Notes from the Breakout Groups in the Columbine Room, Tuesday

Climate change is perceived to be real and relevant to decisions about water.

Climate-change information is starting to affect thinking and decisions. Water utilities and federal water management agencies have used and are using climate-change information from climate science and climate modeling to explore sensitivities of water systems to climate change. Such information and sensitivity studies, despite major uncertainties, have influenced decision-making, typically in small or indirect ways: e.g., causing adjustments in the relative prioritization of contemplated actions or providing rationalization, at least in part, for an increased factor of safety in design (spillway capacity, coastal bridge height). Considerations of climate change can give an extra push to no-regret actions.

Political and economic forces can slow the process of assimilation of information from climate science into adaptation, mitigation and planning. It takes time and effort to revise or create guidelines and regulations, and climate change must compete with other issues for resources. Conversely, the popular press, public opinion, and political forces have potential to overstate or otherwise distort legitimate concerns. Water professionals should be enabled to meet such distractions (teachable moments?) armed with accurate, timely information.

Old habits die hard. Ability to receive and use climate information can be limited by the nature of existing operations. Generational transitions from intuitive procedures to more

system-oriented methods can be needed to lay the groundwork for incorporation of climate-change information into operations.

Uncertainty. The uncertainty in projections of basic climate variables was cited as a key impediment to the use of climate information in decision-making.

- Uncertainties need to be *reduced*.
- Better *quantification* of uncertainties is needed.
- Improved *confidence* in uncertainty ranges is needed.
- Users and providers of climate-change information need to agree on *language* for expression of uncertainty in all its forms. Such language, not apparent at this meeting, might be helpful in addressing (and measuring progress on) the knotty problem of reducing uncertainty.

A "smoking gun" is not necessary for relevance. Concern was expressed that the more speculative aspects of climate change are not communicated to water managers. Is a small change in mean precipitation possibly going to be experienced in somewhat fewer storms of substantially greater intensity? Such a change may not pass the tests for detection and attribution, but the large risk it represents for storm-water management means that water professionals have a "need to know." Non-detection does not equate to non-existence or irrelevance.

Land-cover change. Forcing of climate change by land-cover change was put forward as a likely underrepresented process (wild card) in climate models. Land-cover change might not account for any significant part of global warming, but its basin-scale signal could rival that of global climate change. Why is this not included in regional and global climate models?

What are the other wild cards that are not of first-order importance for global climate but whose importance should be assessed as attention turns to the smaller spatial scales of impacts and adaptation?

Extremes matter a lot. Much attention is given to central measures (e.g., means) of the climate state. Many water systems can be operated to deal with small to moderate shifts in means. Design is often driven by extreme values, which present the greatest risks. What can climate science say about changes in frequency of extreme events, such as the probable maximum flood? What about multi-year droughts? There is value in information about changes in probability distributions (for long-range planning and design) and in even imperfect predictions of incipient droughts (for medium-range operations). What about temporal variability on shorter time scales, e.g., rainfall intensity?

Flat access to climate-model data. It is not yet easy enough to access climate-model outputs and other results from climate science. One-stop shopping for climate-model outputs and downscaled derivative products is either non-existent or insufficiently advertised.

Breadth of climate-model data. Climate-model products are limited in nature. One can obtain monthly means of precipitation and temperature, but what about min/max daily temperature and other "dimensions" of the data?

Continuing dialogue. This workshop was seen as a valuable way to enhance two-way communication between the participating parties. Climate-information users would like to have their concerns heard by the science agencies. We should continue to have meetings like this one, particularly around a meaningful

focus. Evapotranspiration, the largest and least discussed consumer of water at this workshop, was put forth as one such focus of universal concern to water managers.

Climate Services: Beyond Data

- *Training*. Climate-science consumers need access to rudimentary training (short courses, web courses, etc.) in climate science. What are the capabilities and tools of climate science? What is the current scientific consensus on regional patterns of warming and hydrologic change? What are climate models, and what can they tell us? How does one obtain and use climate-model outputs? How can one judge the suitability of a given model or data set for a given project?
- *Consulting*. Climate-science consumers need access to subject-matter experts who are "on call" for advice about various aspects of climate change.
- *News*. A desire was expressed for continuous updates (with higher frequency, less comprehensiveness, and less filtering than IPCC assessments) on key developments in climate science.
- *Observation*. Modeling is not enough. Systematic monitoring of water (precipitation, runoff, groundwater, soil water), with the temporal stability and spatial consistency, is crucial to improving models and understanding and should be a pillar of any national climate service.
- *Evaluation and interpretation* of observed changes in water is an equally crucial climate service. Many water professionals may be the first to see changes underway in the water environment, but they need access to experts with a broader perspective to put these in the context of climate change, natural variability, and other forcing factors.