Edited Version of Final Report to NOAA HDGCR Program (05/20/04), on COLORADO portion of project, for posting. Utah and New Mexico portions were reported separately to NOAA.

PREFACE ADDED 2008: PLEASE NOTE: This document was written to conform with the requirements for a report to NOAA, and is not substantially altered from that, and it is not a working paper or an article. It is posted in response to inquiries and in support of two articles and other references.

Most users of this information may be more interested in the attachments (see contents below) which are the compilation of results.

Since this was written, the development of recommendations for climate-responsive water management in agricultural-urban partnerships has progressed. Current recommendations are available in other materials on this website. Recommendations made at the time of this report are now partly superseded, since NOAA has made enormous changes in weather and climate information provision, and the research program on climate information applications has been very productive; for examples, see the proceedings of the Climate Prediction Applications Science Workshop meeting (2008 is posted at: <http://www.sercc.com/cpasw_index.htm>; 2007: <http://www.cses.washington.edu/cig/outreach/workshopfiles/cpasw07/agenda.shtml>;
2006: <http://cals.arizona.edu/climate/CPASW2006/CPASW2006_agenda.pdf>;
2005: <http://iri.columbia.edu/outreach/meeting/CPASW2005/Abstract/index.html>
2004: <http://www.coaps.fsu.edu/cpasw/>.

For updated information from NOAA, see:
<www.nws.noaa.gov> and select “climate predictions” for access to many products.

Project Title*: An Exploratory Assessment of Potential for Improved Water Resources Management by Increased Use of Climate Information in Three Western States and Selected Tribes.*

NOAA Grant Numbers: NA97GP0407 (years 1 & 2), NA17RJ1229 (year 3)

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I. Preliminary Materials

A. Project Abstract.

The overall objective of this research has been to find ways to make climate information more useful and more effective in the management of water resources in semi-arid regions. Three states were involved: Colorado, New Mexico and Utah. In Colorado, the study focused on water management in the Arkansas River Basin. In New Mexico, the study focused on the Middle Rio Grande. In Utah, the study focused, in part, on the Upper Colorado River Basin but concentrated on the uses of climate information by Native American Tribes in the management of their water resources. Water administrators from the State Engineer down to local ditch companies plus USDA and State personnel were interviewed concerning (1) current uses and sources of climate information; (2) desired additional climate products and their formats; (3) the timing of climate information needs (the various “decision calendars”; and (4) barriers to more effective use of climate information. The information generated in (1) was fed back to the Climate Diagnostics Center which also responded to the requests in (2) by modifying and adding text to its several climate information/forecast web sites. Many parties interviewed in year 1 were re-interviewed in year 2 to further develop the decision calendars and to elicit further requests. The decision calendar with interpretive comments is appended to this report, as are the summarized requests for climate information and materials used in numerous public and professional presentations.

The third year in Colorado was devoted to investigating how climate information might facilitate “water banking” as a mechanism for more efficient water use, while extensive advice was provided to the Office of the State Engineer and other agencies concerning desirable

features of the water bank legislatively approved for the Arkansas River Basin. Water officials and farmers were interviewed concerning attitudes towards this new institution and, where applicable, reasons for opposition. Third year efforts in Utah involved continued interviews and establishment of “feed-back loops” with their client contacts that included major Native American Reservations, the Utah Division of Water Resources, Salt Lake City Public Utilities and the Upper Colorado River Commission.

Major findings relate to (1) sources of climate/weather information (years 1,2); (2) the development and interpretation of decision calendars (years 1,2); (3) the solicitation of requests for additional climate information and its formatting (years 1,2) ; (4) the needs of Native American Tribal groups for climate information related to agriculture and cultural practices (years 1,2,3); and (5) the development of the Arkansas River “water bank” in Colorado as a new institution to increase the flexibility of water allocation in response to changing climatic conditions.

Regarding (1), sources mentioned multiple times included the Bureau of Reclamation, USGS, NWS, NRCS (snotel data), state water resource divisions, Colorado ag met, commercial radio, television, the weather channel and the data transmission net (DTN internet or satellite). Less frequently mentioned sources included the National Drought Mitigation Center, the River Forecast Centers, USAF/USFS (fire information), and state climatologists. Surprisingly, NOAA Weather Radio was not mentioned. A major issue among users was the need to apply local experience to “calibrate” broader regional data and forecasts to the local situation. Assistance in this process would be highly useful. The drought that culminated in the extremes of 2002 greatly increased interest in and awareness of sources of climate information, especially the national drought monitor and forecasts from CPC. The increasing availability of graphical and interactive information on the internet was seen to be important in increasing the utility of climate/weather information. However, many rural areas suffer from slow internet access.

Regarding (2), the detailed 12 month decision calendar is attached to this summary report. The decision calendar is a balance between brevity and adequate background but it indicates what information is needed and when, hopefully being of use to NOAA in prioritizing climate product development. Similar calendars from other regions and for non-agricultural sectors can provide comparisons of regional similarities and differences and help set sectoral priorities.

Regarding (3), information requests centered on 7 classes of information: (a) better warnings of “surprise” events such as Spring snow storms and flash floods; (b) the need for clearer definitions and expressions of the “reliability” of data and forecasts; (c) the practical utility of “now *versus* last year *versus* normal” formats of information; (d) commonly recurring weather patterns and storm tracks; (e) the need for quickly learned procedures for “calibrating” larger scale forecasts and warnings to local areas; (f) better fire-related information; and (g) the importance of current and future soil moisture and humidity information.

Regarding (4), Tribal climate information needs, it is noted that different groups have vastly different levels of technical expertise in agriculture and water management. As a result, priorities for climate information will be different. Drought forecasts and on-going drought information will always be a high priority.

Regarding (5) for Colorado agriculture, the administrative difficulties of shifting water supplies around among ditch companies and conservancy districts has historically reduced the utility of weather and climate information. In the year 2000, the Colorado legislature authorized the establishment of the Arkansas River Water Bank as an experiment. This authorized rather quick, temporary shifts of water among ditches and towns rather than going through a long court-related process. This implies a greater value of climate forecasts so that water can be shifted to the points of greatest short-run value with payment going to the lessor. The Three States Project advised the State Engineer in designing operating regulations for the water bank, in particular keeping the regulations flexible so that different procedures could be tried over time. Interviews with all potentially interested parties provided information on both positive and negative reactions to this new institution. As of this date, no transactions on this electronic bulletin board have occurred in spite of high promise from a theoretical point of view. Causes appear to be that potential traders don't know what level of price to ask or offer and that many potential traders are not familiar with the internet. The Project is continuing its surveillance of this evolving situation.

B. Objectives of the Project.

As noted above, the primary purposes of the project were (years 1 & 2) to determine what uses were being made of weather/climate information by water administrators at all levels in the states of Colorado, New Mexico and Utah and several Native American Tribes, what sources were being tapped, and what needs for new information, new formatting and the timing of information were being expressed. In addition, barriers to the more effective use of climate information were identified, including difficulties in shifting water around among users as climatic conditions changed. This led to the focus of year 3 in Colorado in helping to design the water bank for the Arkansas River so that water administration could be more responsive to climate variability.

C. Approach.

This project examined current and potential uses of climate information in water management in Colorado, Utah, and New Mexico, and in selected Tribes. The research team included three water resources economists with extensive experience in applications and policy in Colorado and New Mexico (Howe, Brookshire and Garcia), a political scientist with experience in Native American and Utah water rights and management issues (McCool), a geographer and attorney and an historian of Native Americans (Smoak) and an anthropologist with extensive experience in the Colorado study area (consultant Weber). An initial hypothesis that different historic and cultural influences would affect concern with climate information applications was rejected. Management institutions, technologies, financial capacity and expertise available for applications appear far more important than cultural differences. We therefore concentrated on current and potential uses of climate information. Focus was on compiling and verifying an annual calendar of decisions which are made on a recurring basis (following traditional ethnography). This narrows requests and identifies times when information is most useful. NOAA collaborators (CDC) provided a website and responded to requests for more textual explanation of available climate information. A second round of interviews focused on the changes in uses of climate information that had occurred since the first interviews and that might have been encouraged by the website changes.

In New Mexico, the team similarly surveyed water users and managers in the Middle Rio Grande. The State and Federal agencies in that basin were found to have extensive experience in the use of climate information. Collaboration with the Pueblos of the region was planned but complicated federal-pueblo-state-municipal-private litigation precluded the completion of that activity. Professor Brookshire has submitted a final report separately that elaborates on their approaches and findings.

In Utah, Professor McCool and Dr. Smoak interviewed local government officials in the Wasatch Front, and several water agencies and districts, and they interview officials from Tribes in Utah and Arizona as well; they reported on this separately to NOAA.

In Colorado, we interviewed the hierarchy of water management in the Arkansas River Valley, from federal and state agencies to ditch companies and irrigators as well as agricultural support persons from USDA and the USDA-Colorado State University Agricultural Extension. Cultivation of extended contact has provided excellent working relationships, and we have been very fortunate to have generous assistance from a group of water experts in the Arkansas Basin as an informal advisory committee.

The third year in Colorado was devoted to supporting use of climate information as a key element of making the Arkansas River Water Bank Pilot Program successful. We believe the water bank with resultant increased flexibility in water management is necessary, though not sufficient, for maximum use of climate information in water management.

D. Description of matching funds used.

No matching funds in the usual sense were provided but the project has received significant support from USDA and CSU personnel in Colorado, not to mention all the interviewees. The advisory group in the Arkansas Valley met several times for most of a day to review the decision calendar and discuss issues of climate information application. The Utah investigators were generously welcomed by Tribal and Pueblo officials in Colorado, Arizona, and New Mexico. The New Mexico team received extensive support from state and federal agencies.

II. Interactions

A. Interactions with decision-makers either impacted or consulted; list; nature of interaction; collaborating local institutions.

The New Mexico interactions consisted of one or two interviews with the agencies listed in their report. The Utah interactions consisted of one or two interviews with the agencies listed in the previous reports, following appropriate protocol and formal permission for research used with all Tribes, Contact was maintained with Tribes, and discussions continued. In Colorado there were interviews with many water officials and users. Interviews, re-interviews, and follow-up questions were undertaken on roughly 90 occasions. The list of interviewees is presented as an appendix to this report.

Co-PI Wiener attended many professional and administrative meetings including the Colorado Water Congress (three times) and the Arkansas River Basin Water Forum (four times). Howe conferred with members of the advisory group and met with a member of the Rocky Ford School Board, who is also the District Conservationist for the NRCS in La Junta, and who has enthusiastically helped in our advisory group. In May 2002, we had a meeting of our informal advisory group, the Otero County Director of Agricultural Extension, and the District Conservationist. We participated in written and oral testimony in the hearings on the final water bank regulations.

B. Interactions with climate forecasting community.

Presentations of findings to date were made to the Climate Diagnostics Meeting in October 2000, and the methods were presented at the American Meteorological Society meeting January 2002 (extended abstracts attached). In November 2000, a major review of Year 1 was held in Boulder to which several NOAA persons from Washington came, including OGP, NWS and OAR representatives. We presented a description of the water bank at the Mississippi River Climate and Hydrology Conference, in May 2002; a description of the social and political issues at the Climate Prediction Assessment Workshop in Alexandria, October 2002; a discussion of barriers and constraints to use of new applications at the NOAA HD PIs meeting, October 2002. In 2003, we presented applications experience and problems at the American Meteorological Society meeting, discussing use of water banking as a drought response. In 2004, we presented findings on social processes in climate applications in water management at the American Meteorological Society, and also made an oral presentation to the Users Conference at the AMS on Needs and Desires for Climate and Weather Information for Small Agriculture. We elaborated further on "learning from and about cooperative extension services" in the proposal, organization, moderation, and write-up of the topic for the Climate Prediction Application Science Workshop in March 2004.

C. Coordination with other projects of NOAA Climate and Social Interactions Division.

The project has been loosely associated with the RISA "Western Water Assessment" project at CIRES/CU/NOAA CDC, by virtue of involvement of Howe and Wiener. We have also been very pleased to observe the convergence of positions and working conclusions between our project and the CLIMAS RISA project, the Southeastern Climate Consortium RISA Project, and the California Applications Project. We also met in 2000 with several water investigators whom we encountered at the PI meeting in 1999 in Tucson and met with many again at the 2002 PI meeting. In the early stages of our project, we shared question sets with several other teams, and have most recently been in touch with Dr. Mark Meo, at the University of Oklahoma.

III. Accomplishments.

A. Brief discussion of research tasks accomplished (data, models, fieldwork).

The research proposal sought to identify the most culturally-diverse water users we could hope to work with in the West, and the hypothesis for that part of the work was that these historical and cultural differences would influence the willingness to accept new climate information, and would influence the forms or means of information preferred. We found those expectations to be false, however true they might have been in the past. Now, differences in interest and capacity to use information are much more related to individual interest, and technical capacity, and institutional constraints on response.

In terms of this reporting format, we performed over 90 interviews, re-interviews, and follow-up inquiries, and several relationships were established which involved continuing contact in response to events, ideas, and opportunities. In the case of the rule-making for the Arkansas River Water Bank Pilot Program, numerous e-mails, phone calls, and visits were involved as well as formal comments and testimony at hearings. NOAA work with Tribes is also on-going, handed off by this group. Most of the interviews involved use of a questionnaire format at first, with follow-on as interest dictated, and showing of an illustrative package of information tailored for the interviewee from NOAA and associated materials. This alone seems to have been of value to many interviewees, particularly in the private sector, who had never known such information was available.

In the Tribal cases, there was no apparent technical capacity constraint, but there were serious data gaps and monitoring gaps that call for serious response, as the Utah team reports establish. These gaps were communicated directly to NOAA collaborators, led by Dr. Andrea Ray at the Climate Diagnostics Center.

In the local government cases there were clearly opportunities to improve use of information by increasing capacity to respond. Equipment and personnel scheduling issues are relatively well-known from the politically sharp issues of snow-plowing apply to other maintenance issues, and to flood hazard responses. The interviewing stimulated interest, though fiscal conditions have inhibited increasing capacity. Increased interest in better weather and climate information applications was very wide-spread after exposure to the information already available.

The drought has dominated concern for the last years, so climate has taken a much larger place on the various agendas in water management at all scales. Interest in increased flexibility in water management has been stimulated in state legislatures as well as in the cities and private sector, so out-reach with available materials was appreciated and timely.

Small agriculture in a marginal area, the lower Arkansas Valley, was a particular focus of the project before the drought, to follow the hierarchy of management from major federal and state agencies to individual irrigators. We established that there were severe limitations from water law and local institutions inhibiting response to potential uses of climate information. The ability to move water quickly and at low cost was very limited, and existing theory on "water banks" had not been implemented in Colorado (NRC 1992, MacDonnell, Howe and Miller 1994; Easter et al. 1998). We found that three potential areas of application of climate information could help small farmers and ranchers. First, long-term "dry-year options" or interruptible supply contracts are very attractive in theory, and have been endorsed by cities, all Colorado counties (See "Colorado 64 Principles of Water Management") and yet have not been fully enabled due to political concerns and fears of additional out-of-basin water transfers. Second, we found substantial opportunity for better pre-season planning for agriculture; this has also been found in RISA work in CLIMAS, SECC, and CAP. In Colorado, however, transferability of water was inhibited, limiting response capacity. Third, we found some interest for in-season re-allocation of water, which was also impractical under Colorado law before the drought stimulated some changes.

Several bills were introduced in the 2000 and 2001 Colorado legislatures concerning water marketing and water banking, in response to pressure from concern over stress on farms and ranches and the significant secondary economic impacts on areas from which water has been permanently transferred (Governor's Commission on Saving Farms and Ranches, report, 2000, Office of the Governor of Colorado, on-line; Howe and Goemans 2002, December issue of Colorado Water, on-line, and Howe and Goemans 2003, JAWRA.) We commented on several bills, with legislative drafting office staff, and subsequently engaged in continuing contact with State Engineer and Attorney General staff drafting the rules implementing HB01- 1354, which authorized the Arkansas River Basin Water Bank Pilot Project. This discussion contributed to establishing the capacity for groups of individuals or ditches to assemble larger volumes for transfer than any might have wished to offer alone; the capacity to use the water bank for climate-informed dry-year option contracts (though limited by the duration of the water bank authorization); and some additional minor features.

We also interviewed potential users of the water bank, agricultural lenders, and potential objectors, to understand their perceptions of the potential and politics of the water bank. This work continues, but during the period of the research here reported, we believe our work was useful in exposing concerns, discovering some answers, and in informal settings, helping proponents and opponents encounter each other in a constructive situation; in this, we were greatly supported by USDA and Cooperative Extension officials and use of their facilities. Assisting establishment of discussion is an important accomplishment, though the end of the story is some years off.

In regard to the "shopping lists" distilled from the interviews, NOAA has faced fiscal constraints on its abilities to respond to requests, but the RISA projects, have made substantial progress in responses. Several were represented at our 2000 meeting, and we have been corresponding with them, most recently at the Climate Prediction Applications Science Workshop, March 2004. Currently, CLIMAS and the Southeast Climate Consortium groups are working on similar lines, and we hope our inquiries have helped. The most obvious parallel is probably the focus on three areas of climate information applications in agriculture (pre-season planning, in-season re-allocation of resources, and long-term planning), which we elaborated in work on the Arkansas Valley Water Bank Pilot Project (see attached "Powerpoint 97 TM" presentation. Similar findings about linkage to irrigation scheduling tools and management flexibility have been reached, and there is also a project in Nebraska addressing this (Dr. Steven Hu et al.)

B. Summary of preliminary findings (how research advances scientific understanding)

Three summaries of research are attached to this report: (1) sources of weather and climate information used by interviewees in 1999-2000; we fervently hope and in some cases know that there has been a significant increase in the variety of sources of information used, and the intensity of interest in climate information. Although our project contributed to interest and use among those we contacted, we cannot take credit for the drought which afflicted the study areas starting in 1999, and has continued through 2004. In response to that, and especially the extremely severe conditions of 2002, the interest in the National Drought Monitor and interpretations has shot up, and in turn there is much more public interest in the climate forecasts from CPC and their interpretations in the media. The political scientist in the project, Dr. Dan McCool, urged attention to constituency development in the November 2000 meeting, but he does not take credit for accomplishing the purpose in this fashion. The most important finding from this part of the research was that there was no dominance of the field, by NOAA or anyone, though in commercial services, DTN was most popular in rural areas because of its availability by satellite transmission rather than internet. Internet, particularly in current highly-graphic and highly-interactive forms, is very difficult over old low-quality telephone wiring; this has important implications for provision of service to rural areas. It may be valuable to repeat the inquiry and see if NOAA's actual centrality in data acquisition and processing and forecasting is now better appreciated by the variety of users.

The second summary, the decision calendar, is informative in several ways. It distills a great deal of inquiry into what climate information users would like, and when, so that information providers can better appreciate users' needs in the cases examined. In the central case study, Colorado's Arkansas Valley, we had the benefit of careful review of the calendar several times by an informal advisory committee, and we thank them for their help. The calendar notes for the other areas are in most cases also verified by the Utah and New Mexico teams. Comparison makes an important point about the geographic and sectoral specificity of climate-related decision-making. Some of the requests would seem to be fairly easily met, given current technology and awareness of interest. Transhumance and pasture allocation obviously calls for information about several places, not just the user's location, and this was aggravated during the recent and on-going drought. The value of forecasts for other areas, including agricultural competitor areas is substantial. This is especially important for marginal agricultural areas, and for marginal operations such as smaller farms and firms that are facing vertically-integrated competition and gigantic agri-business firms with very capable technical services on hand, including weather and climate information interpretation. We call attention to the apparently high cost-effectiveness of this approach (Wiener 2002). Forecast effort allocation might be informed by better understanding of the overlaps and areas of common concern, especially where there is interest in improving service. The timing of forecasts is also important in their usefulness; in particular, allocations of expense must be made in December, for tax management, which makes forecasts then potentially more valuable than somewhat more accurate forecasts in the following year. Similarly, leasing of land and water commitments may be made well ahead of water availability forecasts, which increases the value of information about current and future range and soil conditions and forecasts.

The third summary, the "shopping lists", provides distillation of the requests most often made, with information about the uses and reasons for the request. We hope the distinction between near-term versus long-term is useful, but we caution that our judgment may not be correct on this, and hope that readers will consider both lists. Both the calendar and the shopping lists evolved over time, as our interviewees and advisors had time and opportunity to think over the applications and consider them. The purpose of this compilation is to provide feedback to NOAA and others about the requests we received. For example, flash-flood threats in rural areas are a concern beyond fear for life safety, for instance, and that warning information dissemination is still a concern although development after this research may have helped that.

The "shopping lists" of requests include substantial overlaps in two areas. One is in extreme events at unexpected times; a blizzard in January is within expectations, and a wet blizzard in March is also within expectations, but a heavy snowfall with a sharp drop in temperatures in October is dangerous because even an experienced local resident would not expect it. The "threats" to each activity are often the unexpected events, in shoulder seasons, and this suggests that the "now versus last year versus normal" form of reporting is especially useful for weather- and climate-sensitive activities.

The widespread requests for help in applying what is available already to the users' own locations, which we loosely term "calibration", is a strong call for a complement to the downscaling impetus motivated more scientifically. We were often told that "we have to adjust" the forecasts for weather and later, for climate, because "we're six hours after that, if it's coming from the South", and so forth. Seriously adverse surprise results when expected adjustments are incorrect, even if the forecast for an urban area was more helpful. Working from what most people perceive as "weather patterns", NOAA was asked to help with validation of those patterns, identification of when they seem to be in place and when not, and how to use them or their absence in applying information to rural areas. Requests included identification of commonly recurring weather patterns and storm tracks, to help with prediction of arrival time of frontal events, and better use and availability of archives of radar images.

The second area of substantial overlap concerns the demand for soil moisture, in forecasts if possible, and in extrapolation in the near and mid-term as well. Uses range from forage and grazing management, at all time scales, to fire management and prescribed burn timing. As the fuel loads accumulate in the West, with drought slowing the ability to undertake managed burns, and the political pressures stalemate management, we expect that soil moisture information and forecasting will only increase in importance. The current efforts to answer this call seem to be limited to very modest networks of monitoring, and efforts devoted to downscaling from global circulation models to regional models and smaller grids. The gap between the top-down modeling and place-specific application is very large, for these purposes. Regionally, the climate impacts may be adequately addressed for modeling at scales considerably greater than those needed for resource management.

The value of improved soil moisture information is also clear, for range and farm management purposes, as well as surface conditions. The technical problems of surface windiness and ET forecasts and estimation were often mentioned, with interest in improved forecasts as well as monitoring. Related to this, many people mentioned the farm management value of relative humidity forecasting, for baling hay; this is a critical part of farm income in many operations and it varies by a factor of 3 or 4 depending on the weather between cutting and stacking. We hope the shopping lists will stimulate interest in several such problems reported.

The description of this project as if it were a laboratory experiment or the typical manipulation of a data set would misleadingly imply intent to follow a prescription closely. Part of what we intended was defeated by inability to provide the desired improved climate information products for evaluation in a second round of interviews. But, part of what we intended was to follow the lessons learned in a variety of disciplines: to listen with sincere interest in helping users rather than ourselves. We suggest that the users' own evolution of interest and potential applications even without re-design of products was a valuable finding. In accord with other understandings, we find this supports the notion of "co-evolution" of products as more than market research on which forms are most attractive; (NRC Vision of Climate Services; 2001, Stern and Easterling 1999).

In this, the Utah team has achieved significant progress in building relationships with Tribal governments which may enable NOAA to provide needed service to an underserved group of citizens. In the Tribal cases, drought management may succeed in reducing impacts and impoverishment, as well as reducing frustration of other plans. The reduction of vulnerability to recurrent hazards may be critical to promotion of well-being, accumulation of all kinds of capital for improved resource management, and development. NOAA assistance there is eagerly sought, especially where highly-trained staff (e.g. the Zuni and Navajo administration and agencies, or the Ute Mountain Ute Farm and Ranch Enterprise management) face historical data deficits due to under-service of all kinds.

In Colorado, our persistence has made it possible to influence the rule-making for the Water Bank Pilot Project in ways that make it possible to apply climate forecast information with better results than without these efforts. And, in turn, this may lead to improved agricultural well-being, reduced municipal water supply costs, and salinity reduction. The progress in these areas would not have been possible without the earlier work and listening on the subjects of current and desired uses of climate information, and water management issues for the people who helped us. We feel that this is well within the user-centric vision of climate services recommended by the National Research Council's Vision for Climate Services (2001).

We add that the often-discussed topic of demand for reliability may be overstated, in at least some cases. The sophistication of the risk management undertaken by all participants in agriculture is not diminished by the lack of technical vocabulary employed; in fact, scientific agronomy instantly provides such a vocabulary if it is needed. The methods employed in farming are almost always underestimated. No one has insisted on an unreasonable level of perfection or reliability in forecasts. When pressed, informants said several times that 80 percent reliability would be great, and also that the important thing for them is to have enough understanding of what the forecast means, where it comes from, and how to interpret the probabilistic information. This is, in our view, a communication problem, not a capacity problem. The informal optimization problems confronted in farming are in no apparent way simpler or easier than the problems of climate forecasting, and in fact may be a qualitative degree worse because of the human elements involved in market behavior.

C. Papers and presentations from project (Also see above, under "interactions") (As of May 2004; later presentations are listed elsewhere).

Howe, Charles W. and Christopher Goemans, 2003, “Water Transfers and Their Impacts: Lessons from Three Colorado Water Markets”, Journal of the American Water Resources Association, Vol. 39, No. 5 October

Howe, C.W., Statement for Panel on Water Banking, Arkansas River Basin Water Forum, March 2003, organized by Wiener at request of Forum Committee; published as written by Ag Journal (La Junta, CO), and Pueblo Chieftain, Pueblo, CO.

Howe, Chuck and Chris Goemans, 2002, “Effectiveness of Water Rate Increases Following Water Restrictions”, Journal of the American Water Works Association, October.

Howe, Charles W., 2000, “Protecting Public Values in a Water Market Setting: Improving Water Markets to Increase Economic Efficiency and Equity”, University of Denver Water Law Review, Spring.

Formal presentations by John Wiener: [Note: presentations and publications after April 2004 are listed elsewhere]
2004 Organizer, moderator, reporter of Roundtable Discussion, "Learning From and About Cooperative Extension Services", Climate Prediction Applications Science Workshop, Tallahassee.

2004 Presentation at American Meteorological Society Annual Meeting, "Small agriculture needs and desires for weather and climate information in a case study in Colorado", Seattle. (Extended abstract available electronically and from AMS.)

2004 Poster presentation, at American Meteorological Society Annual Meeting, "Moving Water from Theory and Farms: The Colorado Water Bank Experiment", Seattle. (Extended abstract available electronically and from AMS.)

2003 Presentation "Water Bank and Ditch Interests", to Grand Valley Irrigation Company Board of Directors, Grand Junction, CO.

2003 Presentation at Colorado Section, American Water Resources Association, Annual Meeting, "Moving Water in Drought and the Arkansas Water Bank Pilot Program So Far – Observations from an Outsider", Golden, CO

2003 Presentation and panel organization, "Water Banking and Interruptible Supply Contracts", Arkansas River Basin Water Forum, Pueblo, CO

2003 Presentation at Ditch and Reservoir Company Alliance First Annual Convention, Durango, CO, "The Colorado Experiment in Water Banking: Informal Review for DARCA" (available electronically and from DARCA website)

2003 Presentation at American Meteorological Society Annual Meeting, "Water banking as adaptation to climate variability: the Colorado experiment". Long Beach (Extended abstract available electronically and from AMS.)

2002 Presentation at Climate Prediction Assessments Workshop, Alexandria, VA: "If this is so simple, why is it such a mess? Climate Forecast Applications, Irrigation and Water Banking in Colorado" (Extended abstract available electronically)

2002 Presentation and panel moderator at Principal Investigators' Meeting, Office of Global Programs Economics and Human Dimensions Program, Seabrook SC, "Constraints and stumbling blocks in use of climate information" (abstract available electronically)

2002 Presentation at Natural Resources Law Center, U. of Colorado, Conference on Allocating Water for a Sustainable Future: Lessons from Around the World, "Destroying (by not integrating) Culture and Environment – The Legal Implications of the Common Property Movement And some Notes on the Ditches of Colorado" (available electronically and from Natural Resources Law Center).

2002 Presentation at American Meteorological Society et al. Mississippi River Climate and Hydrology Conference, New Orleans, May, "Moving Water: Water Banks, Forecasts, and Obstacles." (Extended abstract available electronically on request).

2002 Presentation at American Meteorological Society Annual Meeting, Orlando, January, "A Simple Approach to Increasing Usefulness of Forecasts". Orlando. (Extended abstract available electronically and from AMS.)

2001 Poster at American Meteorological Society Annual Meeting, Albuquerque, January. (With Ray and Webb, see Western Water Assessment website, cires.colorado.edu/wwa/)

2000 Presentation to 25th Annual Workshop on Climate Diagnostics, report on "Three States" project, International Research Institute, Lamont-Doherty Earth Observatory, Palisade, NY., October (extended abstract in proceedings volume; available electronically on request).

D. Discussion of significant deviations from proposed work plan (e.g. delayed fieldwork due to late arrival of funds)

Fieldwork (interviewing) was delayed by late arrival of funding, but university financing allowed most plans to proceed. Effective support of the water bank program in Colorado has required far greater time than anticipated or funded.

IV. Relevance to the field of human-environment interactions

A. How results are furthering the field of understanding and analyzing use of climate information in decision-making:

The identification of what information would be useful at what time is fundamental (Stern and Easterling, Making Climate Forecasts Matter, NRC 1999). The process starts with identification of what decisions are made, and what actions or responses are possible. Then, the question is whether institutions (human values, norms, rules, legal structures, practices, etc) prevent making better decisions. Our work on the decision calendars and the method of developing one has provided a simple means of basic intelligence gathering.

B. Where appropriate, how research builds on previously funded HDGEC research.

The study was begun with Roger Pulwarty, whose previous work included study of the use and non-use of climate information in the Pacific Northwest, and later, application of climate information in the Grand Canyon adaptive management program. Helen Ingram, Denise Lach, and Steve Rayner were also working on adoption of climate information in small water systems in the Northwest, and their work was somewhat paralleled in the Yarnal, Cutter, and Dow et al. study in Pennsylvania and South Carolina, to name another set of studies. On the whole, the NOAA OGP Human Dimensions, and in particular, Economics and Human Dimensions programs have worked to provide some coherence and to promote interactions. This study was about "second generation", and among the first to elaborate the traditional ethnographic tool of the decision calendar as an explicit subject of inquiry. This has become popular in many studies. Our work also helped support the efforts of the CLIMAS group, in showing the need for the kind of work underway there in helping people achieve understanding of available information, and making some "customized" products available.

C. How is your project explicitly contributing to the following areas of study?

1. Adaptation to long-term climate change.

Adaptation to long-term climate change will involve many of the choices applicable to adaptation to other stresses, including increased competition for water supply, and decreased or variable supply available to any given sector. U.S. Western water is increasingly troublesome (see Western Water Policy Review Advisory Commission, 1998; Department of the Interior and Department of Agriculture, "Water 2025 Initiative"). This work helped identify climate and weather information needs and desires for the users of 80 to 90 percent of the water in the West, upon whom the greatest burdens of change will fall. Drought may not last, and it may not foreshadow long-term "normals" of the future, but responding to it now is critical, and increasing flexibility in water management is helpful for that. The New Mexico team helped compile requests and desires, as confirmation and complement to the development in the Middle Rio Grande of the "ET Toolbox" and other management improvements. The Utah team, with Dr. Ray of NOAA CDC, helped improve access to NOAA assistance in drought management and climatology. And in Colorado, refinement of the requests into applications that could be achieved with institutional modification was paralleled by assurance that new institutions would facilitate the use of the new information, though much remains to be done.

2. Natural hazards mitigation.

The most valuable contribution here is probably the emphasis from the Wasatch Front municipal and County governments and the irrigation ditches in Colorado on the vulnerability of water management to flash flood hazards, and the value of improved information on threats. The second contribution may be calling attention to the value of improved warnings about shoulder season and unusual conditions affecting agriculture. The line distinguishing hazard from unfortunate weather is seldom clear, but you know when you've crossed way past it, and the sensitivity of rural people may well have been underestimated. We also suggest that there could be useful applications in insurance and risk mitigation practices from improved hazard monitoring and localization in rural areas, with better coverage of events.

3. Institutional dimensions of global change.

Water management is marvelously complicated and may offer the paradigm of institutional dimensions of resource management under change. This study is helpful in clarifying use of a handy tool for inquiry (the decision calendar), and with the follow-on study in progress, may show a progression from inquiry to improved application to refinement and adoption. The apparently simple finding that the social aspects of adoption of innovations can override technical achievement is not one to overlook.

4. Economic value of climate forecasts.

Although this study did not do valuation of the applications requested, we call attention to the breadth of the applications, and that re-interviews often showed changes in interest and desires for application. Realization of the value of forecasts depends in many cases on institutional change and user adjustments in practice to accommodate response to the information. The interest we have seen indicates wide-spread hope for better realization.

5. Developing tools for decision-makers and end-users.

Decision calendars and shopping lists are inexpensive tools to both build constituency interest and to inform information product development. Without entering debate on what is properly public and what properly private in the provision of climate services, we feel it important that there are very large inequities in information interpretation, to the disadvantage of small farming and ranching operations in competition with highly technical agri-businesses. If supplied with calendars and requests, potential users can better determine the extent of interest in a given kind of information, and providers can better determine the allocation of their capacities.

6. Sustainability of vulnerable areas and/or people.

Tribal areas in the Western US are socially and environmentally often among the most vulnerable of all. Small farming and ranching are also economically vulnerable, and that creates vulnerability in the rural economies that depend on them (Howe's work demonstrates this especially well).

7. Matching new scientific information with local/indigenous knowledge.

This is to some extent going on within Tribes, but in the study areas it is taking place only to the extent that farmers wish it were easier to apply forecasts to their local conditions.

8. The role of public policy in the use of climate information.

The inability to respond to climate information under traditional water law in the West has been often noted, and we are very pleased to be eroding that problem.

9. Socioeconomic impacts of decadal climate variability.

Not addressed in particular.

10. Other (e.g. gender issues, ways of communicating uncertain information)

There is a similarity between social justice concepts and the problems of information access inequity and allocation of services in rural areas. One person joked, "Why do they bother with weather forecasts for cities? They all drive everywhere every day no matter what. It only matters to us out here, and to people in airports."

V. Attachments to Format-Specified Report on "Exploratory Assessment of Potential for Improved Water Management Through Increased Use of Climate Information in Three Western States and Selected Tribes"

1. List of abbreviations
2. Sources of Weather and Climate Information Used at Time of Beginning of Project (1999-2000 interviewing)
3. Decision Calendar – Mainly Colorado Case Study with Comparative Notes from Utes, Middle Rio Grande, and others
4. "Shopping List" of Requests for Weather and Climate Information Improvements, near-term
5. "Shopping List" of Requests for Weather and Climate Information, longer-term
6. Potential applications of climate and weather information with a water bank
7. Tribal Contact Protocol

1. List of interviewees, and abbreviations used in tables.

ABQ is City of Albuquerque, Conservation Office
ACEJM is U.S. Army Corps of Engineers, John Martin Dam and Reservoir, Hasty, Colorado
ACENM is U.S. Army Corps of Engineers, Albuquerque District
AM is Alfred Muth, Farmer and Seed Dealer south of Rocky Ford
ARGH is Alliance for Rio Grande Heritage
AVP is Arkansas Valley Range Project , Mr. Gerald Knapp and later also Mr. Tom Simpson
BA is Mr. Bob Appel, Projects Coordinator for Southeastern Colorado, USDA RC&D. We asked him to act as an "expert farmer" (and he is in fact a successful farmer in the Valley).
BH is Mr. Bill Hancock, Otero County Director, CSU Cooperative AG. Extension Service, Rocky Ford
BHman is Mr. Bert Hartman, Bessemer Canal, and former officer, Cattlemen's Association, Avon
BIA is Mr. Preston Fisher, P.E., Supervisory Engineer, Southern Ute Agency, and Mr. Gerry George, Fire Management Officer
BORCR is Bureau of Reclamation Colorado River Regional Office
BORNM is Bureau of Reclamation New Mexico District
BORPC is Bureau of Reclamation, Pueblo, Colorado, and Mr. Tom Musgrove
BS is Mr. Bill Stanton, Chief of the Conservation Planning Section, Colorado Water Conservation Board, Department of Natural Resources, State of Colorado
CC is Catlin Canal Co., Mr. Wayne Whittaker, Secretary
CH is Chuck Hanagan of the Farm Service Agency, USDA, Rocky Ford, or his associate, Ms. Christine Crump, Program Technician
CPIA is Central Plains Irrigation Association (annual meetings, about 20 papers each year)
CSERG is Colorado State Engineer, Department of Natural Resources, Division of Water Resources, Division 3, Mr. Scott Vandiver.
CUWCD is Central Utah Water Conservancy District, Mr. Richard Tullis, P.E., O&M Manager, Orem, Utah
D2 is Colorado State Engineer, Department of Natural Resources, Division of Water Resources, Division 2, Dr. Tom Ley, Hydrologist
DH is Mr. Don Hansen, Holbrook Canal, Cheraw
DCPW is Davis County Public Works Department

DF is Mr. Dave Findley, Farmer and Seed Dealer, Las Animas
DH is Mr. Dan Henrichs, Superintendent of the Rocky Ford Highline Canal (not to be confused with the Rocky Ford Ditch, a different enterprise)
FL is Fort Lyon Canal Co., Mr. Manny Torrez, Superintendent
FM is Mr. Frank McSwan, Farm Manager for Findley Enterprises, and retired feedlot operator, Las Animas
FWSNM is U.S. Fish and Wildlife Service, of U.S. Department of the Interior, New Mexico office.
JD is Ms. Julia Davis, Assistant to Operations Manager, John Martin Dam and Reservoir, U.S. Army Corps of Engineers, Hasty, Colorado.
JV is Mr. Jim Valliant, CSU Cooperative Ag. Extension Service Irrigation Specialist, Rocky Ford
LS is Dr. Lorenz Sutherland, Natural Resources Conservation Service La Junta Office
MO is Mr. Michael Olguin, Director, Department of Natural Resources, Southern Ute Indian Tribe.
MRGCD is Middle Rio Grande Conservancy District
NAV is Navajo Nation
NMISC is New Mexico Interstate Stream Commission
PC is Pueblo Chieftain, the dominant newspaper in the South of Colorado.
PRIID is Pine River Indian Irrigation District (Southern Ute and neighbors' lands).
RF is Rocky Ford Ditch Co., Mr. Ron Aschermann, Secretary
SC is Mr. Scott Cotton, CSU Cooperative Ag. Extension Service Range Specialist, Pueblo.
SE is Southeast Colorado Water Conservancy District, Mr. Tom Simpson, Mr. Bob Hamilton.
SLC is Salt Lake City Public Works Department
SM is Mr. Stephen Miller, P.E., Senior Water Resources Specialist, Colorado Water Conservation Board, Department of Natural Resources, State of Colorado.
SR is Mr. Scott Reed, Principal Agricultural Lending Officer, Valley State Bank, Lamar
SS is Mr. Steve Sherlock, Vice-President, Colorado East Bank, Lamar
SU is Southern Ute Indian Tribe, Mr. Jim Formea, Division Head, Division of Water Resources, Department of Natural Resources.
TF is Dr. Terrence Fulp, Bureau of Reclamation, Boulder, CO.
TS is Dr. Tim Steffens, CSU Cooperative Ag. Extension Service Range Specialist, Rocky Ford.
UCRC is Upper Colorado River Commission
UMU is Ute Mountain Ute Farm & Ranch Enterprise, General Manager, and agricultural management consultant.
UTDWR is Utah Division of Water Resources
ZUNI is Pueblo of Zuni

2. Sources of weather and climate information used at beginning of project

The following table indicates which sources of weather and climate information were mentioned by interviewees in 1999 and 2000. These were sources volunteered without prompting in Colorado, and Utah; the New Mexico interview process was somewhat different.

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Sources mentioned 3 or more times only

USERS OF INFORMATION → / SOURCE OF CLIMATE INFORMATION	Tribes and Pueblos	Federal Agencies (district or state office)	State Agency	City or County Agency	Co-operative Agricultural extension	Conservancy Districts	Ditch and Canal Companies	Individual Farmers	Other users
Bureau of Reclamation	NAV, UMU	UCORC FWSNM	NMISC			SEWCD Dolores WCD			
USGS streamflow	NAV SUBIA	ACENM BORNM BORPC		SLC DCPW	CSU	MRGCD CUWCD	FL		
NOAA (all except as noted elsewhere)	SUBIA	BORNM	NMISC CSERG?	SLC			CC		AR-GH
NWS	NAV ZUNI SUBIA	ACENM FWSNM		DCPW		MRGCD			
NRCS (SNOTEL)	SUBIA UMU	ACENM ACEJM FWSNM	CSERG CWCB UTDWR	SLC DCPW AVP		MRGCD SEWCD CUWCD	CC RF		
RIVER FORECAST CENTERS		U CORC BORNM ACENM BORCR				MRGCD CUWCD			
CO DIV'N OF WATER RESOURCES	SUBIA	BORPC				SEWCD	FL		
CO AG MET	UMU				SC, BA				
LOCAL EXPERIENCE	NAV ZUNI								ALL ?
OTHER REAL-TIME MONITORING	ZUNI UMU	BORNM FWSNM	CWCB	SLC DCPW		MRGCD CUWCD own stns, monitors)			
COMMERCIAL RADIO (see note)	ALL ?	ALL?	ALL?	ALL?	ALL?	ALL?	ALL?	ALL?	ALL?
TELEVISION	ALL? SUBIA			AVP			CC RF		ALL?
WEATHER CHANNEL	SUBIA			AVP	SC				
DTN (DATA TRAN NET.) INT. OR SAT.	UMU			DCPW	LS JV SC				FL says increasing users

Note: Commercial radio said to be alarmist and sometimes misleading in Eastern Colorado; others agreed it can be hard to use. Television is also felt to be alarmist but less so. All those who mentioned television also agreed it has to be "calibrated" for rural areas – time to arrive, etc. of weather systems.

Note: Many interviewees were aware that most sources take basic data from NOAA and then aply interpetation or labeling; some were not aware, but most seemed to be.

Other Sources Mentioned Twice:

U.S. Army Corps of Engineers – used by NMISC, FWSNM
National Drought Mitigation Center – used by NAV, CWCB

Intellicast (WSI Corp.) – used by ZUNI, NMISC

Other Sources mentioned Once:

USAF/USFS – used by SUBIA for fire information
NOAA GRADS – used by BIA for fire information
NOAA Atlas of Precipitation – used by UTDWR
Western Regional Climate Center – used by NMISC
Colorado Climate Center, State Climatologist – used by CWCB
Utah State Climate Center – used by SLC
Cable News Network (cable TV, satellite TV) – used by ZUNI
Weather Banks, Inc. – used by ZUNI
Weather News Inc. – used by ZUNI
Weather Underground – used by ZUNI
Unspecified internet – used by ZUNI
Weather Fax – used by DCPW
Chicago Board of Trade – used by UMU
Satellite, unspecified – used by UMU

NOTE: no one mentioned NOAA Weather Radio; when asked, several people in Colorado said (1) area of forecast coverage too large, so not useful, and (2) reception in mountainous or rural areas is poor.

3. Monthly decision calendar and summary

This section provides a distilled reporting of some findings from the interviews. Many important requests are not calendar-specific, and appear on the "shopping lists" of short-term and long-term requests, rather than the calendar. Here, we summarize the requests that concern information most wanted at particular times, to support decisions which recur annually. These are highlights from our findings, but we emphasize that there are important differences in timing and interests from place to place, and that the range of decisions and forecasts requested is greater than shown. Although this is the Colorado report, we include for comparison some calendar notes from other areas in the project so far. Full information about the New Mexico, and Utah and Tribal items is provided in those state reports.

NOTE: The decision calendar sometimes refers to organization profiles. These are descriptions of each organization and relevant water management decisions, provided in the New Mexico reporting from Dr. Chris Garcia and Dr. David Brookshire.

We did not ask our interviewees and advisory group to distinguish between weather and climate, so the characterization in the summary table is our interpretation, though it is not a final judgment. There was widespread support for the idea of a "seamless suite" of forecasts, from emergency alerting on a time-scale of minutes up to days, to long-lead seasonal forecasting. In discussion, we heard also that there is considerable interest in the emerging 10-14 day forecasts, and in general, hope for improved forecast and skill measures in the period up to a month ahead. This may be especially useful for scheduling activities such as maintenance and construction-like work; the Utah team noted this in municipal and county government interviews, also. Although farming doesn't seem to apply such judgment, ditch and canal management does in irrigation areas.

The interest in improved weather forecasting, especially for threats, seems to fit well with NOAA/CDC Director Dole's goal of "staged forecasts". The distinction between weather and climate is not useful for most people; what they want to know is how to weight the risks.

This calendar does not include all of what was mentioned, and does not reflect the wide individual variation in some important efforts, but we believe it to be reasonably representative of the majority of operations in the lower Arkansas Valley.

The decision calendar format used here is a balance between brevity and adequate background, and a simple form is used to accommodate future use in other formats and electronic communications. We hope it will suggest generalization and application in other places, and facilitate comparability across places and studies. As shown below, it also lends itself to straightforward compilation and comparison of the requests or predictions wanted, which we hope will help answer questions about what forecasts are most wanted, for what, and when.

This selection does not reflect a judgment on priority, importance or cost-benefit analyses, or the number of dollars or people involved. We explicitly note that we are not recommending any particular policy result, such as "this shows that NOAA must allocate more to X and less to Y", but we suggest that such decisions could be informed through use of this kind of information, and offer some interpretations and recommendations following the calendar.

Explanation, Abbreviations and terms used:

Cx = climate (as in general forecast; temperature, precipitation, etc.)
Wx = weather
D = days
ET = evapotranspiration
F = forecast
SF = specific event/condition forecast
RF = rolling (continually or frequently updated) forecast
HF = hydrologic or hydroclimatic forecast
GF = general climate forecast
FF = flash flood
ONDJFMAMJJAS = months; beginning with October, the start of the water year.
PC = precipitation
Threats = loose term for conditions that impose risk on subject operation or activity
T = temperatures

Interviewees and sources: abbreviations for lists and tables (for details, see state team reports) (does not include all attendees at meetings): same as listed above for table of sources mentioned.

A. October

Reservoir managers at all scales are concerned with supply over the coming winter, for both agricultural and environmental purposes. ONDJFMAM flow forecasts are requested very widely, for fish flows and also for small operators conserving their reservoirs and stock tanks.
The second most wanted item is 0-7 D and 0-14 D forecast of "threats"; at this time of year, this is primarily threats of early frosts and storms that would stress livestock. Stock is left on summer ranges as long as possible, but must be brought closer to home before the weather threatens them. The longer they can stay on the range, the more feed is left for the winter and spring to come. In the Arkansas valley, some operators exercise flexibility to either graze off stubble, leave some for moisture capture over the winter (very highly recommended now, CPIA), or take off stubble and begin land preparation for a new crop. There is also some land preparation by some farmers, plowing for weed control and soil quality if there is high clay or silt content. For irrigated farms, this is insensitive to climate, but weather and soil moisture can prevent these operations.

Arkansas River Decisions	Primary Target of Forecast Request	Other Relevant Forecast
10-1 – Pueblo spill (rolling decision)	ONDJFM flows, snowmelt yield	0-14D flashflood threat (rolling)
10-2 – Fish flows (rolling)	ONDJFM flows, snowmelt yield, AMJJAS PC? (River flow management in Upper Ark.)	0-14D flows (rolling)
10- 3 – Trans-mountain pumping	ONDJFM flows	High altitude freeze-up affects timing of decision
10-4 – Land preparation for increased moisture conservation or infiltration, may vary with crop anticipated	OND PC, wind; JFM 0-7D PC	JFMA flows (before snowmelt); land treatments after corn harvesting; also, reclamation re-seeding in some areas
10-5 – Livestock moving (down from high elevation and change in pasture for other reasons)	0-7D threats, OND PC and Cx extremes	Snow on low pastures supplies water, saves other source; also, some plant toxicity problems are relieved by killing frost
10-6 – Sell livestock	ONDJFMA Cx extremes, MAMJJA growing season for forage	Calves often sold now
What's Going On	Forecasts Wanted	Misc. Notes
Frost kills or stops growth	Killing frost date is useful, especially if it will be unusually early or late	Last corn brought in. Last harvests outside-grown late vegetables for Farmer's Markets
Very little irrigation still in progress; land preparation may begin, or grazing off the stubble	0-14 D PC	Possible that long-lead FC would be useful for some farmers in regard to tillage for maximizing soil water infiltration, if it includes windiness.
Winter Wheat – last planting (almost always planted much earlier)	May be timed by soil moisture; field preparation usually in August, planting then or Sep.	Final planting dates vary by county for crop insurance purposes; it was October 1 for Otero and neighbors in 2002, and the 15th farther South.
Milo is being harvested (grain sorghum); there may also be "cane" cut, which is forage sorghum	Freeze date is useful if it can be forecast, because the milo "hardens" and is storable then	
Dryland farmers are harvesting the last sunflowers, milo	Weather forecasts, freeze date	
Utes Decisions		

Stock moving "down" (Southern Utes and Ute Mountain Utes)	0-7D FC weather extremes, snow events	Same considerations as elsewhere: range forage is paid for, feed on the ranch is conserved and if insufficient, must be purchased.
Begin marketing of crops (Ute Mountain)	Long-lead for coming year, for own area and competitors	When to sell crops or hay is financially critical for many operations. The farm manager at Ute Mountain and CSU Ag Extension emphasized this.
Apply additional water and plan earthen ditch maintenance, (Southern Ute, and PRIID neighbors)	Date of hard freeze; may not occur until December but 0-7D, 0-14D FC would be helpful for planning	If surplus water is available, additional irrigation to increase soil moisture is good, but ditch maintenance needed before the hard freeze may take priority.
Middle Rio Grande Decisions		
Winter fish flows – for sports fish on the Chama. NM Game and Fish, MRGCD, BORNM	ONDJFMAM flows, snow water yield and PC	
Reservoir management for compact administration	snow melt yield and timing, tributaries to Rio Grande	
Take or postpone delivery of San Juan-Chama "project" water for City and for MRGCD	ONDJFMAM flows and PC, snow melt yield and timing – potential use for long-lead FC	Take delivery by 12/31 or seek waiver to store to 4/31.
Zuni Decisions		
Fish and Wildlife Management of flows (rolling)	Long-lead in-stream flows, and PC for water availability, especially in wetlands of high interest	See Zuni report

B. November

Very similar to October... This is the beginning of water year for Central Utah Water Conservancy District. A few especially business-oriented farmers are beginning tax preparation and financial plans.

Arkansas River Decisions	Forecast Request – Primary Target	Other Relevant Forecast
11-1 Winter water – store direct-flow water rights or use for irrigation (special arrangement in Arkansas Valley, Pueblo and John Martin Reservoirs)	NDJFMA flows, snow yield	NDJFAM Precip in irrigation areas, wind. Also of interest: reservoir losses – greater if warmer and windier, and if later freeze-up.
11-2 Schedule canal and ditch maintenance, often while dry but not hard-frozen	0-14 D lead on flows, precipitation, hard freeze date	Dry times in the canal is what is of interest, local gauge information wanted
11-3 Plan timing for carrying water for filling private off-channel storage reservoirs	NDJFMAM flows; 0-14 D lead on FF and local flows	0-28 D lead on flows

11-4 Cull herds, sell stock	NDJFMAM PC and local stream flows; local reservoir losses	Calf sales continue; Current and long-lead reservoir forecasts (so snow yields and long-lead Cx general)
11-5 Earliest onion set and seed and other vegetable seed orders, incentives for early corn seed orders	General coming year climate, winter moisture-relevant conditions and early season moisture and flows	Competitor region climate; Flows Feb-September also wanted in particular, for information on irrigation capacity. (Early vegetables get better prices, but small though growing market still in Arkansas)
What's Going On	Forecasts Wanted	Misc. Notes
Crop marketing (timing of sales) and (rarely) forward contracting (more often used in vegetable crops for packers; at low ebb now in Arkansas).	long-lead for year ahead, and long-lead for competitors' regions	Recent efforts to revive local contract vegetables by pickle plant. Announced in Oct 2002 that they hoped to have target acreage signed up by Feb.
Fall calving	Threats forecast (especially frontal passages with sharp changes)	Rapid changes in temp, precip, or humidity can stress
Begin financial planning (not all farms and ranches; some)	Long-lead for next year	Critical decisions in Nov and Dec on whether to take expenses this year or next.
Utes Decisions		
Plan snow plowing (BIA at Southern Ute) and continuing ditch maintenance (PRIID/BIA)	0-7D FC for snow events and staffing, 0-14D for planning	Crew allocation and avoiding conflicts are important for budget
Utah Decisions		Misc. Notes
Minimum flows or more	Stated snowpack forecast (snow water yield, AMJJ melt period)	Precipitation and flow forecasts for fall, winter, and spring might be useful if adequately reliable.

C. December

Many decisions that might benefit from long-lead forecasts begin in December and January. The forecast for the coming growing season is especially useful. For irrigators and water managers, the forecast of the coming snow yield begins to become more and more important for planning, as the year continues. The "threats" forecast is also widely requested, because irrigation ditch and canal managers are interested in the conditions for maintenance as well as livestock operator concerns. The farmers want the forecast for their competitors' regions as well as their own.

We are also informed that some farmers order seeds or onion sets in December, to assure getting their choice. There are also discounts for early payment and order for seeds. Many farmers may wait much longer. In 2002, seed orders were much later than usual, and included much less corn and more "grazer" sorghum and grasses. (Seed companies have the ability to shift distribution around large regions in response to conditions, but may run out of supply of a particular kind of seed.)

The financial management issues are very important, because the lending cycle partly reflects farmers being on calendar year tax basis. Contracts for seeds, equipment, irrigation technology, feed and seed purchases, and contract growing can be used to shift expenses between this year and next, and allocating them to one year or the other can be very important. Water purchases may also be part of this, where well users' associations are collectively purchasing augmentation water required for use of wells. It is possible that water banking might also be advantageous in December. Similarly, sales may be made in December to shift revenue, as well. It is possible that long-lead 13 month forecasts issued in early December could be the most useful for agriculture; flow forecasts as well as precipitation, temperatures, and soil moisture are all wanted. This would also include the forecasts for competitor regions.

An important limit on agricultural ability to respond to climate information suffers from conflicting incentives from the various agricultural programs which provide financial incentives for some crops, and less directly, from programs which provide incentives for establishing "base acreage" and base yield figures for land that may be used in the conservation, wetlands and grassland reserve programs. There are also financial incentives from federally-supported or provided crop insurance programs, which may be unavailable for any given crop in a particular county. In the Arkansas, the most common crops have programs, but the situation is complex. There are 495 separate insurance programs, crop by crop and county by county, in Colorado alone as of June 2003 (USDA Risk Management Agency website). The net result from the complicated set of programs may be to discourage experiments and increase the relative risk for unusual choices, which in turn may influence financing from private sources as well as federal assistance programs. It may be very useful to seek coordinated review with the USDA of how these programs interact with potentially improved forecast application. They are typically adjusted with each "Farm Bill" (the last was 2002; the next would be expected in 2007, so the timing may be good).

True crop-switching may become more attractive in the future, but we are advised that despite the reasons for it in theory, it may be slow in coming. An agricultural economist pointed out that there are already forecasts or outlooks for beef, corn, wheat, and other commodities, but this information has little impact on decisions. On the other hand, there is increasing "rationalization" of much of agriculture as farm land and commercial production continues to be consolidated into fewer operations, and economic pressure from international trade affects farm economics.

Arkansas River Decisions	Forecast Request – Primary Target	Other Relevant Forecast
12-1 Own storage (rolling decision)	Want 0-7, 0-14, 0-28 D flows if possible	Coordination of filling own reservoirs with NOV 3 Carrying water and NOV 2 O&M is a fine art, and maximum knowledge of natural inflows would help.
12-2 Ditch maintenance (at lower elevations)	0-7 D flows, 0-14 D flows if possible, especially FF and fast melting snow	(At higher elevations, earthen ditches usually hard-frozen by now; too hard to work with)
12-3 Crop choices (rolling)	Snow yield (for measure of irrigation availability), Early growing season (favors choice of vegetables), so Long-lead Cx FMA, and long-lead Cx MJJAS for rest of growing season.	Crop choices reflect chances for timing with best prices (early or late) as well as times to mature for different varieties. Soil temperatures control some planting, and soil moisture is useful.
12-4 FINANCIAL decisions	General Climate, extremes	Please see text above. The critical decisions for calendar-year taxpayers include

		payment of an expense in one year or the next, receipt of income allocation, and so on.
What's Going On	Forecasts Wanted	Misc. Notes
Ag. extension does a lot of seminars and educational programs in December and January		Might be most useful time to disseminate long-lead forecasts with educational information
Middle Rio Grande Decisions		
Reservoir management; final decision on taking delivery of San Juan/Chama project water or seeking waiver	Expected snowmelt; FC of monsoon timing and intensity	USACE profile; MRGCD profile
BORNM seeks sales/leases of water for ESA purposes largely from San Juan/Chama contractors (rolling through March-April).	MAMJJA flows and snow yield and timing	BORNM profile
(In 1998) Alliance decision to file Notice of Intent to File Suit on behalf of silvery minnow	NOAA FC for 1999	Alliance profile

D. January

Very similar to December, except for the financial issues... Decisions are firming up, for crop selections, plans for marketing crops, and ordering seeds and other inputs. Some lenders are beginning their cycle about now, depending on local practice; the farm loan specialists work hard to be aware of local conditions and markets, and often have farming experience. In the Arkansas, local processors have contracted for vegetables, but this almost entirely ended, and in the last two years may have begun again. The ending was attributed to labor costs and cheaper imports, such as the often-mentioned 55-gallon drums of Mexican tomato paste and cucumbers from far away. The return of local contracts may depend on transportation costs and delays (e.g. for cucumbers, timing matters), and local efficiency from improved irrigation technology, and that in turn may depend on reliability of water supply – and hence, either owning adequate water rights or having a reliably-operating market in place.

Arkansas River Decisions	Forecast Request – Primary Target	Other Relevant Forecast
1-1 Water purchases (rolling to March 15, April 1 or "project" date)	Snow yield, flows MAMJJAS	
1-2 Vegetable contracting, (not much, currently) seed purchases continue	Long lead general Cx, FMAMJJAS, especially unusual conditions	Competitors' regions, growing season – small orders for seed and later orders cost more than larger and earlier so timing of forecasts and decisions has different effect on small versus large farms.
What's going on	Forecasts Wanted	Misc. Notes
Seed shipments begin to arrive at dealers, who may	General seasonal for the growing season with special	

still change their orders as well as pass through customer orders	interest in extreme conditions	
On-going educational efforts, on-going plans for marketing, crop choices, and financial reviews; some tax plans	Interpretation of forecasts for commodity prices if possible; may include carry-over conditions (e.g. 2001 dryness carried into 2002)	
Utes Decisions		
Plan irrigation season and crop selections (BIA at Southern Ute for PRIID)	Snow water yield, MAMJJAS flows	
Utah Decisions		
Water basin irrigation water availability planning	Snow water yield, MAMJJAS flows, up-dated	See report. Also valuable: ET forecasts and reservoir loss information. State coordination with the 11 planning basins would also relate to state responses to drought indices.
Central Utah Water Conservancy District flow regulation (rolling through snow-melt)	Snow water yield, SNOTEL used constantly. Long-lead forecasts may be useful; also periods greater than 7D forward.	Flow adjustment is balance of ESA and fishery goals against value of conserved water left in storage, which may be needed for fish flows later.

E. February

Similar to January... Some early planting, some early land preparation activities are begun at lower elevations. In the Arkansas, decide by the end of the month if there will be a different request for supplemental irrigation water to Southeast Colorado Water Conservancy District. Municipal requests may also be submitted, for the 51% municipal share of the Frying Pan-Arkansas "project water". In 2002, for the first time, municipalities requested their full 51%, which even further decreased the allocations available to the irrigators.

Many ditch shareholders got less than 10 days access to water, and estimates of how much would be available were revised downward several times. These mis-estimates cost considerable crop loss due to inability to finish some or all of the acreage planted by a farm.

Interactions with the crop insurance program are complicated, due to inability to ensure if there is no reasonable expectation of success, timing of insurance effectiveness, conditions deemed to constitute insured "prevented planting", and rules covering re-planting and final planting dates.

Arkansas River Decisions	Forecast Request – Primary Target	Other Relevant Forecast
2-1 Early irrigation	0-7, 0-14, 0-28 D FC, especially PC, and wind	Soil moisture FC would be useful for FMAM. Note that scheduling may involve release from reservoir if stored water to be used, instead of direct flow water rights. There must also be sufficient "head" to get the water to the ditch

		and then through the ditch to laterals and fields.
2-2 Tillage and planting timing and choices	0-7 D FC, with wind (avoid heavy equip on muddy fields, avoid erosion from ill-timed land preparation)	Soil moisture monitoring may be useful; seed germination conditions (soil temperature for some crops)
2-3 Special precautions for calving, young livestock?	Threats, especially "cold snaps" or rapid temperature change, snow storms	Veterinary or self-administered animal health expenses can easily overwhelm profit margins for a given animal.
Utes Decisions		
Plan field allocations, and select crops (Ute Mountain Utes)	Long-lead for coming seasons (MAMJJAS), own and competitors	
Decide extent of dryland corn planting	FMAMJJAS precipitation, especially important	The professional farm managers said this was a wide-spread decision, and that corn seed and inputs are expensive, so losses hurt
Continue planning irrigation season and Vallecito Reservoir management (BIA at Southern Ute)	Snow water yield, MAMJJAS flows, unusual timing FC	The PRIID, administered by BIA, has complicated responsibilities if there are unfulfilled water rights
What's Going On	Forecasts Wanted	Misc. Notes
Calving (continues through March, depending on place and choices)	0-7 D "threats" such as frontal passages with sharp changes	Calving for Southern Utes may be most threatened, because of elevations and terrain

F. March

"Threats" forecasting is wanted, and calving is underway most places, though it is spread out more than traditionally, and lambing. Time is running out to adjust plans for the coming growing seasons, so the long-lead is wanted, through September. The timing of the spring melt, as well as the snow water yield, is a matter of great interest. In New Mexico, the forecast of the monsoon timing is also wanted. By now, all specially ordered seeds have been requested, and dealers are stocked with what they expect to sell to others. Also, the last grazing in farm fields is usually finished, and then the land is prepared for next planting; the timing may benefit from weather and two week forecasts, in Arkansas.

Arkansas River Decisions	Forecast Request – Primary Target	Other Relevant Forecast
3-1 Schedule Irrigation (rolling) and allocate stored winter water, stored water from own reservoirs, and direct-flow water rights	0-7 D FC, especially FF threats, wind, snow-pack, storm probabilities (late Spring is especially important in Colorado watersheds); timing of melt, conditions affecting run-off	Note that this involves timing requested release from reservoir, and diversion into ditches and the fields. The 2002 Drought illustrated the capacity for low soil moisture at high elevations to dramatically decrease run-off
3-2 Project water purchase	Snow yield, MAMJJAS flows	
3-3 Reservoir use, BOR management decisions	Snow yield, MAMJJAS flows, run-off timing if possible	Easy access to stream gauges wanted
3-4 Fish flows (management	timing of melt, storm and	Easy access to gauges,

by BOR in cooperation with users, for Upper Arkansas)	precipitation probabilities until melt and run-off	monitoring and system storage capacity
3-5 Crop choice – last chance to avoid much higher costs later if failure requires replanting. May not be done until April. Note: seed choices are by now likely to be limited, and prices are not discounted in most cases.	Long-lead MAMJJAS Cx in general, extremes, and similar information for competitors' regions. Planting decision uses 7-14D, and is sensitive to rainfall, especially if heavy (for seed and equipment reasons).	Soil moisture is the real objective, because decision at this late date reflects either feared extreme, or market information and need to reduce risks (opportunity to gain seems to depend on earlier commitments in most cases – confirm.)
3-6 Special precautions for young livestock?	0-14D rapid changes in temperature, storms	Calving is often done now (controlled by breeding timing in previous year, so subject to previous year's long-lead forecast in the future)
Utes Decisions		
Plan for cutbacks in deliveries if necessary, Towaoc Highline Canal Committee, Ute Mountain Utes	Snow water yield and Long-lead MAMJJAS for summer – especially late season – PC and water availability	Soil moisture FC in the long term, but for irrigators, the snow water yield and long lead PC to begin with.
Plan for cutbacks in deliveries if necessary, Towaoc Highline Canal Committee, Ute Mountain Utes	Snow water yield and Long-lead MAMJJAS for summer – especially late season – PC and water availability	Soil moisture FC in the long term, but for irrigators, the snow water yield and long lead PC to begin with.
Adjust planting and crop planning as appropriate; plant some crops early if possible	0-7D, 0-28D, and long-lead FC of PC	In Spring 2000 there were 3 inches of rain just before water delivery would have started, so the whole season started early and ended late.
Calving continues	0-7 D FC	As above noted.
What's Going On	Forecasts wanted	Misc. Notes
fertilizer application	0-5 D FC PC	Fertilizer effectiveness or loss to runoff is strongly affected by soil moisture when applied, and amount and intensity of precipitation shortly after application. This has important implications for non-point source pollution.
Other planting – small amounts of other grains, and some vegetables now in small quantities in the Arkansas.		Spring wheat may be planted, oats and barley may be planted. There is very little of these in the Arkansas Valley now, but there is some in other parts of Colorado.
Middle Rio Grande Decisions		
Reservoir management	FC of monsoon timing and intensity	USACE profile
BORNM planning allocation of water purchased for ESA purposes (rolling through irrigation season)	MAMJJAS flows and snow yield and timing	BORNM profile

MRGCD decision on request to irrigate conservatively or institute rotation.	MAMJ flows and snow yield and timing	MRGCD profile
Colorado Rio Grande Compact (rolling through irrigation season)	MAMJJAS flows and snow yield; FC of monsoon timing and intensity, also 30 D FC of flow, T and PC	CO State Engineer profile
Zuni Decisions		
Plan reservoir and wetlands management	MAMJ PC, flows, reservoir losses, soil moisture; 15 D and 30 D FC requested	See report. Zuni interests include a wide range of agricultural and pastoral enterprises. Water uses may be traded off between herd support and soil moisture.
Utah Decisions		
Storm water and flash flood planning, operations and maintenance allocations (rolling)	MAMJJAS FF threats forecasting	Scheduling O&M of stormwater facilities is usually a trade-off with other municipal activities.

G. April

Similar to March... Planting not done in March is done now, as soon as conditions allow (e.g. corn is best planted with sufficiently warm soil temperatures). Irrigation begins for most purposes, and well users begin pumping. There are also crop insurance purchases and some commodity program sign-ups due; most by mid-April but programs vary. There are also "last planting dates" specified in many programs, after which that particular crop in that particular county is not insurable. There are also considerations of when crops meet different qualifications for being insured or not; programs vary substantially with the intent being to allow for geographic differences, and historic local practices. Many reservoir management agencies announce the size of a share or allocation of the water for the year, on April 1. This is a commitment to providing that amount; this is discussed elsewhere in the report.

Arkansas River Decisions	Forecast Requested – Primary Target	Other Relevant Forecast
4-1 Move water (rolling)	0-14 D FC, especially FF	
4-2 Schedule various ditch maintenance operations (rolling)	0-14 D FC, especially FF	Coordinates with moving water decisions
4-3 Pueblo Reservoir Spaces, adjustments in Turquoise if needed	Snow yield, melt timing	Long-lead PC and temp and wind (affect reservoir losses)
4-4 Planting, land preparation as needed	0-7 D, 0-14 D FC, especially heavy PC, FF threats	
4-5 Special precautions for young livestock? (Calving continues)	0-7 D FC of threats, especially for sudden changes	Last 20 years, trend to spreading out calving times, for better marketing, but still most in April and May
4-6 Federal range reviews – finalizing allowed grazing levels on allotments or permits for coming year. Stocking	May want long-lead (Federal range managers were not interviewed for this project)	Private land owners may use these stocking rates as helpful information.

rates can vary by 40% (perhaps more in drought declaration situations).		
4-7 Move stock "up" to summer ranges or pastures, depending on weather and conditions	0-7, 0-14 D FC of threats, especially	Generally, the earlier the stock move "up" to pastures and off feed, the better, but too early can damage range, and weather stress for calves can be very expensive.
4-8 SEWCD Allocation (formally announced May 1, but decision in April)	MJJAS flows, so snow yield, and long-lead PC, MJJAS	Primarily based on stored water and snow-water yield estimates; melt timing would also be useful
Utes Decisions		
Pine River Indian Irrigation Project share allocation (not in Arkansas) – Southern Utes and neighbors	Uses current reservoir holdings; would like to consider long-lead flows forecast	
Move stock "up" (Ute Mountain Utes)	0-7D, 0-14D FC of threats, and especially rapid temperature changes	Ute Mountain Farm and Ranch move stock "up" at some time; the elevation of the summer ranges affects timing.

H. May

Similar to April; "locked in" for most decisions now... Vegetable and fruit crops may become vulnerable. Also, different crops with different timing for water needs may begin to complicate ditch company calls for water from the winter water available in storage, or reservoirs that irrigators have "off-channel", such as the large storage of the Fort Lyon system. Some crops may be re-planted if damaged by hail, but the decision is local, in practice and in the rules for any given crop insurance contract. Very young corn, for example, can recover, while older corn may not. Our advisors mentioned that Dr. Merle Whitt, of Kansas State University and Extension has done extensive work on decision tables for replanting, and it is thought that the Risk Management Agency may have applications for some of this information. We do not know how that would relate to climate forecasts, but will recommend consideration.

Arkansas River Decisions	Forecast Requested – Primary Target	Other Relevant Forecast
5-1 Irrigation amount (rolling through growing season – end September usually)	0-7 D FC including wind	Soil moisture FC, better soil moisture monitoring, wind and ET, ideally
5-2 Moving water (rolling, continues through season)	0-7 D FC, especially FF threats, 0-14 D even better	
5-3 Bulls chosen	Maximum long-lead that has reliability	
What's Going On	Forecasts wanted	Misc. Notes
continuing with rolling adjustable decisions		

I. June

Flash flood threats to ditches and canals are very important, as just about every water conveyance is in use. Two other sets of forecasts are also wanted. Farmers want 0-7 D forecasts for alfalfa harvesting, all the way through the summer, including the relative humidity. And there is widespread interest in forecasts of evapotranspiration and reservoir evaporative losses. This becomes increasingly important as the summer passes, while there are still chances to adjust reservoir and stock tank storage.

Hail damage to crops is thought to be most likely in June and early July. There was one storm in 1997 which did $22.5 million damage in an hour and half, east of Pueblo, with very large hailstones.

Arkansas River Decisions	Forecast Requested – Primary Target	Other Relevant Forecast
6-1 Drain high reservoirs (BOR management in cooperation with users)	0-7 D FC especially for FF, 0-14 D even better	FF threats information for high as well as lower elevations in Arkansas drainage.
6-2 Early fruit and vegetable harvesting, especially for direct sales, farmer's markets	Threats, such as hail or hail-conducive conditions	This continues all summer, but early and late produce brings the highest prices. Some other crops ripen.
6-3 Timing of Alfalfa cutting– (rolling). This is also the last chance, in mid June, to plant short corn in the Arkansas	The "alfalfa forecast" of 0-5 D or longer, longer is much better, of PC, wind, relative humidity	See details in Colorado state report – this would be useful for both high and low elevations where any hay is cut, as well as alfalfa.
6-4 Recreational uses (rolling through August); Upper Arkansas rafting business is economically important. In future, Pueblo City Recreational In-Channel Diversion may become important.	Flow forecasts for Upper Arkansas Basin, FF threats FC.	Coordinates with the demands for other flows from upper reservoirs to intermediate diversions and Pueblo Reservoir

J. July

Similar to June... Different weather threat conditions appear in the higher elevations, but hail and thunderstorms with flash flood impacts on ditches and damage to crops (especially fruit and vegetables) are the most common problems in the Arkansas.

Arkansas River Decisions	Forecasts Requested – Primary target	Other Relevant Forecasts
7-1 SEWCD re-allocation (if water availability permits)	JAS flows, long-lead general	Soil moisture, PC in particular (e.g. unusual Monsoonal conditions?)
7-2 Recreational flows management (Upper Arkansas rafting and in future,	0-7 D FC, flows FC (may not need augmentation in June, but by July will likely be	Coordinates with fish flows decisions, and with information on calls for water rights

Pueblo City Recreational In-Channel Diversion	interest in additional flows in Upper Arkansas)	
7-3 Harvesting winter wheat, alfalfa cutting may be done	0-7 D Wx; wind, etc., Good weather for cutting and drying; avoid cutting before rain, but need dew or humidity for baling alfalfa successfully	Some winter wheat is harvested in June, in warmer areas (e.g. Kansas is earlier than Colorado, Texas earliest).
What's Going On	Forecasts Wanted	Misc. Notes
"playing the hand…" In the Arkansas, milo might be planted in the 1st week. Sorghum or sudan grass might be planted at the end of July and cut off at first frost.	Hail forecasting is still wanted.	Forage grasses can be replanted in May or June, but very little can be usefully planted in July. Hail damage is a loss that can't be covered except with insurance.
Hay may be bought or sold as "standing" to operators who have equipment and labor	Regional forecasts, especially for the rest of the growing season and increasingly for the winter, are wanted, for areas to which sales may go. The "alfalfa forecast" is still important	In 2002, DF and FM informed us that 70% of the alfalfa and graze hay was exported from the Valley to Oklahoma and Texas

K. August

Also similar to June, but increasing interest in short-term forecasts for harvesting some crops.

Arkansas River Decisions	Forecasts Requested – Primary Target	Other Relevant Forecast
8-1 timing of harvest of melons and chiles	Weather for picking; make most money with ripest fruit and best quality	
8-2 Alfalfa may be planted	Weather-dependent; ideally, should be 6 to 8 weeks growth before frost	
What's Going On	Forecasts Wanted	Misc. Notes
continuing adjustments of irrigation application, fish and recreational flows, and stock water may be an issue where small reservoirs and flows are drying. Marketing decisions may be made, for the sale of hay already put up, or winter	Competitors' regions are of interest, to help judge marketing and timing of sales.	Market information is already reflecting weather and how crops are "finishing up". Winter wheat is "in", corn has been coming in and continues.

wheat harvested and corn.		
Harvesting, baling continues	weather, humidity, dew	
Feed and graze sales continue, depending on conditions	See above	Competitor and market regions are watched, for weather and for prices being received

L. September

The agricultural season is winding down, but threats to livestock, on the summer ranges, are becoming important, and there may still be some planting of winter wheat. The Interior Department is reaching decisions on the Colorado River Annual Operating Plan, based on expectations for the year ahead; the role of forecasts may increase in the future.

Arkansas River Decisions	Forecast Requested – Primary Target	Other Relevant Forecast
9 1 plant winter wheat (may have been planted in August); plant alfalfa	0-7 D FC, especially thunderstorms, frost date	Long-lead for next Spring and Summer
9 2 Colorado River Annual Operating Plan (Secretary of the Interior; has indirect effect on trans-mountain diversion in some cases. Not interviewed for this project. (See work of Ray and Webb, OGP RISA project; NOAA CDC)	Snow yield of coming Spring	May be possible to consider additional climate forecasts; not clear if the process can accommodate that. (See "shopping list".)
9-3 Marketing of crops some livestock sold, some livestock may be "brought down", depending on locations and condition of higher summer range (or moved from leased land in some cases); balancing forage, stubble, and feed needs.	The long-lead in general for the coming year, and for the coming year for competitors' regions.	Some operators will make a choice to graze off crop residues, or leave them to increase roughness for moisture capture over the winter. Contemporary recommendations favor increased roughness for many places and crops
What's Going On	**Forecasts Wanted**	**Misc. Notes**
Early-maturing soy harvested (other varieties after frost)	Weather for harvesting	
Feed and graze sales continue, depending on conditions	See above	Competitor and market regions are watched, for weather and for prices being received

M. Summary of requested predictions

An important note: We carefully decided to NOT distinguish between predictions, forecasts, and information, for purposes of this study, so we are calling anything said about the future a "forecast", to distinguish that from other statements or monitoring etc. As with the rest of the findings, we are not precisely characterizing the issues in meteorological terms. This is not because we think this is trivial and merely technical – just the reverse: whether an answer is available already may depend on thorough understanding of what the requestor "really" wants and is trying to cope with, and that also applies to answers that might become available in the future.

One of the most difficult and valuable products of this research will be synthesis of this information into more useful form for help in establishing priorities for NOAA and its collaborators. We report our work in the hope that it will serve as a beginning rather than stopping point in this task. And, we add that as use of climate information increases, in co-development with the tools needed to respond to it, we expect that new emphases and priorities for the information users will also emerge. This report, therefore, will be snapshot of preferences at the time we inquired, rather than lasting guidance.

The list of forecasts requested, from the Colorado decision calendar:

The number corresponds to the decision table, and indexes information in the detailed reports.
(The "type" descriptions are:
SF for "specific forecast", such as specific elements of weather or climate or threatening conditions
HF for hydrologic or hydro-meteorological forecast
GF for "general forecast", such as the long-lead forecasts of climate and temperature; or
RF for "rolling forecast", such as where a short-term forecast such as 0-5 day flash flood potential is requested on a continuing basis through a season or specified period. This is either a special emphasis or an added dimension of the forecast.

N. Raw set of forecasts requested, from Colorado decision calendar

(Explanation of "type" below; Wx/Cx is characterization as weather or climate forecast, with loose characterization of weather as including periods up to 14 days ahead)

Number	Subject MONTH	Type	Wx/Cx
	OCTOBER		
10-1	ONDJFM FLOWS	HF	Cx
10-2	ONDJFM CLIMATE AND FLOWS	GF, HF	Cx
10-3	HIGH ALTITUDE FREEZE-UP DATE	SF	Wx
10-4	LOCAL WEATHER, WINTER SEASON CLIMATE	SF, GF	Wx
10-5	LOCAL HARD FREEZE DATE	SF	Wx
10-6	CLIMATE EXTREMES, COMING YEAR CLIMATE	GF	Cx
	NOVEMBER		
11-1	NDJFMA FLOWS, RESERVOIR LOSSES	HF	Cx
11-2	0-14D LOCAL FLOWS, HARD FREEZE DATE	SF	Wx

11-3	RAIN AND SNOW EVENTS, 0-7D, 0-14D	RF	Wx
11-4	CLIMATE EXTREMES, COMING YEAR CLIMATE	GF	Cx
11-5	COMING YEAR CLIMATE	GF	Cx
	DECEMBER		
12-1	0-7D, 0-28D FF, PC, FAST MELTING SNOW EVENTS	RF	Wx
12-2	CLIMATE, ESPECIALLY SNOW WATER YIELD	GF, HF	Cx
12-3	CLIMATE FORECAST, OWN AND COMPETITOR REGIONS	GF	Cx
12-4	CLIMATE FORECAST, OWN AND COMPETITOR REGIONS	GF	Cx
	JANUARY		
1-1	SNOW WATER YIELD, MAMJJAS FLOWS, ARKANSAS	HF	Cx
1-2	CLIMATE, OWN AND COMPETITORS' – LONG LEAD	GF	Cx
	FEBRUARY		
2-1	0-7D, 0-14D, 0-28D, PRECIPITATION, HIGH WIND, FF	RF	Wx
2-2	0-7D PRECIPITATION	RF	Wx
2-3	THREATS TO YOUNG LIVESTOCK	RF	Wx
	MARCH		
3-1	0-7D,0-14D FLASH FLOOD, THREATS, HIGH WIND	RF	Wx
3-2	SNOW WATER YIELD, MAMJJAS FLOWS	HF	Cx
3-3	SNOW WATER YIELD, 0-28D PRECIPITATION, FLOWS	HF	Wx, Cx
3-4	MELT TIMING, STORM PROBABILITIES	RF, HF	Wx. Cx
3-5	LONG-LEAD FOR GROWING SEASON (MAMJJAS), OWN AND COMPETITOR'S REGIONS	GF	Cx
3-6	THREATS TO YOUNG LIVESTOCK	RF	Wx
	APRIL		
4-1	0-7D, 0-14D PRECIPITATION, FLASH FLOOD, FLOWS	RF HF	Wx
4-2	0-7D, 0-14D PRECIPITATION, FLASH FLOOD, FLOWS	RF, HF	Wx
4-3	SNOW WATER YIELD, AMJJAS FLOWS, RESERVOIR LOSSES	HF	Cx
4-4	0-7D, 0-14D PRECIPITATION, HIGH WIND	RF	Wx
4-5	THREATS TO YOUNG LIVESTOCK	RF	Wx
4-6	GROWING SEASON CONDITIONS	GF	Cx
4-7	0-7D, THREATS LOCALLY AND AT DESTINATION AREA	RF	Wx
4-8	MJJAS FLOWS, SNOW WATER YIELD, LONG-LEAD	GF, HF	Cx
	MAY		
5-1	0-7D PRECIPITATION, HIGH WIND,	RF	Wx
5-2	0-7D, 0-14D PRECIPITATION, FLASH FLOOD	RF	Wx
5-3	MAXIMUM CREDIBLE LONG-LEAD FORECAST	GF	Cx
	JUNE		
6-1	0-7D PRECIPITATION, FLASH FLOOD	RF	Wx
6-2	0-7D THREATS (ESPECIALLY HAIL), WIND, HUMIDITY	RF	Wx
6-3	0-7D PRECIPITATION, WIND, HUMIDITY (DEW EMPHASIS)	RF	Wx
6-4	SNOW MELT TIMING, FLASH FLOOD, FLOWS IN UPPER ARKANSAS	RF	Wx
	JULY		
7-1	JAS FLOWS, LONG LEAD SEASONAL	HF	Cx
7-2	0-7D FLOWS, UPPER ARKANSAS	RF	Wx
7-3	0-7D PRECIPITATION, WIND, HUMIDITY (DEW)	RF	Wx

	AUGUST		
8-1	0-7D PRECIPITATION, FLASH FLOOD	RF	Wx
8-2	0-7D PRECIPITATION, WIND, HUMIDITY (DEW)	RF	Wx
	SEPTEMBER		
9-1	0-7D PRECIPITATION, FLASH FLOOD POTENTIAL	RF	Wx
9-2	SNOW AND WATER YIELD NEXT 12 MONTHS	HF	Cx
9-3	CLIMATE, OWN AND COMPETITORS' – NEXT 12 MONTHS	GF	Cx

4. Discussion of requested predictions from the decision calendar

In order for this work to be most useful to NOAA resource and strategic planners, several questions should be answered, even if the answers tend to change with time. First, how many of the requests are collapsible into a smaller set, due to being the same in some way or ways? Second, what are the relative values or priorities for the requests?

A. Hydrologic and hydro-climatic forecasts

Prediction of spring and summer flows, or snow-water yield, in MAMJJAS, for example, depending on the month when requested, appears in requests almost all year, [1-1, 3-2, 3-3, 4-3, 4-8, 7-1, 7-2, 9-2], and requests for prediction of winter flows appeared in several of the other months [10-1, 10-2, 11-1].

Therefore, one might collapse this as generic request for a rolling prediction of flows, (meaning, a continuing or frequently up-dated prediction), perhaps combining methods or offering several combinations of ensemble forecasting, ESP-style as used by River Forecast Centers, monitoring and SNOTEL information, etc. (We note that this also indicates desire for the products of hydro-climatology research underway at several of the Regional Integrated Science Assessment projects.)

The particular interest in flow forecasts surely relates to our focus on water management decisions, but even so there was surprisingly higher interest in forecasts of water supply than of general climate. This may have been biased by our focus on irrigated agriculture, as well, though range management interests in flow are substantial, because of stock watering needs. On the farm, general forecasts requested were essentially for "my coming year versus my competitors' coming years". One professional consultant said that even if he expected a really good crop of corn, if he knew everyone else would have a good year too, he might not plant any. There may be a lurking question of what sectors or activities are affected by "climate in general" as opposed to climate-driven outcomes such as flows. To the extent that specific outcomes are most important to potential users, research orientations may be affected.

B. Forecast threats to livestock, flash flood, and other forms of weather forecast applications or extensions

In general, we heard requests for rolling weather forecasts, or specific event or condition weather forecasts for something in every month except January, and we presume blizzards would still be of interest then. The inference we draw relates to the quality and usefulness of the forecast information that people get in our study areas; this is described in section 2 above in this report.

Request for prediction of flash flood threats occurs from March through September [3-1, 4-1, 4-2, 5-2, 6-1, 8-1, 9-1]. For reasons described in detail in the state and synthesis reports, irrigation ditches are vulnerable to flash floods. Ditches also seek to capture free water. Request for prediction of threats to livestock relates to the period of calving and lambing, February, March and April (though there is some counter-cyclical Fall calving), and timing of moving stock to summer ranges that are usually at higher altitudes, and moving them back "down" as late as possible, in

October and November, April and May (depending on place and elevation for stock moving). A calf with an illness can often be treated for about the amount of profit likely from the entire operation for that animal; when margins are thin, costs become critical.

Two other kinds of weather forecasting are also especially wanted in the calendar results. These concern the forecast of weather conditions relevant to timing of some kinds of farming operations. One Spring day, one of the authors had a sad conversation in a small town, encountering a man who said he'd just seen thousands of dollars of beet seeds fly away in a wind-storm. More often, surprises in weather can result in damage to soils and access from bad timing of rain or snow melting. Untimely precipitation can also interfere with fertilizing, herbicides, and pesticides, increasing wasteful runoff and pollution as well as costs and perhaps requiring re-application.

This list might also include "the baling forecast", which would actually be a forecast of certain conditions affecting alfalfa, and also other hay crops (though these are somewhat less sensitive to baling conditions). Alfalfa is important for irrigators because of its ability to use "extra" water for more growth, or stop growth and stay healthy in dry periods, and provide income two to four or even five times a year for three or four years after establishment. Alfalfa is grown on more acres than any other crop in the Southeast Colorado Water Conservancy District lands. Alfalfa must be adequately dried to avoid molding in bales, but not too dry to bale badly. Prices in 2000 and 2001 ranged from $45 to $120 per ton, (there were some much higher prices in the 2002 drought) depending on quality; there are also increasing sales at higher prices for delivered and stacked bales for horses. The quality depends on the stage of growth of a plant when it is cut, and the environmental conditions during curing and baling. For many farm-ranch operations, a good year or a bad year can result from the quality of the alfalfa bales sold; for others, the crop is important fodder for wintering livestock. High quality irrigated acreage is increasingly being used in vertically-integrated agribusiness for feed in dairies located far away.

The price of a bale or ton of alfalfa can be halved by baling conditions alone, regardless of the nutritional quality at time of cutting. Farmers, therefore, often keep some desperate hours waiting for the dew to be just right for baling, often working through the night. And surprises in rapid drying due to high winds and temperatures can be as expensive as rain at the wrong time. Wetted crops may have to wait for drying again, and the delay in this step can reduce the size of future cuttings. Alfalfa may be cut four times in the Valley if things go well, providing cash income during a time when expenses have been incurred and harvests are not in yet, but it depends on the age of the stand as well as the field and weather. There are a few other points to note. First, alfalfa is remarkably flexible, in its ability to grow more rapidly in response to added irrigation or precipitation, or to go dormant in dry times. So, water may be allocated much more flexibly than in the case of crops such as corn or soybeans. Second, alfalfa is usually planted every three or four years in the Valley, so it can be quite low in cost in a given year, depending on the farm's rotation. Third, alfalfa is almost always useful for local sales, if not used on the farm itself, or can be sold for transport if it is good quality, in regional markets. In 2002, hay and alfalfa traveled all over, because of the drought, but even in normal years the Arkansas Valley sends a great deal to feedlots and dairies in New Mexico, Texas, and elsewhere. Fourth, alfalfa is a nitrogen-fixing crop which improves the soil for other crops in the rotation. Almost everyone grows some alfalfa, if only to use "extra" water if it is available, rather than waste it. And the price received can vary much more than that for other field crops, making for a good or bad year.

The information wanted is humidity, evapotranspiration, and windiness at the surface. This is also widely desired for other purposes, but we call this particular application to attention because it illustrates the significant potential benefits that might be achieved from a relatively simple application of such information, were it made available.

These weather forecast requests should be considered in light of the shopping list requests for help in making local application of forecasts (weather and climate) that are already being made for other areas or at larger scales. We call this "calibration", to distinguish it from down-scaling of the forecasts. Instead, this process would involve providing information to help users make judgments normally made on the basis of long experience in a place. Old-timers can tell what a Pueblo forecast means for some place north of Las Animas, if the frontal passage is identified, for instance. But where the conditions are more localized, as in convective thunderstorms, guidance is often reduced to hunch or instinct. This is further discussed in the "shopping lists" section. We hope that much of this can be done quite economically.

C. General climatological forecasts

Research into potential applications of the long-lead seasonal forecasts from NCEP and others was a primary purpose of this work (and its funding). Given the relatively obvious utility of such information, it is not surprising that there was considerable interest. In terms of the calendar of decision-making, however, we found some fairly distinct opportunities for application. For the benefit of the Arkansas Valley, December and March may be the most important times for issuing a new long-lead forecast, because of the financial, water and agricultural decision-making under way at these times. This seems to be confirmed by the enterprise budgeting information, and when expenses are incurred (see section below on agricultural financial calendar). These are relatively short periods when forecasts are most useful – when decisions are adjustable to use them. This is not to say that long-lead forecasts would be undesirable in other times; in the calendar above we note requests in September through January, and again March through May, but conditions affecting prices, market/sales decisions, and future prices are always interesting. When the best issue-times would be for Yuma, or the Central Valley of California, would surely be different. Perhaps this study will help establish an approach to answering such questions.

For the Ute Mountain Utes and the Southern Utes, as an illustration, the timing of most-wanted forecasts may be different. The Tribes are not far apart, but the interests of the small Southern Ute (and Pine River Indian Irrigation District neighbors) livestock operators involve bottomland haying, small irrigation operations, and much higher elevations than the highly technical large-scale agricultural operations of the Ute Mountain Ute Farm and Ranch Enterprise. January forecasts of the coming water yield are universally wanted, and March forecasts are also relevant to the irrigation district, but which later forecasts of conditions are most wanted is not as clear. The December-issued forecasts could become more important as financial sophistication increases in the Pine River/Southern Ute area, or the future may include more people supporting their farms and increasingly recreational farming in that area.

An example of the differences in farm ability to respond to information also comes in regard to the baling forecast described above. The state-of-the-art Ute Mountain Ute Farm and Ranch Enterprise cannot interfere with the cutting and baling crew schedules, because the costs of a poor result from a few days' baling is less than the cost of disruption of the rest of the schedule. This would not be true for most farms in the Southern Ute and Arkansas Valley areas.

5. "Shopping List" of near-term requests not as clearly related to the decision calendar (note: headings intentionally numbered rather than lettered)

In order to get more information than that which was easily related to the annually recurring decisions in the calendar, we probed for other concerns and requests. The following "shopping lists" synthesize what we found in the Arkansas Valley, with some additions from other areas in the study. Sources of some of the requests are identified, if the point was made by an official; other requests are not identified to individuals. We also include here some additional information to further explain some points which appear in the calendar as well as on these lists.

We distinguish short term requests, in the sense that the request may be fulfilled in the near future; these are numbered here. Those which may be farther away, "long-term requests", are lettered.

1. Flash floods, threats and basic monitoring information gaps

We found a widespread complaint that the lack of basic climatological and hydrological information – literally baselines in some cases – will hamper use of new information and forecasts. "Threats" information is largely apparently within the scope of conventional weather forecasting, but actually outside the geographic scope of adequate efforts or coverage. Flow monitoring is clearly valuable, and the capacity to detect and respond to surprises is limited.

A. Threats examples – A surprise blizzard

JV and LS: Request: In October of 1999 there was a surprise blizzard in Eastern Colorado, which demonstrated the value of improved warning, or "threats" awareness. Thousands of bushels of corn were lost and many cattle died from drowning in ditches while being driven by high winds and snow. The cattle could have been moved with more additional notice; they were not far away from farms, and the corn could have been harvested with somewhat more notice. An advisory was issued at noon, warning at 3 PM, and the storm was very heavy by 7 PM. It was said to be a "classic Albuquerque low". Warnings that short didn't save much trouble. With a week, cattle could have been moved, corn taken in, and alfalfa baled before it got wet and lost a lot of quality. With even a couple of days, cattle could have been saved. How much warning could be given is unknown, but these agricultural advisors hope it could be better. During the event, there was little or no news or forecasting about what the storm was doing, and how conditions would change; this again cost potentially valuable opportunities to take steps that were soon foreclosed when the clearing weather turned to blizzard conditions again (BA).

Calving, lambing, and stock moving (also appears in calendar)

SC: Threats information of several kinds would be very useful for range and livestock management. First, there are critical periods for livestock: when to move the animals down from the higher ground to winter pastures, and calving/lambing times. For each of these, forecasts a week to perhaps two months ahead would be very good, because the response to threat information can be slowed by the realities of rounding up cows, for instance, and the response can be critically expensive even if it is successful. The longer the lead time, the less likely the event will be an emergency or expensive.

DF, FM, and others noted that high winds can be very expensive for planting, due to lost seed and misdistribution of seed. This calls for good localized weather forecasts. Storm cell motions would be useful, also; the radar images for the cities would be great for the planting times.

B. Ditch threats from flash floods (also appears in calendar)

BIA, FL, and others: Ditches can be threatened by unexpected precipitation, while "free inflow" from tributary areas can be used to conserve other supplies. So there is great interest in avoiding having a full ditch when a flashy event occurs, and less urgent interest in avoiding wasted inflows which cannot be used or stored under some conditions.

Describing John Martin Dam and Reservoir operations, JD noted that management during serious flood events depends on maintaining dam safety first, and reducing damages from high flows as the next priority. Above the reservoir, inflows from unmonitored tributaries, including canals and ditches, may add to releases from upstream reservoirs and flows from gauged stretches. Downstream, the inflows from un-gauged tributaries may already be creating high flows, so that releases from John Martin might be reduced if possible. Better weather coverage and precipitation estimation in the whole catchment would be ideal, though practicality is another issue. Ms. Davis emphasized the importance of best possible information in emergency situations where on-scene persons may have to make hard choices; the manual and guidance can only be useful with the necessary understanding of what is happening.

JD is especially interested in knowing about threats such as flash-flood conditions, a week ahead or a little more. The time frame comes from the time it takes water to move down the river from upstream reservoirs, and the time it takes to get water out of canals and ditches. (Some notes on the system in appendix, along with notes on the consequences of flash flood experienced some years ago.) The direct application in dam operations would be to smooth out changes in releases. Releases from the reservoir are usually planned a week ahead, for the benefit of downstream recreation safety, and agricultural users of the bottomlands. Slow and gentle changes in the flow levels below the dam are always preferred. On the reservoir, recreation is increasingly important, and this may be increased by new State investments recently proposed. Safety for boaters and staffing for emergency responders is important and affects staffing for other activities.

The use of week-ahead information would be improved by coordination with real-time flow measures. These are used as much as possible but more gauges would always be nice.

Because of the hydrologic and topographic situation magnifying flash flood hazards in particular, and the sometimes challenging weather of the Eastern Plains, it would be good to have forecasts of unusual levels of threatening conditions.

C. Basic flow monitoring

BS, SM of Colorado Water Conservation Board, JD, RF, FL: Basic forecasting improvements for rural areas could benefit people. Although Colorado has relatively better stream gauging than most states, the network is very limited in flash flood usefulness. It does well for riverine slow-rise flooding, but increased gauging would help with flash flood threats. Can NOAA help with USGS to plan and place gauges most effectively?

The floodplain management section of the CWCB wants improved gauge information before, during and after snow-melt, especially for warning of unusually rapid melt-off. Additional automatic warning systems might be cost-effective; can a live operator be automatically notified that conditions are abnormal. Also, GIS-integration of the gauge readings should be more available. BS and SM agreed with comments of others that the 1999 Southeast Colorado flooding had been poorly identified even while it was in progress, and was not appreciated until it was a very large event. The network of gauges in Colorado is relatively good, compared to other states, but still not very good for events that are not slow-rise riverine flooding.

D. Surprises

BA, LS, JV, BIA, UMU, SU: The threats and surprises forecasts – conditions that allow surprises and nearer-term chances of a surprise – may actually have much larger value in "shoulder seasons" when extremes are not anticipated, than when such events are expected. This may be of interest in terms of allocation of forecaster efforts and resource allocations; we have no information on the annual calendar for the National Weather Service or other parts of NOAA, though fiscal year considerations are probably important in planning.

JD: Emergency management training is also important, including what Ms. Davis said are informally called "get there exercises" in which people literally go through the motions under surprise constraints, to realistically simulate disasters and the accompanying wash-outs, loss of communications, failed equipment, and so forth. Simulations can always be improved with better scenarios. Although most of the emergency management situation is outside of NOAA's scope, one area of special interest is provision of "what's coming" information to local officials. In a real case, some officials were uninformed of multiple flood crests moving down a reach, which could have led to very sad results without good luck from almost accidental radio monitoring by someone with better incoming information. The Corps tries to help as much as possible with other local government involvement, but the time and money needed are always a problem for everyone in the rural areas. The threats of cascading flash floods and canal failures are quite serious in the lower Arkansas, given the long narrow valley topography.

E. How these relate:

The common problem is limited support for a variety of basic management tasks because of insufficient monitoring of stream flows and weather conditions. We are struck by how widespread these feelings are; see also the requests for more SNOTEL information and stations. The point may be that these requests support more basic observations and data operations that are already well understood. In the Drought year of 2002, the lack of basic information was especially lamented, in part because of the dramatic downward revisions of water availability estimates. The very high rates of sublimation and high-elevation soil moisture deficits unexpectedly changed the snow-pack to run-off ratio in most places (Luecke et al., 2003, DiNatale, p.c. 2003)

2. Soil moisture and evaporative losses information

There were several different requests for information and forecasting, and climatology support. These concerned potential benefits from better management of soil water and small water storage, as well as large reservoir losses.

UMU: Soil Moisture Request: For this recently-established highly technical farming operation, infiltration of water is a problem because of soil chemistry here; several measures are used to monitor, and some amendments improve this, but more information is wanted. They want to substitute telemetry for the intimate knowledge a small farmer would have after many years. They want more weather information , such as wind and relative humidity, to help with this. They have purchased their own high-quality weather station but want to get more detail and smaller-area information. It is important that they already have the flexibility in their equipment and management to use small-area information for adjustment of irrigation and amendments. They are also interested in considering collaboration with NOAA and others on long-term projects.

Fall soil moisture levels and changes over the winter are useful but currently not well enough measured or known. (This might not be within NOAA's areas but using the climate forecasts and improved weather forecasts might be easier and more productive if there was better soil moisture information.)

SC: Soil Moisture request: Range management can benefit from better soil moisture information, particularly if it can be based on remote sensing and modeling with weather information and forecasting. The agricultural community is under-equipped with monitoring and insufficiently inclined to monitor. But there is increasing interest in soil moisture and measures, and therefore increasing benefit can be expected from information. The open ranges of the Eastern Plains are underserved; the only readily available information is coming from COAGMET, and is expressly oriented for crop, rather than range. This need is reflected in the "Steffens-Cotton Proposal", noted elsewhere. In addition, managers trying to keep livestock watered are often faced with the problems of short-term prediction of stock tank levels and losses, which affect how far cattle and sheep are from water and therefore where they can be grazed. A mistake requiring trucking water can be expensive.

Forecasting of soil moisture might be possible or more effective with increased local monitoring to match with observed weather conditions, and eventually soil information as well. Because the climate forecasting is advancing, local calibrations of the information should not be neglected. Ground-level wind information is missing and very important, as noted by LS. Dr. Sutherland has been frustrated in otherwise successful efforts to adequately model soil moisture and erosion relationships by lack of wind data, and monitoring at appropriate heights.

Better forecasting of evaporative losses and solar radiation, and better forecasting of solar radiation (cloudiness?) as well as windiness is requested. Agricultural extension people have mentioned that this kind of forecast might be useful for farming as well. The Colorado Water Conservation Board also wants this; many commercial and municipal users pay for private consultants to advise them on conservation measures such as lawn watering requirements.

The Fort Lyon Canal manager told us in 2001 that a number of private operations were providing soil moisture measures and irrigation recommendations to farmers trying to conserve their water. In 2002, there was little measurement mentioned, due to the extreme drought, but the interest in this service may increase as result of the carry-over soil moisture deficits in much of Eastern Colorado in 2003 (see Drought Monitor website).

An additional source of interest may appear from increasing calls for improving agricultural irrigation efficiency, such as the Department of the Interior and Department of Agriculture combined "Water 2025 Initiative" (see website), announced in Spring 2003. This expresses increasing pressure to transfer agricultural water to municipal uses and concern for the impacts on rural areas affected by transfers.

In general, while evaporative losses are a known concern for large reservoirs (according to TF, BOR), smaller operations may be more sensitive, and the economic impact of irrigation at wrong times, running short, or wasting water that does not benefit urban users was suggested to be significant.

3. Calibration, storm patterns and general weather patterns

SC: There is a great deal of "local knowledge" in ranchers with very long histories in a place, who can mentally make the calibration from some weather news about a better monitored or served place, such as nearest big city, to adjust that for their own location. Everyone does that to some extent, but there are a huge number of newcomers on small rural acreage who do not have the experience to do it well. This is part of the "calibration need". The challenge is to apply high technology to substitute for long experience, and complement it. There are several approaches, but they probably all are some form of increased correlation of available measures, such as daily wind fields and weather maps, with increased density and strategic sampling of local conditions in representative areas. The other part of "calibration" is ground-up information that correlates to modeling and large-area observations, so as to develop practical down-scaling for places of concern.

Two particular needs identified were for better data acquisition from rural places that "get the weather first", and better identification of the typical storm and frontal tracks that bring weather. These are certainly interactive and will help each other. LS, BA and SC, independently, mentioned how there are several "usual" patterns that bring weather of concern to their areas, and they wish these were more carefully observed. They expect that these local (multi-county scale) patterns could be usefully integrated with forecasting for larger scales, to get better predictions and more effectively localize forecasts. This is intuitively done by people in rural areas seeking to apply their experience to extrapolate from forecasts and weather radar information from places better served, and would seem to be an area ripe for progress in the near future. This request fits neatly with other comments on the ease of use of visual loops of mapped storm tracks, and how people would like to see "it's here now, moving westward about 25 mph, will get to there by noon, then next place by sunset…" And, in fact, several people mentioned how the Hurricane Center has set the standard for easy to see information, with probability cones ahead of the storm, arrows and such visuals.

4. Form of information

A. Generally

The localization of threat information for the Arkansas Valley is not very good, since watches and warnings are given for several counties at once. His ideal form of information would be a "tracking" visual on a map, like those presented for the public during hurricane watch and warnings. The present location of a storm cell could be shown, with a set of cones of likeliness of travel. The outer cones would have lower probability than the inner cone, if there was such

information. For frontal passages, perhaps time of passage could be indicated on the map. Also on a map, he would like current and perhaps recent-period loops of radar locations of events.
BIA: Preston Fisher, the Supervisory Engineer, and Gerry George, the Fire Management Officer, felt that loops were well understood and helped people see patterns.
BA also noted, as a general problem, that local radio stations are often very competitive with each other, and with stations from the nearest big cities. They may over-dramatize forecasts and events, in an effort to attract more listeners and hold listeners longer. This may reduce the usefulness of weather information, especially as the listeners begin to expect such distortion.
BA: He would also like to have probability of precipitation event presented with a measure of confidence in the forecast. The box to show a measure of confidence around a dot for the most probable point was mentioned (extent of box showing something such as 1 or 2 standard deviations, or 30 percent chance of being below or above the "dot").

B. Now versus last year versus normal

TS, BIA: Now versus Normal versus Last Year: This was first suggested to this study by Dr. Tim Steffens, and readily confirmed by many. The BIA officials felt that this sort of comparison is what people can best relate to, with the sense of normal and the last year being interesting and mentally fresh, and of great interest compared to the present. Dr. Steffens' perspective, from cattle management and marketing and range science, was based on asking, " where the forage grasses are now compared to last year?" And where "should" they be? This idea was very well liked by others as well.

C. Better connection between information sources

Existing information on NOAA and other websites is not easily used, in part due to lack of connection between tabulated data and sites of origin of the data, and other geographic context. Improved linkage between sites and historical information would help (this point made by Preston Fisher of BIA, and more gently by many). For example, the metadata on stations does not explain why there are gaps or periods of record which end a long time ago, or where the station is located.

5. Local packages

BIA: Local packages of weather and climate information would be ideal, with place-based sets of information, from which one might link to topical information. But, it would be their preference to be able to log on to an internet source and get what they want organized by a map and perhaps then a menu of materials for that place. One relatively straightforward element might be a set of suggestions for adjustment of a forecast for a given point, (e.g. a city with a forecast office), to different elevations and perhaps directions (such as would be suggested if typical storm tracks were identified). Terrain that has predictable effects on frontal passages or storm tracks should be considered for this purpose also.

6. Improved and different snow information

A. Generally:

SU: Snow sublimation request:
Better information on sublimation losses of the snowpack would be useful. The losses are currently unpredictable, but with better information on this, forecasting from earlier information on snowpack might be improved. TF: Snowpack is the essential forecasting datum for the BOR Colorado management as a whole, because it is such a dominant portion of the system's inflows. There are many desirable sub-basin and basin parts of these pictures that could be beneficial as well. The management questions for any given part of the river's "plumbing" vary with its inflows and the demands for outflow, so there is desire for knowledge of the variations in local inflows. The value of the forecasts will reflect the capacities for storage of a given runoff, and the options for use in lower places in some way, and the ability to adjust upper sources or contributors in response to variation in the normal runoff quantity and timing. Each facility should be considered

individually. Dr. Fulp is considering how to accomplish this in a useful fashion. For SNOTEL sites, the aspect of the site and how well it represents the basin would be useful information for interpreting the data. Additional sites should be considered for increasing representation of snowpack concentration and probable melt timing.

B. Timing

SC: Management of irrigation water might be improved by longer anticipation of timing – especially of unusually rapid or early melt-off. The water systems in Southeast Colorado and Wyoming, for example, cannot accommodate a rapid run-off without compromising flood safety criteria. The result is that water may be "lost" and unused, or stored below where it is needed or would have highest value. To the extent that forecasts can inform users of different probabilities of rapid run-off, there may be currently unconsidered opportunities to avoid losing the possible high flows.

C. More and better SNOTEL sites

There is agreement that increased SNOTEL monitoring would be helpful. They would like better wind information as well. The lack of monitoring of mountain conditions seems to be very widespread. The CWCB wants more easily accessed and used information on the location and representativeness of the SNOTEL sites from which information is well reported. Can there be more information on relations between the sites and the larger-scale outcomes under different weather patterns? "Old-timers" in the field know where the sites are and "have a feel" for some of this, but it is not easily acquired.

7. Frost dates

SU: Frost dates request – for travel and earthen ditches
The "normals" are already available, we think, from information on the website (easily accessed for station data, but what about interpolations for other areas?), but there is also interest (as in UMU) in forecasts for unusual dates. However, the reason mentioned was the onset of two conditions: the hard freeze prevents further work on ditches, in the Fall, and the onset of mud makes travel more difficult and damaging, and some work much more difficult. (Driving on mud can dramatically increase erosion, for example.) Soil temperatures are useful for this, rather than for timing of planting.

UMU: Request – Frost Dates forecast for crop management:
In order to take advantage of unusually early or late frosts, and reduce losses from unusual frosts, forecasts of those "last and first" dates would be desirable. This seemed similar to other requests for forecasts oriented to unusual or unexpected events, as opposed to events that are seasonally expected. Note that the UMU lands in the Farm and Ranch Enterprise are considerably lower and dryer than the Southern Ute lands, and thus concerns are different, even in the case of why frost dates are of interest. Similarly, frost dates may be valuable for others on the UMU Reservation for reasons similar to those on Southern Ute.

8. Fire and burn weather

SU: Fire weather and climate: Timing of controlled or planned burns is clearly a difficult and important application of weather and climate information. While most attention is given to immediate forecasting for the place in question (a task recognized as seriously difficult), there are also questions for the longer-term. Timing of a burn is critical. In regard to higher-fuel load and non-annual burning, perhaps knowledge of a dry next year or multi-year period (or wet) might affect the desirability of doing more or less burning in the present year. In general, field burning is apparently much less dangerous than forest and range burns, and field burns are probably annual without much regard for conditions or forecasts.
Staffing for burns is variable; weather and climate information may help anticipate needs. (To what extent was this useful in 2000?)

BIA: The very sophisticated weather information user, Fire Management Officer George, asked that we mention that he likes the GRADS 10-day outlook, but would like it better linked to maps.

The disastrous fire season of 2002 took place after the interviewing on this topic had concluded, and we are pleased that there have been significant increases in weather and climate information support for fire prediction, risk assessment, and event management.

9. Range Grass Growing Conditions

A. For livestock

TS and SC: Grass growth is the critical variable for cattle operations using range lands. Forecasts available early enough to effectively adjust the stocking rates might benefit operators. The dates would be highly sensitive to location, elevation, and the current weather, but calving limits the time when cow-calf pairs are sent to range. January is probably not too early, and March is getting to be late for usefulness, but it may depend on other factors affecting sale prices, and the structure of local cattle markets. (Feed lots exist, in part, to provide an even flow of stock for slaughter, and this is a complex market with highly uneven power and capitalization.) These forecasts would be similar to the degree day forecasts, but might include further information if there is expectation of unusually early heat, or other differences from normal. This information may be readily convertible from existing forecast information. (Some other angles on this are provided in monthly notes.)

The value of hay varies substantially with weather, and monitoring of conditions is necessary for best cutting time (after maximum growth as related to amount of water wanted to be applied, and before the hay dries or goes to flower after water stopped or conditions dry up). As discussed in "Steffens-Cotton Proposal", the difference in grasses is very important for when to graze or not, and when to cut or not, and elevation and temperature are key control on which species dominate.

TS proposed a valuable research program, which SC agreed would indeed be beneficial and cost-effective, and this is described elsewhere as "Steffens-Cotton proposal".

B. For wildlife management

MO: Based in part on the Tribal interests in Native species and wildlife management, Mr. Olguin (Director of the Department of Natural Resources, Southern Ute Tribe) asked for consideration of climate information that would help there. Dr. Steffens' forage grasses information might help, as well as information on stressful conditions for animals that may not have much impact on vegetation directly (e.g. especially deep snow, long-lasting severe cold or heat, and icing that affects movement or forage). One may also speculate that other conditions such as unusual growing or threat conditions may be useful when more management is applied, as in closure or opening of areas to livestock. Also, long-term forecasts of various conditions may be informative for herd size management. In many places, there is interest in knowing more about the balance of live stock with wildlife, and improved management capability may increase flexibility of response to changes in values.

10. Range cattle watering conditions and small reservoir ET losses

There are critical cost variables in ranching away from river supplies on which the rancher has good water rights. If the cattle are able to get water in only one place, it must have enough, or additional water may have to be trucked to the cattle. This is a serious cost, especially with high gasoline prices. Interestingly, the day after Scott Cotton mentioned this, a State Senator from Pueblo called for a special session of the legislature suspend Colorado state gasoline taxes because of high price impacts on the small agricultural operators. News coverage did not mention drought. Illinois and Indiana suspended their state taxes on gasoline in the summer of 2000 (Colorado Daily June 30, 2000). However, perhaps due to the poor financial condition of state governments in 2002, we observed no similar tax suspensions.

The responses to water shortage in small reservoirs is to move the cattle, increase the water supply, or establish different sources; all of these have costs. The most common problem, however, is inability to foresee the limits on a given small reservoir. The rates of evaporative loss can be very high, where there are very shallow conditions, and hot and windy days. Can windiness be added to the forecasting for the next few months, to improve ability to predict reservoir status with greater lead time?

Another consideration for cattle watering on the range is whether there will be unappropriated or junior water left in streams to which grazers may have some access after senior rights are satisfied. Knowing there is a good chance may change one's choices about where to have cattle.

11. Cloud seeding forecasts – Colorado

The Colorado Water Conservation Section performs several other functions, including permitting for weather modification. There are 8 permits currently on file, though a few are inactive since the last few years have been quite wet. The majority are efforts to increase snowfall in the very early season for a ski area (Vail, Beaver Creek, Aspen, Telluride). Another effort is to increase snowfall in the catchment for a reservoir from which the Northern Colorado Water Conservancy District draws. These permits disallow cloud seeding whenever snowpack is above a specified threshold. These have all been somewhat intermittent in operations, depending on the year in question.

The permit with most persistent use is actually held by an association of western Kansas counties, which has used cloud seeding in threatening clouds to reduce hail (and hail damage) for 18 counties for roughly 20 years. The seeding takes place in clouds upwind of the areas sought be benefited, so a strip of land on the state border has been included as benefited in order to secure a Colorado permit. Not all of the counties contribute every year to the operation but there is apparently strong belief that this reduces hail size and thus hail damage. They have reported a reduction in the number of claims for hail damage. Utah is believed to be allowing a considerable amount of cloud seeding also.
The permittees and the regulatory agency would benefit from more detailed wind field information with which to judge both the location of seeding efforts, and to evaluate the effectiveness. Currently, some of this is provided to some of the permittees by private consultants, but the State would benefit from better information.

Another surprising effort is a propane-explosion device that generates a very large noise, called a "hail cannon", which is believed to weaken and break up hail stones. They are also being regulated, and can be a significant nuisance to neighbors. and there is fear that effects on air traffic are not well understood. Mr. Stanton is unaware of any scientific support for this device, and would be pleased to know if there is any information in NOAA.

After the interviewing on this topic had been done, to some surprise the Denver Water Department decided to invest approximately $700,000 in cloud seeding and related measurement, in 2002. There was considerable controversy (e.g. at Colorado State University's Drought Seminar, December 4, 2002) over this decision, based on the lack of evidence of success in past efforts. Some meteorologists claim significant advances in the art, but we know of no decisive showing of success. The Southeastern Colorado Water Conservancy District also invested $140,000 in cloud-seeding, with undemonstrated benefit (Water News 2(4), December 2002).

12. Colorado water availability task force, and drought mitigation and monitoring forecast requests

The Colorado Water Conservation Board's Bill Stanton and Steve Miller requested 30, 60, and 90 day forecasts for drought conditions, for the Water Availability Task Force. This may be easily selected from existing information.

The Conservation Section, Bill Stanton in particular, is part of the Water Availability Task Force of the state's Drought Management organization (which uses several other task forces to coordinate responses when there are water availability problems). The Task Force includes National Weather Service and Colorado State Climatologist participation as well as representatives from may other agencies, so it is a very sophisticated user of climate information with full access to information. Bill Stanton regularly monitors a variety of sources, including the USDA/NRCS information, SNOTEL coverage, reservoir storage information, Colorado Climate Center, Drought Monitor and PDI and SPDI sources, SWSI, and others. The Drought monitoring is useful, and forecasts oriented to that would be good.

The National Drought Policy Commission recommendations on indicators and monitoring are also relevant, and NOAA was urged to implement them.
In the severe drought of 2002, NOAA staff from the Climate Diagnostics Center participated in all meetings of the Water Availability Task Force, and Drs. Wolter and Hoerling were often quoted in the Colorado newspapers and television. Events have thus superseded this recommendation!

6. "Shopping List" of longer-term interests and climate information goals

A. Irrigation season forecasting for water banking

Eventually, there will be a need for sufficiently reliable and sufficiently well-accepted irrigation season forecasting to allow for effective water banking. The Colorado legal situation is described elsewhere in this report, and there are many possible variations on how water markets might operate, but some of the critical elements may include (1) early-enough forecast to minimize wasted investment (e.g. planting wrong or unused seed), and facilitate making alternative management arrangements to minimize soil erosion, provide forage or meet other goals; (2) sufficiently reliable forecast (not necessarily perfect, of course) that all or an adequate number of participants in the market can commit to transactions; the problem is to compromise on all the parties' risk aversion and relative losses from misjudgments or failed forecasts. This would be a sufficiently accurate forecast of snow water yield, timing, and other precipitation to support adequacy of consensus to "make a market". The transactions must be designed so that the risks of incorrect forecasts are acceptably distributed, and externalities are minimized.

It may be valuable in pursuit of this goal to undertake examine each of those sources, and to inquire on the extent to which available irrigation water comes from snowmelt, monsoonal or seasonal precipitation, and the extent to which needs are sensitive to local drought indices such as soil moisture and other measures. Drought indices for each potential market area may have to be locally specified.

The Arkansas Valley also has complex water trading and transfers, due to the ability to divert flows from trans-mountain diversions into the Valley, and then again over the Front Range into the systems used by Denver, Aurora, Colorado Springs, and others. The trend at present is toward some resolution or legislative action to clarify the State's interest, and perhaps establish some limits on water marketing in Colorado, and perhaps conditions on out-of-basin transfers. This is an area of lengthy and rich literatures, and considerable speculation. It shows a strong interest in forecasts of the water year as a whole.

Charles Howe's 2000 article, "Protecting Public Values in a Water Market Setting: Improving Water Markets to Increase Economic Efficiency and Equity", University of Denver Water Law Review 3(2): 357-372. is a strong and clear summary of many important issues. A variety of additional interests might be served by effective use of climate variation forecasts, in the opinion of one author (other participants in the study may not agree).

(A) Soil maintenance is underserved in current economics – partly due to application of the positive discount rate, and for other reasons, but should be recognized as a public interest (e.g., non-point source water pollution and sedimentation warrant treatment as a public good or bad).

(B) maintenance of agricultural land in agriculture as re-capitalized and more flexible production units seems desirable at least in principle, as long as people are willing to keep doing small agriculture.
(C) The key to intermittent transfers and some reasonable level of equity may be contracts which are essentially long-term sales of options that can be exercised under specified conditions or with agreement, at specified times, or else with penalties.

And, (D), side deals such as support for farmers' markets and recreational access should be strongly encouraged and creatively approached – these would be partnerships between areas of origin and new places of use. In each case, more effective allocation of resources and more cost-effective forms of agriculture and combinations of agriculture and subsidy/externality may be amenable to improvement with increased flexibility for any given year's activities and improved capacity to apply climate forecasting.

The potential combinations of climate information and water marketing are discussed further in another section of this report. [NOTE: See project summaries posted on this website.]

B. Localization of forecasts ; geographic specificity

There is widespread interest in getting the benefit from larger-scale climate models and understanding of teleconnections, from local governments and water users on up to larger-scale water managers. The request for more effort to tie the big models to the smallest scales was common. The interests were also widespread, from water management per se to snow safety and flash flood conditions, and the surprisingly widespread interest in reservoir loss and evapotranspiration information (from small livestock operators up to the Colorado River system). Given the challenges and expense, however, there was also strong support for the idea of "calibration" and help for local people in making better use of existing forecasts and models, by better relating what happens at the point of interest compared to the point of forecast.

C. Requests and concerns for long-term climatology support for decision-making and risk understanding

There were a variety of requests for long-term forecasting, for a variety of purposes; of course, the underlying concern is usually to maximize the return on infrastructural investment.
Dr. Fulp noted possible relevance of very long-term forecasts for consideration in Colorado River management. Fulp is also concerned with the lack of application of forecasting in river management as a whole, and hopes to participate in efforts for improvements.

1. Long-term forecasting for the Colorado River Basin

This is not likely a surprise, given the enormous importance of the River.

2. Long-term drought prospects

CWCB - BS and SM: It would be useful to have a clear indication of how reliable the news is about past droughts and the research on extent and severity. New research seems to be appearing often, and it is hard to know how to weigh it. In the 2002 Drought, there was great interest in the "paleo-drought" studies, and Dr. Woodhouse (a NOAA scientist) vaulted to fame and frequent citation for her work on dendrochronology and its information for inference of past climate variation.

3. Long-term climate as driver of water supply

SU: Long-term climate concerns: There may be particularly strong interest in Southern Ute Tribe and others where long-term climate variation acts to reduce water supply and no feasible alternatives are currently known. The Native American water rights may be qualitatively different from other rights recognized by the State and Federal governments in terms of their transferability (and hence value as an economic asset). They may also be subject to unforeseeable difficulties in substitution or supplementation, for legal or economic reasons. And there may also be concerns not unique to Tribes, such as losses in carriage contracts which are specified not in terms of water "put in" but in water that is "delivered" to another user. Where reservoirs are losing more to evapotranspiration, the distribution of the losses may not be clear. This has become increasingly important in considerations of additional storage facilities for drought mitigation in Colorado, where the legislature enacted a bill calling for a referendum to approve $2 Billion in bonding capacity, with provision that at least one major project at great expense will be selected for construction, if not more. [Note: this was “referendum A”; it was defeated.] Storage to yield ratios for new reservoirs are an important issue (Luecke, D. et al., 2003, What the Current Drought Means for the Future of Water Management in Colorado. Available on-line from Trout Unlimited, <www.cotrout.org>)

4. Long-term forecast for organizational management

Army Corps of Engineers planning and budgeting for maintenance is based on a three years advance programming effort. JD speculated that long-term maintenance and staffing plans might benefit from consideration of multi-year cycles, if adequate reliability is achieved in forecasting, because work needed in wetter areas may not be as urgent in dryer areas. Funding is always an issue. In the very long term, the Corps has some land management responsibilities also, in association with wetlands as well as dams and levees and harbors.

In the middle range, specific operations and maintenance activities might be better scheduled if there were good forecasts of wetter or dryer periods. Which actions should or may be postponed, and which must not be postponed or should be moved to earlier timing? One example was maintenance and lubrication of a large kind of gate that is used for rapid (flood-related) releases.

Part of the job is easier and faster in dry times with low water, and testing can be done, but the need is to have that accomplished before high water. The Corps does not compromise on safety, but optimal scheduling might reduce costs and staff juggling, as for specialists who serve many facilities.

5. Very long-term forecasts for irrigation needs

BIA and SU: There was also interest in the longer-term changes in climate that would affect irrigation needs, and water supplies. The BIA Supervising Engineer, Mr. Fisher, is project manager as well for the Pine River Irrigation Project, and therefore is interested in what may affect his project's reservoir, both in supply and demand.

6. Long-term forecasts for breeding and stock selection

SC: Livestock operators want to breed the most suitable cattle and sheep for the conditions they face. Some choices are quite important, in the value of breeding bulls being bought and sold, and in the outcomes from different breeds in different conditions. There is potential benefit in choice of qualities to seek from knowing more about next year's conditions. The need here is really for information about the likelihood of extremes as well as means, since success depends on resisting losses in all conditions, and maximizing gains of weight. The lead time is fairly long; breeding is 9 months ahead of calving, and there is additional lead time for negotiation of stud services or purchase of breeding bulls. And, once the information is public and widely used, there will be secondary effects from competition being at the new level. Now, however, the next step is for increased use of the long-lead forecasts with the "local calibration" mentioned elsewhere, starting about a year ahead. Unfortunately, this does nothing to narrow down the request, but it shows another benefit from the complete forecasting suite of products.

D. The concept and application of probable maximum precipitation

The Colorado Water Conservation Board supervises the dam safety program in the state, and officials are concerned that the PMP idea may apply more accurately, at least in current practice, in the Eastern U.S. than the West. If the PMP application is unnecessarily strict, it may be imposing needlessly high costs on dams. Consequently, not only is expense too high, but officials also fear that small water development may be needlessly inhibited by these high costs. In light of concerns that climate variability may be increasing, the request for some reconsideration of the whole concept and how to achieve optimal dam safety regulation seems important. The fundamental basis of information on which PMP is calculated seems increasingly suspect if there is climate variation either greater than previously thought, or under pressure of anthropogenic climate change. There may be substantial inefficiency from mis-specification, such as from over-design of facilities.

E. Reliability standard and measures of confidence:

JV and LS: We asked them about the quality needed for a forecast, and they said, as a first estimate, that 80 percent accuracy would be good enough for them to act on, and they thought it would be good enough for most farmers. UMU: The professional agricultural managers and consultants volunteered the 80 percent figure as well, at Ute Mountain Ute Farm and Ranch. The usefulness of information is not limited to forecasts meeting such a standard, however, and as BA suggested (in accordance with leading literature such as Katz, R. and A. Murphy, Eds., 1997, The Value of Weather and Climate Information, Oxford), less confident information – properly understood as such – could still be very useful. Bob Appel suggested error bars or some other measure of confidence as part of any forecast. (This point was discussed as well by the "Three States and Tribes" team in a meeting.) We make no representation of any detailed understanding here, because we did not press our informants on their understandings of accuracy or reliability (though in each case these people are highly educated and not likely to have been speaking without a firm grasp on probabilistic information in their own technical fields.)

F. Bureau of Reclamation, River Forecast Centers and climate information

TF: There are important policy issues associated with the Annual Operating Plan for the Colorado River as a whole, and perhaps limits on the authority to include or respond to forecast information in the Annual Plan as a whole. But, there are also Monthly Updates, and Facility Plans which might incorporate forecast information. There seems to be a great potential for integration of the new forecast information with the existing ESP modeling from the River Forecast Centers. (After these interviews were held, we learned informally of various efforts to improve forecasts by the RFCs, and we do not know the current status of this situation.)
The Annual Operating Plan includes some of the factual basis for the determination of whether the Secretary of the Interior may declare that there is "surplus" which may be allocated to California or other Lower Basin claimants, in accord with the Upper Colorado River Basin act of 1968. [Note: later agreements and Department of the Interior actions affect operations now.]

The Colorado River system as a whole has such large storage capacity for the benefit of the lower basin that management has generally been concerned with very large scale changes in hydrology only. Because there has been a "surplus" in the sense of the "Law of the River", there has been little pressure to accommodate planning situations such as those developed in the "severe sustained drought" study (Powell Consortium 1995). The potential for improved management on smaller scales may not be fully explored yet, and it may benefit from climate forecast information in ways not yet fully considered. Dr. Fulp hopes that some scenario exercises might be undertaken The range of choice is not easily specified in general terms because of the varying contracts and obligations to which each facility is subject. But, that information is largely incorporated in the "Riverware" modeling which Dr. Fulp helped create.

In 2001, we wrote that, "There is also potential for considering very long-term forecasting of general trends such as PDO as well as ENSO influences in river management as a whole, though the reliability of the information would probably have a direct bearing on the extent to which such considerations would be useful outside the Bureau and agencies charged with some foresight as well as operations management. This is probably several big steps ahead, but may be of interest to NOAA's researchers." In 2003, finalizing this report, we are impressed at the remarkable progress made by NOAA scientists in this area.

G. Forthcoming growing season degree-days

SC: Agronomists use degree-days (combination of day length, relative humidity, temperature) for description of crop requirements and optima. The best choice of crop or variety can be identified with standard forms or charts of crop requirements. (This might be expanded in the future to include more easily available information on the sensitivity and vulnerability of crops to climate variations.) The modification of the current forecasts to degree day information would therefore have big potential benefits for crop adjustments.

7. What to do with these requests? Considering the calendar and the "shopping lists"

There are two directions for application. First, the National Weather Service or perhaps Forecast Service Offices in appropriate areas may wish to consider how their forecasting operations can explicitly identify how their current services provide answers, already available, and perhaps consider how other answers might be pursued. The climate programs may find the timing of forecast issuance requests useful, as well.

Second, we suggest that the NOAA collaborators who work with OGP may find it useful to consider how the requests from this project match with those from others, such as the CLIMAS study on vulnerability to climate variability in the farming sector (Vasquez-Leon et al., Dec. 2002).

A. Everyone wants better weather forecasts – but priorities within this include focusing on threats (see calendar and requests 1, 7)

Most of agriculture revolves around plants and animals that are fairly well adapted to "normal" conditions, but they're often pushed in ways that expose them to earlier or later dates, or unexpected locations and conditions. This puts a premium on unexpected conditions such as early or late frosts, sudden changes in weather, and so on. The forecast of a surprise event in a shoulder season may be more useful than when seasonal changes have taken place; when to plant is somewhat adjustable, but after planting, as one person said, hail forecasts are a big help if you can get your car in the garage in time to keep the windshield in one piece so you can see the ruined corn.

Structural vulnerability of irrigation systems to flash flood hazards is particularly acute, so severe storm information is important all the time. The coincidence of flash flood hazard with other thunderstorm hazards increases the value of improved forecasting. The tornado forecasting effort has inspired many to hope for better hail and local intense rain forecasts, and ideally, warning about the possibility of microbursts. This may relate to the extent and adequacy or intensity of radar and other remote sensing coverage, which is thought to be poor in rural areas. That in turn adds motivation to the next point. Basic information gaps, such as reductions in SNOTEL funding and stream gauging were frequent complaints.

B. More help in applying available forecasts to local situations ("Calibration" as opposed to downscaling)

One often sees calls for vast increases in modeling capacity and computational speeds, to downscale to smaller and smaller grid sizes, and incorporate more and more detail and achieve better realism. Unfortunately, simpler but perhaps quite cost-effective approaches to improving local information seem to lack appeal to both science funders and researchers. In discussions with our informants and advisors, we have elaborated a notion of "calibration" – working from known weather patterns and local conditions to help people make their own adjustments or applications of forecasts made for different places. This may be too "low-tech" to attract much scientific attention, but that could be a help in working with various partners.

The majority of our advisors have a fairly strong sense of how things usually happen in their place. For example, we often heard such remarks as, "If conditions are such-and-such, then the snow usually gets here about four hours after Pueblo gets it". On probing, this reflects belief in a weather pattern that is thought to be most common. The same person might also say, "Well, if the storm is coming from the Southwest, it can do strange things on the way… sometimes it turns and acts like an upslope…" We think the important point is that regardless of the accuracy of any such characterizations, long experience has suggested that there are some apparently common patterns which are larger than local micro-scale terrain effects. The question then would be, are

there? Can the NWS and allies provide more than a windrose for the year, and more than a windrose for each month? Not that this would be undesirable, but beyond this, are there figures available such as "For June, 80 percent of the thunderstorms in the blue area on this map take place when there is a cold front coming southward and a warm front moving northwesterly"? Or, "In March, storms which have brought significant amounts of snow and water content are almost always a feature of the jet stream moving in a loop that looks like this…. over the Rockies"?
If general weather patterns are identifiable for areas like the eastern plains of Colorado, that information would be helpful in itself, and also would help with the next step. That is, to provide guidance on applying forecasts for urban foci to the rural areas. There may be, for example, a forecast for Pueblo, and that may be adjusted to provide a forecast for Lamar, but for someone dozens of miles out of town and not between these points, right now there is only experience and hunch about how to use that information. This relates in turn to the preference for certain forms of information, as in (4), below.

It may be possible, at moderate or small expense, to provide two changes. First, educational materials would be helpful, for farmers and ranchers, about weather patterns in areas of concern. this could also include guidance on adjusting for terrain or elevation, and other factors. If this were widely available, with clear explanation and some help-line service, it could also be used by small towns and others looking for more localized information. Second, if forecasters were asked to incorporate relevant information that would help in this, they might habitually include remarks about the directions and speed of fronts, what might change that, and so forth. Television weather often specifies, and shows, fronts moving through urban areas, but there is much less effort (and perhaps less accuracy) for rural areas where few will be affected.

One interesting issue in this approach is how much information forecasters have that is not communicated, due to thinking it has not value. Who cares about the back of beyond? But, it is a small extra cost to add a few sentences to a forecast or text discussion. Where there is no apparent pattern in effect, knowing that is also useful.

There is a huge popular interest in weather, especially in the rural and agricultural areas, and it would be very good to undertake partnerships with local media and local schools to develop this "calibration" work. Schools can keep records and see how well the guidance worked for example, and they can work out local tables and charts for "here compared there", and so forth.

And that leads to the next point. Note also, however, that this idea of calibration also helps meet the request for more localized packages of information; especially with school partnerships, since these would start with local climatologies and identification of weather patterns.
This kind of local partnership could also support requests B and C, for better localization in the long term and for better climatology for decision support. Even request E, for reliability standards and measures would be helped.

C. Support development of partnerships and expert systems to show applications of climate information in the U.S.; start with Agricultural Extension.

Schools are always interested in their own places, and should be invited to help in this. But universities and Agricultural Extension services are apparently underused. There are some exceptions (e.g. Dr. Schneider, funded by NOAA OGP), but we found that in Colorado there was little effort available to undertake new projects. Weather readings are a daily activity for many Experiment Station and Extension staff persons, but long-term research efforts are increasingly hard to fund and staff. So, private sector interests may have to be brought in, with careful limitation on the extent to which they are allowed to monopolize uses or dissemination of public research and information. There is considerable disgust with feeling that cities get great help but in the country you have to pay a lot for the same thing.

Beyond the forecasts, there appear to be important opportunities for development of expert systems which can link existing information and forecasts to locally-obtainable information, such as one's own soils' qualities, and existing models and tools such as the "Cropflex" irrigation scheduler that can be downloaded from Colorado State University (there are similar programs from Kansas State and Nebraska, also; CPIA 2002, 2003; see website of Central Plains Irrigation Association for information on presentations and see Colorado State for the model itself.) Presently, we are informed by the Cropflex principal author, Dr. Israel Broner, that one can easily use this tool to see some outcomes from inputting different sequences of weather and irrigation, made up or "true"; so, it can be used to see effects from synthesized or predicted conditions. The next step will be adding range forage species and more soil conditions and qualities, to extend use for non-farming applications.

Modest funding with considerable educational benefits for graduate students from several disciplines could support demonstration programs for linking and elaborating some of these tools and basic measurements for a variety of test sites. With reasonably good localization (and guidance on how others would calibrate the results for their own locations, as above), this might produce low-cost helpful improvements in seasonal interpretations of available climate forecasts. (See also "Steffens-Cotton idea in section on other ideas.)

D. Develop the new climate divisions for more useful applications

The Arkansas Basin is within one climate division in the current mapping, and this may be misleading when climate forecasts are combined with new applications for improved soil moisture and agricultural forecasting. The work by Dr. Klaus Wolter of the Climate Diagnostics Center which has been informally presented seems to be an excellent means of increasing the value of existing data and increasing the usefulness of future forecasting efforts.

E. Additional forecast timing, effort allocation and similar issues

1. Soil moisture over the winter

October and November, depending on elevation, are the times after harvest and before hard freeze when land treatments may be undertaken, and these could be informed by forecasts for the winter season's weather conditions and moisture conditions. Soil moisture is always critical information for farming and range, and it is increasingly important (e.g. in recommended "best management practices" -- BMPs) to manage to retain stubble and roughness for moisture retention. In some areas, the BMP will probably not change, but before the hard freeze it may be quite helpful to know if there is an unusual chance of especially dry or wet or warm or windy conditions over the coming winter season.

2. Extreme weather probabilities over the winter and coming year

Livestock sales are extremely complicated by the price effects of many sellers and buyers reacting to the same news at the same time, which can be commodity prices that affect feed prices and thus expected profitability to feedlots and others. On the whole, more information seems to be desirable, though we are not making this assertion with confidence. We suggest that NOAA enlist Dr. Jim Mjelde, Dr. Dan Hallstrom, and others whom it has already funded, to seek further elaboration of livestock management issues in regard to forecasting. It is fairly clear that the very large firms that make up an oligopoly in commercial meat processing are in full possession of state of the art climatology, and that small firms cannot afford this. This informational asymmetry creates advantage for those already advantaged by size and sheer capitalization, which unfortunately raises issues of public policy about who benefits or does not benefit from public science which is not directly useful without expensive interpretation. This issue has been raised elsewhere, but it has not been resolved to our knowledge (e.g. in the discussion in Stern and Easterling, 1999). Other National Academy and National Research Council deliberations also relate to this (e.g. "A climate services vision"), but optimal allocation of efforts can only be judged by some position on this. Given the extent of expense in agricultural policy and the public interest in land management on the majority of the surface of the country, there is certainly grounds for pursuing the issues.

3. The early December forecasts for the coming year

As discussed in the Calendar, allocation of expenses to one year or the next is an important December decision which might benefit from forecasts at this time. One point we raise without any recommendation is that timing of decisions on county options in crop insurance may also warrant an effort while the forecast can influence date setting and considerations of prevented planting to the extent that these are or can be made regionally flexible.

4. February forecasts may become more valuable

Although these mechanisms are just getting started, dry-year options or interruptible supply contracts may create interest in forecasts at this time, when many farming operations can either do the best thing for a year of normal operations or a year when much of the water will be transferred elsewhere.

5. Hydrology and flow forecasting for Bureau of Reclamation projects

The West is served by critically important big water projects, which typically allocate water based on shares of the estimated amount available. We appreciate that there many research efforts in progress to improve the forecasting of available water supply, but despite this there were some very unpleasant surprises in 2002 (post-mortems are beginning to appear, but already see Luecke et al. 2003 noting that municipal expectations were under-informed on soil moisture in watersheds and other factors. Just so, other major water managers were unpleasantly surprised, and so were their users. We think this suggests that more monitoring is certainly indicated, and also that more forecasting support could help. The techniques used are already under revision, but the techniques coming into use might not yet be extended to local applications. Without adequate background in this area, our recommendation is only that NOAA might want to be assured that this is being considered. (See requests A and C, and F),

6. After-April updates – especially for more sensitive areas

April 1 is the traditional date for assigning volume to shares of "project water", but as climate variability may increase, there may be increasing value in updates that would help with in-season reallocation of resources. Should water banking and other management flexibility increase, the ability to respond will increase the value of information. Schneekloth (2002, 2003) and others are offering increasingly popular guidance on water-stress management, and highly responsive agriculture will surely become more common. In regard to allocation of effort, areas which rely on ground-water (e.g. the Sculpture Springs Valley examined in the CLIMAS report) are much less sensitive to short-term fluctuations than those dependent on surface water, and in turn, it is usually thought that greater storage in proportion to demand reduces sensitivity (see review in IPCC 2001). Linking forecast effort to well-understood engineering principles like these could be helpful guidance. This responds, incidentally, to requests 2, 5, 9, 10, and A, B and C.

F. A variety of other recommendations, described in detail in section so named

In this section, a variety of other recommendations are summarized. These arose from the interactions with our informants and advisors. Some came more or less directly from them. Some resulted from reflection on the issues raised.

1. Range management and climate forecast applications workshop.

In the course of interviewing, Dr. Tim Steffens offered a very useful suggestion, as a request for a project with which NOAA might help. Later, Scott Cotton, another range management extension specialist offered some additional ideas, and provided background.

There is insufficient clearly-organized and accessible information on the relationships between climate variation and growth of major forage grasses. The information desired would be easily available on internet, but also disseminated through newsletters, local news media, and however appropriate. It should be presented in fashion intended to make its use as easy as possible. The relationship between climate and growth should be described in terms of normal, last year, and this year's progress so far and projections based on current forecasting. The growth of the grasses should be described as above-ground and below-ground, to inform users of root development and capacity to recover from grazing. For each location, the major forage grasses should be identified, with links to information on their grazing values, times of growth, and information about altitude variation.

The lack of this information complicates management for both livestock and wildlife, and beneficiaries would include small acreage, larger livestock operators, and wildlife managers. A workshop could be designed to cover some relevant climatology, some of the agronomy of the forage grasses, and how these relate, to identify gaps in knowledge and gaps in knowledge about how to apply what is known to particular places, with use of moisture and other factors. It would also be useful to consider estimates of the value of improved information, for livestock production, range management for wildlife and management for environmental concerns. A research agenda should be developed to help coordinate and cumulate research.

Because of the interest in this area and the high concentration of expertise at the University of Wyoming, Colorado State University, and the University of Colorado-CIRES-NOAA group, and the presence of two interdisciplinary projects on regional assessment of climate impact, the high plains/short grass steppe of Eastern Wyoming and Eastern Colorado is an excellent starting point. Further strength for the effort can be added by the advisory groups created by the CSU Great Plains Climate Impact USGCRP assessment project (Ojima et al.) and the agricultural colleges and extension services at UW and CSU. The CU-CIRES-NOAA group offers leading climate diagnostics expertise.

2. Ute Mountain Ute long-term observation proposal

The Ute Mountain Utes have equipped their Farm and Ranch Enterprise with state-of-the-art weather monitoring, and precision agriculture equipment. Much of this could be used for other purposes, if there were suitable partnerships developed. The West Slope is not apparently well studied in most ways, and this set of expertise, instrumentation and environmental interests should be of value to most land and water management agencies. Comparison of local weather observations and their relation to other observations could be useful, and the level of monitoring already present could be useful to compare with other study sites.

The Tribe should be respectfully approached with ideas that reflect the need for long-term ecological monitoring and range management studies, as well as greater understanding of irrigation and salinity in this climate. The Tribe has for some years offered an educational program on soil and water management, and has several partnerships in progress with the Bureau of Reclamation. This recommendation is based on observing the potential for mutual benefit.

3. Spot weather forecasting applications

The National Weather Service provides "spot weather forecasts" for some agencies which are planning controlled or prescribed burns. The means by which these forecasts are prepared might be considered for more general use or perhaps for modification as help for local forecast applications.

4. Agricultural efficiency improvements – see appendix: agricultural efficiency proposal

There is growing interest in improving agricultural irrigation efficiency, as a way of increasing overall system efficiency, and increasing farm returns on assets. The rationale is described in an appendix on this topic.

5. Rural internet access and communication problems – a note to website designers and managers

JD, LS, JV, others: INTERNET ACCESS PROBLEMS
Several of our advisors (JD, LS, JV) urged us to report that older telephone lines may have so much static that access to any source is difficult, regardless of the quality of service available. The more modern the source (e.g. satellite images or loops) the more difficult it is to get this

information to come across adequately. In weather emergency conditions, high wind, rain or snow may aggravate this difficulty and make the sources useless. This is particularly important where people at home cannot access information about conditions. The Corps at John Martin Dam has a high quality line, but others cannot get that service in emergency management situations. Reliance on the internet can be a problem. During good weather, service can be poor or blocked as well.

Interoperability and communications problems are serious for both forecast and emergency information communications in multi-jurisdictional areas with many small groups in large spaces without funding for new equipment. Progress on emergency coordination might come from solving the problem in general. The 911 phone system, for instance, suffers from the multiplicity of telephone and cell phone service providers, whose operators must attempt coordination of the responses, often from far away and perhaps with little or no knowledge of current emergency service provision – for example, ambulances may be dispatched from volunteer fire departments, fire districts, cities or hospitals, some of which maintain ambulance districts. The service areas are not matched to zip codes, telephone exchange prefixes, or even county boundaries in some cases. Half of Bent county, at the time of one interview (April 2000) was in no fire district. Further complicating this situation is the problem of very low levels of paid staffing and equipment availability. To the extent that NOAA weather radio can serve as a backstop or common denominator for emergency communications, it could be a life-saver.

6. The role and goals of crop insurance, and its relation to climate forecasting.

There are a variety of potential applications of climate forecasting in crop insurance applications, including some which may alter the balance of interests presently served. For instance, if the Risk Management Agency were operating as a private insuror seeking profits, it might apply forecasts of a dry year to disqualify those who apply for insurance, on the ground that there is likely to be prevented planting so the insurance is unavailable. Or, it might disqualify applicants or areas on the grounds that the forecast establishes that there is no reasonable expectation of adequate water supply. Insured farmers, on the other hand, might find it especially useful to apply for insurance at high levels of coverage when they have forecasts predicting that yields will be low, and apply for insurance at only catastrophic levels of coverage (highly subsidized, does not pay a high percentage of expected yield) if they expect a good year. Careful use of the forecasts, assuming adequate skill, would increase the net benefits to farmers and decrease the net economic well-being of the insuror; in effect, risk management would be improved for the farmers at public expense. That might be a good thing and also perhaps an economically good thing, if it were cost-effective in place of other subsidies or supports for various policy reasons. Because crop insurance is county-specific, in some dates and in calculations of expected yields or estimates of losses, there is a great deal of localization built into the current plans. This might be considerably impacted by application of forecasts, and it would seem valuable for USDA and NOAA to consider some effort to develop understanding of the potential consequences from either USDA Risk Management using forecasts, or farmers using forecasts, or both. These might be considerably different.

It may be valuable to investigate using the crop insurance tool to influence water management. This clearly is a major policy choice. One can imagine requiring combinations of dry-year options, reserve programs, and insurance plans to smooth and distribute risks, possibly with premia paid by all parties to an arrangement (e.g. urban transferees as well as agricultural transferors).

8. Potential applications of climate and weather information with a "water bank" mechanism in place: Three ways to apply climate

information [Note: this section has been partially superseded by continuing development; see Project Summaries posted elsewhere]

A. Dry year options:

These are long-term contracts, as described just above; they are intended to be used in place of permanent "sell-out" and loss of irrigation use ever after for the lands from which water is sold. Permanent transfers have different effects from those which will take effect only in dry years, but so far the legal and engineering costs of "interruptible supply contracts" or "dry-year options" have been so high that cities considering them have just gone ahead with permanent sales of water rights, and leased water back to agriculture as convenient (interviews with Broomfield, Boulder, Thornton, Westminster officials, 2002). The Northern Colorado Water Conservancy District has also considered the problem (interview, 2002). No one is against the idea, and everyone appreciates the value to agriculture of retaining the property right, even subject to loss of use in some years. But, the legal threshold of being first to do it is likely to be a high expense, high-effort trip to the Colorado Supreme Court, and it would be essentially a gift of that expense to the agricultural community from the citizens of whatever municipality decided to make it. Instead, cities just buy the water rights, and lease the water back to agriculture when it is not needed. This involves the same transactions costs, and more advantages in the additional flexibility for the city. There are also some other options for "emergency" temporary water supply plans (recently enacted HB02-1414, and HB03-1008 with forthcoming rules).

There is a new law (HB03-1334) authorizing these contracts, so we expect developments soon, but it is not clear how useful this will be, because of the limitation that they can operate only in a year when the Governor has declared a state of drought, or the year following a declaration. This is considerable progress, since the duration of these contracts does not seem to be limited. The question is whether the drought declaration will constrain operations to too few years for this to meet many uses. The Drought Mitigation Plan does not answer this question, since there appears to be considerable discretion.

But, where drought increases the need for municipal water supply, as it did rather dramatically in 2002, there may be more will to make unusual deals. At the time of writing, there is little formal information available about the ways cities acquired more water; anecdotally, it has been a time of serious pursuit of agricultural water as leases for this year, and apparently, for 2003 as well. The long-term climatology surely will help inform people considering dry-year options, since the municipalities want very long-term commitments. The reasoning is that the cities "sell a tap forever" – so they need supply commitments for a long term. But they are also interested in the potential cost-savings from increasing supply in dry years only, when there is by definition very little need for additional infrastructure. No new storage is needed, only some new connections in some cases. The benefits in theory would be the savings from avoiding the next-cheapest source of supply.

B. Pre-season planning and crop-switching: easier said than done?

There are substantial opportunities for benefits for agriculture from pre-season planning. For any given year, if institutions allowed, it would be ideal to be able to lease water, and to reasonably well estimate the demand compared to the supply. With some degree of knowledge of the likely supply, it becomes more attractive to invest in water-intensive crops, anticipating larger supply, or perhaps to plan low-water crops and transfer some water for a guaranteed return no matter what else happens. One can easily imagine the range of possibilities, and how they can incorporate improved knowledge of one's own growing season, that of the likely competitors, and one's own farming or ranching conditions. In regard to knowledge of competitor conditions, for example, several farmers mentioned that if other places with lower costs of production were going to have a good year, they wouldn't compete in onions. On the other side with widespread drought there has been very high demand for alfalfa and hay and prices have been much higher than normal this year. The producer must match the uncertainties of the yield with the uncertainties of the financial and price outcomes from the larger markets.

Two agronomy considerations make the use of pre-season planning attractive. One is the availability to select different cultivars; corn (maize) can be had with 80 to 150 day growth periods. For instance, for the sweet table corn market, there are much better prices for the earliest and the latest fresh corn. For the feed corn markets, timing is much less important. The other is the difference in when crops need water is also important; spreading out the critical growth stages by different choices may mean the difference between success and failure with the same water supply. Current research in agricultural extension in Colorado and Nebraska includes efforts to identify and teach the differences between providing less-than-ideal water supply during vegetative growth stages versus reproductive growth stages, and relating yield differences to finances (Schneekloth 2002, 2003, Central Plains Irrigation Association 2002).

NOTE: There has been substantial progress in developing techniques for limited irrigation and deficit irrigation since this report was written; many developments are covered in the proceedings of the Central Plains Irrigation Association, posted annually, for region-specific work; for general work, the traditional literature in agronomy is indicated, and for current applications of research, see each state's website for the Co-operative Extension Service.

So far, there is little interest in crop-switching as a response to drought, according to our advisory group's observations over the 2002 year. This is also supported by the preliminary report from the Colorado State University annual survey of agriculture (Schuck et al. 2003). The survey did not consider cultivar versus crop switching, so it is possible that changes in the kind of corn were not reported. It is also possible that many farmers were committed to their plans for reasons related to crop insurance contracts, and maintaining base acreage for various federal programs. It would be valuable to inquire further. It may be possible to achieve greater flexibility in the future if other elements (including financial and risk management) are also adjusted to harmonize with more responsive decision-making.

NOTE: An unprecedented level of crop-switching was elicited by the boom in corn-growing for ethanol in 2006 and after; see USDA sources, such as crop statistics, and Westcott, P.C., 2007, U.S. Ethanol Expansion Driving Changes Throughout the Agricultural Sector. Amber Waves Sep. 2007; <http://www.ers.usda.gov/AmberWaves/September07/Features/Ethanol.htm>. The economic dislocations of this switch are still reverberating in crop and livestock operations.

Flexibility to switch among crops is limited in important ways by the timing of water availability. RF and AVP mentioned that what water you have controls your choices. Holbrook, for example, was said to be unable to plan on winter wheat because it didn't have the early and late season water needed. In general, the senior priorities can much more easily respond to the market, and therefore have more ability to farm the high-value crops. Juniors, on the other hand, must rely more on safer crops, and will plant more alfalfa since it can use a great amount of water or get by with lower production if the water is short.

Each ditch must make its own decisions, based on water rights and ability to get more, and within the ditch soils may make a difference sometimes. We were advised that if you locate the CRP (Conservation Reserve Program) lands, those maps will identify the worst soils for you.
No other limits on crop-switching were mentioned; we asked specifically, and were told that there was no problem with herbicide carry-overs or such things. But, those who did not feel the need would not take a chance. Rocky Ford, in particular, would always have the water, and so did not need to worry about switching away from the traditional uses for that farm.

1978 was the last year for any beets in the lower Arkansas – transport to mills just got too expensive. The tomato business declined a lot in the early and mid 1980s, and the last contract was in 1995, California competition just got too hard to beat. And, local buyers in the past couldn't actually take very much at a time; one plant in La Junta long ago could contract for 100 acres, but the last one could only take 10 acres or so.

There is still one vegetable buyer in the Valley, in La Junta, but it is held now by the last of a series of owners. There were informal statements that these owners are now buying cucumbers from Mexico in semi-trailer truck loads, because the previous owners engaged in business practices and suffered reverses of fortune such that farmers would not sign any further contracts with them, before they sold out. The ill will was said to have persisted.
But, Jim Valliant, Lorenz Sutherland, Ron Aschermann and Gerry Knapp all agreed that labor prices had become a big problem with vegetables in the Valley. Even the melon growers were having troubles. The Rocky Ford growers had the late and early water that is needed for vegetables and fruit, but were moving away from vegetables regardless of local buyers.

Bob Appel added an important point: milo, also known as grain sorghum, sweet sorghum, and rarely "cane", is an important cattle fodder crop, which is baled and fed. Unlike Alfalfa, it is harvested only once, but it is very flexible compared to most crops. It can be planted in early Spring, and harvested in mid summer. It can also be planted as late as June 1, and then harvested as late as October 1. This makes it possible to use milo as a cheap substitute for a corn crop that failed early in the year (as can happen most often from hail on young plants). An important implication from water timing acting to limit ability to switch is that it provides additional incentive to switch from surface water to groundwater use if possible.

C. In-season re-allocations:

Another set of possibilities comes from the increasing ease of use of irrigation scheduling computer models. Hanley et al. 2002 provided a good review of some fairly high-end modeling work, at the 2002 AMS meeting, and this suggestion is pitched at a somewhat different target. One of the problems faced by downscaling efforts is the problem of localizing the results for terrain and the hydrologic responses of different soils. And, the time scales involved are important. One way to partially "end-run" some of the problems is to work with localized (farm-specific or even field-specific conditions) inputs, and shorter time-scales. Using models now available that run very quickly on desk-top computers, (Cropflex, KanSched), one can input continuous updates of precipitation received, and even (soon, perhaps) adjustments for evapotranspiration losses. These are distillations available for free on internet from sources such as the Cooperative Agricultural Extension Service of Colorado State University and USDA (Central Plains Irrigation Association 2002 and see <http://ccc.atmos.colostate.edu/~crop/>). This means that the rest of the season can be reasonably modeled. It will be possible to use this kind of tool to input forecasted conditions, to see how things would play out, as well, with translations from climate forecasts to hydrology that are becoming more feasible, as other papers in this symposium are showing.

NOTE: Since this report was written, several irrigation scheduling and water allocation decision support systems have been produced by Extension and other researchers, including work by Dr. Norm Klocke and others for Nebraska, “Water Optimizer” (<http://real.unl.edu/h20/>) and Dr. James Pritchett and others for Colorado; see <http://limitedirrigation.agsci.colostate.edu/>.

It will soon be considerably easier to compare expectations based on current conditions and current prices for future crops, and prices for water, to consider in-season reallocations. Here, quick and low-cost water transfers are especially important. Farmers with low-value crops may realize higher returns from transfers to those with high-value crops in need of additional water, if weather changes adversely impact supply or soil moisture. Ability to use the increased evaluation capacity, however, depends on being able to make the transfer. Currently, there may be high flexibility on a very local scale, such as on the same lateral or nearby on the ditch, but larger areas within which trades can occur would include larger variations in productivity and probably potential gains from trade.

D. Increased incremental flexibility – useful to have

The current lack of flexibility in whether or not to use all available water, and difficulty of changing the rate of return or productivity from use, may thus be eased by the combination of new information and the ability to respond to it. Presently, there is limited ability to incrementally adjust operations, before or during the year, because of the fear that declining use of water rights risks losing them, and the lack of useable temporary transfers for many potential participants. Municipal buyers or lessors can easily accommodate additional shares of a ditch company's supply, for example, where the effect is to increase the city supply back upward to where it had previously been, so new connections or conveyance are not required. Where there is no new plumbing needed, things are faster. But even here, many of the transfers that interviewees mentioned were possible with little new information needed simply because there had already been substantial investment in quantifying the transferable amounts for similar transfers. These conditions do not often apply to agriculture-agriculture transfers.

E. The Engineering Needs – a non-trivial investment

The lack of transactions in water in many places means that there may be very little existing information on the return flows, suitable for quantification of the transferable fraction of a water right. This is critical for defense of the pattern of return flows required to maintain legally vested water rights. When a transfer is sought, the water court will normally hear testimony based on local investigations as well as review of adjudicated water rights, and other change applications; in fact, one of the objections raised to the Water Bank Pilot Project was that it takes so much work to do this that some objectors believed it impossible for the State Engineer's office to quickly review proposed transactions. The counter-argument, however, was that there had to be some level of adequate engineering estimation to make this work, even if there was some error, and that this was on offer. The reversibility of changes is an additional persuasive factor.
(The rules are available at <http://water.state.co.us/pubs/rule_reg/arkpilotrules052302.pdf>, and see <http://water.state.co.us/pubs/rule_reg/arkriverbasis.pdf>.)

The core issue was whether the "acceptable factors" for calculation of transferable consumptive use would be acceptable. Legally, these are rebuttable presumptions, and the question is who bears the cost of proving them wrong (an objector) or right (a party seeking the change). The expense of making a proof either way could be substantial, so the lack of protest or litigation is an important accomplishment, which reflects the potential benefits if this can be made to work. Another way to consider this is a new agreement that the risks are worth the experiments with temporary transfers.

Although not explicitly relevant, there is also important new engineering technology and modeling being developed, and this very likely affected the outcome. Oddly, this comes in part from the litigation by Kansas versus Colorado, over claimed failure to meet the interstate compact obligations. This has resulted in an extremely high level of monitoring on the Arkansas River. The social acceptance of the adequacy of engineering "off the shelf" is likely to be higher than previously, but it is not clear that there is adequate acceptance yet. and the expectation that mistakes causing injury will be caught is reasonably high, as well.

F. Salinity reduction and the public interest – an additional motivation for transfers

There have been substantial improvements in water and salt transport and flow modeling from the Colorado State University Water Resources Research Institute and Department of Civil Engineering. In particular, see Gates et al. 2002, showing highly localized salt source identification and salinity in studies of an area roughly 80 km along the river and major canals; this is complementary to on-going work at field-scale in several locations, with very localized mapping of the height of water tables and salinity changes over time (presentations have been made regularly by Dr. Luis Garcia, e.g. at Colorado Water Congress, January 2003).
(Gates, T. K., Burkhalter, J. P., Labadie, J. W., Valliant, J. C., and Broner, I., 2002, Monitoring and modeling flow and salt transport in a salinity-threatened irrigated valley. *Journal of Irrigation and Drainage Engineering*, ASCE, 128(2), 87 - 99. (This is available on internet by download; browse to the journal name.) There is also a powerful demonstration of the CSU capacities at <http://www.ids.colostate.edu/projects/spmappresentation/>.

NOTE: Gates et al. have published several updates and new reports, including Gates, T.K., L.A. Garcia, and J.W. Labadie, 2006, Toward Optimal Water Management in Colorado's Lower Arkansas River Valley: Monitoring and Modeling to Enhance Agriculture and Environment. Fort Collins: Colorado State University, Water Resources Research Institute, C.R. 206, and Agricultural Experiment Station T.R. 06-10.

The water bank may offer the capacity to re-allocate land and water for a wide variety of purposes, if the institution can be established. This would include important opportunities for public interest, recreational and amenity value improvement, and the capacity to increase economic efficiency for all water and land uses. It depends on adequate engineering support and adequate legal capacity to allow low-cost changes in use and place of use.

VI. Protocol for Contact with Tribes, by Dr. Daniel McCool

NOAA Project:
"Exploratory Assessment of the Potential
for Improved Water Management by
Increased Use of Climate Information
In Three Western States"

Protocol for Initiating Contact and
Interviewing on American Indian Reservations

CONSULTATION:

For 500 years non-Indian people have been coming to Indian Country in order to obtain something they want: land, resources, information or political advantage. Our project is different; we are traveling to Indian reservations to help tribal water managers more effectively utilize climate data. It is crucial that we convey that message from the very beginning. Indian people are sensitive to the issue of being exploited by non-Indians. Thus, any work we do on Indian reservations requires a candid, honest and complete explanation of its purposes and potential benefits. We should be clear at the outset that our questions are designed to help NOAA better serve tribal needs, and that, as a beneficiary of the study, the tribe is entitled to have access to the information being developed at all stages of the study.

First, it is important to understand the geographic, legal and historical context of American Indian nations. Today, Indian America consists of over 550 tribes, with a total population of just under two million. Federally recognized Indian reservations total 56 million acres; Alaskan Native trust lands comprise another 44 million acres. The United States signed nearly 400 treaties with American Indian tribes; these treaties, and successive agreements and congressional statutes, created a very complex legal relationship between Indians and non-Indians.[i] Federally recognized Indian tribes have a legal status that is unique in our federalist system of government. Tribal governments enjoy standing as semi-autonomous governing entities--a condition Charles Wilkinson has aptly described as "measured separatism."[ii] At one time Indian people had an exclusive relationship with the federal government; state governments held no power over Indian reservations. That policy has been modified by the U. S. Congress in certain situations, but Indian policy is still primarily the responsibility of the federal government.

Today tribal governments are recognized as autonomous entities that should be an integral part of any policy decision that affects Indian people. When President Clinton came to office, he declared that Indian policy would henceforth be based on a "government-to-government" relationship between tribes and the national government that would reflect "respect for the rights of self-government due the sovereign tribal governments."[iii] This is important because we will be viewed as agents of the government; this project is funded by the federal government, and each of us is associated with a state university.

The cornerstone of this relationship is *consultation*, a term that has been legally defined by federal law, and is now a required part of any interaction with Indian tribes. In 1993 The Department of Interior, which includes the Bureau of Indian Affairs, developed a department-wide consultation policy: "Bureaus and offices are required to consult with the recognized tribal government with jurisdiction over the trust property that the proposal may affect.... All consultations with tribal governments are to be open and candid so that all interested parties may evaluate for themselves the potential impact of the proposal on trust resources."[iv] In 1998, in an executive order, President Clinton clarified and affirmed the federal government's commitment to consultation:

> In formulating policies significantly or uniquely affecting Indian tribal governments, agencies shall be guided, to the extent permitted by law, by principles of respect for Indian tribal self-government and sovereignty, for tribal treaty and other rights, and for responsibilities that arise from the unique legal relationship between the Federal Government and Indian tribal governments.... Each agency shall have an effective process to permit elected officials and other representatives of Indian tribal governments to provide meaningful and timely input in the development of regulatory policies on matters that significantly or uniquely affect their communities.[v]

This policy of consultation has had a direct impact on the relationship between Indian tribes and NOAA. Claims that an aboriginal medicine wheel existed at the site of the new NOAA building in Boulder gave impetus to the agency to develop a heightened sensitivity to Traditional Cultural Properties (TCPs). The agency's description of the consultation process is quite revealing:

> Procedures that are "business as usual" are often alien to the Native American Indian sovereign governments, therefore, agencies should not require tribal representatives to conform rigidly to procedures that may be alien to them. To require that they conform to our procedures is not in keeping with the spirit of the laws governing consultation. Negotiation and consultation with the sovereign nations requires that the federal agency be sensitive to and cognizant of cultural values, socioeconomic factors, and the administrative structure of the tribes, including economic

> circumstances, seasonal availability, or other constraints that may limit the ability of individuals and groups to participate and respond in a timely manner.[vi]

It is important that the research funded by this project abide by the President's Executive Order, and the NOAA policy on TCPs.

MAKING CONTACT

Every Indian tribe is an autonomous government with its own formal and informal protocols. The initial contact with tribal officials is best made through informal channels via an individual with whom the P. I. has already established a relationship of mutual trust and respect. Due to the perverse nature of our history with Indian peoples, tribal officials are understandably suspicious. A formal letter requesting participation in our project may go unanswered; it is preferable to make contact through personal connections, at least initially. The focus of the initial contact should be on establishing a link to the relevant elected and appointed tribal officials who would be most interested in our project. The objective is to explain the research and how it may be useful to the tribe. We should keep in mind that every tribe is unique; there is no such thing as the "Indian way" of doing things. In addition, each tribal government may have a unique cultural and administrative system to deal with water management; what may work at one reservation may not work at another.

It is preferable to obtain written permission from tribal officials to conduct our project on the reservation. Thus it may be necessary to make a presentation before a tribal council, and request an invitation to proceed. We should not assume that a tribal government welcomes our presence. Nor should we assume that the requisite approvals and permissions will occur according to our time-table. Questions of land and water use are life-and-death issues on western reservations; a tribe's survival as an autonomous cultural and legal entity depends on their ability to protect these resources. Thus, what may appear as a relatively straight-forward issue to us may in fact be a question of considerable moment to a tribal government.

As we proceed with the project over the next two years, we should strive to keep the tribal government informed of our progress and all our activities on the reservation. In addition, we should provide for numerous opportunities for feedback from tribal officials. Thus it is best if we can maintain a regular set of contacts at each reservation who know us, understand our project, and can see the benefits that climate data have to offer. At the end of the project we must make sure that these tribal officials receive our final report, and have an opportunity to continue working with NOAA when they deem it advantageous.

FORMAL LETTER:

Once personal contact has been made with the appropriate tribal officials, it may be appropriate to send a formal letter that briefly describes the research, and requests permission to conduct the research on the reservation. This should be accomplished soon after the initial contact is made. The P. I. should ask the official with whom you have established a relationship to designate who should receive the formal letter, and if copies should be sent to others (the tribal council, the tribal chair, other water managers, etc.). A model letter is provided below to serve as a template for the initial correspondence:

Dear (Tribal Official):

It was a pleasure talking/meeting with you last week. As we discussed, I am submitting this letter to provide a written description of our project, and a request for permission to conduct this project on the XX Reservation.

This research project, funded by the National Oceanic and Atmospheric Administration (NOAA), is designed to help water managers more effectively utilize climate data. NOAA produces a great variety of climate data programs; we are interested in finding out how these data programs might be made more useful to the XX Water Resources Department. The long-term objective of NOAA is to help tribes and other water managers enhance their water management capability by effectively incorporating climate data into the water management decision-making process. We are helping NOAA modify its climate data service so that it will be more useful to tribal water managers. This project covers three states and includes a variety of different kinds of water management entities, including several Indian tribes.

The research plan calls for two rounds of interviews with tribal water managers. In the first round, we will attempt to gain an understanding of how tribal water management decisions are made, especially in regard to climate-relevant decisions. We will then take this information to NOAA and work with them to improve the utility and relevance of their climate information products. We will then return to the reservation for a second round of interviews to see how the new climate information can be effectively incorporated into the water management framework. It is important to note that the NOAA climate data is provided as a service to the tribal government, and is free of charge.

We recognize the sovereignty of the XX Tribe, and seek your permission to conduct this project on the reservation. We will conduct all research in accordance with the policy of mutual respect via a government-to-government relationship, and consult with tribal officials throughout the tenure of the project. It is our objective to provide an effective link between NOAA services and interested tribal water officials; the ultimate goal is improved water management.

Thank you, and we look forward to hearing from you.

It may require the relevant tribal officials some time to reach a decision and respond. It is perhaps a good idea to occasionally call the personal contact to check on the progress of the request. It is possible that some tribal officials may prefer to reply via a phone call rather than a formal letter.

SUM:

The key phrases that should describe our interaction with tribal water management officials should be: on-going consultation, mutual respect, a government-to-government relationship, and the provision of a service.

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[i] See: Vine Deloria and Raymond DeMallie, Documents of American Indian Diplomacy: Treaties, Agreements, and Conventions, 1775-1979. Austin: University of Texas Press, 1999.

[ii] Charles Wilkinson, American Indians, Time, and the Law. New Haven, CT: Yale University Press, 1987, p. 14.

[iii] William Clinton, Memorandum for the Heads of Executive Departments and Agencies, titled "Government to Government Relations with Native American Tribal Governments." April 29, 1994.

[iv] Order No. 3175. Office of the Secretary, Department of the Interior. Bruce Babbitt, No. 8, 1993.
[v] Executive Order 13084--Consultation and Coordination With Indian Tribal Governments. May 14, 1998
[vi] NOAA website, page on the New NOAA-Boulder Building, policy on "Cultural Resources and Consultations with Native American Indian Tribes."