Front Range Water Provider Climate Change Workshop
Friday, November 17, 2006
Meeting Minutes

Presentation: Marty Hoerling from NOAA: Outlook for Water in the West at 2050

*CA considers climate change as a risk element necessary to incorporate into water management operations and decisions
*CO could learn from CA
*Desire to emphasize middle of the road scenarios-which is beneficial, but not always appropriate
*Need to consider all scenarios in order to avoid certain surprises and consequences
*Q: Are we past peak water flow for the CO River?
*Due to warming trends, other factors, we could end up losing 30% of average snowpack
*There is a trend
*Lake Mead: At drought level: below 1125 ft-Been declining since 1999!
*There is this notion that too much water is going downstream. Logic is, that if we built more storage, water will innately come. This is not the case

Review of Literature: Projected impacts of climate change on the Colorado River Basin

1. *Charles Revelle: For a hypothetical 2 degree C warming, 10% reduction in precip= 45% reduction in streamflows
2. *Jim Hansen and David Rind, 1990: Journal of Geophysical Research: "Potential Evapotranspiration and the Likelihood of Future Drought
    Warming could exceed Palmer Drought index of 3
3. *Gleick and Nash paper: Colorado River Basin and Climate Change: GCM models used in NRCC
4. *Third Assessment Report: 2001:
    Weren't specific in where droughts would be located-very general
    Broad range of warming-hard to base policy around
5. *Christensen, 2004: " Effects of Climate Change on the Hydrology and Water Resources of the CO River Basin
    Used climate models from Third Assessment Report
    (side note) Sentiment that more studies will result in crystal clear scenarios
    CA will just act-no more studies
    Observed Annual Temperature Anomaly: West, specifically Colorado have experienced 1.5-1.75 degrees warming- Model agreement in warming in the West! (1.5-1.75 degrees C)
6. *IPCC AR4 models statistically correlated to the observed 2000-2006 time scale record
    5% decrease in precipitation projected in IPCC AR4
    New models used in Fourth Assessment project a 2.8 degree C warming by 2050!

7. *Milly, November 2005: "Global pattern of trends in streamflow and water availability in a changing climate"
    *Use runoff models that incorporate various elements of climate parameters
    *Models used in IPCC AR4: 10-30% decreases in runoff in western N.A.

8. *Hoerling and Eischeid: SW Hydrology: "Past Peak Water in the West"
    *Warmer air temperatures are certain-amplify drought
    *CO and Intermountain West: Change in annual PCPN evapotranspiration: 30% decrease
    *Change in Palmer Drought Index: 2035-2060: Decline of 4-8 PDS1 values
    *Formed regression variables to forecast CO streamflows based on palmer drought index: r2= 62.5%
    *Projected Streamflow Change at Lees Ferry: average results from model inputs
    *Models have major deficiencies in precipitation projections: no conclusive data
    *Use precipitation values from 1900-1950 results in more variability in terms of CO River streamflows
    *Warming is causing an increase in demand in nature
    *Currently there is maybe one model (Milly) that predicts that CO River Streamflows will actually increase

9. *Rocky Mountain section of the Assessment: 2003
    very wet models that were predicting up to 150% increase in precipitation: drove policy to the extent that concern was placed on flood instead of water scarcity
    Not reliable models

Key Points:
***Warmer, drier, increased water scarcity**
***Lees Ferry flow will decline below 20th century consumptive uses within a few decades**

Nolan Doesken, State Climatologist, Colorado Climate Center
Quality Assessment of Colorado's Long-Term Temperature Data

*This talk will not be about precipitation projections
*This talk will address why there is caution and concern regarding making bold statements about warming scenarios-difficult to detect trends

*Attitude after 2002 was much more conducive for talking about climate change
*(Side note: Big difference in thinking about water in CA versus CO: Colorado has a complex precipitation pattern-highly variable versus CA who has one distinct dry and wet trend)
*Systematic weather data collection began in the S. Platte basin and in other parts of Colorado
*Problem with NWS stations is that they are not maintained
*NWS stations are weak in terms of detecting trends, the more narrow the trend-the harder it is to detect
*Changing instrumentation caused discontinuity in observations
*Time of observation also changes the outcome of data: now data is collected for previous day in the mornings, prior to 1950's: collected at sunset

*Change annual mean temperature on upwards o 1-3 degrees C!
*Q: Where is the artificiality in terms of changing time of collection?
*A: Double sampling problems: collected in the morning will double sample the lowest temperatures
*A: The reset reading will pick up the minimum temperature and often times will be the minimum temperature for the day! Thus, there is a bias for cooling if temps are in fact collected in the morning

*Disconnect of monthly max and min temperatures: don't track identically-which poses problems when attempt to impose a temperature trend based on historical data
*NWS station on campus on Colorado State: Reliable station
There is no disconnect in temperature readings dating back to 1890:
There is a warming trend explicit in the temperature trend
*Cheesman*Colorado Springs Airport: Compute difference in max and min temperatures between the two stations
*Migrating upwards to 15-20 degree difference between max and min temps for the two stations:
Result: unreliable source of temperature data! Too many variables to know why there is such a difference between the two stations=had to toss the data!
*Reliable long-term analysis stations: Cheyenne Wells, Akron, Rocky Fort, CO. State Campus
*Temperature trends for Akron-it appears visually that there is a warming trend in the last 7 years-but not noticeably higher- visually speaking
*There is no great long-term analysis stations in the mountains!
*Mountain stations aren't entirely reliable because you move a station just a bit could result in noticeably different temperature reading

Klaus Wolter, NOAA-ESRL
Colorado Temperature Trends

*You have to find the best compromise with the data we got. There is no station that is completely perfect in terms of data analysis
*Comparing data from the 1950's is beneficial because it serves as a benchmark in terms of similar hydrologic conditions of today
*Need a lot of weather stations in Colorado because climate is highly variable as opposed to say, Iowa
*Correlation in Gunnison, Alamosa basins is low due to extreme climate conditions of the area
*Method: pick 4-5 "best" stations for each new climate division; compute seasonal average T max&min, compute linear trend
*Have to be very careful about temperature variability
*Beginning and End year of trend can be very important-tweaking it slightly could result in a different trend
***The biggest trend is spring warming with correlation of .25**
***Minimum temps have increased more than maximum temperatures**
*Don't have as many clear calm nights as in the 1950's-could be a factor in increasing minimum temperatures

*Spring warming, fall cooling for northern front range as a general assessment

Bottom Line:

There are regional differences but there is commonality
*The spring season are statistically getting warming across
*Warming: 1 degree warming for max temps, 2 degree warming for min temperatures
*NC part of the state has been warming the fastest, i.e. Steamboat Springs
*SE plains have actually warmed the least
*(side note: Arkansas Valley is great place to look at 100-year average)
*Based on the data we have, it is really tough to give a 100-year analysis
*There appears to have been a decline in near-surface wind speed over the last five years
*Temperature is going up, however there is other factors that cause evapotranspiration-like near-surface wind speed
*Humidity has also increased-perhaps, not entirely trust data
*THUS, potential evapotranspiration is down despite higher Tsfc, if you trust re-analysis data in comparison to the 1950's
*Q: Are there other ways to look at temperatures, i.e. temperature indicators such as peak run-off so that you could avoid any bias that occurs in long-term temperature observations? –Eric Kuhn
*A: Yes, earlier run-off, growing season, tree-ring records could give temperature clues-high elevation trees, when vegetation starts to bloom
*Q: Any research done on cloud cover?
*A: Yes, there was a trend of increasing cloud cover for the 1990's, however in the last few years the trend has decreased. Nolan Doesken
*A: There is also a man-made increase in cirrus cloud cover that can also result in warmer temperatures –Klaus Wolter

General Points Made by Eric Kuhn: Colorado Climate Center & Brad Udall, Director, Western Water Assessment

*From the water perspective, how are we going to adapt to climate change impacts?
*Inertia from climate system will result in warming even if emissions were to dramatically decline
*What is the time-frame to determine CO river flows? 1905-2000? USBR is willing to talk about different hydrologic regimes
*Note: USBR is willing to talk about different hydrologic regimes-meeting on climate change on November 8
*Reclamation EIS was tossed out by a federal judge in California because it only included historic hydrologic data and did not include climate data
*Political pitfalls: If it strictly turns into a regulatory problem of coal emissions and other fossil fuel emissions-need to move in a positive direction
*There is a push for mitigation as opposed to adaptation
*Rocky Mountain Climate Center has an agreement/understanding with Bill Ritter to incorporate such info into future policy decisions

Side Note on IPCC National Assessment
*IPCC Group 1: Science of Climate change

*IPCC Group 2: Adaptation and Vulnerability
*IPCC Group 3: Mitigation

Discussion
Alfredo Rodriguez: City of Aurora
*Currently have not incorporated climate change into operations
*Have worked with Boulder in terms of seasonal forecasting which has obvious residue from climate change. Contracted Hydrosphere to make these new seasonal forecasts for streamflows, along with Boulder and Colorado Springs. WWA involved too.
*Operating weather station out of Quincy and Aurora Reservoir to measure evapotranspiration. Also adding new weather stations around Aurora.
*Concern is use of older data- (*unsure of point made here)
*Interested in SNODAS.
*Concern with disconnect in water rights when the hydrograph shifts-many water rights are specifically based on dates, and a designated time-frame for releases
*How will water rights and attached legal framework handle a shift in hydrograph?
*What is the impact on snowpack? If knew more, could then do hypothetical "what if" managing scenarios
Q: Where does water for Aurora come from?
A: 25% from CO R, 25% from Arkansas R, 50% from S. Platte R, >5% GW. Colorado River water goes into the Arkansas by way of the Fry-Ark project. Water is then pumped to Aurora by the Otero pump station, which is shared with Colorado Springs.
Q: How did operations/releases change with the 2002 drought?
A: Leased agriculture water from the Arkansas River
Q: Has water use increased in terms of per capita?
A: 121 gallons per day during the drought season, last three years: 161 gallons per day per capita

**Bob Steger: water for most cities represented here are from similar sources/basins. Thus, any previous studies or future proposals about potential changes in water supplies could potentially benefit everyone. He suggested that cities share results with each other.

Carol Ellinghouse, City of Boulder
Ares of Concern and Needs:
Bottom line: what does climate change mean for water supply?
How do such changes interact with or affect water rights? Water could be in the streams, but without water right to divert it, it is unavailable.
City has been developing a water rights model of Boulder Creek which shows the interaction between historical streamflows and water rights. They would like to use this model in conjunction with a model of potential future streamflows to see how changes in streamflows might affect water rights.
***Wants potential changes in precipitation due to climate change to be translated into streamflows. [This sentiment was shared by all water providers.]**
*City has a drought plan that defines acceptable levels of reduction in water availability. -- Idea being that drought is a normal occurrence for this area and that residents need to be comfortable with occasional reductions

*Need for a complex study that looks at which climate models apply to Boulder and inputs such scenarios into water rights system to see how well the system performs.
*Particularly interested in earlier runoff timing and subsequent effect on reservoir levels
*Snow vs rain ratios
*Will there be any increase in demand at lower elevations? i.e. longer growing season on eastern plains and how will this impact supplies?

*2002 city of Boulder began working with historical streamflow reconstructions of the Colorado River provided by Connie Woodhouse of NOAA
*Demand side: What levels of water use reduction are acceptable?
- Reliability criteria: recurrence interval for droughts of different severities and relative reductions in water supplies.
- Nor economically feasible to be 100% reliable 100% of the time.
*Long term goal: 10% reduction in water use by build-out
- Reached it already since 2002. This included winter water use, which means that there were significant structural changes (e.g. low flow toilets and washing machines).

Looking at simple analyses of possible streamflow changes related to climate change:
- 10% reduction in streamflows
- 25% increase in variability of streamflows
Working with Status and Hydrosphere to create a more complex model using climate model results and Boulder's streamflow/water rights model. – handout with preliminary results –

Interested in effects of earlier runoff and the relationship between temperature, elevation and snow cover:
- Fall temperatures correlate to snow sticking.
- Spring temperatures correlate to melting.
- What elevations will see snow vs. rain in these seasons?
*Majority of water supply comes in May and June-and carries through the whole year for Boulder.
*Perhaps earlier runoff would be better suited- 8 week filling time instead of 6 week window- , as long as agricultural diversions do not also divert earlier.
*Lower streamflows might result in increased augmentation of flows for Boulder due to the nature of agriculture releases and operations
*It appears that runoff is a week earlier right now in Silver Lake watershed
*Need to look at increased reservoir space, pipelines to move the water around
*Q: Why would the growing season remain the same if runoff begins earlier? Robin Webb, NOAA
*A: Depends on the crops grown, agriculture management operations. They are observing more temperature changes in the mountains than on the plains.
*Q: What kind of things can scientists do to help water managers talk to their boards?
*A: Examples that other towns are in fact incorporating such information into management operations-Esther Vincent

*A: Break down public barriers: drought is a part of life here! Get used to water restrictions-Carol Ellinghouse
*A: Need reliability criteria concerning the severity of drought for 20, 50, 100 years and what that means in terms of water supply
*Eric Kuhn: If temperatures go up by a few degrees, will consumptive use increase as well? Do we have confidence in our natural flow database? No. There is a lot of uncertainty. Water managers must figure out the risks of incorporating climate change into their planning.
-- (Kevin from C. Springs) Hard to quantify climate change.
-- (Mark W. from Denver) Growth is the biggest problem facing water managers on the Front Range, and it is hard to deal with that and the possible effects of climate change.
-- (Carol E. from Boulder) When they established the reliability criteria, it was easier for the city council to think about risk. But in general it is hard for the city council to think about 50 or 100 years ahead like the water managers have to think.

***Brett Gracely, Colorado Springs:**
*Emission of carbon dioxide is a part of management operations (power generation) - discussions of impacts are not uncomfortable for board members, they want to reduce emissions. Interested in the Rocky mountain climate Organization's Colorado Climate Change Project because they are thinking of building a new power plant in the Arkansas Basin.
*Colorado Springs reservoir and water supply operations are similar to Boulder
*Approached by AWWA with how to incorporate climate forecasts into management operations
*System model used in water management operations does not incorporate physical or geographical data into the system, i.e. climate parameters
*Need to develop some sort of conduit between climate forecasts/streamflow changes and water rights modeling system for their long-term plan.
*Work on stochastical analysis: change in use of historical data
- Current model output has a lot to do with the order of years-steps towards shuffling years around to get an understanding of firm yield.
- Just by changing the order of years resulted in a lot of firm yield variability
- Need to focus on not what is more likely and what different scenarios will do to the water supply

Kevin, Colorado Springs:
*Mitigations: cloud-seeding program for the last four years, interruptible contracts to lease water from Arkansas Valley farmers temporarily
*Utility needs to determine whether they need new storage or new supplies, and what is the best way to deal with the possible futures due to climate change.
*No way to plan for shortages – like Boulder does – because their water supply hydrology is too variable.
*Challenge lies in how to communicate climate change information-end up being translators for information that water managers certainly don't know

*Eric Kuhn: inconclusive data regarding to what degree cloud seeding will help streamflow on the Colorado River. CWCB is concerned about "water robbing" – cloud seeding takes water from places down wind that would otherwise get the precipitation.
Q: Marty Hoerling: Are you considering what warmer temperatures will do to energy demand?
A: Yes-certain financial considerations: How much coal are we going to need? How soon are we going to have to purchase another generator?

Mark Waage, Denver Water
*The new board is more interested in climate change. – hand out –
* DW's new definition of reliability is having water supplies to meet needs in all water years currently modeled by tree ring reconstructions, but by enforcing water use restrictions.
*Interested in using more SNOTEL sites, working with NRCS. Especially interested in getting observations of soil moisture and wind.
*They have a water rights model, but not a good hydrology model.
*Solution is demand management
*Using saved water to supply growth then the system is even more vulnerable and unprepared for climate change. (i.e. demand management is not the answer.)
*EIS for Moffatt System to expand supply is using climate change scenarios.
*Now there is too much emphasis on using more ground water to meet future demands. Pumping consumes too much energy and will just contribute to more emissions and global warming.

Bob Steger, Denver Water
*Currently Denver Water is working with Stratus, Consulting, NOAA, and Colorado Basin River Forecast Center to identify how temperature changes (from 12 GCM outputs) will affect precipitation and streamflows.
*3 Climate Change Scenarios used:
    *Pessimistic scenario: 8 degree F increase, 20% reduction in streamflows
    *Optimistic scenario: 3 degree F increase, 10% reduction in streamflows,
    *Middle of the road scenario
    - handout on scenarios
    - Don't necessarily want to deal with picking which model is best
    - Focus on the streamflow changes out of the climate scenarios
    - Are these scenarios the best ones to use?
    - Marty Hoerling: we can give you guidance on which climate model to use.

*(Side note: NOAA Missouri Basin River Forecast Center is developing a streamflow model to predict runoff in the South Platte River. First step is to get virgin flows, second step is to get flows related to water rights.)
*(Side note: To incorporate yet another element into the NEPA process just further stagnates the process even more)
*(Side note: climate change could contribute to the pine beetle infestation: need a cold snap to kill the bugs. DW is helping finance a study in the Frasier Experimental Forest to measure hydrologic change due to an increase in beetle damage.)

*Q: Nolan Doesken: 2004 summer temps averaged 8 degrees cooler than average summer temps in 2002. What was the difference in water use between those two years?
A: 2002: 220,000 acre feet vs. 2004: 190,000 acre feet. Water use was lover in 2004, but what is the impact of restrictions vs. weather? In 2002, the impact of water use restrictions was not felt until half way through the summer. Since 2002, people are continuing to conserve water in general, both indoor and outdoor. Conservation has to some degree, compensated for growth.
*Q: Nolan Doesken: How does that affect streamflows in the South Platte?
A: In the future, Denver will use more reclaimed water, which will decrease S. Platte flows.

Esther Vincent, Northern Colorado Water Conservation District
*We need to look at the reality of a call on the Upper Colorado River for the Lower Basin.
*The political sentiment is improving: discussions about climate change are not as doom and gloom-working towards something approachable and realistic
*Recommended by Mark for use by Northern Board members: look at AWWA pamphlet regarding climate change
*A lot more information is available and thus is beneficial
*There is increased acceptance of the science that is out there, also beneficial
*Involvement in discussions about how to deal with climate change by more water providers
*Currently Northern is not incorporating climate change into management operations
*Q: What about towns/cities that are within the Northern jurisdiction?
*A: Not really-there isn't this public outcry for it. Frankly it would make things easier if there was-Board members would listen

Alan Ward, Pueblo
*Has a model to look at future scenarios with lower water supplies. These reduce firm yield, but Pueblo will still have adequate supplies because they have "plenty of water" and senior water rights on the Arkansas.
*Model takes past years' hydrologic and precipitation conditions and shuffles various water years around in order to generate an idea of how the city's water supplies would fare.
*Pueblo uses 1965-present time scale for input into drought modeling- this time period lacks multiple periods of sustained drought that are commonly used by other municipalities (For example, 1950-2000 time scale contains drought of 1950's and the drought that began in 1999.)
- Not as a concern: growth is not currently a problem
*Use existing model structure in attempt to mimic climate scenarios
*Marty Hoerling: Current water supplies are just one step above the 2002 drought. That is, because 2002 came at the tail end of a wet period, not as severe snowpack conditions could materialize into very similar water supply scenario reminiscent of 2002 because we start each water year now with reservoirs 50% full.

Name?, City of Thornton
*Haven't really tackled the problem
*Thought about it qualitatively
*Feel as if there isn't data enough to convince Council that they need to do rate increases due to water scarcity
- What is the cost of preparing for climate change? A long term increase in supplies means higher tap fees and/or higher water rates.
- Many of their water rights depend on diverting a lot of water at one time into canals, these are only in priority for a short window of time. Do they need to enlarge the capacity of their canals or enlarge storage facilities or buy more senior water rights?
*Study by Denver could benefit Thornton
*2006: Currently possess 1885 water rights that didn't even come into priority! 5,000-6,000 acre feet loss as a result
*Shouldn't have to "plan on" emergency restrictions-then they are no longer emergency
*If you can't develop Colorado River water, then you need to look to agriculture water
*Need to plan for long-term sustainable agriculture crops
*System yield is based on operating exchanges-
what will climate change do to such exchanges?
Do we need to plan for more water treatment? Structural changes?
*Q: How can you justify water planning for climate change? Tough question for the newer municipalities

Robin Webb: Pressure reducing valves: possibility to gain electricity by creating power as water flows downhill through trans-basin pipelines. (?)
- Will come into play more if carbon caps are initiated that will cause electricity rates to increase

General Discussion
Q: Veva McCaig, CWCB: How many municipalities have drought mitigation plans? (Those to respond to drought shortages) How many of those resulted from 2002 drought? Do any of those plans have triggers set in place to initiate a certain stage of drought planning?
A: C. Springs: Not always helpful to have oversimplified triggers
A: Aurora: Update management plans: 60% thresholds: above-no regulations, 4 levels of restrictions depending on reservoir storage, snowpack levels, etc.
A: Denver: triggers did not "go off" in 2002
A: Boulder: drought plans are helpful, but water managers need the flexibility to institute restrictions as necessary.

CA Energy Commission EPA regarding climate brochure
*Q: Would a pamphlet like this be beneficial for CO? –Brad Udall
*A: Mark Waage: Temperature scenarios would be beneficial
*A: Esther Vincent: Beneficial for customers-referral document
*A: C. Springs: Refer the public to such a document with contact information, scientists, a public information tool

*Q: Does it make sense to meet on a more regular basis –liaison between water managers and NOAA-Brad Udall
*A: Help with gaining more knowledge on the issue
*A: Good way to trade hydrology information
*A: Great for discussion at AGU meetings-often discuss climate change without the background to do so
*Brad Udall: Warming scenarios are fairly decent out to 2025-should lean on those
*Robin Webb: Need consistency in the use of climate scenarios between municipalities. Need for comparable data. Begin to lose people if different towns use different scenarios.
*Brad Udall: 3/8 RISAs are centered on Colorado River. Have RISA's sign a memorandum with CA that sets up a structure with a council, funds, meetings to collaborate and gain support for such an effort