River Basin, Colorado¶
IPCC-SRES-Emission Scenario: A2 ("medium-high emissions")¶

Rationale: The hydrologic scenarios were chosen to be consistent with the climate change scenarios identified by Linda Meares. 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.¶

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

Parameter¶	Impact¶
Streamflow Amount¶	5-10% decrease¶
Snowpack Accumulation and Melt¶	later fall accumulation, earlier spring melt; high elevation mid-winter accumulation may be similar to present¶
Streamflow Timing¶	earlier by 7 days¶
Soil Moisture¶	significantly less during summer¶

Streamflow Amount: Annual natural streamflow 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.¶
Streamflow Timing: Snowmelt-driven streamflow 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.¶

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Hydrologic Scenarios for Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin (J. Barragán, in coordination with L.O. Meares)

Hydrologic Scenarios for Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin (J. Barragán, in coordination with L.O. Meares)

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

Parameter¶	Impact¶
Streamflow Amount¶	20-25% decrease¶
Snowpack Accumulation and Melt¶	later fall accumulation, earlier spring melt; potential for substantially early melt and decreased yield if high dust deposition¶
Streamflow Timing¶	earlier by 14 days¶
Soil Moisture¶	extremely low in summer and fall¶

Streamflow Amount: Decrease in precipitation and increase in temperature both act to reduce annual streamflow totals. Projected streamflow 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.¶
Streamflow Timing: Snowmelt-driven streamflow 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.¶

General note on Hydrologic Variability and Extremes:¶
 Hydrologic variability will continue even in the face of human-caused (anthropogenic) climate change. The basin has experienced episodic drought and wet periods in the past. Paleoclimate reconstructions indicate that the potential exists for longer and deeper droughts than experienced in the historic record. Projected warming would exacerbate the impact of precipitation deficits on streamflow, soil moisture and snowpack. The potential for lower low-flows in summer and fall also exists, particularly in the extreme change scenario. There is also the potential for occasional higher peak flows in summer, because individual thunderstorms may be stronger even if total precipitation decreases.¶

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Hydrologic Scenarios for Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin (J. Barragán, in coordination with L.O. Meares)

Climate Change Adaptation Framework – Tab 5

Climate Change Adaptation Framework[§]

Gunnison Climate Change Workshop[¶]
Southwest Climate Change Initiative[¶]
December 2-3, 2009[¶]

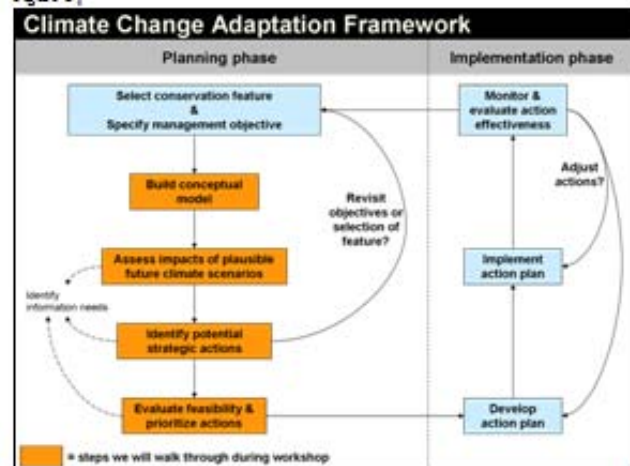
At the workshop, we will present an iterative framework for developing strategic actions for climate change adaptation[§]. The climate change adaptation framework is designed for collaborative application in a given landscape by a multidisciplinary group of managers, conservation practitioners and scientists, and includes the following steps (Figure 1):[¶]

- 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, 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 triggers, 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?[¶]

[§] The Climate Change Adaptation Framework presented here is adapted from Cross et al. (in prep.) (<http://doi.org/10.1002/ece3.100>) and The Nature Conservancy's "Conservation Action Planning Guidelines for Developing Strategies in the Face of Climate Change" (October 2009) (included in workshop folders).[¶]

- 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—a just or reevaluate actions if needed to address system changes or ineffective actions.[¶]

Figure 1[¶]



Definitions – Notebook Tab 5

Gunnison Climate Workshop Definitions¶

- ¶
1.→ **Adaptation to climate change:** An adjustment in natural systems in response to a changing climate in order to moderate adverse impacts or capitalize on novel opportunities (IPCC 2007). Adaptation involves anticipating the influence of climate change and using this information to make proactive choices to achieve objectives.¶
- ¶
2.→ **Adaptive capacity:** The ability of a system to adjust, to moderate, to take advantage of, or cope with novel conditions (IPCC 2000). Enhancing an ecosystem's adaptive capacity is an effort to reduce the system's vulnerability and/or strengthen its ecological resilience through management or mitigation.¶
- ¶
3.→ **Adaptive strategies:** Three approaches to adaptive strategies are resistance, resilience, and enabling natural resources to respond to changes, e.g., improving habitat connectivity to enable species movement (the latter is the most proactive approach).¶
- ¶
4.→ **Climate change impacts (hypotheses of change):** How climate change will specifically impact conservation features and their ecological attributes. Vulnerability of the systems—the combination or exposure and sensitivity of the ecology of the species or ecosystem (e.g., *significantly reduced snowpack will alter the spring and summer hydrologic flow regime for a riparian ecosystem*).¶
- ¶
5.→ **Conceptual ecological model:** Illustration of the climatic, ecological, social and economic drivers that affect a selected species or ecosystem. A box and arrow diagram representing ecological relationships to help understand and communicate potential ecological impacts of climate change on conservation features.¶
- ¶
6.→ **Driver:** An ecological element that causes a change in an organism, community, ecosystem, or other ecological component of the landscape.¶
- ¶
7.→ **Exposure:** The degree, duration, and/or extent to which a system is in contact with a perturbation, often depicted by analysis of historic climate and future climate projection data (such as changes in temperature or precipitation).¶



Participation & Interaction

Ground Rules

- Participate
- Don't Dominate
- “Boss-Free Zone”
- Everyone advocates
 - but the team decides
- Cell phones off
- No email or side conversations
- Have Fun



Questions?

INSTITUTE
ENVIRONMENT

Climate Change Adaptation Framework

Planning phase

Implementation phase

Select conservation feature
&
Specify management objective

Build conceptual
model

Assess impacts of plausible
future climate scenarios

Identify potential
strategic actions

Evaluate feasibility &
prioritize actions

Monitor &
evaluate action
effectiveness

Implement
action plan

Develop
action plan

Identify
information needs

Revisit
objectives or
selection of
feature?

Adjust
actions?

 = steps we will walk through during workshop

