GLOBAL WARMING EFFECTS ON EXTREME WEATHER

HEARING

BEFORE THE

SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

JULY 10, 2008

Serial No. 110–43

Printed for the use of the Select Committee on Energy Independence and Global Warming

globalwarming.house.gov

U.S. GOVERNMENT PRINTING OFFICE

62–525 WASHINGTON : 2010

For sale by the Superintendent of Documents, U.S. Government Printing Office
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GLOBAL WARMING EFFECTS ON EXTREME WEATHER

THURSDAY, JULY 10, 2008

HOUSE OF REPRESENTATIVES,
SELECT COMMITTEE ON ENERGY INDEPENDENCE
AND GLOBAL WARMING,
Washington, DC.

The committee met, pursuant to call, at 1:32 p.m., in Room 210, Cannon House Office Building, Hon. Edward J. Markey [chairman of the committee] presiding.

Present: Representatives Markey, Blumenauer, Inslee, Solis, Cleaver, Hall, McNerney, Sensenbrenner, Shadegg, Walden, and Blackburn.

Staff present: Ana Unruh Cohen and Stephanie Herring.

The CHAIRMAN. Welcome. Welcome to all of our guests here today at the Select Committee on Energy Independence and Global Warming and our hearing on "Global Warming Effects on Extreme Weather." This hearing is called to order.

Global warming is a tale of extremes. It is not enough water; it is too much water. It is Californians battling to protect their homes from drought-filled wildfires; it is Midwest communities sandbagging levees to hold back the floodwaters. It is public health officials protecting the elderly from dangerous heat waves; it is water utilities trying to provide drinking water for a growing population. It is farmers trying to cope with not enough water or too much water.

Certainly floods, droughts and heat waves have always occurred. But by loading up the atmosphere with global warming pollution we are loading up Mother Nature's dice for more extreme weather.

As global warming pollution increases, we are rewriting the book on the planet's weather and climate. In the latest eye-opening reports from the United States Climate Change Science Program, scientists are predicting increases in heat waves, extreme rain and drought. And if we do nothing to change the course of these events, we may not like the way this story ends.

Thankfully, this story is not finished. We can still choose how it ends. We must take action now to protect the most vulnerable amongst us from these extreme weather events. And there are solutions.

Today we will hear from a panel of experts who understand the extreme weather challenges our Nation will face but are also actively working toward solutions to these challenges. Their testimony today will guide us toward a path of increasing our resilience to extreme weather.

But we cannot simply treat the symptoms and fail to address the underlying sickness. As we increase our Nation's resilience to extreme weather, we must also dramatically reduce our global warming pollution.

Even with the best preparation, we have too many examples that point to our limited ability to cope with extreme weather. We need to look no further than the recurring annual death toll from heat waves, or to the wildfires that burn millions of acres every year in the West, or to the cities that struggle to provide water for their growing populations, for their agriculture or for their hydroelectric power production. At the same time, extreme precipitation has caused the current devastation in the Midwest.

Perhaps no weather disaster highlights or weakness to climate challenges than our inadequate response to Hurricane Katrina, which still haunts us several years later. Today we have several students in the room who have seen the devastation of extreme weather and our Nation's failure to cope with this devastation firsthand. These participants in the Southeast Climate Witness Program were all displaced by Hurricane Katrina and are now studying the vulnerability of their regions to future storms and climate change.

We thank them for their work and for coming to this hearing today. They illustrate that climate change is not just an environmental or economic issue, but it has impacts on real people and their communities.

Global warming will push weather outside the range of what we used to know as normal. This also means that old methods of water protection will no longer be sufficient to meet the climate challenges for the future. We must protect society's most vulnerable people from the impacts we can no longer avoid, while reducing global warming pollution to avoid a climate crisis. It is time for this Congress to write climate legislation that will ensure that the next chapter of our story is one that protects people and the planet.

That completes the opening statement of the Chair, and now we turn and recognize the ranking member of the select committee, the gentleman from Wisconsin, Mr. Sensenbrenner.

[The prepared statement of Mr. Markey follows:]

THE SELECT COMMITTEE ON
ENERGY INDEPENDENCE AND GLOBAL WARMING

Opening Statement for Chairman Edward Markey
Global Warming effects on Extreme Weather
Select Committee on Energy Independence and Global Warming
July 10, 2008

Global warming is a tale of extremes.

It is not enough water. It is too much water.
It is Californians battling to protect their homes from drought-fuelled wildfires.
It is Midwest communities sandbagging levees to hold back the flood waters.
It is public health officials protecting the elderly from dangerous heat waves.
It is water utilities trying to provide drinking water for a growing population.
It is farmers trying to cope with not enough water, or much too much.

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As global warming pollution increases, we are rewriting the book on the planet's weather and climate. In the latest eye-opening reports from the United States Climate Change Science Program, scientists are predicting increases in heat waves, extreme rain, and drought, and if we do nothing to change the course of these events we may not like the way this story ends.

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Mr. SENSENBRENNER. Well, thanks very much, Mr. Chairman.

I heard the imperative of my distinguished chairman from Massachusetts that we have to write this legislation. As I recall reading his press releases and that of the majority party, that was supposed to be passed by July 4th of last year, and we still don't have anything on the calendar.

All that said, severe weather has imparted humanity since our earliest memories. Just ask Noah. Floods, droughts, hurricanes, tornados and other natural disasters are something we humans have been learning to adapt to throughout time.

Last month I saw firsthand the effects of severe weather. Wisconsin was among the States hard hit by floods that wreaked havoc through much of the Midwest. Thirty Wisconsin counties were declared disaster areas, including all five in my district. The county of Waukesha suffered $90 million in damages, and many people were homeless because of the flooding.

Wisconsin has seen many floods, and they often come with summer rains. For better or for worse, it is part of my State's natural meteorological cycle. And while flood waters can't always be stopped, there are ways that people can adapt to these cycles and mitigate the damage and harm caused by them. Through technology, planning and management, there are things we can do to adapt to weather extremes.

And if the scientific forecasts are correct, we will have to adapt. Projections show that no cut in greenhouse gasses, no matter how steep, can stop some warming over the next decade. That is why I believe adaptation should be a high priority in confronting climate change.

While Wisconsin was recently overflowing in water, other parts of the country had precious little. And management of these resources will become more important if the temperature continues to rise.

One of our witnesses today, Dan Keppen of the Family Farm Alliance, says farmers in the West are already preparing to adapt to a warmer climate. His testimony will also point out the need for a balance of both water conservation and supply enhancement, a streamlined regulatory process that helps the development of new infrastructure, and a prioritization of research needs. I agree and welcome him and all of the witnesses here today.

In discussing priorities, Mr. Keppen pointed out that in California some have projected it will take 2.5 trillion gallons, or 2,500 billion gallons, of water to produce that State's goal of a billion gallons of ethanol. Here is another reason to oppose this wasteful fuel subsidy and the mandates which were quadrupled in last year's energy bill.

These mandates and subsidies are already driving up the cost of food and doing nothing to drive down the cost of gasoline. This is a waste of water, and we are going to be paying for this micromanagement of this part of our economy for years to come if we don't wake up and see the problems that it causes.

Adapting to climate change in severe weather will require balance, coordination and prioritization. Through these methods we can sometimes help prevent or often worsen the sting of these weather events. But sometimes there is nothing we can do but to prepare, and then sometimes even that is not enough, as the people of my State learned that last month.

I yield back the balance of my time.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Washington State, Mr. Inslee.

Mr. INSLEE. Just a couple comments.

You know, I come from Washington State. We got a little rain up in Washington State. And people don't think Washington State is, sort of, an epicenter of extreme events. We don't have many tornados or hurricanes. But, last year, we had a rain event that, for the first time in 135 years, closed Mount Rainier National Park and literally destroyed a lot of the places I had grown up with, really, really beautiful places.

I went hiking at a place called Sourdough Mountain last summer, and right in the middle of coming down this mountain is this huge gash about 60 feet deep. It looks like somebody took a giant knife and just cut a big gash down this mountain where this little, teeny, tiny creek had absolutely gone insane in this incredible rain event.

And that kind of rain event is completely consistent with more frequent rain events of more intense duration that we expect to see in the future. No one can say specifically that that rain event was associated with global warming, the science does not allow that, but it is something we expect.

And the reason I mention that is that, when people talk about these events, that mountain, Sourdough Mountain, had been there for a long, long time. There weren't gashes like that on that mountain, at least during my lifetime. And I just mention it because this is something that hits places even with mild weather, like the State of Washington, which has the mildest, dampest, grayest environment in the country.

The second thing I want to say is that, when we think of extreme weather events, we are thinking of extreme in the human sense, but there are extreme weather events that can cause enormous differences in the world that are just, like, a half a degree.

The very small changes of just a few degrees in the Arctic are totally changing the entire ecosystem of the Arctic. The Arctic ice cap is predicted to be gone in toto by late summer within the next several decades. And there is some indication that this year could see an 80 percent or plus reduction of the Arctic summer ice cap this year. And there was a 70 or 80 percent reduction last year, which shocked the scientific community.

The point I want to make is that relatively small—we wouldn't think of a 3- or 4-degrees Farenheit change as an extreme weather event, but in the context of changing whole ecosystems, that is extreme. And I think we have some work to do.

Thanks.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Arizona, Mr. Shadegg.

Mr. SHADEGG. Thank you, Mr. Chairman, for holding this hearing.

I would like to begin by welcoming Dr. Jay Golden of my home State of Arizona to the committee. Dr. Golden is working on a number of exciting projects at Arizona State University dealing with innovative renewable energy-generating technologies and energy-reducing materials and surface treatments, among other things. I look forward to the testimony of Dr. Golden, as well as to that of the other members.

Examining the effects of a warming climate, regardless of what is ultimately determined to be the cause of that warming, is important to our country and very important to my State of Arizona and to my city of Phoenix, which sits in a very warm portion of the Nation and is affected and I think is a great example of a heat island. I think it is critically important for us at both the local, State and national level to identify how these events are brought about and how to handle the impacts of these weather-related phenomena.

As a young boy growing up in Arizona, I can remember the summer weather which would always bring storms to the valley from the southeast. It was called the monsoon season, and they would bring huge dust storms north. And, in those days, the storms would move all the way through the city of Phoenix and pass on to the northwest. This is the exact opposite of the weather pattern we have in the wintertime, when our storms would come from the northwest and move to the southeast.

Interestingly, over my lifetime, as Phoenix has become a much bigger and bigger city, with miles and miles, square mile after square mile of concrete and asphalt and tall concrete and glass buildings, I believe we have seen a tremendous impact of what I would call the heat island effect. And now almost none of those storms make their way all the way through the valley and emerge on the other side. They tend to hit the valley and go out around it.

I am personally fascinated at how much modern building materials affect that urban environment and can affect these issues. And I think it is very important for us to know how to adapt various building materials to accommodate that, maybe not to have the heat island effect be as extreme, and also various insulating materials. We all know that, for a long time in this country, landlords would build large commercial buildings without properly insulating them or thinking about their energy footprint, recognizing they were going to pass on the bill for the operation of that building to somebody else.

So I think this is important. And while we cannot play God and control the weather, we can certainly adapt to it, as we have for hundreds of thousands of years. We need to focus our efforts on using our available resources as efficiently and as effectively as possible. And for that reason, Mr. Chairman, I thank you for holding this hearing.

And I yield back the balance of my time.

The CHAIRMAN. Gentleman's time has expired.

The Chair recognizes the gentlelady from California, Ms. Solis.

Ms. SOLIS. Thank you, Mr. Chairman, for having this hearing.

Communities across California, as you know, are really feeling the climate change. In fact, right now, we are experiencing well over 1,700 fires that have been caused in California either by lightning or by human activity. What we need to look at, I believe, is that we, as humans, have created a lot of our own problems and we, as humans, have to then create solutions to those problems. So I am hoping that we will hear from our witnesses today that they can help us address this issue.

I am very concerned because even in a community like Long Beach, which is not too far away from where I live, they are expecting to see that there will be a big dip in their water tables there, providing millions of water for individuals, But that is slowly dipping to almost 30 percent. So these are dramatic events that are taking place in southern California.

Last year at this time, we had severe fires, fire storms. We are not even in that period right now in California where the Santa Ana winds are whipping up. That is going to happen later on, after August and September. And we know that we are really overutilizing our resources, and we have to attend to these very, very important issues.

So I yield back the balance of my time and look forward to hearing from our witnesses.

The CHAIRMAN. The gentlelady's time has expired.

The Chair recognizes the gentlelady from Tennessee, who was here first.

Mrs. BLACKBURN. Thank you. I appreciate that, as my colleague and I both arrived about the same time. And, Mr. Chairman, I thank you for the hearing.

And I want to welcome our witnesses and thank them for coming before us to talk about extreme weather and global warming. And everyone agrees that extreme precipitation events are on the rise, but the question for many of us is, is this a trend or is it just natural, a natural occurrence?

And, Mr. Chairman, I have two articles that were published in Water Resources Research and the Australian Meteorological Magazine that shed some light on the issue. And I have used them in my preparation for today, and I would like to submit those to the record.

The CHAIRMAN. Without objection, they will be included.

[The information follows:]

WATER RESOURCES RESEARCH, VOL. 44, W07402, doi:10.1029/2007WR006471, 2008

Trends and multidecadal oscillations in rainfall extremes, based on a more than 100-year time series of 10 min rainfall intensities at Uccle, Belgium

Victor Ntegeka[1] and Patrick Willems[1]

Received 27 August 2007; revised 12 February 2008; accepted 4 March 2008; published 2 July 2008.

[1] Investigation was made on whether the recent historical changes in frequency and amplitude of rainfall extremes can be considered statistically significant under the hypothesis of no trend or temporal clustering of rainfall extremes. The analysis was based on a 107-year time series of 10-min Peaks-Over-Threshold rainfall data obtained from the Uccle station in Belgium. Rainfall intensities were aggregated at levels ranging from 10 min to the monthly scale, and defined for different seasons and block lengths between 5 and 15 years using sliding windows. Perturbations in rainfall extremes were derived, which represent the empirical quantile changes. Significant deviations in rainfall quantiles were found, which persisted for periods of 10 to 15 years. In the winter and summer seasons, high extremes were clustered in the 1910s–1920s, the 1960s and recently in the 1990s. This temporal clustering highlights the difficulty of attributing "change" in climate series to anthropogenically induced global warming. Research in a variety of climate phenomena is essential for the attribution of changes in the climate.

Citation: Ntegeka, V., and P. Willems (2008), Trends and multidecadal oscillations in rainfall extremes, based on a more than 100-year time series of 10 min rainfall intensities at Uccle, Belgium, *Water Resour. Res.*, *44*, W07402, doi:10.1029/2007WR006471.

1. Introduction

[2] Due to the recent climate change stir, various researchers have sought for new techniques to probe the temporal variability of various observed time series. One of the most popular studies has involved the study of trends and cycles within the long-term instrumental time series [e.g., *Osborn et al.*, 2000; *Hu et al.*, 2003; *Brunetti et al.*, 2006; *Wang et al.*, 2006; *Brunet et al.*, 2007]. Long-term temporal analysis of trends and cycles is crucial in understanding the natural variability within the climate system [*Türkes et al.*, 2002]. The long-term historical series can also be used to project future behavior, and to reconstruct paleoclimatic data [*Casty et al.*, 2005]. Through statistical analysis, quantitative assessments of the time series can identify patterns manifested as trends and cycles. The Pettit test, Student t-test, Mann-Kendall test, Spearman's rho-test are some of the tests that have been used for trend detection within the time series [*Ozer et al.*, 2003; *Alexander et al.*, 2006; *Novotny and Stefan*, 2007]. Fourier and wavelet transforms have also proved to be crucial in the detection of cycles [*Pozo-Vázquez et al.*, 2001; *Labat*, 2005; *Kang and Lin*, 2007].

[3] The study of temporal changes in extreme events identifies anomalies which can be attributed to different phenomena. One of the key areas has been the detection of significant trends and cycles in precipitation which has been linked to other factors. For instance, some studies have used trend detection in precipitation series to explain changes in discharge series [*Burn and Hag Elnur*, 2002; *Small et al.*, 2006] while others have linked the trends to temperature fluctuations [*Burns et al.*, 2007] which are then linked to climate change. In addition to trend detection, spectral analysis has also been found to be useful in spotting periodic cycles within the precipitation series [*De Jongh et al.*, 2006; *Blanckaert and Willems*, 2006]. Some studies have compared the cyclic or oscillation patterns with oceanic or atmospheric oscillation phenomena [*Uvo et al.*, 1998; *Rodriquez-Fonseca and de Castro*, 2002; *Shabbar and Skinner*, 2004; *Tootle and Piechota*, 2006] or even astronomical data like the sunspots [*Hiremath and Mandi*, 2004; *Yadava and Ramesh*, 2007].

[4] This paper describes an empirical statistical analysis of trends in rainfall extremes, which is unique for reasons regarding the type of rainfall series and the statistical method used. The analysis is based on the long-term high-frequency homogeneous rainfall series at the climatological station of the Royal Meteorological Institute of Belgium at Uccle that starts in 1898 and which is continued to date [*Demarée*, 2003]. The series is recorded by the same measuring instrument (a Helmann-Fuess rain gauge) at the same location since 1898 and processed with identical quality since that time. Trends or changes thus cannot be attributed to instrumental changes; the measuring accuracy is homogenous. The measuring frequency is unique as well: 10 min with more than 107 years of continuous data. The period 1898–2004 has been considered for the present study.

[5] Previous studies have examined the Uccle series albeit with varying record length, statistical properties and different analytical tools. The existence of trends and cycles

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0043-1397/08/2007WR006471$09.00

based on previous studies has been somewhat unclear. *Vaes et al.* [2002] examined the trends in the Uccle (Belgium) precipitation (1898–1997) based on peaks-over-threshold values and found no significant persisting trends. The most recent period (last 7 years) was not included. They used linear trend assumptions for the number of rainfall extremes over time. *De Jongh et al.* [2006] studied the trends and cycles in the precipitation record for Uccle for a 105 years time span using the Mann-Kendall trend test and wavelet analysis. Statistically insignificant trends were identified in the annual total precipitation, winter total precipitation (December, January, February), and the monthly total precipitation. The wavelet analysis did not reveal dominant periodic cycles in the monthly volumes over the time. *Blanckaert and Willems* [2006] conducted a spectral analysis based on Fast and Windowed Fourier Analysis and wavelet analysis based on the hourly series for the period 1898–2001. It was concluded that there were no dominant cycles in the rainfall extremes, possibly due to the high noise-signal ratio (strong natural variability in the rainfall extremes). The present study makes use of an alternative method based on frequency-perturbations or quantile-perturbations of extremes. While frequency techniques focus on how often an event (a quantile) may occur, perturbation techniques determine the relative magnitudes of events based on a certain baseline. The frequency- or quantile-perturbation analysis compounds the two concepts thereby making it possible to study the changes in the extremes for particular return periods. The approach adopted aims to provide an insightful temporal assessment of the trends and oscillations of rainfall extremes.

[6] The specific aim of the statistical analysis is to determine whether the recent historical changes in frequency and amplitude of the rainfall extremes can be considered statistically significant under the hypothesis of no trend or temporal clustering of rainfall extremes, but accounting for the randomness in the occurrence of rainfall extremes (as observed in the full available series since 1898). The objective for the study is not to predict future trends, but to detect trends and cycles in retrospect. Since precipitation extremes can be precursors of floods, the analysis is carried out for different aggregation levels (time spans over which the rainfall intensities are averaged) spread over the range of concentration times along Belgian rural and urban catchments. These are the relevant timescales for the rainfall used for determining the peak flows downstream of the catchment, and range from 10 min to the monthly scale. The timescales are analyzed on a seasonal basis. Also, the effect of clustering in time on the temporal variability of the frequency and amplitude of the rainfall extremes is taken into account. Statistical significance of the trends and clusters identified is tested based on the parametric bootstrapping technique [*Efron*, 1979; *Vogel and Shallcross*, 1996].

2. Methodology Based on Extreme Value Analysis

2.1. Peaks-Over-Threshold or Partial-Duration-Series Extremes

[7] This study has the particular focus to extremes. The definition of what constitutes an extreme event is debated. An extreme event may be selected based on frequency, intensity or threshold exceedance and physical expected impacts. It depends on the intended use in design or future planning.

[8] Extremes are extracted from a series by applying a threshold, which implies that the analysis is valid only for those values above a certain return period. The selection of the threshold is, however, subjective. There is no universal technique used for the selection of the threshold. *Lang et al.* [1999] proposed that the selection of the threshold should be based on the distribution of the Peaks-Over-Threshold values and the hypothesis of the independency. The extremes for this study partially conform to the definition offered by *Pickands* [1975]. *Pickands* [1975] stated that independent extremes extracted from a univariate series after applying a threshold can be fitted to a Generalized Pareto distribution (GPD), at least asymptotically toward infinitely high threshold. For practical applications, the threshold needs to be high enough to ensure that the extremes can be fitted to the extreme value distribution. Due to the nature of the study, selection of an optimal threshold (threshold that most accurately fits the distribution) is not restricted. Applying an optimal threshold would in some cases reduce the number of events and thus affect the number of events from the extracted blocks of years. The extreme value distribution parameters are essential in the parametric bootstrapping procedure for testing the significance of the historical trends and clustering or temporal oscillations (based on Monte Carlo calculations).

[9] Also, the identification of extremes requires the use of an independency criterion. Extreme value theory assumes total statistical independency of the sampled extremes thereby providing a theoretical basis for distribution fitting [*Beirlant et al.*, 1996; *Madsen et al.*, 1997]. In the present study, the independency criterion is based on a procedure for extracting Peaks-Over-Threshold (POT) values for rainfall which is similar to that of extracting Peaks-Over-Threshold values for discharges [*Willems et al.*, 2007]. The independency criterion for discharge events states that two consecutive events are independent if the occurrence of one event does not affect the occurrence of the other event. The main criterion for event extraction consequently is the interevent time. *Willems* [2000] proposed for extreme value analysis based on the Uccle rainfall series a minimum of 12 h interevent time considering two events happening within the same day or night as one event. The extraction of POT values at all timescales lower than 12 h was based on this minimum interevent time. For higher timescales, two rainfall values were taken independent when they originate from rainfall intensities during nonoverlapping time intervals. The longest dry spells between two successive rainfall peaks selected can be considered to split the time series in "nearly independent" rain events. According to the extreme value analysis terminology [*Rosbjerg*, 1985], these events are referred to as the Partial-Duration-Series (PDS).

[10] The POT/PDS rainfall extremes are extracted based on the moving average of rainfall intensities at the timescales that are relevant for the hydrological applications. The time span of the moving window is the aggregation level and it covers the range of concentration times of the river and sewer catchments of interest: from 10 min (only relevant for urban drainage applications) to the monthly timescale (river hydrology). For the different aggregation

levels, the independency interevent time is taken as equal to the aggregation level for those levels above the minimum (i.e., 12 h).

2.2. Aggregation Levels and Timescales

[11] Aggregation levels or timescales of 10 min (no aggregation), 60 min (hourly), 1440 min (daily), 10080 min (weekly) and monthly volumes are used in the analysis. In addition to the aggregations the data is also grouped in blocks of years ranging from 5 to 15 years. Therefore, the analysis is based on a particular aggregation level for a particular block of years. For instance, given an aggregation level of 10 min and 10 years blocks, the analysis involves studying the statistical properties based on 10 min POT extremes grouped in 10 years blocks for the period 1898–2004: 1898–1907, 1908–1917, ..., 1988–1997, 1995–2004. However, these decades are not sufficient for a complete temporal analysis. Therefore, a sliding window is used in the analysis. The sliding window requires the shift to the right of one year which leads to a new set of 10 years blocks: 1899–1908, 1909–1918, ..., 1989–1998, 1995–2004. Note here that the last block does not shift because 2004 is the last available year in the series. The sliding window is applied n times, where n is the number of years in a block. It is on the basis of the POT values grouped according to these blocks that the statistical analysis of trends and oscillations is applied. The sliding window option allows intrinsic trends and oscillations within the rainfall series to be captured, which would otherwise have been unnoticeable.

[12] The analysis is carried out for the four climatological seasons: winter (December, January and February), spring (March, April, May), summer (June, July, August) and autumn (September, October and November).

2.3. Rainfall Distributions

[13] The probability distribution of point precipitation intensities has been examined in previous studies for the Uccle series [*Willems*, 2000; *Mohymont*, 2005]. *Willems* [2000] presented a systematic methodology, which derived the type of the distribution and the optimal threshold. The exponential distribution has been suggested as presenting a good approximation to the underlying precipitation process: more specifically a two-component distribution to represent storms of two different types (air mass thunderstorms and cyclonic/frontal storms). This was done for durations in the range 10 min till 15 d. *Willems* [2000] discovered that the two-component exponential distribution was valid for aggregation levels less than 2 d while a one-component distribution was valid up to 15 d.

[14] However, *Willems* [2000] based his analysis on aggregated values up to 15 d. One of the temporal scales included in this study is the monthly scale. Because of the independency criterion of the minimum interevent time of at least one month, the number of monthly extracted POT data would be limited, leading to more uncertainty. Therefore for the monthly scale, the aggregation and use of the independency criteria is ignored. Only a threshold is applied to the series after calculating the cumulative monthly volumes. With this adjustment, the 3-parameter Weibull distribution is found to have better fit to the monthly seasonal volumes than the exponential distribution. Calibration of the distributions was done by regression techniques in quantile plots (QQR method; e.g., *Beirlant et al.* [1996]; *Willems et al.* [2007]).

[15] The distributions are considered above a threshold, which is taken equal or higher than the optimal one defined as the threshold where the mean squared error of the higher empirical quantiles is minimal. Considering the number of series to be analyzed, selecting the optimal threshold for each series would involve computational constraints. For instance, for the period 1898–2004 there are 107 series for each season. If for each series an extreme value distribution is to be calibrated accurately it would require that each series is fitted for a different threshold while having a constant threshold for all the series would simplify the distribution fitting computation for all the 107 series. An initial assessment (not shown) reveals that although the fits are not accurate for some series they are reasonable approximations as long as the selected threshold is high enough. The thresholds used in this study are also selected such that there are a sufficient number of points (around 5) per year in a particular season. For example, the analysis includes estimates of the rainfall distribution parameters. If these are based on few points, the resulting estimates would be less representative of the characteristics of the rainfall distribution.

3. Quantile-Perturbation Approach

[16] The proposed method investigates the historic changes in the ranked extremes. The method combines aspects of frequency, used in extreme value analysis, and perturbation, used in climate change impact studies. The technique is analogous to the frequency-perturbation approach applied by *Harrold et al.* [2005] and *Chiew* [2006] for deriving climate change scenarios from climate models. For climate change impact analysis on a daily rainfall series, instead of applying one factor (e.g., monthly change) for the entire daily time series (e.g., for same month) they decided to apply different factors based on the ranked daily values. The perturbation factors were calculated as ratios of two similarly ranked values obtained from the future (climate model scenarios) and the observed time series. The proposed method, however, is solely based on historical data. Since the perturbation is a relative change it requires two series. For the climate-model based approach, one of the series is taken as the reference or baseline series while the other is a future scenario series. In the present study, one of the series is derived from the long-term historical distribution while the other series is taken from a particular block (subseries) of interest. For example, given a particular block of 10 years, one of the series contains the actual POT values within the block while the other series is derived from the distribution of long-term historical values (from the entire period of 107 years). The POT values within the block were ranked (where i is the rank of each POT event), such that they can be related to empirical return periods $10/i$ (or L/i for block series of L years length). After ranking, the POT values correspond with quantiles $x(L)$, $x(L/2)$, ..., $x(L/i)$, ..., where $x(L/i)$ is the quantile with empirical return period L/i. The same procedure is applied to the full 107 years series, leading to quantiles $x_g(107)$, $x_g(107/2)$, ..., $x_g(107/i)$, ... The perturbation factors then correspond to the ratios $x(L)/x_g(L)$, $x(L/2)/x_g(L/2)$, ... It is clear that the return periods L, $L/2$, ... do not necessarily coincide with the

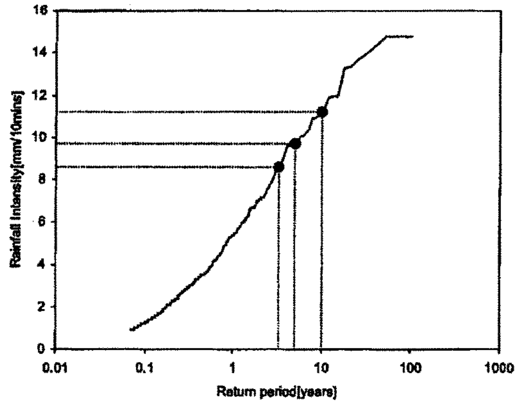

Figure 1. Precipitation quantiles in long-term baseline calculation for 10-min summer rainfall.

empirical return periods of the POT events of the full 107 years series. In that case the $x_g(L/i)$ values are derived by linear interpolation from the closest (higher and lower) POT events. Figure 1 illustrates the estimation of the first 3 values in the reference series for a 10-year summer block. The curve contains all the summer POT values in a 107 years period.

[17] It is noteworthy that for the quantile-perturbations, the two series used have to be ranked before the ratio is calculated. The use of ranked data ensures that the percentage changes in the extremes are accounted for. The method of comparing unranked values in time is not sensitive to possible changes in extremes. For instance, by comparing day to day, one might compare dry days with wet days and thus the resulting perturbation would be misleading. It is therefore better to use a frequency analysis approach, which uses ranked data rather than the unranked data. Figure 2 shows the multidecadal 10-min perturbations together with the exceedance probabilities (ranks) for the summer period. Figure 2 does not explicitly show the temporal variability of the perturbations. To achieve this, one perturbation factor can represent all the perturbations for each decade. A single perturbation factor for a particular block of years is calculated as the average of all the perturbations above a particular threshold. Therefore, Figure 3 would in effect have only 10 points with each point centered in the middle of the block. Using a sliding window of 1 year, a different set of blocks is obtained with new perturbations. Figure 3 shows the temporal variation obtained from several blocks; similar to those in Figure 2, with each point representing the average perturbation of a 10-year block. Repeating the averaging over the different blocks assigns one factor to each block, which eventually leads to a temporal variation of the perturbation factor. This means that the perturbation can be seen as a quantile perturbation for extreme rainfall conditions above a certain return period. Table 1 shows the selected thresholds and corresponding empirical return periods.

[18] Calculation of the average quantile perturbations assumes that above a certain exceedance probability or rank, the perturbations are fairly constant. In other words, the slope for a particular block of the perturbation-exceedance probability plot is not significantly different from zero. To test this, the slope is explicitly calculated and compared with the bootstrapped confidence interval.

[19] Figure 4 shows some of the expected outcomes of the slopes for selected periods. There are positive slopes for the 1938–1947 and 1995–2004 blocks, and negative slopes for the 1898–1907 and 1928–1937 blocks. Whether or not these slopes are significant depends on the hypothesis testing.

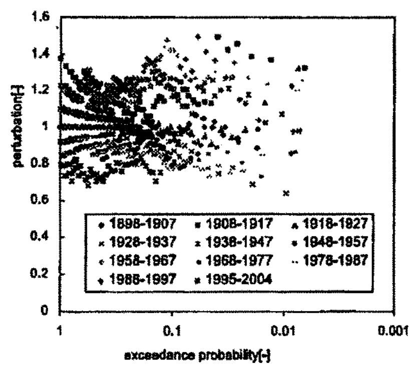

Figure 2. Quantile perturbations for 10-min rainfall extremes and 10-year blocks for selected summer periods.

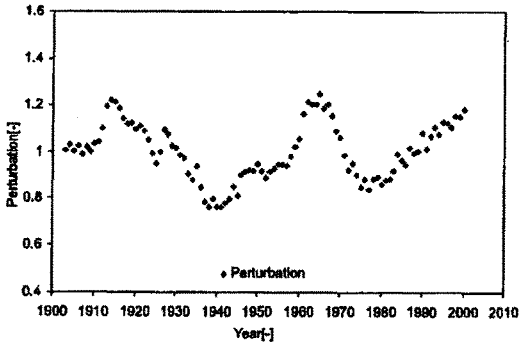

Figure 3. Estimates of average quantile perturbations for the 10-min rainfall extremes and 10-year blocks for summer periods.

[20] Quantile perturbations may result from the changes in the magnitude and/or the frequency of extreme rainfall events. In an attempt to separate these two effects, perturbations have also been calculated for the mean POT (magnitude) and for the number of POT events (frequency). Results are shown hereafter, combined with the confidence intervals calculated, in Figures 5 and 6. The mean POT represents an average POT value for the set of POT extremes in a given block.

4. Monte Carlo Confidence Intervals

[21] Climate change is related to the statistically significant variations from the natural variability that persists for both short and long periods, up to decades or longer. It involves shifts in the frequency and magnitude of sporadic weather events [*IPCC*, 2001]. Confidence intervals can be used to define a region of natural variability or randomness. Thus they can also be used for testing hypotheses of significant deviations under the hypothesis of no trend or temporal clustering of rainfall extremes. Since a confidence interval defines a region of expected variability, any region outside the confidence bounds is considered to be statistically significant (hypothesis rejected of observed changes being solely caused by natural variability) while the region within the bounds is statistically insignificant (hypothesis accepted). Using this criterion, one is able to discern the statistical significance for a given hypothesis.

[22] The approach used for this study is based on the parametric bootstrapping method which requires that a sample of rainfall extremes is first fitted to a distribution after which random samples are generated from the distribution, and confidence intervals are estimated. This approach was originally introduced for independent data [*Efron*, 1979] but has evolved over time to allow for the analysis of dependent data by the use of the block bootstrapping [*Vogel and Shallcross*, 1996]. Block bootstrapping groups data in blocks from which the resampling is made and thus preserving the time within the series. However, since the POT values are extracted after using independency criteria, the data is assumed to be independent. Even though frequency analysis eliminates the time aspect within a particular block; through ranking, the use of several blocks restores the time aspect since the statistics (e.g., 95% confidence intervals) can be calculated for each sequential block. By serial plotting the statistics for each block, the temporal evolution of the statistic is realized.

[23] The parametric bootstrapping Monte Carlo procedure is described below.

[24] 1. POT series for the entire period are extracted from the Uccle rainfall series.

[25] 2. The series are then further separated into seasonal blocks for different block lengths.

[26] 3. Considering a particular block, a rainfall extreme value distribution (two-component exponential or Weibull for the monthly timescale) is calibrated to the n POT values above the threshold considered.

[27] 4. Using the Monte Carlo methodology, p random samples are generated from the calibrated distribution with each sample containing n POT values.

[28] 5. Each of the p samples is ranked and the confidence interval calculated from the ranked values. The ranks can easily be converted to return periods using the empirical plotting positions. Note that for each rank number or return period, there are p possible values. On the basis of these values, the confidence interval is estimated from the rank range, for a selected level of confidence α. For example, for $p = 1000$ and a 95% confidence interval ($\alpha = 0.05$) the confidence interval is given by the 25th and 975th values after ranking.

[29] This study opts for $p = 1000$. Seasonal blocks of 5 to 15 years (winter, spring, summer, and autumn) from 1898–

Table 1. Thresholds Above Which Average Quantile Perturbations Were Derived

Statistic	Season	10 min	1440 min	Month
Threshold, mm	summer	1	0.05	47.5
	winter	0.8	0.045	40
Return period, years	summer	0.09	0.1	0.46
	winter	0.13	0.1	0.44

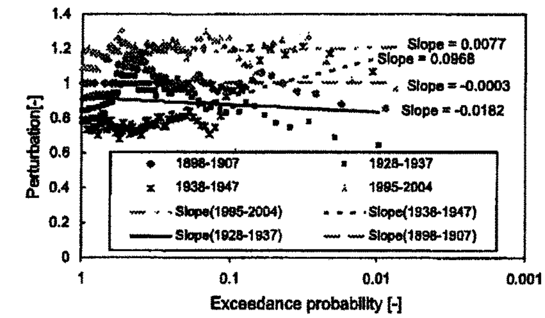

Figure 4. Slope estimates of quantile perturbations versus return period for 10-min rainfall extremes and 10-year blocks for summer periods.

2004 are considered in the analysis which involves a large volume of data generation: 107 blocks * 4 seasons = 428 series with 20 to 220 POT extremes each.

[30] From the random samples generated by the parametric bootstrapping Monte Carlo technique; each containing the same number of events as the parent data, different statistics can then be obtained for each sample. This study uses the average quantile-perturbation factors (average for the higher return periods). It is from this ensemble of statistics that a confidence interval is defined.

[31] After evaluating the perturbation temporal evolution, the confidence interval is also estimated and superimposed on the same plot. It is then graphically possible to identify periods that depict significant deviations under the hypothesis of no trend or temporal clustering of rainfall extremes. Figures 5 and 6 summarize the results obtained for the 5 and 15 years blocks respectively. These figures show the results for 10 min, daily (1440 min aggregated from 10 min) and monthly volumes. The perturbations, number of events and mean POT values have been included for both summer and winter.

5. Statistical Hypothesis Testing on the Clustering of Rainfall Extremes

[32] The perturbation time series analysis investigates whether the most recent changes can be considered to be statistically significant in comparison with the natural temporal variability. Identifying statistically significant trends and cycles enables one to assess the likelihood of climate change effects during the most recent periods. The confidence intervals in Figures 5 and 6 represent the 95% bounds of random variation under the null hypothesis of no trends and no clusters (hypothesis of independent random and serially uncorrelated rainfall extremes). These intervals define regions of acceptance of the null-hypothesis. Outside these regions the hypothesis is rejected. On the basis of the hypothesis tests, periods of statistically significant behavior can be identified.

[33] The variability of the perturbations of the historical precipitation shows some attributes of trends and oscillations or cycles. With the varying block lengths, periods of clustering of extremes may be identified. For instance, if a particular period shows an indication of higher perturbations (showing clustering of rainfall extremes) for a particular block length then other block lengths can be used to check the persistence of the perturbation. If the period with high perturbation is consistent for all the block lengths, then the clustering of events for that period is plausible. The block length may also be linked to the objective of the analysis. For example, the Intergovernmental Panel of Climate Change [*IPCC*, 2001] uses decadal analysis for climate change. The 15 year block length may be used to test the perception that the most recent years since the 1990s have experienced more climate change effects compared to the previous periods.

[34] Figure 7 shows the slope of the perturbations above the selected thresholds (Table 1) for the different aggregation levels and monthly seasonal volumes. The hypothesis that the slope is not significantly different from zero can be generally accepted. The slope is significantly different from zero only for short periods, e.g., Figure 7 in for the 1940s, 1960s and 1990s for 10 min summer rainfall and the 1910s, 1960s, and 1970s for 10 min winter rainfall. Note that the significant periods appear with 5% chance (or 5% of the independent time moments) even when the zero slope assumption holds for the entire period. Since the significant periods are not of long lengths, this may be the case. On the other hand, significant slopes are indications of high variability of extremes, which matches with clustering of the rainfall extremes (see next section).

[35] The temporal variability of the perturbation (Figures 5 and 6) is made possible by using average perturbations above the thresholds shown in Table 1 for each block of years. The null hypothesis of a fairly constant perturbation above these thresholds can be tested from the slope of the perturbation-exceedance probability plots. If the "0" lies within the confidence interval, the slope is not significantly different from zero and the null hypothesis of a fairly constant perturbation factor above the threshold is accepted. Conversely, if the slope is significantly different from zero, then the higher extreme events have significantly different perturbations from the lower extreme events or vice versa. The hypothesis of a fairly constant perturbation is rejected.

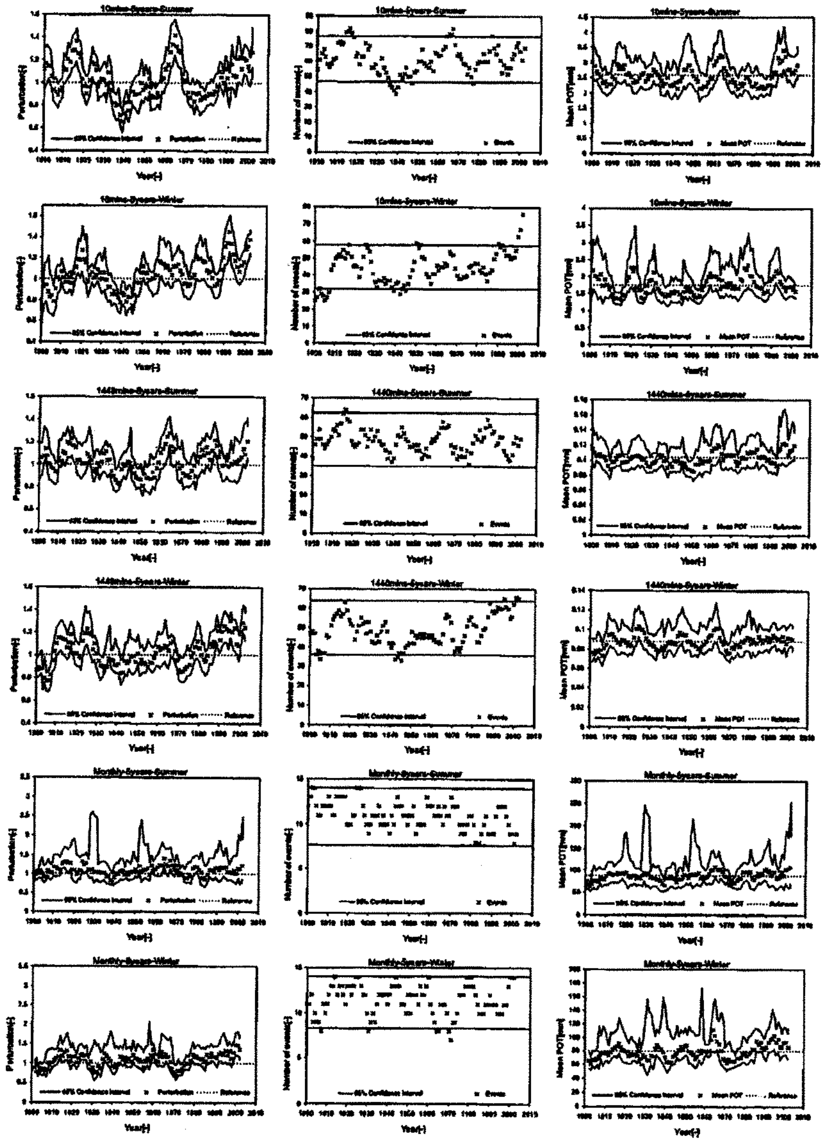

Figure 5. Estimates of average quantile perturbations, number of events and mean POT values for 10 min, 1 d, and 1 month rainfall extremes and 5-year blocks for summer and winter periods, together with 95% confidence intervals.

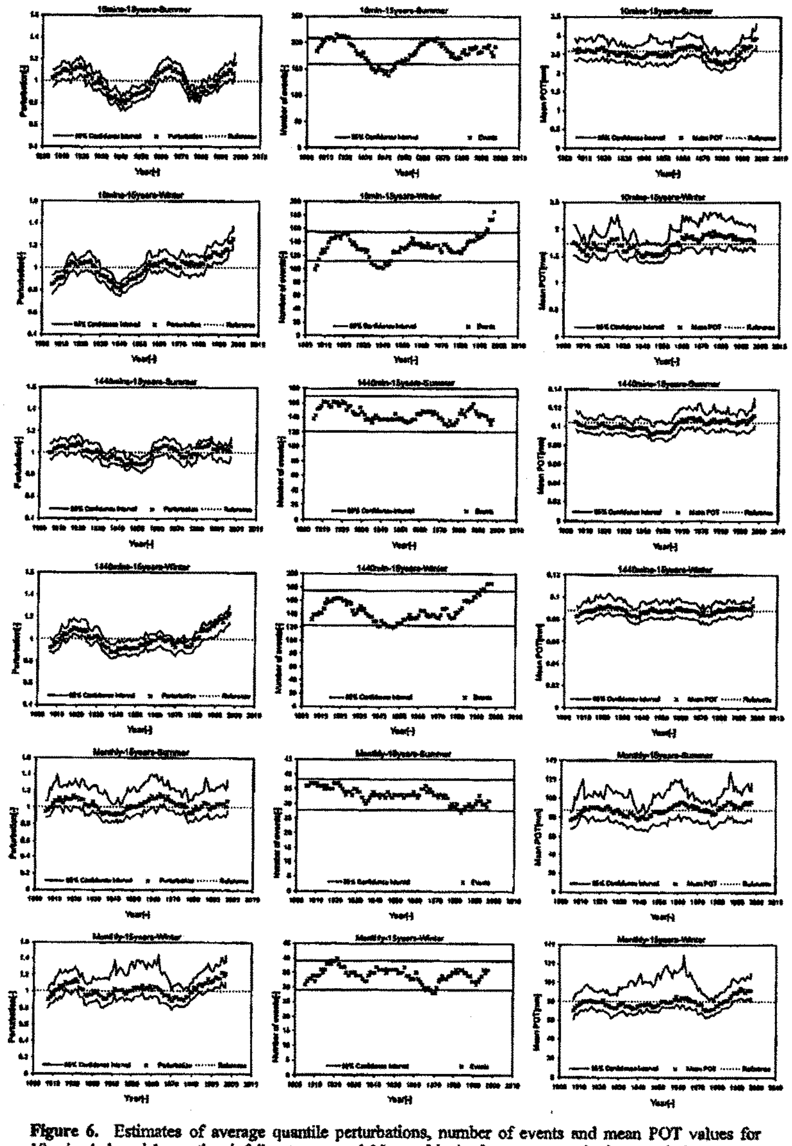

Figure 6. Estimates of average quantile perturbations, number of events and mean POT values for 10 min, 1 d, and 1 month rainfall extremes and 15-year blocks for summer and winter periods, together with 95% confidence intervals.

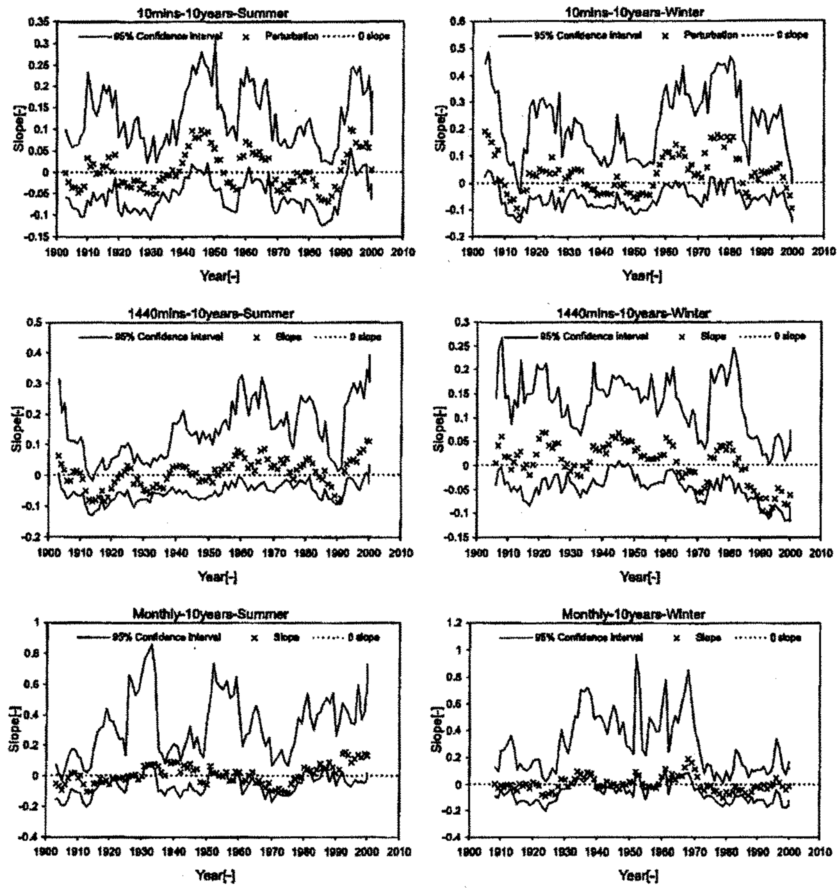

Figure 7. Perturbation-exceedance probability slope estimates for 10 min, 1 d, and 1 month rainfall extremes and 10-year blocks for summer period, together with 95% confidence intervals.

[36] Hereafter, the results in Figures 5 and 6 are discussed separately for the summer and winter periods.

6. Results and Discussion

6.1. Hypothesis Testing Summer Average Perturbations

[37] The summer perturbations for 10 min show some prominent observations (Figures 5 and 6). The perturbation 1 reference represents the long-term expected precipitation (rainfall extremes expected in the block periods following the 107 years). The reference provides the basis for testing the null hypothesis that the perturbations are not significantly different from it. For the 1910s and early 1920s, the confidence boundary is above the reference (hypothesis rejected), which implies that the period received significantly higher extremes in comparison with the reference. Similarly, the 1930s and 1940s received significantly low extreme precipitation. The 1960s had significantly higher extremes. The 1970s had significantly low extremes and the 1990s had significantly higher extremes (up to 20%) and a positive trend. From these observations, cyclic tendencies may exist for the wet and dry periods within the summer extremes

based on the 10 min aggregation level. A cycle of 30 to 50 years may exist in summer. However, confirmation of cycles cannot be made with the available 107 years. Longer time series would be required due to the duration of the cycles.

[38] On a daily scale, the perturbations are generally lower than the 10 min perturbations. The 1910s were significantly higher than the reference with the 1950s significantly lower. The 1960s remained significantly higher and the 1990s showed an insignificant increasing trend (up to 15%). Although there are periods of high and low significant extremes, cyclic behavior is less clear for the daily perturbations. The most recent changes (since the 1990s) do not show significant trends.

[39] The monthly perturbations are almost insignificant for the whole period; a few significant periods exist. The 1960s still remain significantly higher and a small period in 1910s shows significantly higher extremes. The most recent changes (since the 1990s) do not show significant trends. Although the perturbations show some cyclic behavior, the cyclic behavior can be explained by randomness; the confidence interval contains the reference during the periods with high perturbations. In other words, the peaks are not significant.

6.2. Hypothesis Testing Winter Average Perturbations

[40] Perturbations for 10 min have two distinct significant periods. The 1930s and 1940s are significantly lower than the reference. Also from the mid-1980s, there is a positive significant trend of the perturbations. With two dissimilar significant periods (one being a positive and the other being negative), cyclic existence cannot be implied. Other cyclic behaviors are insignificant since they can be explained by randomness. A longer time series is required to be able to detect presence of cycles. One notable observation is from the 1920s, 1960s, 1980s, and 1990s. A closer look reveals that the peaks have been increasing gradually and eventually becoming significantly higher than the reference in the 1990s (up to 20%). Therefore it is logical to conclude that perturbations have been enhanced and that clustering of events and possibly climate change can explain the significant peak in the 1990s. There is also an increasing trend from the 1950s although the trend eventually becomes significant from the 1990s onwards.

[41] For the daily timescale, the perturbations are lower than the 10-min winter perturbations. There are short periods (less than 2 years) with significant perturbations. These periods may be considered insignificant with a 5% chance of being right, e.g., 1920s. The 1910s and the 1990s have significantly higher perturbations than the reference. The 1930s, 1940s, and 1970s have lower perturbations than the reference. There is also a slight enhancement of the peaks similar to the 10 min perturbations. After the 1980s, there is an increasing positive trend until the most recent years (up to 20%). The positive trend may be partly explained by climate change. Also, the natural variability may explain the increase since it is possible that another cycle could be on its way.

[42] The monthly perturbations have some short significant periods which may be considered insignificant, i.e., the 1910s. The recent period; since the 1990s, has a positive significant trend similar to the 10 min and the daily time steps. The cyclic behavior is less pronounced since the oscillations can be explained by randomness.

6.3. Synopsis Hypothesis Testing Average Perturbations

[43] For all the aggregation levels, it becomes apparent that the perturbations in the winter season are significantly higher than the 1 reference over the most recent decades (from the 1990s) compared to the summer season. Multi-decadal oscillations become apparent, with periods of 10 to 15 years length, where high rainfall extremes are clustered in time, and other periods with less or lower rainfall extremes. The overlay and comparison of results for different seasons and timescales (Figure 8) indicates presence of higher rainfall quantiles in the 1910s–1920s, the 1960s and recently during the past 10 to 15 years. Lower rainfall quantiles occurred in the 1930s–1940s, and the 1970s. Other studies in Europe revealed similar trends. *Pauling and Paeth* [2007] also found that the extreme winter precipitation in Europe has become more intense (1951–2000). *Pekárova et al.* [2003] studied various rivers and found for Europe the 1940s and mid-1970s to be anomalously dry.

6.4. Frequency and Amplitude Hypothesis Testing

[44] The perturbation factor combines attributes of frequency and amplitude. Counting of events above a threshold explains the frequency aspect while the ratio of similar quantiles explains the amplitude aspect. Consequently, the number of events and mean POT can be used as measures for the frequency and amplitude respectively.

[45] The perturbation pattern for number of events (Figures 5 and 6) is more similar to the pattern of the quantile perturbations for the 10 min and daily aggregation while for the monthly seasonal volumes the mean POT perturbation has a similar pattern to the quantile perturbation. Since the 1990s, short-durations (10 min and daily aggregation) have a higher number of events than can be explained by randomness; the frequency of extremes has increased for the winter season. This is in agreement with the general perception that the frequency of extreme events has increased in recent years [*Prudhomme et al.*, 2003; *Beniston and Stephenson*, 2004]. The number of events falls outside the 95% confidence interval, which could be calculated this time analytically based on the Poisson process. This explains the constant upper and lower boundaries. Averaging the Monte-Carlo based confidence intervals leads to the same boundaries.

[46] Alternatively, counting the number of events can give a quick assessment of the significant periods for the 10 min and daily aggregation. Computation of the number of events involves less computing time compared to the parametric bootstrapping technique. Nevertheless, the quantile perturbation factors are more robust because they encompass aspects of frequency and amplitude while the number of events may only explain the frequency. However, for the monthly volumes the mean POT variability is similar to the variability of the quantile perturbation. Therefore, for the monthly volumes, the mean POT (rainfall event amplitude) contributes more to the quantile perturbation when compared to the number of events (rainfall event frequency). For smaller timescales, the opposite appears.

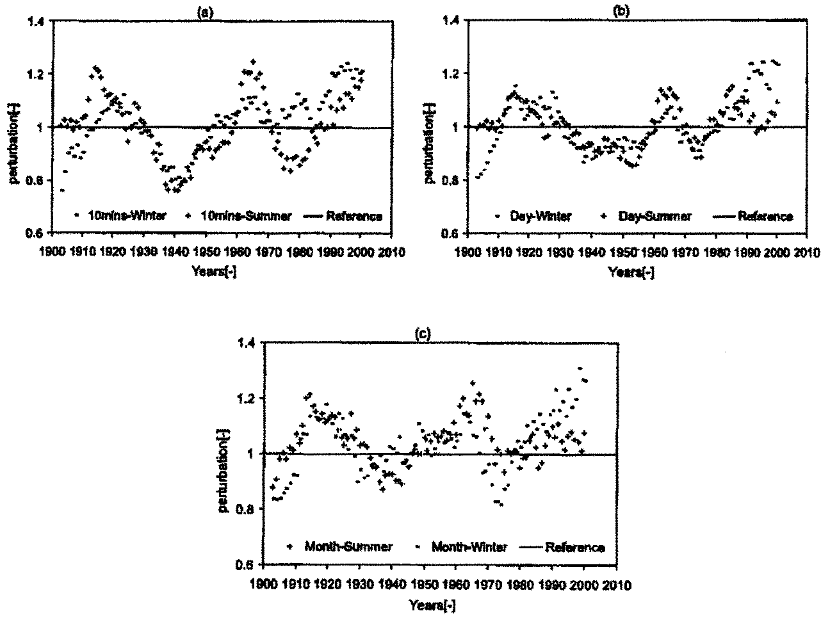

Figure 8. Comparison of average quantile perturbations for (a) 10 min, (b) 1 d, and (c) 1 month rainfall extremes and 10-year blocks for summer and winter periods.

6.5. Autumn and Spring Perturbations

[47] The transitional seasons of autumn and spring were also analyzed. For brevity, only a few plots with confidence intervals for autumn and spring are shown in Figure 9. Other timescales for autumn and spring can be found in Figures 10 and 11.

[48] In contrast to the observations for winter and summer, there were no persistent clusters and trends for autumn. Spring, however, had some clustering periods with a few indications of increasing trends for the most recent decade similar to the winter trends although the cluster periods were limited. The 10 min and daily (1400 min) timescale perturbations for spring had significant positive trends for the most recent decades, but the 10 min trends were more pronounced. High rainfall extremes for the spring were mainly persistent in the 1980s; at the daily and monthly timescales. It is notable that the clustering period for spring differs from the cluster periods in summer and winter.

6.6. Block Length

[49] In Figures 10 and 11, the results of the average quantile perturbations are compared for the 5 years, 10 years and 15 years block lengths. Similar results are found for these three block lengths. Also, the results for the autumn and spring climatological seasons are presented in these figures.

7. Conclusions

[50] We have investigated the seasonal behavior of the rainfall extremes at different aggregation levels relevant for both rural and urban hydrology. The proposed method of analysis is unique as it retrospectively combines aspects of frequency and perturbation. The resulting displays of trends and oscillations provide supplementary knowledge on the past behavior of extremes, which can be linked to other climate phenomena.

[51] The observed significant increasing trend in quantile perturbation for the winter season suggests that the extreme precipitation has become more intense during the most recent decade (the 1990s) for all aggregation levels studied. Furthermore, there has been an increase in the number of events especially for the short durations during the winter season. However, the trend in the summer season quantile perturbation for the most recent decade is not significant although there have been significant periods in the past, e.g., the significantly wet 1960s. In the two transitional seasons, spring showed evidence of significant positive

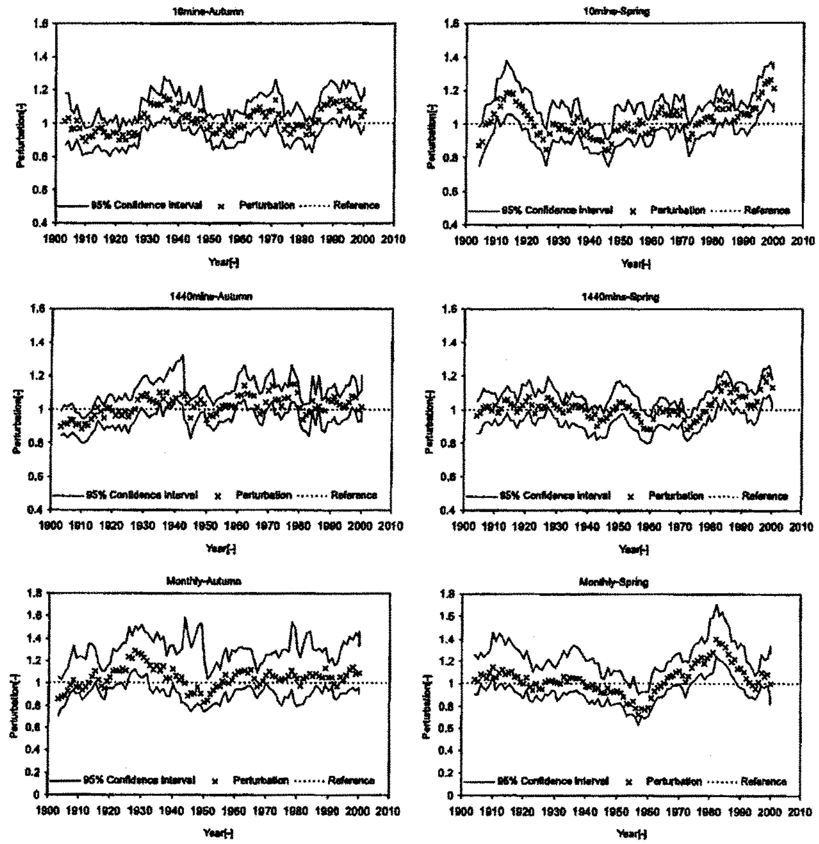

Figure 9. Estimates of average quantile perturbations for 10 min, 1 d and 1 month rainfall extremes and 10-year blocks for autumn and spring periods, together with 95% confidence intervals.

trends for the most recent decade, while this was not the case for autumn.

[52] From the analysis, it is also apparent that high rainfall extremes do not occur randomly in the time, but are clustered: there is evidence of temporal clustering. The clustering of wet events in summer for the periods of the 1910s–1920s, 1960s and the 1990s is consistent for most of the aggregation levels studied. The winter season also shows some clustering during the same periods. These multidecadal oscillations of rainfall extremes reveal signs of cyclic patterns for both winter and summer with the cycles having periods ranging from 30 to 50 years. The period of 107 years, however, is not long enough to affirm the existence of cycles.

[53] The quantile perturbation factor combines variability in the number of extremes and the variability in the size of the extremes (the precipitation intensity). It is apparent that both factors have similar patterns although the variability in the number of extremes is more correlated (similar tendencies) with the quantile perturbation factor for the short durations. For the monthly seasonal volumes, the intensity

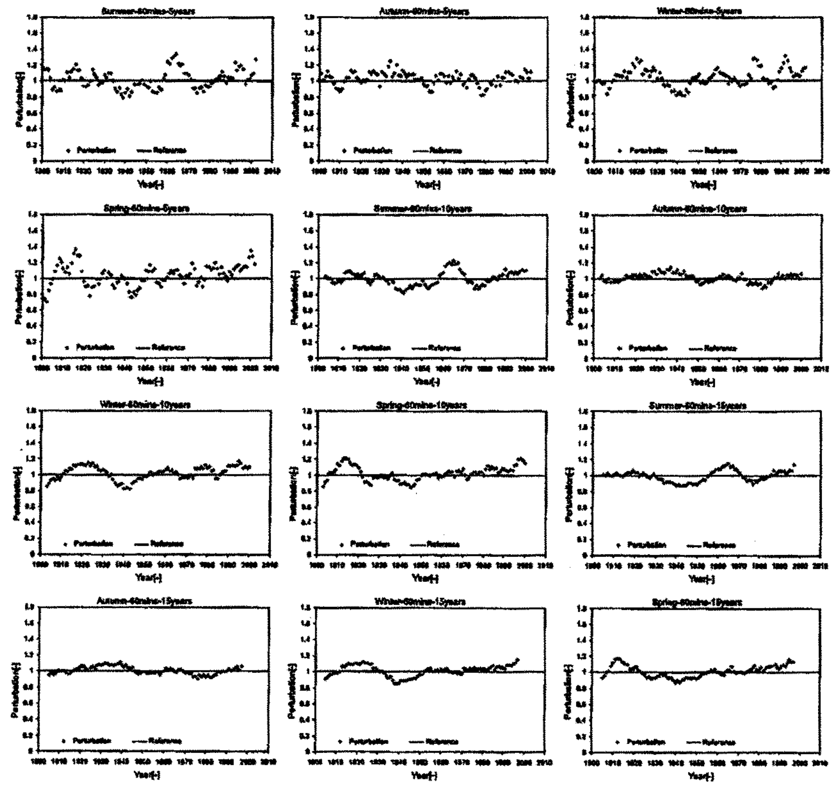

Figure 10. Quantile perturbations for 60-min rainfall extremes for 5-year, 10-year, and 15-year blocks for summer, autumn, winter, and spring periods.

(mean Peak-Over-Threshold) is more correlated with the perturbation factor.

[54] Although no strong conclusions can be drawn on the evidence of the climate change effect in the historical rainfall series, it appears from the analysis of multidecadal oscillations that the increase in the number of flood events in Belgium during the past 15 years [*Guha-Sapir et al.*, 2004], apart from the land use trends and evolutions in water management, can possibly be explained by climate change, as becomes evident from climate model simulations [*Palmer and Räisänen*, 2002; *Christensen and Christensen*, 2003], and also by a cluster of rainfall extremes. A decreasing trend in the oscillation component might have been initiated recently. For the winter season, if we assume that the cluster in the 1990s is similar to the cluster in the 1960s (from the point of view of the oscillation component), results in Figures 5, 6, 8, 10 and 11 indicate that the oscillation component might be of equal importance in comparison with the climate change trend. The quantile perturbation (around 20% for 10 min rainfall aggregation level) is indeed twice that high than in the 1910s–1920s and the 1960s. In the summer climatological season, the quantile perturbation during the past 15 years is not higher than the perturbation in the 1960s; the climate change effect, therefore, is not visible in the Uccle series for this season. The high number of recent extreme summer thunderstorms might be totally explained by the oscillation effect. The authors recommend further investigation of the consistency of the multidecadal oscillations for other regions and based

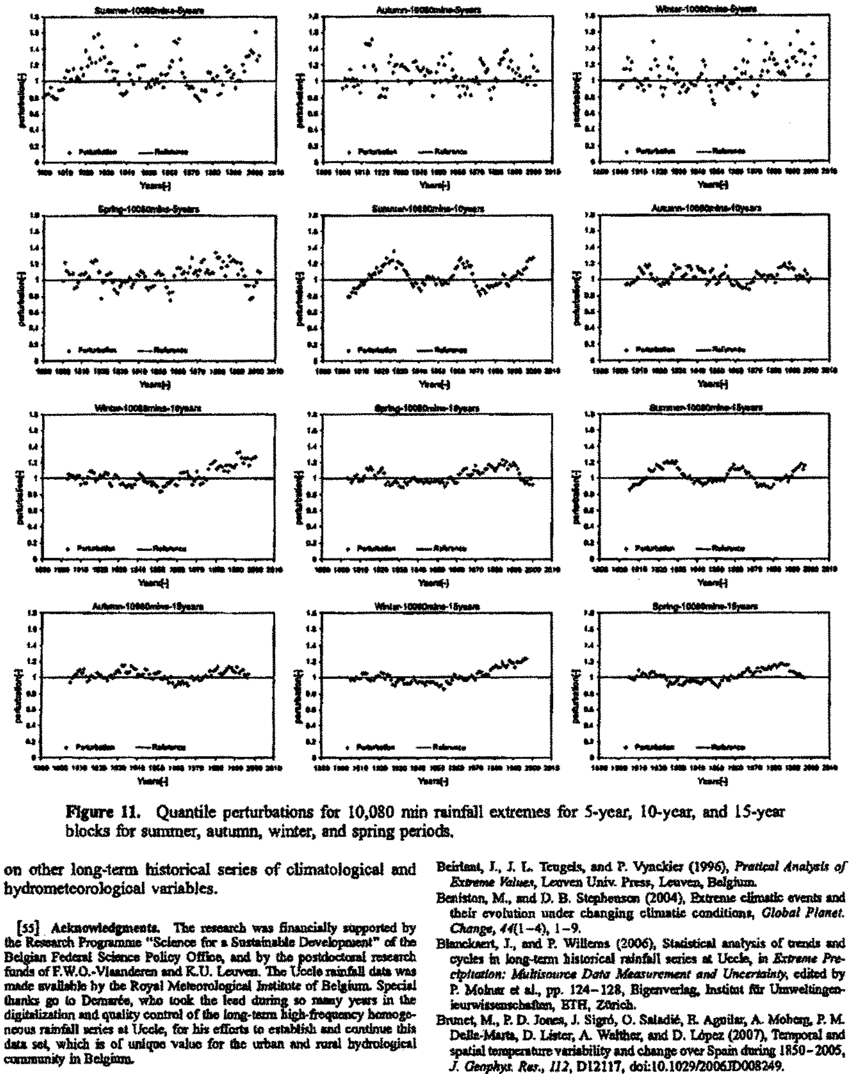

Figure 11. Quantile perturbations for 10,080 min rainfall extremes for 5-year, 10-year, and 15-year blocks for summer, autumn, winter, and spring periods.

on other long-term historical series of climatological and hydrometeorological variables.

[55] **Acknowledgments.** The research was financially supported by the Research Programme "Science for a Sustainable Development" of the Belgian Federal Science Policy Office, and by the postdoctoral research funds of F.W.O.-Vlaanderen and K.U. Leuven. The Uccle rainfall data was made available by the Royal Meteorological Institute of Belgium. Special thanks go to Demarée, who took the lead during so many years in the digitalization and quality control of the long-term high-frequency homogeneous rainfall series at Uccle, for his efforts to establish and continue this data set, which is of unique value for the urban and rural hydrological community in Belgium.

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Aust. Met. Mag. 57 (2008) 1-11

Southeast Australian thunderstorms: are they increasing in frequency?

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(Manuscript received May 2007; revised December 2007)

Trends in warm season thunderday incidence are examined over southeastern Australia. There has been a significant increase in the number of thunderdays from 1941-2004, but much of this increase may have been a result of changes in observing practices in the mid 1950s. When data earlier than this are removed, some significant trends remain. There have also been smaller increases since 1970, mostly in the early part of the warm season (October-December). These increases may have been caused by changes in the atmospheric processes that affect this region. Examination of temporal trends in surface and 500 hPa temperatures and several instability indices since 1970 showed an increase in temperature and an increase in the number of days that instability is present in the atmosphere, as measured by the Total Totals index. It is unclear whether these increases are caused by localised phenomena or changes in some larger scale meteorological processes caused by climate change or other large-scale processes. Significant issues remain regarding the homogeneity of the thunderday record.

Introduction

There is a developing consensus that the increase of greenhouse gases in the atmosphere is causing higher temperatures (e.g. IPCC 2001). It is unclear, though, how climate change might affect small-scale meteorological phenomena such as thunderstorms. Most research has been on the dynamics of thunderstorms, particularly severe ones, rather than long-term trends in their behaviour. IPCC (2001) concluded that there had been no systematic trends in thunderday frequency in the rather limited regions that had been examined, and a similar conclusion was reached in IPCC (2007). In Australia, a climatology of severe thunderstorms for New South Wales was compiled by Griffiths et al. (1993), and other climatologies have been compiled for other States (Grace et al. 1989; Harper et al. 2000). More recently, a nationwide analysis of thunderstorm distribution was undertaken by Kuleshov et al. (2002). In compiling their analysis, they noted that there were a number of inhomogeneities in the observational record of thunderdays, as well as an apparent difference between the quality of thunderday data at Bureau of Meteorology and non-Bureau stations. These issues and others have made the analysis and interpretation of the thunderstorm record problematical, in Australia and elsewhere (Doswell 2005).

As a result, few trend analyses have been performed. Kuleshov et al. (2002) found no overall systematic trends in thunderdays at analysed stations from 1970-1999, although they indicate that in the earlier part of that period, a number of stations had fewer thunderstorms than in the later part. For cool-season

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tornadoes. Kounkou (2007) used reanalyses to examine trends in favourable environments, finding a slight increase since 1960 in the western part of Australia, but many such trends are likely to have been due to changes in the quality and type of observational data ingested into the reanalyses. Nevertheless, a systematic analysis of thunderstorm trends in southeastern Australia, and their possible causes, has not been performed. This study examines temporal trends of warm-season thunderdays and instability indices associated with thunderstorms recorded at several Australian Bureau of Meteorology stations. The data are examined for the presence of inhomogeneities, and relationships between thunderstorm occurrence and instability indices are examined to determine the physical reasons for any detected trends.

Several authors have identified atmospheric instability indices associated with thunderstorm development (Doswell 1985; Rasmussen and Blanchard 1998; Craven et al. 2002; Brooks et al. 2003). These indices include the following:

- Convective Available Potential Energy (CAPE; in J/kg), the maximum energy available to an ascending parcel of air;
- Lifted Index (LI; Galway 1956), the temperature of a parcel lifted to 500 hPa subtracted from the temperature of the surrounding environment at 500 hPa. The more negative the LI is, the more unstable the atmosphere. This index is also calculated at 700 hPa; and
- Total Totals (TT; Miller 1972), an index that combines the temperatures and dew-points at 850 hPa and 500 hPa to establish thunderstorm development potential:

$$T_{850} + Td_{850} - 2T_{500} \qquad \ldots 1$$

where T_{850} is the temperature at 850 hPa, Td_{850} is the dew-point at 850 hPa and T_{500} is the temperature at 500 hPa. Many other indices have been proposed as indicators of thunderstorm formation, but the ones listed above are among the most widely used and will be examined in this analysis.

For index values above certain thresholds, convective instability is to be expected. Hanstrum et al. (2002) investigated the thresholds for case studies in Australia that produced multiple tornadoes. They examined instability indices for both cool season (Apr-Sept) and warm season (Oct-Mar) events, finding distinct differences in the amount of instability that produced a severe event in the two seasons. They concluded that the amount of CAPE needed for a severe event in the cool season was at least 500 J kg^{-1} less than in summer. Other indices such as LIs at 700 and 500 hPa were less negative for cool season severe thunderstorm events than their summer counterparts.

Here, we focus on warm season thunderstorm and index trends. The data and methodology are discussed in the next section, followed by a discussion section and brief concluding remarks.

Data and methodology

Data reliability is a critical issue in a study of this kind. Changnon (2001) compiled phenomena reports and correlated them with synoptic observations of thunderdays, but crucially he restricted his analysis to official meteorological stations with trained observers. This study does the same, limiting the data analysis to those stations that have a long reporting history by Bureau staff and that have a minimum of seven observations per day. This eliminated the problems noted by Brooks et al. (2003), who found that volunteer-only stations tended to exaggerate storm occurrences. This also eliminates the problem noted by Kuleshov et al. (2002; their Appendix A) of differences in the data archiving practices between Bureau and non-Bureau stations prior to 1987. The sites chosen for the examination were all staffed by Bureau Technical Officers and data from these sites are considered of high quality (Brewster and Hicks 2002).

Changes in observing practices can cause artificial trends to be introduced into climate data. The observational record at the Bureau sites was examined to determine if there were any changes in practices that might contribute to data inhomogeneities over the selected analysis period. Two possible influences were identified. A change to the manner in which thunderday observations are reported occurred with the release of the *Australian Meteorological Observers Handbook* (Bureau of Meteorology 1954), which stated that the reporting of thunderdays in the phenomena section of the manual could now include all thunder being heard at the station. Previously, storms needed to be located within five miles of the station to be reported. Thus this change should cause an artificial increase in the number of observed thunderstorms after the mid-1950s, as thunder can be commonly heard at greater distances than five miles. Nevertheless, consultation with Bureau personnel suggests that this change to observing practices should have been introduced into Bureau observational practices in 1954 or 1955, so any trends after this time could not be due to this effect. Additionally, in 1994, the procedure for recording thunderstorms was slightly modified by entering a code of 'no or yes' instead of 'blank or 1'. This was implemented to avoid any confusion regarding whether the observation had been overlooked or not. This change will have no effect on our results but is merely mentioned for completeness.

The stations in southeast Australia chosen for detailed analysis were Laverton, Mt Gambier and Wagga Wagga. These are considered of high quality and meet the guidelines of Changnon (2001) and Brewster and Hicks (2002), and also have daily temperature and wind sonde measurements at 9 am and 9 pm so that instability indices could be calculated. Both thunderday and index trends were examined at these locations. It was decided that it would be useful to extend the analysis of thunderdays to include other Bureau of Meteorology observation stations for a comparison across a wider area of southeast Australia. The additional stations analysed were Mildura, Adelaide Airport and East Sale (Fig. 1).

Thunderday data were available for varying time periods at each selected station: Laverton, from 1941 to 1998; Mt Gambier, 1943-1991; Wagga Wagga, 1943-2003; Mildura, 1947-2000; Adelaide, 1956-2001; and East Sale, 1944-2001. The varying time periods of the data were caused by a number of factors. In 1998, radiosonde launches were moved from Laverton to Melbourne Airport. After 1991, observations at Mt Gambier were reduced to fewer than seven observations per day, thus reducing their reliability. In addition, the trend analysis was extended to the most up-to-date data available in the archive at the time of analysis, and this end year varied from station to station.

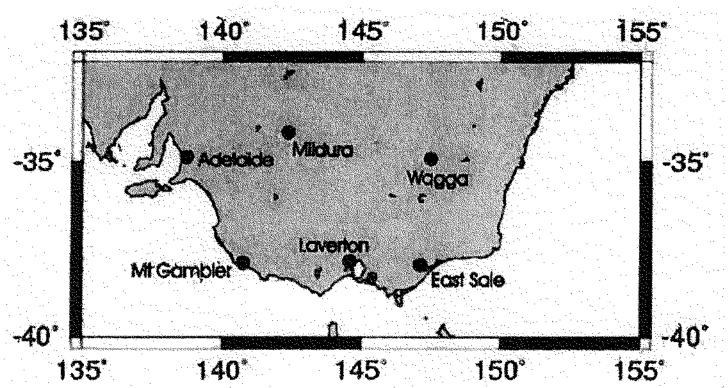
The Bureau of Meteorology Helindex software (Smith 1997) was used to compute parameters from the sonde data such as CAPE, LIs, TTs and vertical wind shear, the vector difference between winds in the lower and upper troposphere. Surface to 3 km shear of greater than 12 m/s is considered convectively important for thunderstorm development (Craven et al. 2002). Indices were calculated beginning in 1970, the commencement of electronic archiving of sonde data. After initial investigation, it was decided to omit CAPE from this study. The reason for this is that prior to 1987, the Bureau archived sounding data at the standard levels only, which give insufficient vertical resolution for a good discrimination of trends in CAPE. Thus trends based on thresholds for CAPE prior to 1987 would be erroneous and any analysis after 1987 is an insufficient period for establishing long-term changes.

The trends for the remaining indices were analysed in three stages. The first stage was to extract the daily values for the instability indices calculated by Helindex. Multiple entries were deleted so that one daily value remained; in about 90 per cent of cases, this was a morning reading. The second stage was to develop thresholds so that temporal trends of the indices could be established. Current thresholds of indices for the prediction of severe thunderstorm development are as follows:

TT $\geq$ 51	(BMTC 1995)
LI at 700 hPa and 500 hPa $\leq$ -2	(BMTC 1995)
Shear $\geq$ 12 m s^{-1}	(Craven et al. 2002)

Since severe thunderstorms are relatively rare events, in order to maximise the statistical detectability of any trends, the thunderday trends analysed in this paper include both severe and non-severe thunderstorms. For this reason, the established severe storm thresholds were lowered so that the indices could represent all forms of thunderstorms. After consultation with Bureau of Meteorology forecasters, the index thresholds for non-severe storms were set as follows:

Fig. 1 **Locations mentioned in the text.**



TT ≥ 49
LI at 700 hPa and 500 hPa ≤ 0
Shear ≥ 10 m s^{-1}

Trends in the number of days that these conditions were satisfied were calculated for all warm season (W) thunderdays (October-March). To examine sub-seasonal trends, the data were further divided into early warm season (EW, October-December) and late warm season (LW, January-March). Once the temporal trends for the indices were established, they were correlated with thunderdays at Laverton, Mt Gambier and Wagga Wagga, in order to establish a physical mechanism for any detected trends in thunderdays. Detrended correlations with indices were calculated over a reference period of 1970-2000, although not all stations had data available over this entire period, as previously discussed.

Results

Thunderdays

Annual numbers of all warm season thunderdays from 1941-2004 at Laverton, Mt Gambier and Wagga Wagga are shown in Fig. 2, and trends for all analysed stations are shown in Table 1. The stations shown in Fig. 2 all demonstrate upward trends in observed thunderdays, and most stations analysed in Table 1 show significant upward trends when the entire period of record is analysed. If the period before 1956 is removed from the data, to account for the change in observing practices noted previously, significant upward trends remain at Laverton, Mt Gambier and Adelaide Airport.

Because of concerns regarding data homogeneity, a break-point statistical analysis (e.g. Fawcett 2004) was performed on all warm season thunderday data, for the entire available period of record for each station. At Mt Gambier and East Sale, breaks were identified around 1960, which tends to support a mid or late fifties change in observing practices. Breaks at Wagga Wagga and Mildura occurred in the early 50s, while Laverton showed a break at 1968 (Fig. 3). The size of the discontinuity at Laverton is large: values that are above average before 1968 become well below average after 1968. This points to a possible inhomogeneity in the data-set of unknown origin. Finally, Adelaide had insufficient data in the 1950s to investigate possible inhomogeneities at that time.

When the period since 1970 is analysed, thunderdays for the warm season as a whole appear to be increasing at four of the six selected stations, although with the exception of Adelaide Airport, these trends are not significant. Most of this increase appears to be occurring in the early part of the warm season, as

Fig. 2 **Trends in warm season thunderdays from 1941-2004, for (a) Laverton; (b) Mt Gambier; and (c) Wagga Wagga. Line of linear regression best fit is also indicated.**

(a)

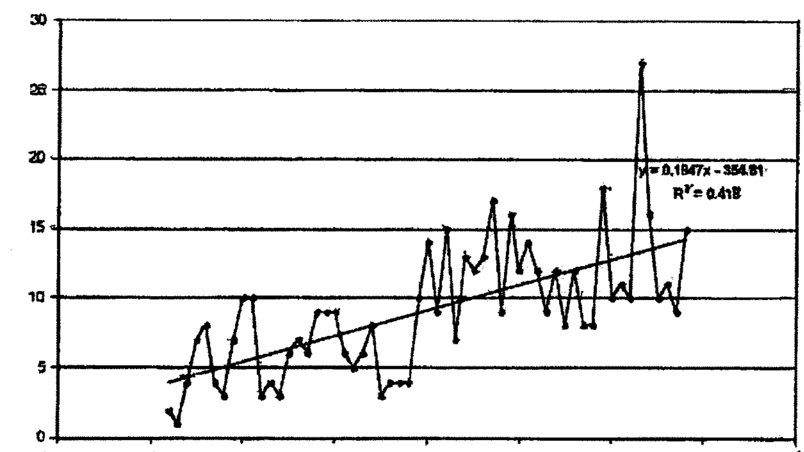


Fig. 2 **Continued.**

(b)

(c)

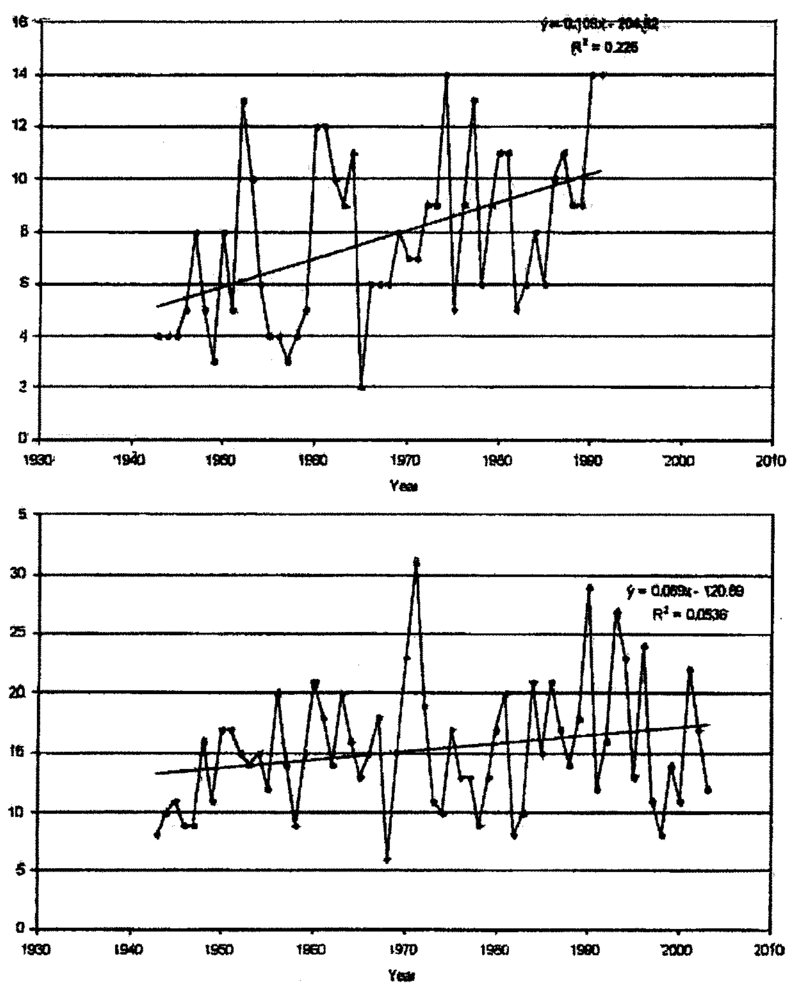


Table 1 shows that trends in the late part of the warm season are mostly negative.

Thunderstorm indices

The thunderday trends since 1970 at the locations mentioned above, while not large, seem to suggest that the overall increase in thunderdays may not be localised phenomena, but may be caused by changes in some meteorological process that affects the southeastern Australian region as a whole. Accordingly, trends in thunderstorm indices were examined in order to elucidate possible forcing mechanisms that could be causing the trends in thunderdays.

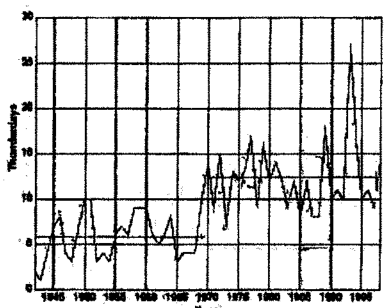
Table 1. Trends per year in number of days of observed conditions as specified in the table. Trends in bold type are significant at the 95% level (two-tailed test). W refers to the entire warm season (October-March), EW to October-December and LW to January-March.

		Laverton	*Mt Gambier*	*Wagga Wagga*	*Mildura*	*Adelaide Airport*	*East Sale*
Thunderdays*	W	**0.185**	**0.108**	0.069	0.029	**0.082**	**0.164**
	EW	**0.110**	**0.064**	0.010	**0.056**	**0.114**	**0.081**
	LW	**0.076**	**0.042**	**0.063**	-0.104	-0.015	**0.092**
Thunderdays (1956-)	W	**0.186**	**0.122**	0.013	-0.033	**0.082**	0.071
	EW	**0.112**	**0.092**	-0.017	0.047	**0.111**	0.034
	LW	**0.071**	0.010	0.033	**-0.075**	-0.015	0.022
Thunderdays (1970-)	W	0.039	**0.125**	**-0.048**	0.060	**0.130**	-0.034
	EW	0.045	**0.091**	**-0.021**	0.057	**0.124**	0.066
	LW	-0.012	-0.026	-0.008	-0.022	0.067	-0.032
Total-Totals days	W	0.136	**1.114**	0.783	--	--	--
> 49 (1970-)	EW	0.034	0.760	**0.569**	--	--	--
	LW	0.053	0.149	0.216	--	--	--
Shear days	W	0.499	**3.618**	**2.516**	--	--	--
> 10 m s^{-1} (1970-)	EW	0.134	0.353	**1.457**	--	--	--
	LW	0.309	**3.057**	**1.199**	--	--	--
Days LI500	W	-0.065	-0.309	**-1.975**	--	--	--
< 0 (1970-)	EW	-0.043	-0.109	-0.519	--	--	--
	LW	-0.004	-0.365	**-1.116**	--	--	--
Days LI700	W	-0.052	-0.233	**-1.566**	--	--	--
< 0 (1970-)	EW	0.017	-0.116	-0.412	--	--	--
	LW	-0.044	-0.170	**-0.899**	--	--	--
T850 (1970-)	W	0.020	0.033	0.046	--	--	--
	EW	0.047	**0.065**	0.043	--	--	--
	LW	-0.004	0.005	0.048	--	--	--
Td850 (1970-)	W	-0.067	**-0.103**	-0.043	--	--	--
	EW	-0.023	-0.065	-0.014	--	--	--
	LW	**-0.132**	**-0.172**	-0.073	--	--	--
T500 (1970-)	W	0.033	0.036	0.027	--	--	--
	EW	0.044	0.034	0.025	--	--	--
	LW	0.023	0.052	0.018	--	--	--
T850*	W	0.002	0.028	0.002	--	--	--
	EW	0.011	**0.065**	0.014	--	--	--
	LW	-0.003	0.015	0.000	--	--	--
Td850*	W	**-0.070**	**-0.080**	-0.009	--	--	--
	EW	**-0.075**	-0.047	-0.006	--	--	--
	LW	**-0.051**	**-0.123**	-0.013	--	--	--
T500*	W	**0.015**	0.020	0.018	--	--	--
	EW	**0.020**	0.026	0.021	--	--	--
	LW	0.010	0.024	0.017	--	--	--

*Laverton 1941-1998; Mt Gambier 1943-1991; Wagga Wagga 1943-2003; Mildura 1947-2000; Adelaide 1956-2001; East Sale 1944-2001.

Trends in TT, surface to 3 km shear and LIs at 700 and 500 hPa were examined and compared to the trends for thunderdays at Laverton, Mt Gambier and Wagga Wagga. Trends in TT values since 1970 (Table 1) are positive at all selected locations, with statistically significant trends at Mt Gambier and Wagga Wagga. Similarly, increased numbers of high shear days were found at all locations, with statistically significant increases at Mt Gambier and Wagga Wagga. In contrast, trends in days of high instability as indicated by the Lifted Index are mostly negative, implying decreased convective development, particularly at Wagga Wagga.

Fig. 3 Break-point analysis for Laverton warm season thunderdays, showing discontinuity in the data record around 1968.



Comparison between index and thunderday trends

A comparison was made between trends in thunderstorm incidence and instability to identify possible forcing factors for the observed thunderstorm trends. Figure 4 shows the changes in thunderstorm and index values over the period since 1970. There are some gaps in the data of unknown origin; a possible explanation relates to the changeover from manual to electronic archive (R. Hicks, Bureau of Meteorology, personal communication). Figure 4 shows that there is substantial interannual and even some decadal variability superimposed upon the trends calculated in Table 1. For instance, days of high Total Totals values at Wagga Wagga were common in 1970, became less frequent in the late 1970s, and have gradually increased since then. To assess the strength of the interannual relationship between thunderdays and the stability indices, detrended correlations were performed between warm season detrended values of thunderdays, TTs, shear and LIs for Laverton, Mt Gambier and Wagga Wagga for the period 1970-2000. The results (Table 2) indicate that none of the indices were well correlated with thunderdays at Laverton, but seasonal variations in both LIs were well correlated with thunderdays at Mt Gambier, and well correlated with LI at 700 hPa at Wagga Wagga.

A multiple regression analysis was also performed to determine whether an effective predictor of interannual thunderstorm variation could be constructed from variations in the indices. Three indices were chosen as predictors: TT, shear and LI500. The results (Table 3) show that no effective predictor could be constructed using this technique for Laverton, but that significant relationships were constructed for both early and late warm seasons at Mt Gambier and warm and late warm seasons at Wagga Wagga. This suggests that instability is closely related to warm season thunderstorm incidence at Mt Gambier and Wagga Wagga, but that other factors play a more important role at Laverton.

Comparison between long-term trends and thunderday trends

As mentioned above, sonde data for instability calculations were available only from 1970. To investigate possible longer-term climate effects on thunderstorm incidence, trends were calculated in seasonally averaged 850 hPa temperature and dew-point, and 500 hPa temperature over the entire period of thunderday record (Table 1). A fairly consistent pattern of drying and warming is seen at all three stations. While surface warming would tend to increase instability, all other things being equal, drying would tend to decrease it, as would increases in 500 hPa temperature. There is no clear signal in these trends that would explain the increases in thunderstorm incidence since 1956, unless surface warming is dominating the instability over this time. We discuss this issue further in the next section.

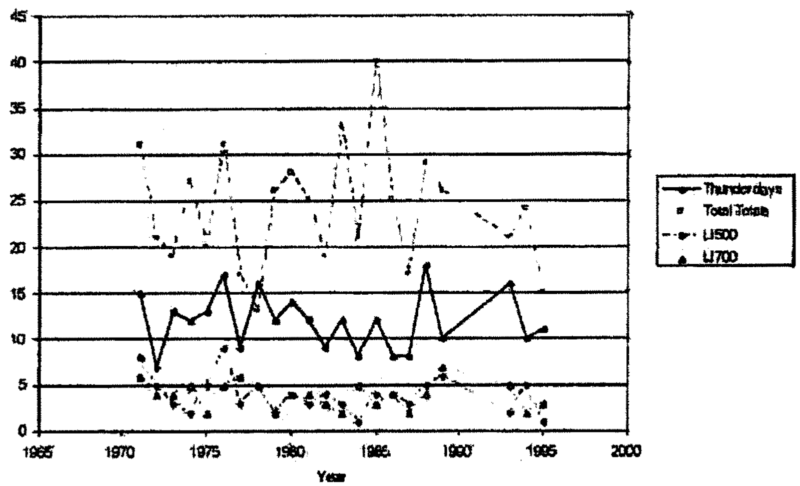
Discussion

There are strong trends in thunderstorm incidence in the observed thunderday record over southeastern Australia from the late 1940s onwards. When the early part of this record before 1956 is excluded, due to changes in observational practices introduced from 1954 onwards, some of these trends remain. When the analysis is repeated for data from 1970 onwards, the significant trends largely disappear, except at Adelaide Airport. This may simply be an effect of sample size for some stations, for example Mt Gambier. Kuleshov et al. (2002) also found an upward trend at this station in their analysis of the period 1970-1999. After 1970, most thunderday trends in the data analysed in this study are upward, particularly in the early half of the warm season, but they are mostly not significant.

There are some indications that the environment in this region has been trending towards more unstable conditions since 1970, although these trends are not uniform across all indices. The trends since 1970 in the number of days of high Total Totals values are upwards, with increases in values at all three stations. There are also increases in the number of days of high

Fig.4 **Comparison between trends in thunderdays and index trends for: (a) Laverton; (b) Mt Gambier; and (c) Wagga Wagga.**

(a)



(b)

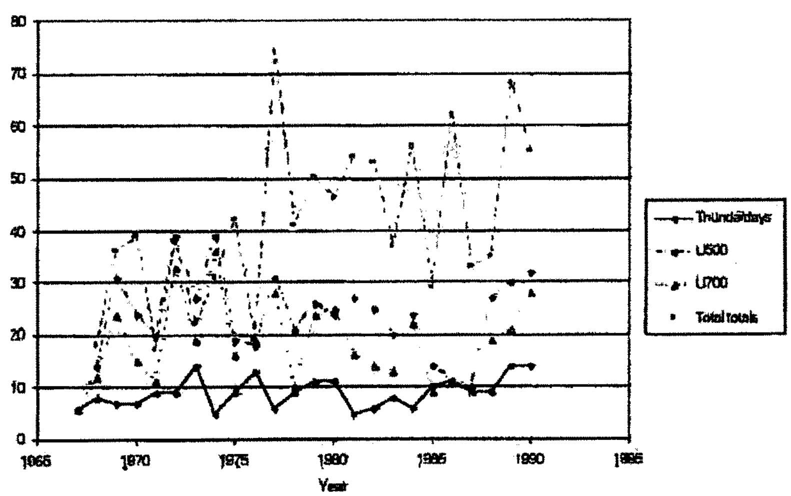


Fig.4 Continued.

(c)

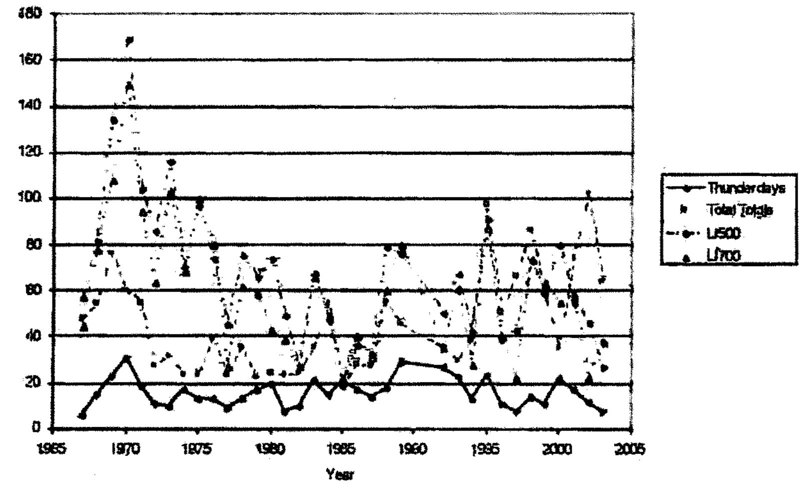


Table 2. Detrended Pearson correlations between thunderdays and days of significant instability over the period 1970-2000. Bold values are significant at the 95% level (two-tailed).

	Laverton	*Mt Gambier*	*Wagga Wagga*
Total Totals > 49	0.135	0.219	0.343
Shear > 10 m s^{-1}	-0.123	0.020	0.148
LI 700 < 0	0.207	**0.690**	**0.543**
LI 500 < 0	0.363	0.499	0.284

Table 3. p values of multiple regression analysis predicting thunderdays with values of TT, shear and LI500. Bold values are significant at the 95% level.

	Laverton	*Mt Gambier*	*Wagga Wagga*
Warm	0.441	0.097	**0.033**
Early warm	0.140	**0.008**	0.116
Late warm	0.147	**<0.001**	**<0.001**

shear, but there are mostly decreases in the number of days of negative Lifted Index values (i.e. days of more lifting potential). Results of correlation analysis suggest that Lifted Index values were most correlated with actual thunderday incidence. Multiple regression analysis suggested that a strong association could be constructed between thunderday incidence and a suite of indices, with the Lifted Index being the strongest contributor.

In order to explain the reasons for trends in the indices since 1970, trends in values of 850 hPa temperature, 850 hPa dew-point temperature and 500 hPa temperature were calculated and are shown in Table 1. These indicate that since 1970, overall in this region there has been warming and drying at 850 hPa, and warming at 500 hPa. This is consistent with the longer-term trends in the same variables mentioned above. Since these quantities are the components of the Total

Totals index, this suggests that the observed increase in Total Totals must be explained by a dominant increase in 850 hPa temperature, as the direction of change of the other variables implies a decrease in Total Totals values, which is not observed. The trends in the Lifted Index values must be dominated by drying conditions at lower levels, as there has been an increase in surface temperature as well as 850 hPa temperature over southeastern Australia since 1970, but this would act to decrease the Lifted Index, not increase it. An increase in 500 hPa temperature would also act to increase the Lifted Index, so this may be a contributing factor.

The warming and drying of southeastern Australia over the past several decades would seem unfavourable for increased thunderstorm development, unless the observed surface warming were large enough to dominate the instability index calculations, as the Total Totals index appears to suggest. The main trend relationship appears to be between some increases in thunderstorm incidence and increases in the Total Totals values, whose increases appear to be dominated by low-level temperature increases. Note that previous work (Davis 2006) found that thunderstorm incidence in this region was positively correlated with the SOI. Given that the SOI trends since the 1950s have been negative, this would not provide an explanation for an increase in thunderstorm incidence.

The question of remaining data inhomogeneities is a difficult one. Break-point analysis identified a very obvious discontinuity in the thunderday record at Laverton around 1968, which may be the cause of the significant upward trend in this variable since 1956. There is no obvious cause for this discontinuity, however. Upward trends in thunderday incidence since 1956 at Mt Gambier are still evident even if data from before the analysed break year of 1959 are discarded (not shown). Significant upward trends remain at Adelaide Airport after 1970. Thus not all of the thunderday trends can be easily explained by data discontinuities.

Projections of the effect of climate change indicate that temperatures in southeastern Australia will continue to warm, while it is also likely that the region will be drier (e.g. CSIRO 2001). Thus the trends identified in the present study may continue. Niall and Walsh (2005) noted, though, that simulations with the CSIRO Mark 3 climate model (Gordon et al. 2002) indicated no significant increase in days of extreme Total Totals values (> 55 °C) over southeastern Australia in a warmer world. These Total Totals values are considerably in excess of the threshold values chosen in the present study, however, as Niall and Walsh (2005) examined future projections of damaging hail incidence rather than typical thunderstorm behaviour.

Thunderstorm formation requires not only a source of instability, but also high atmospheric moisture levels and a trigger, such as a cold front (e.g. Kuleshov et al. 2002). Significant future trends in triggering events such as cold fronts could change the number of convective events even if instability remained unchanged. Simmonds and Keay (2000) note that mid-latitude cyclone numbers appear to be decreasing south of the continent but becoming more intense, and projections of future climate indicate that this is likely to continue, with mid-latitude storm tracks located generally further south than at present (Cai et al. 2003). The possible effect on cold front numbers and intensities in southeast Australia in a warmer world is unknown. It is also possible that some portion of the trends in thunderday incidence shown here could be caused by changes in frontal activity rather than instability, although the two are likely to be strongly correlated. Without a synoptic climatological frontal and trough analysis, however, this hypothesis remains speculative.

Another issue that could affect our analysis is the possibility of sonde instrument changes over the period of the data record affecting the temperature trends analysed here. There have been several changes in Australian sonde devices over the past 30 years (B. Trewin, Bureau of Meteorology, personal communication) and studies have shown that these can affect data homogeneity (e.g. Free et al. 2002; Lanzante et al. 2003; Durre et al. 2006).

Conclusion

There has been a significant increase in the number of thunderdays in southeastern Australia from 1941-2004, some of this probably due to a documented change in observing practices around 1955. Nevertheless, some of these trends remain when data after 1956 are analysed. Smaller increases have also occurred since the late 1960s. Increases are most pronounced in the early part of the warm season (October-December). Analysis of trends in instability indices suggest that there is an accompanying upward trend in days with high Total Totals values and high shear, although trends in Lifted Index values over this time have been tending towards less instability. The trends in the Total Totals values are ascribed to the increase in lower tropospheric temperature that has occurred since the late 1960s in this region. As projections of climate change indicate a continued increase in surface temperatures, this may have a similar effect on Total Totals values that are characteristic of thunderstorm incidence.

A similar analysis of thunderday trends in other regions of Australia is recommended to establish if the increase is Australia-wide or isolated to particular areas of the country. Comparison of trends in instability indices derived from large-scale reanalysis and trends in radiosonde data at other locations should be performed. Further research is required to establish a direct link between the increase in atmospheric instability and the driving mechanism causing the changes, whether climate change or changes in some large-scale meteorological process.

Acknowledgments

The authors would like to thank the Bureau of Meteorology for generously supplying data and software for the completion of this project. A number of Bureau personnel provided advice on the production and analysis of the data, including Kevin Parkyn, Kevin Smith, Neil Moodie, Ivor Blockley, Harald Richter, Robin Hicks and Harvey Stern. Bob Cechet of Geoscience Australia provided funding for the project as well as advice on statistical analysis techniques. Richard Wardle of Monash University provided software for the break-point analysis. The University of Melbourne provided computing resources. Deborah Abbs of CSIRO and two anonymous reviewers provided useful comments.

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Mrs. BLACKBURN. I thank you, Mr. Chairman.

These papers found that the intensity levels were high in some years and low in others and a significant increase in the number of thunder days, but they concluded that there was nothing unusual about the recent trends. And I look forward to hearing from you all on these. The trends could not be attributed to global warming, and most increases weren't due to climate change. Instead, the changes actually stemmed from new observational practices that caused artificial trends in climate data.

And we also have some research on the Tree-Ring from their international conference. And we are looking forward to covering that with you and hearing from you on these issues again.

We want to make certain that we have accurate data, that we have accurate models, and that we are making the appropriate decisions as we look at the issue. And I thank you all for your time and your preparation.

I yield back.

The CHAIRMAN. The gentlelady's time has expired.

The Chair recognizes the gentleman from California, Mr. McNerney.

Mr. MCNERNEY. Thank you, Mr. Chairman.

This hearing is timely, and it is important. I am from northern California, north of my colleague from southern California. And we are experiencing drought, heat, and excessive fires, massive fires. People who live in the district are breathing smoke in 110-degree weather. So there is a lot of concern about the future, what that means.

This sort of event is consistent with what I believe global warming will bring California, is deserts claiming territory farther and farther north. How is that going to manifest? It is going to manifest by fires, and it is going to manifest by heat and drought. So I am concerned, and I want to see that we take the right steps.

And part of that is understanding exactly what the experts believe is in store for us, so that we can not only prepare, we can mitigate, we can adapt, and we make the right decisions in a bipartisan way. So I look forward to your testimony. Thank you for coming today.

And I yield back.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Oregon, Mr. Walden.

Mr. WALDEN. Thank you, Mr. Chairman, and thank you for holding this hearing.

I want to join in here in terms of what climate change may mean for those of us from the West. And I think my colleagues from California spoke of the fires that they are unfortunately experiencing. And Oregon usually follows California in the fire wave of the season.

And I think the two things that come to mind are, first of all, we know from research data and testimony from the Forest Service that our forests are going to be really impacted. If it gets hotter and drier and more drought, as you all have talked about, then you are going to have more bug infestation, disease and forest fires.

And our forest fire officials have come to me and—both firefighting officials and forest supervisors—have said, "Give us the authority you gave us in the Healthy Forest Restoration Act," which has worked well around our wildland urban interfaces. Let us do that out in the condition class 2 and 3 lands that are most out of whack with balance and nature, so we can get ahead of this a bit, get those forests thinned, so that they can be more adaptive to the change in climate and be able to exist the wildfire that we know will come, because it will be thinned out, you won't have the ladder fuels, and therefore fire will act like it used to act before we suppressed fire.

Secondly, the issue that I think that we all in the West, especially the arid West, need to be cognizant of is that if it is going to be drier, then we need to look at how we manage water and especially how we store water. Because if the snow packs do recede—although, this year, we seem to have had an abundance of snow, which was nice, especially for those of us who are skiers—but if we are going to see a reduction in snow pack, then we need to focus on how you do off-stream storage, how you do additional storage of water, and how we allocate that in an appropriate way, how we best manage our water.

We are going to get some great testimony, I think, today from Dan Keppen, who I will introduce later, on this topic and on others.

So I think there are things that Congress could do to change the law that would help on water management, storage, forest health and survivability of our forest, reducing greenhouse gas emissions, and reducing the threat of fire.

Thank you, Mr. Chairman.

The CHAIRMAN. The gentleman's time has expired.

[The prepared statement of Mr. Cleaver follows:]

U.S. Representative Emanuel Cleaver, II
5th District, Missouri
Statement for the Record
House Select Committee on Energy Independence and Global Warming Hearing
"Global Warming Effects on Extreme Weather"
Thursday, July 10, 2008

Chairman Markey, Ranking Member Sensenbrenner, other Members of the Select Committee, good afternoon. I would like to welcome our distinguished panel of witnesses to the hearing today.

Last month's floods in the Midwest devastated seven states, displaced thousands of residents, and took over a dozen lives. The long-term losses of the floods remain to be seen. However, a portion (about two percent) of the corn supply in Iowa was destroyed due to the disaster and prices are expected to rise and supply could still be strained. Other incidents of extreme weather – like Hurricane Katrina in New Orleans and the Gulf Coast and the cyclone in Myanmar in May of this year – highlight the recent incidence of dangerous weather events occurring in our world recently.

What we must know before we can act is the reason why these events have occurred, and if global warming is in fact a catalyst for extreme weather. If so, do we have the power to slow or even stop these effects from reaching a breaking point, where they can harm people and industry? I am hopeful that our guests today can provide us with scientific expertise on this subject. I especially want to welcome to the hearing today Dr. Jimmy Adegoke, Associate Professor and Chair of the Department of Geosciences at the University of Missouri, Kansas City. Following his dissertation work at Penn State, he focused his attention at the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University. At UMKC, he is currently engaged in modeling cross-scale connections between processes that influence heat stress and air quality in urban areas. I am confident his experience with climate and land sciences will be of great benefit to the Committee today.

I thank all of our witnesses for their insight and suggestions, and I appreciate them taking the time to visit with our committee this morning.

Thank you.

The Chair will now recognize the gentleman from Arizona for the purposes of introducing our first witness.

Mr. SHADEGG. Thank you, Mr. Chairman.

We are very pleased to have in the Maricopa County area in Phoenix, Arizona, Arizona State University, a recognized excellence center in higher education. And I have relied on them many times this year for expertise and advice on issues confronting the Congress.

I am pleased to welcome, as I mentioned earlier today, Dr. Jay S. Golden. Dr. Golden has a wide background, not just from academia. He has served as an environmental crimes detective. He served as regional operations vice president for a Fortune 500 company. He established his own multi-State environmental and engineering firm, and then returned and received his Ph.D. in engineering from the University of Cambridge and a master's degree in environmental engineering and sustainable development from the Cambridge-MIT Institute.

He currently serves as an assistant professor in the School of Sustainability, an affiliate of the Civil and Environmental Engineering Department at Arizona State University. He founded and serves as the director of the National Center of Excellence on SMART Innovations for Urban Climate and Energy.

His research is focused on the climate-energy nexus, including quantifying and developing mitigation strategies that address the resulting environmental, human health, energy and economic impacts.

He was appointed to the United Nations Life Cycle Management Task Force. And, finally, he directs the Sustainability Energy Fellowship, which educates some of our most exceptional students in environmental and energy and sustainability issues.

Dr. Golden, we welcome you here to the committee.

STATEMENT OF JAY S. GOLDEN, DIRECTOR, NATIONAL CENTER OF EXCELLENCE, SMART INNOVATIONS FOR URBAN CLIMATE AND ENERGY, GLOBAL INSTITUTE OF SUSTAINABILITY, ARIZONA STATE UNIVERSITY

Mr. GOLDEN. Congressman Shadegg, I thank you for that introduction.

Mr. Chairman, Congressman Sensenbrenner and other members of the committee, thank you for this opportunity to address you on these important issues.

The national center which I direct supports local and regional agencies to develop strategies to reduce vulnerability and risk associated with extreme weather events. We focus on heat waves, the urban heat island effect, and the relationship to reliable electricity delivery.

First allow me to present some driving factors behind our research and why I believe greater Federal action needs to be taken to support State, regional and local governments as they seek to protect our national security.

Factor number one is more people in the United States die from heat-related events than all other weather-related phenomena combined. That is, more Americans die each year from extreme heat than lightning, hurricanes, tornadoes and floods combined.

Factor number two, global climate change, which will increase human health vulnerability as more frequent and extreme weather events, including heat waves, impact our country. In their 2008 report, the U.S. Climate Change Science Program concluded that abnormally hot days and nights and heat waves are very likely to be more frequent. Additionally, since the record hot year of 1998, 6 of the last 10 years have had annual average temperatures that fall in the hottest 10 percent of all years recorded in history for the United States.

Factor number three is the urban heat island effect. Over half of our planet's population now lives in cities, up 30 percent from 50 years ago. In 2000, more than 8 out of 10 Americans lived in metropolitan areas. With increased population comes rapid change in our land cover and an increased use of engineered materials for our buildings. These retain our heat in our cities, contributing to the urban heat island effect.

As an example of the urban heat island effect, the average annual temperatures in the combined urban-rural areas of Phoenix, Arizona, have increased 3.1 degrees Fahrenheit during the 20th century. However, mean annual temperatures in just the urban portions of our region have increased 7.6 degrees Fahrenheit.

Factor four, a vulnerable electrical system. In the United States, parts of our electrical delivery capability are at increasing risk of failure. Urban heat islands and heat waves are almost certain to cause increased demand. By 2025, U.S. electricity consumption is projected to grow by 50 percent over 2003 levels. To meet this rising demand, an equivalent to almost 950 new power plants of 300 megawatts each will be needed.

The primary means of adaptation to climate change is mechanical cooling, air-conditioning. The greater the demand, the more fragile our system becomes, as older units fail due to mechanical breakdowns and its heavily laden power lines stretch and sag from heat.

My recommendations: Action number one, develop a stronger and more integrated urban research focus. Because no one mission agency in the Federal Government has responsibility for all the components of a city, no government body is funding research that looks at how all the parts fit together. Who will synthesize all this information to a model or models that incorporate as much data as possible? Fundamentally, Congress should direct agencies and the NRC to look for ways to create synergistic urban research programs.

Number two, a dedicated urban satellite system. Remote sensing from space can and needs to play a vital role in protecting human health and the environment from climate change, urban heat islands, and failures of electrical power systems. Scientists continue to develop and refine very complex predictive models to gain a greater understanding of urban and global climate change. However, the current dedicated satellite system that provides the basis for our ability to prevent human harmful impacts is in jeopardy of phase-out, abandonment and/or failure.

Action item number three, streamline and enhance electricity interruption reporting requirements. We lack an effective and consistent national-level program that examines the interactions of the built environment, climate and safe electricity delivery for our cities, let alone an effective way to track outages. At best, our current system can be considered confusing and less than adequate. We need to increase our understanding of electricity outages of different scales. In short, we need a new, comprehensive and rational power outage reporting system.

Finally, I strongly urge this committee and Congress to support the development of a report to all appropriate committees of Congress on the issues of heat waves, urban heat islands, and human health vulnerability.

The proactive effort will provide Congress greater insights and multi-stakeholder recommendations on three primary topics: identify existing and emerging needs of local and regional governments to prepare and respond to human health vulnerability resulting from heat waves, urban heat island effect, climate change, and power outages; number two, examine the roles and capabilities of Federal agencies to support local and regional governments and suggest programs to improve these capabilities; finally, provide recommendations for future research initiatives that can reduce vulnerability and improve our national security.

I strongly caution that the timing of such an effort must be immediate. By waiting and not addressing these issues in the present day, we risk our population and our national security today and into the future.

Thank you.

[The statement of Mr. Golden follows:]

Testimony before the:

SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING

U.S. HOUSE OF REPRESENTATIVES

July 10, 2008

By:

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Director

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on SMART Innovations for Urban Climate & Energy

Global Institute of Sustainability

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INTRODUCTION

Mr. Chairman, Congressman Sensenbrenner, Congressman Shadegg from my home state of Arizona, and other members of the Committee: My name is Dr. Jay Golden, and I am an assistant professor and director of the EPA-designated National Center of Excellence on SMART Innovations for Urban Climate & Energy at Arizona State University.

Although our Center has a long name, our mission is straightforward. We are a group of researchers from various engineering and science disciplines that work together to provide policy makers with information about how materials affect energy use and climate, especially in urban environments.

More specifically, our work helps local and regional agencies to develop strategies to reduce vulnerability and risks associated with extreme weather events. We focus on heat waves, the urban heat island effect, and their relationship to reliable electricity delivery.

I speak to you today not only as an academic, but as former environmental-crimes detective, hazardous-materials responder, manager of a Fortune 500 company, small-business owner and, after being called upon to assist in the aftermaths of 9-11, someone who went back to school to earn his PhD and dedicate himself to make a difference for my children and for our country.

To that end, I have been dedicating my life's work towards the issues of climate change and vulnerability. First, allow me to present some of the driving factors behind my research and why I believe greater federal action needs to be taken to support state, regional, and local governments as they seek to protect our national security.

FACTOR #1 – Heat-Related Deaths

More people in the United States DIE from heat-related events than all other weather related phenomenon COMBINED.

That is, more Americans die each year from extreme heat than from lightning, hurricanes, tornadoes, and floods combined. (Weisskopf et al. 2002). Additionally, according to the US Census, the US population is aging; the population over age 65 is projected to be 13% by 2010 and 20% by 2030 (that's over 50 million people). Older adults are more vulnerable to temperature extremes, suggesting that temperature-related deaths will increase.

FACTOR #2 – Global Climate Change

Global climate change will increase human-health vulnerability as more frequent and extreme weather events, including heat waves, impact our country.

In their 2008 report, the US Climate Change Science Program and the Subcommittee on Global Change Research concluded that "abnormally hot days and nights and heat waves are very likely to become more frequent."

Since the record hot year of 1998, six of the last 10 years have had annual average temperatures that fall in the hottest 10% of all years on record for the US. Recent studies have looked at "Heat Waves" for the US and North America. These studies found that there is an increased likelihood of more intense, longer-lasting, and more frequent heat waves (Meehl and Tebaldi, 2004; Schar et al. 2004; Clark et al. 2006). This finding is especially true in the southeastern, southwestern and western US.

In a soon-to-be published paper, Sterl and others assessed extreme high temperatures around the globe through 2100. Their research warned of dangerously high temperatures predicted for densely populated areas including the Midwest.

Their study projected heat wave events in 2100 reaching 117°F in Los Angeles, 110°F in Atlanta, and116°F for Kansas City. Those projections are for the end of the century but even going out just 40 years from now heat waves will be 3 to 5°F degrees hotter than now and will probably be longer lasting.

FACTOR #3 – Urban Climate and Urban Heat Islands

Over half of the planet's population now lives in cities, up 30% from 50 years ago, and urban areas are gaining ~67 million people per year. By 2030, approximately 5 billion people are expected to live in urban areas—60% of the projected global population of 8.3 billion (US Census 2008; UN 2002). The US grew by nearly 33 million people between 1990 and 2000, the largest 10-year population increase in our history. The fastest-growing region in the past decade was the West at nearly 20%, which added over 10 million people. The fastest-growing states in the nation were all in the West: Population in Nevada (66%), Arizona (40%), Colorado (31%), Utah (30%) and Idaho (28%) have increased dramatically. California recorded the largest numeric increase of any state, just over 4 million people. In 2000, more than 8 out of 10 people lived in metropolitan areas[i], and 3 in 10 were in metro areas of at least 5 million people (US Census 2000).

Along with increased population comes rapid change in land cover and increased use of materials. What are the consequences of the change from vegetated surfaces to engineered infrastructure? Less water evaporates from plants and buildings and other structures retain more heat during the day and time. And sustained higher night-time temperatures increase the vulnerability to human health.

On average, the world has warmed by 1.33°F over the last century, with most of that increase occurring in the last 30 years (IPCC 2007). In many urban areas, however, the rate and intensity of warming have increased much faster. Over the 20th century, average annual temperatures in the arid subtropical Phoenix region (33°26'N, 112°W) have increased 3.1°F (Brazel et al. 2000). However, mean annual temperatures in the urban portions of our region have increased 7.6°F.

The 0.86°F per decade warming rate for Phoenix is not an isolated experience. For example, Los Angeles's rate was 0.80°F per decade; San Francisco, 0.20°F; Tucson, 0.60°F; Baltimore, 0.20°F; Washington, 0.50°F; Shanghai, 0.20°F; and Tokyo, 0.60°F (Hansen et al. 1999).

FACTOR #4 – A Vulnerable Electrical System

In the US, parts of our electrical delivery capability are at increasing risk of failure. The same land-cover and urbanization trends are almost certain to cause an increased demand for electricity due to increased mean global and urban temperatures and more prolonged heat waves.

The primary means of "adaptation" to climate warming is through the use of mechanical cooling (air conditioning). As described earlier, observations and models of climate change indicate that these elevated temperatures are being sustained longer into the evening that greatly augments "peak" electricity demand. The greater the demand, the more fragile the electric system becomes as older units fail due to mechanical breakdowns and as heavily laden power lines stretch and sag from heat. Beyond the human health impacts, there are significant financial implications. Researchers estimate annual service interruptions cost our country between $80 and $120 billion (Eckles, 2006; LBNL, 2004; Freeman, 2006).

Each of these four factors I have described must be examined and understood as a "system" that has many influences and many feedbacks. As one example, consider that CO_2 emissions from the US electric-power sector have grown by 27% since 1990, and CO_2 from electric power represented 39% of energy-related CO2 emissions in 2004. In cities with populations >100,000, peak-utility loads increase 1.5–2% for every 1°F (0.6°C) increase in summertime temperature, By 2025, US electricity consumption is projected to grow by 50% over 2003 levels. To meet this rising demand while retiring inefficient older plants, 281,000 MW of new power-generation capacity will be needed by 2025—equivalent to almost 950 new power plants of 300 MW each[ii] (EIA 2005).

A new generation of technologies and innovations, "SMART Innovations" (Sustainable Material and Renewable Technologies) are going to be needed if we are to meet this increased demand for electricity and protect our population while minimizing emissions of carbon dioxide that contribute to climate change.

THE FEDERAL GOVERNMENT – LOCAL GOVERNMENT NEXUS

Through my experiences with the cities of Chicago, Tucson, Phoenix, Philadelphia, New York, London, Seattle, Dallas, and Washington DC, I have gained insight into how the federal government can provide more needed support for cities and counties—large and small, urban and rural.

These governments and their officials are on the front lines in preventing, responding to and seeking ways to mitigate the impacts of climate change on their citizenry. Examples include the 1995 heat wave in Chicago that resulted in 739 deaths and the August 2003 heat wave in Europe that killed an astonishingly 35,000 people. These are certainly dramatic events, yet they are not isolated. The US experiences significant and multiple heat-related events each year such as:

Missouri: During a July 1980 heat wave, deaths increased by 64%. One in every 1,000 residents of St. Louis and Kansas City was hospitalized for or died of heat-related illness. Individuals of lower economic means were at 6 times greater risk of getting heat stroke (Jones et al. 1982). The hazards continue, as a recent study shows that residential customers of Kansas City Power and Light r used 42% more electricity in 2007 that in 1986 (Missouri 2007). In July 2006, Kansas City Power and Light broke energy records in the midst of a heat wave.

Wisconsin: During July 12-15, 1995 the Milwaukee County Medical Examiner's Office received reports of 197 deaths. Of these almost 50% were heat related. (US CDC 2001).

Michigan: Regional government is investigating how the state's two largest utilities, Detroit Edison and Consumers Energy responded when 720,000 customers were left without electricity, some for up to a week, just last month.

California: A 15-day heat wave in July 2006 caused power interruptions and a reported 136 deaths. Just a few weeks ago (June 21, 2008), workers from the LA Department of Water and Power accidentally broke a line that led to widespread power outages that cut power to LAX airport and the UCLA Medical Center and necessitated that several oil refineries burn off gas to relieve pressure, triggering an air quality/human-health warning.

Connecticut: Over 60,000 customers of Connecticut Light and Power and Con Edison were without power May 26, 2008 due to high winds with a subsequent event in June that left another several thousand without power.

Tennessee: Last August, Memphis maximum temperatures "dropped" to 94°F which was the first time in 10 days they did not top 100°F.

Although human-health impacts are felt more in urban areas, the urban heat island and increased and sustained heat waves also concern rural regions. Much of the electricity supplied to urban areas is generated in rural regions. Decreased air and water quality, water quantity, and waste byproducts affect the quality of life in rural areas as well as the health of ecosystems.

Lastly, at a time of increased food costs, sustained and increased temperatures also hurt crop yields and dairy production.

INITIAL PROGRESS

My testimony today and the facts I have presented are not meant to give the impression to this committee that little is being done at the federal level. Quite to the contrary, it has been my experience that some of our federal agencies deserve a great deal of credit for their current efforts. In particular:

The Environmental Protection Agency through its Office of Atmospheric Programs – Climate Change Division has been working to support local, regional, and state governments to better prepare for climate change and extreme heat events. In 2006, the EPA took the lead on developing an Excessive Heat Events Guidebook in partnership with NOAA/National Weather Service, the Centers for Disease Control and Prevention, and FEMA. This widely distributed guidebook is providing an initial platform for local governments to predict, assess, notify, treat, and mitigate Extreme Heat Events

The Climate Protection Partnership Division of EPA has also been managing a small but well-respected group called the "Heat Island Reduction Initiative" that has been successful in issuing best-practice guidance to local, state, and regional governments.

The National Center for Environmental Health at the US Centers for Disease Control and Prevention has been stepping up efforts to tackle the issues of climate change and human health. They have developed the modeling capabilities related to health system function, public health economics and ecosystem changes relevant to health. As this program is able to expand, it will provide a much-needed national resource.

Additionally, the National Weather Service has developed and continues to expand its Heat Advisory, Excessive Heat Warning, and Excessive Heat Watch program, a key tool for preparing emergency responders and health-care providers to respond to extreme heat events.

Finally, over the last year I have worked with these agencies engaging state, regional and local officials around the country to develop the tools, research, products, and other support they need to address extreme weather, urban heat island, and electricity reliability.

The feedback has been loud and clear. Much more needs to be done to better prepare our local governments to address this highly complex problem so that we can reduce the vulnerability of human populations and protect our national security. As a starting point, the National Center of Excellence is about to launch a cyber-enabled virtual organization at www.Heat-Waves.org

This site will serve as a national platform where the research community, regulatory community, industry and local practitioners can come together to share the latest scientific findings, models, remote-sensing products, as well guidance documents and regional programs, policies, and initiatives.

RECOMMENDATIONS

All this shared information however, is just a starting point. Given the growing risk to our country and the increasing needs of our local and regional government, greater support and resources must be provided to our leading federal agencies. I therefore put forward to you Mr. Chairman and members of the Committee the following personal recommendations:

Action #1: Develop a Stronger and More Integrated Urban Research Focus

Cities are increasingly recognized as key focal points for both government policy and research, because they are where the most people live today (both nationally and globally) and where most future population growth will occur. They account for a large aprt of carbon and other toxic emissions, and their citizens are responsible for major consumption of energy, water, materials, and food. Cities are also hubs of innovation. Perhaps most importantly, cities today are taking proactive stands related to sustainability issues. Addressing sustainability problems like water supply, air quality, urban heat, public health, and energy security within the context of cities offers economies of scale that might lead to real solutions that can benefit millions of people relatively quickly. On the other hand, cities can be major sources of environmental stress and inertia.
Given the importance of cities for economic, social, and environmental policy, both in the US and abroad, it's remarkable how little in the way of federal funds are targeted at understanding and solving urban problems. Because no one mission agency has responsibility for all the components of a city, no government body is funding research that looks at how all the parts fit together. Instead, the EPA looks at urban water, solid waste, and air-quality, Department of Transportation looks at highway infrastructure and traffic, NOAA looks at urban climate, the Forests Service considers urban forests, and NASA develops new remote-sensing platforms. Who will synthesize all this information into a model that incorporates as much data as possible? Fundamentally, Congress should direct agencies and the NRC to look for ways to create synergistic urban research programs.

Action #2: Dedicated Urban Satellite

This action closely aligns with Action Item #1. Remote sensing from space can play a vital role in protecting human health and the environment from climate change, urban heat islands, and failures of electrical-power systems. Scientists continue to develop and refine complex predictive models to gain a greater understanding of land-use/land-cover changes, environmental indicators, and, increasingly, the role of urban temperature on microclimates, electricity reliability, and human health.

Changes in land surfaces, land use, and ecosystems all have great significance in our ability to understand and more effectively predict:

1. Expanded danger from storms and other meteorological phenomena
2. Adverse global and localized climate impacts
3. Dangerous urban environmental impacts
4. Human health vulnerability from urban heat island effects, heat waves and blackouts.
5. Dangers associated with nuclear, biological and chemical dispersion and associated human health/environmental vulnerability
6. Energy and peak electricity demand planning and vulnerability
7. Air quality and surface-water quality compliance and impacts
8. Surface transportation infrastructure degradation
9. Water consumption and resource management

During this time of increasing threats due to urban and global climate change the need for dedicated satellite systems that provide the basis for our ability to prevent harmful impacts is in jeopardy of phase-out and abandonment and/or failure. Only two Landsat spacecraft are in orbit; data acquired from Landsat 7 is of reduced quality due to a scan-line corrector failure, and Landsat 5 is operating well beyond its design lifetime. The ASTER sensor (onboard the Terra spacecraft launched in 1999) is also now operating in an extended mission mode. Even when these systems have been fully operational, their use in urban monitoring has been limited due to the competing demands for operational time, their orbits and repeat times, and the specific instruments they contain.

As costs continue to lower and technologic sophistication increases, the possibility of designing a cost-effective urban satellite system with greater capabilities and resolution is becoming a reality. Our nation needs its governmental agencies, industries, and universities to collaboratively design, construct, launch, and direct operations of an Urban Satellite System. With this tool, we can provide local and regional governments with detailed analysis and tracking of cities that will aid in planning, infrastructure management, emergency-response preparation, and mitigation strategies. Climate models being developed for urban regions are only as good as the data that is being entered. The time for significant improvement in data sourcing is upon us, but not without the realization of an American Urban Satellite System.

Action #3: Streamline and Enhance Electricity Interruption Reporting Requirements

We lack an effective and consistent national-level program that examines interactions of the built environment, climate, and safe-electricity delivery for cities, let alone an effective way to track outages. At best, our nation's current system can be considered confusing and less than adequate.

The Energy Information Agency defines eight criteria by which utilities have to report major disturbances (service interruptions) within one hour and four criteria by which utilities have to report major disturbances within six hours.

The North American Electric Reliability Corporation (NERC) has been given the name of "Electric Reliability Organization" by the Federal Energy Regulatory Commission which, in essence, declares NERC's role as the independent entity with authority to develop and enforce mandatory standards for the reliability of the bulk power system.

NERC works with the *Eight Regional Entities*:

- Florida Reliability Coordinating Council (FRCC)
- Midwest Reliability Organization (MRO)
- Northeast Power Coordinating Council (NPCC)
- Reliability First Corporation (RFC)
- SERC Reliability Corporation (SERC)
- Southwest Power Pool (SRP RE)
- Texas Regional Entity (TRE)
- Western Electricity Coordinating Council (WECC)

Disturbance Reporting, as defined in standard 1-EOP-004 (Effective 1/1/2007), requires a preliminary written report to be filed with NERC and with the regional reliability entity. Each regional reliability entity has to establish reporting procedures to facilitate the preliminary reporting in its region.

Further complicating the issue is that the states have very different reporting requirements if, in fact, they even have reporting requirements. And none of the many reporting requirements were established with considerations of understanding human health and national security vulnerability from climate change.

At a time of anticipated increased heat waves, growing urban heat islands and increased demand for electricity, we need to increase our understanding of electricity outages of different scales. To examine the economic, environmental, and social impacts of our climate-electricity system and make appropriate recommendations to reduce our collective and individual vulnerability, researchers and agencies need access to highly accurate and refined data. In short, we need a new comprehensive and rational national power-outage reporting system.

Action #4: Create a Multi-Agency Working Group to Recommend Actions to Reduce Human Health and Environmental Vulnerability from Extreme Heat Events

Finally, there is a larger group of experts representing government, industry, and universities that need to be brought together to expand this preliminary list of actions.

I strongly urge this committee and Congress to support the development of "A Report to All Appropriate Committees of Congress" on the issues of heat waves, urban heat islands, and human health vulnerability.

This proactive effort will provide Congress greater insights and multi-stakeholder recommendations on three primary topics:

1. Identify existing and emerging needs of local and regional governments to prepare and respond to human heat-health vulnerability resulting from heat waves, urban heat island effect, climate change, and electricity outages.
2. Examine the roles and capabilities of federal agencies to support local and regional governments and suggest programs to improve these capabilities.
3. Provide recommendations for future research initiatives that can reduce vulnerability and improve our national security.

Because of their mission to protect human health and the environment as well as their efforts to date, the US Environmental Protection Agency would seem to me to be the logical agency to lead such an effort.

I strongly caution that the timing of such an effort must be immediate. By waiting and not addressing these issues in the present day, we risk our populace and our national security today and into the future.

About Arizona State University (ASU)

ASU has a vision to be a New American University, promoting excellence in its research and among its students and faculty, increasing access to its educational resources and working with communities to positively impact social and economic development.

Further, ASU is a public institution where sustainability is a fundamental precept underlying its teaching, learning, research, and business missions; and that seeks to produce knowledge and discover solutions to global problems of sustainability.

- ASU's Tempe campus has one of the nation's largest enrollments on a single campus at 51,481 students. ASU has a total of 64,394 at its four campuses.
- ASU is ranked as one of the top 100 universities in the world by the Institute of Higher Education.
- Economics professor Ed Prescott became the university's first Nobel laureate, earning the Nobel Prize for Economics in 2004.
- ASU's 2007 freshman class included 148 National Merit Scholars, more than any public university in the Pac-10 conference.
- ASU has the most undergraduates (11) named to USA Today's Academic First Team of any public university in the nation. Only Harvard (21), and Duke (12) have had more. The USA Today Academic Team rankings began in 1990.

About ASU's Global Institute of Sustainability

The Global Institute of Sustainability is the hub of ASU's sustainability initiatives. The Institute advances research, education, and business practices for an urbanizing world. http://sustainability.asu.edu.

About ASU's School of Sustainability

Established in 2007, the School of Sustainability, the first of its kind in the world, offers transdisciplinary degree programs that advance practical solutions to environmental, economic, and social challenges—especially as they relate to urban areas. http:schoolofsustainability.asu.edu.

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[i] Urban - All territory, population and housing units in urban areas, which include urbanized areas and urban clusters. An urban area generally consists of a large central place and adjacent densely settled census blocks that together have a total population of at least 2,500 for urban clusters, or at least 50,000 for urbanized areas. Urban classification cuts across other hierarchies and can be in metropolitan or non-metropolitan areas. A metro area contains a core urban area of 50,000 or more population, and a micro area contains an urban core of at least 10,000 (but less than 50,000) population. Each metro or micro area consists of one or more counties and includes the counties containing the core urban area, as well as any adjacent counties that have a high degree of social and economic integration (as measured by commuting to work) with the urban core.

[ii] A typical smaller and newer power plant has a capacity of 500MW, would run ~5,000 hours/year = 2.5 billion kWh/2.5TWh 10^{12} Older plants are more likely to be 1,000MW / 1GW Average US household uses 11,000kWh Arizona household uses ~12,500kWh per year Air Conditioning is the largest consumer of residential electricity in the US.

The CHAIRMAN. Thank you, Dr. Golden.

Now I am going to recognize Congresesman Walden.

Mr. WALDEN. Thank you for that courtesy, Mr. Chairman.

And I want to welcome Dan Keppen, who is a good friend and one of the West's finest advocates for family farmers and ranchers.

He is a fellow Oregonian. Dan resides in Klamath County, which is in the southern part of the district I have the honor of representing. And Dan has, for the last 3 years, served as the executive director of the Family Farm Alliance, which is a grassroots farmer advocacy group that aims to ensure the availability of reliable and affordable water for irrigation in the West.

Before joining the Family Farm Alliance in 2005, Dan served 3 years as the executive director of the Klamath Water Users Association, where I worked closely with him on one of the West's most prominent and challenging water management issues, the Klamath Reclamation Project.

And if anyone can speak with authority about the importance of water in the West for farms and families and communities, it is Dan Keppen. After all, few people were more involved in helping find solutions in the 2001 water cutoff in the Klamath Basin than Dan. He is a real expert on water and farm issues, knows full well the impacts that a change in the weather can have on those who make their living from the land.

From 2000 to 2001, Dan served as the special assistant to the Bureau of Reclamation's Mid-Pacific regional director in Sacramento, where he advised and assisted with planning, managing, directing and coordinating a variety of reclamations water management activities.

He received his master of science degree in civil engineering from Oregon State University and a bachelor of science degree from the University of Wyoming.

It is my pleasure to welcome before the committee Dan Keppen. And I look forward to his testimony and that of the other witnesses.

Thank you, Mr. Chairman.

STATEMENT OF DAN KEPPEN, EXECUTIVE DIRECTOR, FAMILY FARM ALLIANCE

Mr. KEPPEN. Thank you, Mr. Walden and Chairman Markey and members of the select committee. I appreciate this opportunity to testify today.

Again, my name is Dan Keppen. I am the executive director of the Family Farm Alliance. World headquarters in Klamath Falls, Oregon. We represent irrigators in all 17 western States. We are also committed to the fundamental proposition that western irrigated agricultural must be preserved and protected for a host of reasons, many of which are often overlooked in the context of other policy decisions.

The topic of this oversight hearing is not only important to the alliance, it is also relevant to water users, farmers, ranchers and small communities all over the western United States.

My board of directors in 2007 made climate change a priority issue for our organization to engage in. And last year we released a report entitled, "Water Supply in a Changing Climate: The Perspective of Family Farmers and Rancher in the Irrigated West." I would like to respectfully submit this to be included in the hearing record today.

The CHAIRMAN. Without objection.

Mr. KEPPEN. Thank you.

Our report shows that climate change could further strain fresh water supplies in the American West. It provides several examples of studies that focus on specific regions or watersheds in the West, and they indicate that, for the most part, from the Colorado River Basin to the Pacific Northwest to the Central Valley of California, climate change has and will continue to impact water supplies and the users dependent on those supplies in the future.

The Western Governors' Association has developed findings that are consistent with our examples of climate impact to water supplies across the West, as reported in our document. In general, Western Governors predicts four general predictions: smaller snow packs and earlier snowmelt; more rain than snow; extreme flood events which could be more common and become larger; and droughts and higher temperatures which could be more intense, frequent and last longer, which will obviously have an impact on irrigators.

In some areas, western water supplies are already challenged by the demands of agriculture, urban growth and environmental enhancement. Global climate change, we are told, will further reduce those supplies.

So how will we meet the ever-increasing demand for water in the West in an era when there will be an ever-decreasing supply? We recommend an adaptive approach, as well, to dealing with the uncertainties of climate change. Even if current efforts to mitigate for greenhouse gas emissions are successful, the climate is still predicted to warm considerably over the next several decades, which will have impacts on water supplies and water users.

Improved conservation and efficiency by urban and agricultural water users is certainly part of the solution, but only one part. We must begin to implement a balanced suite of both conservation and supply-enhancement actions. Conservation alone will not supply enough water for the tens of millions of existing and new residents expected to live in western cities during the coming decades. We believe it is possible to meet the needs of cities and the environment in a changing climate without sacrificing western irrigated agriculture.

It is time to start developing and implementing the water infrastructure needed to cope with the changing climate, meet the needs of a growing population, protect our environment, and support a healthy agricultural base in the West. We need to streamline the often slow and cumbersome Federal regulatory process to improve, modernize and expand our water infrastructure. Finally, we must prioritize our research needs to accomplish useful studies that inform water managers and their users of key actions that must be accomplished to deal with the changing climate.

My boss, president of the board for the alliance, is Patrick O'Toole, a rancher from Wyoming. He testified before the Senate Energy and Natural Resources Committee last year on S. 2156, the Secure Water Act, sponsored by Senators Bingaman and Domenici.

This bill includes water science initiatives, water-efficiency programs, and additional actions that will help us adapt to the water-related impacts of global climate change.

These provisions closely matched similar recommendations made in the report that we developed. While there is not currently a companion bill introduced in the House, we would encourage the House to take up a similar bill to help speed its enactment into law.

We believe change of climate will further strain freshwater supplies in the American West. We must begin to plan for that now and not wait until we are forced to make decisions during a crisis. Now is the time to enact sound policies and encourage continued investment in irrigated agriculture.

Reallocating farmers' water supplies will diminish domestic food production at exactly the same time global warming is predicted to severely adversely impact food production worldwide. Relying on agriculture to be a shock-absorber to soften or eliminate the impending water shortage is not planning. It is an easy fix that carries with it enormous consequences to our society and our Nation.

While much of the debate surrounding what to do about climate change is centered on mitigation for greenhouse gas emissions, we believe that climate change policies for irrigated agriculture in the future need to address adaptive approaches that prepare for the worst-case scenarios predicted for western watersheds.

Thank you for this opportunity to appear before the committee again, and I would happy to answer any questions you might have.

[The statement of Mr. Keppen follows:]

Dan Keppen
Executive Director
Family Farm Alliance

Testimony Before the Select Committee
on Energy Independence and Global Warming
United States House of Representatives

Oversight Hearing
on
"Global Warming Effects on Extreme Weather"

July 10, 2008

Chairman Markey, Ranking Member Sensenbrenner, and Members of the Select Committee:

Thank you for the opportunity to appear before you to discuss climate change and water supply impacts on Western irrigated agriculture. My name is Dan Keppen, and I serve as the executive director of the Family Farm Alliance (Alliance).

The Alliance is a grassroots organization of family farmers, ranchers, irrigation districts and allied industries in 16 Western states. The Alliance is focused on one mission: To ensure the availability of reliable, affordable irrigation water supplies to Western farmers and ranchers. We are also committed to the fundamental proposition that Western irrigated agriculture must be preserved and protected for a host of economic, sociological, environmental and national security reasons – many of which are often overlooked in the context of other policy decisions.

The topic of this oversight hearing is not only tremendously important to the Alliance, it also is immediately relevant water users, farmers, ranchers and small communities all over the West.

Alliance Involvement with Climate Change Issues

It is clear that climate change discussions will provide the forum for many other important policy issues to be addressed in the near future. The climate debate will be one where many interests will try to force their agendas. Those who have a balanced, practical and effective approach to dealing with climate change impacts will be viewed as reasonable parties. The Alliance board of directors in February 2007 made climate change a priority issue for the Alliance to engage in.

The Alliance in September 2007 released its climate change report, entitled "Water Supply in a Changing Climate: The Perspective of Family Farmers and Ranchers in the Irrigated West". The report was prepared by a climate change subcommittee, Advisory Committee members, and water resources experts from around the West. Our report shows that climate change could further strain fresh water supplies in the American West. We must begin to plan for that now, and not wait until we are forced to make decisions during a crisis.

Alliance President Patrick O'Toole, a rancher from Wyoming, in June 2007 was invited to testify on this matter before the U.S. Senate Energy and Natural Resources. In the past year, our organization has been invited to speak on this topic at meetings sponsored by the California Agricultural Irrigation Association, Water Education Foundation, National Water Resources Association, Idaho Council on Industry and the Environment, Nevada Water Resources Association, and the Mid-Pacific Water Users.

President O'Toole, in December 2007, testified before the Senate Energy and Natural Resources Committee on S. 2156, the SECURE Water Act, sponsored by Senator Bingaman, Senator Domenici, and others. While there is not currently a companion bill introduced in the House, the bill includes water science initiatives; water efficiency programs; and an attempt to better understand and adapt to the water-related impacts of global climate change. S. 2156 contains some provisions that are very close to the recommendations provided by the Alliance in its white paper and testimony before Mr. Bingaman's committee in June 2007. The Alliance would encourage the House to take up a similar bill to help speed its enactment into law.

Current and Projected Impacts of Climate Change to Western Farmers and Ranchers

In the past two years, the public has been inundated with a flood of new studies that focus on projected climate change impacts to Western water resources. Predictions and conclusions reached about the impacts climate change will have on future water resources availability are as varied as the Western landscape. However, we are increasingly hearing reports that predict dire long-term hydrologic consequences for the West. Several studies further focus on specific regions or watersheds and are briefly discussed below.

Arizona

Experts in Arizona say that climate change is occurring and will likely have more impacts in the future to water resources. A climatic water budget runoff model has been developed for the Salt and Verde River basins of central Arizona[1], which used the outputs of six global climate models to estimate runoff in the future under assorted "scenarios" developed by the Intergovernmental Panel on Climate Change. Due to projected warmer temperatures by the year 2050, projected changes in runoff for the two basins suggest that the runoff from the Salt and Verde will have approximately an 85% chance of being less in the future due largely to warming in the study area. This could have significant impacts for these two basins, which have six dams, a variable hydrology, and a total storage capacity of 2.3 million acre-feet (as compared to the 27 million acre-feet capacity of Lakes Powell and Mead on the Colorado River).

[1] CLIMATE CHANGE 2050: IMPACTS ON RUNOFF FROM THE SALT AND VERDE RIVER SYSTEMS. PRESENTATION TO THE FAMILY FARM ALLIANCE ANNUAL CONFERENCE, February 22, 2007, Dr. Robert C. Balling, Jr., School of Geographical Sciences, Arizona State University

California

A report released in 2006 by the State of California[2] predicts that climate change will result in a drastic drop in the state's drinking and farm water supplies, as well as more frequent winter flooding. The report suggests that warmer temperatures will raise the snow level in California mountains, producing a smaller snowpack and more winter runoff. This means more floodwaters to manage in winter, followed by less snowmelt to store behind dams for cities, agriculture, and fish. By the year 2050, the statewide snowpack would shrink by 5 million acre-feet less water, more than the total capacity of Lake Shasta, the state's largest reservoir.

By 2050, the State study predicts that average snowpack in the Sierra Nevadas is likely to diminish by more than a third, and more precipitation will fall as rain rather than as snow, making it harder for reservoirs to capture for the long summer the same amount of water. The dwindling snowpack could reduce deliveries of Sierra supplies to Central Valley farmers by 10%.

According to another recent study developed by the University of California[3], agricultural water users in the Central Valley are also the most vulnerable to climate warming. For the driest climate warming scenario assessed, the predicted hydrology would reduce agricultural water deliveries by about a third. For that dry scenario, the study speculates that, while financial losses to the agricultural community would be compensated by water sales to urban areas, much of this loss would likely result in an uncompensated structural change in the agricultural sector.

Colorado River Basin

A February 2007 report by a National Research Council (NRC) committee[4] says agriculture is the likeliest target for shifting use to urban needs in the fast growing West. But it cautions that "the availability of agricultural water is finite." It adds that rising population and water demands "will inevitably result in increasingly costly, controversial and unavoidable trade-off choices" in managing a shrinking resource. Future droughts may be longer and more severe because of a regional warming trend that shows no signs

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[2]OUR CHANGING CLIMATE – ASSESSING THE RISKS TO CALIFORNIA, A summary biennial report from the California Climate Change Center, 2006.

[3]CLIMATE WARMING AND WATER MANAGEMENT ADAPTATION FOR CALIFORNIA, Stacy K. Tanaka et al, Department of Civil and Environmental Engineering, Department of Agricultural and Resource Economics, University of California, Davis 95616

[4] COLORADO RIVER BASIN WATER MANAGEMENT: EVALUATING AND ADJUSTING TO HYDROCLIMATIC VARIABILITY, National Research Council, Division on Earth and Life Studies, Water Science and Technology Board, 2007.

of dissipating, the NRC report notes. It also states that a preponderance of evidence suggests that rising temperatures will reduce the river's flow and water supplies.

The committee also looked at how a steadily rising population and related increases in water demand will affect Colorado River water management. The population across the western United States has grown rapidly. Despite some successful water conservation efforts, urban water use in the region has increased significantly along with the expanding population. Increasing urban water demands are often met through sales, leases, or transfers of water rights from farm users. Water transfer agreements will be limited in their ability to satisfy growing, long-term demand, according to the NRC committee, and such agreements may also cause problems for third parties, such as downstream farmers or ecosystems. Technology and conservation measures are useful and necessary for stretching existing water supplies, the committee acknowledged, but any gains in water supply will be eventually absorbed by the growing population.

Pacific Northwest

Last April, the Intergovernmental Panel on Climate Change released a report[5] that predicts climate-change related impacts to water resources in the Pacific Northwest. Similar to predictions made in other parts of the West, dwindling mountain snowpack is expected to make summer water scarce especially east of the Cascades, where agriculture is a strong component of rural communities.

Snowpack in the Cascade Range holds two-thirds of the region's stored water. As it melts during the dry summer months, it fills rivers, generates hydropower, and helps meet the water needs of irrigation, fish, recreation and growing urban areas. However, Cascade snowpack has diminished in the past 50 years and is expected to further shrink. Projected warmer winter temperatures will cause snowpack to melt earlier in the spring, which could exacerbate both spring-time flooding and late-summer drought conditions. This prediction does not bode well for irrigation-dependent eastern portions of Oregon and Washington.

Utah

A 2003 study directed by Congress and led by Utah State University professor Frederick Wagner[6] lays out a variety of possibilities if temperatures increase from nearly 4 to 6 degrees Fahrenheit by 2100. The potential scenarios range from increased precipitation

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[5] CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, World Meteorological Organization and the United Nations Environment Program.

[6] Professor emeritus of the Department of Forest, Range and Wildlife Science at Utah State University.

(with decreased snowpack and greater downstream flood risks) to decreased precipitation (desertification and a decline in water resources). In all scenarios, water management changes would be required, and the worst-case scenario would likely trigger water transfers from agriculture to urban areas, which would contribute to a sharp decline of farming and ranching. Water resources experts in Utah also realize that new surface water storage projects may be necessary to capture more snowmelt or more water from other sources[7]. The Southern Nevada Water Authority – which has essentially used up its share of Colorado River water - is already planning to take groundwater out of aquifers under the Utah-Nevada state line and pipe it to Las Vegas. Ranchers in this area are fighting this proposal.

Summary of Anticipated Impacts to Agricultural Water Users

The Western Governors' Association (WGA) last year testified in support of a bill that would reorient and fully fund the U.S. Global Change Research Program to make it more user-driven. The WGA testimony mirrors many of the common themes and findings developed in the reports identified above. WGA found that we can expect to see the following general effects and impacts caused by warming future temperatures in the Western U.S.:

- Smaller snow packs and earlier snowmelt will affect reservoir storage and demand for water and impact productivity and value of hydroelectric generation;
- More rain than snow is likely, with uncertain projected impacts to overall precipitation amounts in specific areas;
- Extreme flood events could be more common and larger.
- Droughts and higher temperatures would be more intense, frequent and last longer, which would increase stream and reservoir evaporation, diminish surface water supplies, and stress groundwater supplies and water quality.

Despite the highly variable and uncertain nature inherent with climate change predictions, it can safely be concluded that, in the West, with a warming climate, there will be less water stored in our biggest reservoir...the snow pack. More water in the form of rainfall and runoff will come at farmers and ranchers sooner in the season, when it may not be useful and may even present a threat.

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[7] Professor Jack Schmidt, Utah State University, Dept. of Aquatic, Watershed, and Earth Resources, quoted in "Global Warming: What about water?", *Salt Lake City Tribune*, October 30, 2006.

What are Irrigators, Water Agencies and Businesses Doing to Address Climate Impacts?

While a great deal of scientific inquiry and public discourse has been focused on climate change and its possible consequences for the planet's future, Western irrigators and irrigation districts are concerned about the problems threatening their water supplies today – drought and urban population growth. Event without climate change, these factors present an immediate crisis for agricultural water users in the West. If the effects of climate change are anything like those outlined in the research discussed here today, Western irrigated agriculture could be greatly impacted, and possibly eliminated. This is, of course, worrisome to farmers and ranchers and their communities. It ought to be of great concern to nation as a whole because climate change may result in a disruption of food production worldwide. If that is what is in store for us, then this country cannot afford to lose the food production capacity of Western irrigated agriculture.

The response of irrigators and water agencies to current water supply challenges can provide some insight into the possible measures that might be taken to cope with long-term water supply reductions resulting from climate change.

Drought Response

Much of the West is currently in drought or facing reduced water supplies as a result of environmental regulation. In response, farmers and water agencies are taking creative measures to conserve water and increase the efficiency of irrigation. Here are a few examples.

- In the San Joaquin Valley of California, state-of-the-art drip irrigation systems water some of the most productive farmland in the world.

- Further north, in the Sacramento Valley, producers and local governments are working to develop a regional water management program that will help address not only water quantity challenges, but also water quality and environmental issues. Those same growers 15 years ago were key players in a state-managed drought water bank that temporarily transferred local water to southern California to meet other statewide needs.

- In Idaho, water users are working with state and federal agencies and the Nez Perce Tribe to settle longstanding disputes and create more certain water supplies.

- Along the Columbia River, irrigators are developing water exchange programs to increase supply reliability while improving salmon habitat.

Pressures of Urban Population Growth

The West is the most rapidly growing part of the United States. Yet, water supplies there are essentially static. In some areas, urban demand for water -- and land -- is straining agriculture and rural communities to the breaking point. New environmental water demands imposed by regulatory agencies or courts also first look to agriculture. This is happening in every state, but farmers and ranchers point to some striking examples:

- A report released in 2006 by Environment Colorado found that, from 1987-2002, Colorado lost an average of 460 acres per day of ag land. The report predicts 3.1 million more acres will be lost to development by 2022.

- Arizona's massive Salt River Project (SRP) in a few years will cease to provide water to agriculture in order to meet new demands exerted by development.

- In Las Vegas, Nevada, over 70,000 new residents are moving in every year, and urban water officials are looking to rural areas to satisfy its growing thirst.

- A restoration agreement developed for the Platte River could potentially dry up hundreds of thousands of acres of farmland in Nebraska and Wyoming, in order to reallocate water to meet the perceived needs of imperiled fish and wildlife.

- The California Department of Conservation indicates that more than 1 million acres of farmland in the state was converted between 1988 and 1998. Last year, California's population officially topped 37 million, a growth rate of 1.4 percent, representing 500,000 new residents in the last fiscal year.

Farmers, ranchers and rural communities cannot solve the water supply problem created by the Western population boom. Nor can they be expected to sacrifice their livelihoods for the "greater good" of golf courses, strip malls and housing developments.

Farmland is disappearing at a time when the U.S. needs a more stable domestic food supply (just as it needs a stable energy supply). We are concerned that this critical issue – which becomes even more serious when viewed in the context of projected climate-change impacts to water supplies - is being overlooked by our national leaders.

A reliable, safe and sustainable domestic food supply is just as important as a strong military to the protection of our national interests. The post 9/11 world of terrorist threats makes the stability of domestic food supply even more pressing.

What are Western Irrigators Doing to Reduce Greenhouse Gases?

Western farmers and ranchers are already taking actions to reduce greenhouse gases and other possible contributors to climate change. Some of these actions are undertaken consciously with this objective in mind; others have been implemented as part of the broad portfolio of actions that successful farmers have to take to stay profitable in today's economic and regulatory climate. In virtually every Western state, there are examples of activities that agricultural producers are taking that have an overall effect of reducing carbon dioxide emissions, which many policy makers believe are a primary contributor to global warming. These actions include:

- Use of cleaner and more efficient diesel engines;
- Reduction of energy needs on farms;
- Use of biodiesel;
- Low-till practices;
- Involvement in conservation programs, which provide incentives to set aside thousands of acres of farmland for wildlife habitat;
- Selling carbon credits to industries for approved management actions.

Probably most obviously, and most importantly, crops turn carbon dioxide into oxygen. Further, new research suggests that irrigation has kept croplands cool, countering to some extent the rising temperatures caused by greenhouse gas emissions over the last half century.[8]

Recommended Strategies to Address Potential Impacts

Western water supplies are already inadequate to the demands of agriculture, urban growth and environmental enhancement. Global climate change, we're told, will further reduce those supplies. We recommend an adaptive approach to dealing with the uncertainties of climate change. Even if current efforts to mitigate for greenhouse gas emissions are successful, it is our understanding that the climate is still predicted to warm considerably over the next several decades. This tells the irrigation community in the West that we must begin to prepare for a warmer climate and be able to adapt in order to survive its projected impacts.

So how will we meet the ever-increasing demand for water in the West in an era when

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[8] Kueppers, L. M., M. A. Snyder, and L. C. Sloan (2007), IRRIGATION COOLING EFFECT: REGIONAL CLIMATE FORCING BY LAND-USE CHANGE, *Geophys. Res. Lett.*, *34*, L03703, doi:10.1029/2006GL028679.

[8] WESTERN WATER SUPPLY ENHANCEMENT DATABASE, Family Farm Alliance, 2005.

there will be an ever-decreasing supply? Improved conservation and efficiency by urban and agricultural water users is certainly part of the solution, but only part,

1. Implement a Balanced Suite of Conservation and Supply Enhancement Actions

We believe that it is possible to meet the needs of cities and the environment in a changing climate without sacrificing Western irrigated agriculture. To achieve that goal, we must expand the water supply in the West. There must be more water stored and available to farms and cities. Maintaining the status quo simply isn't sustainable in the face of unstoppable population growth, diminishing snow pack, increased water consumption to support domestic energy, and increased environmental demands.

It is simply ludicrous to believe that conservation alone will supply enough water for the tens of millions of new residents expected to arrive in Western cities during the coming decades. Farmers and ranchers understand that conserved water cannot realistically be applied to instream uses, as it will more likely be put to beneficial use by the next downstream appropriator or held in carryover storage for the following irrigation season.

Many water projects are ready and waiting to be developed in the West[9]. While conservation and recycling programs have done a tremendous job of meeting new growth, still, only a small amount of new water has been developed in the past 30 years. We cannot continue to "conserve just a little more" forever. It's time to start developing and implementing the water infrastructure needed to cope with a changing climate, meet the needs of a burgeoning population, and support a healthy agricultural base in the West.

2. Streamline the Regulatory Process to Facilitate Development of New Infrastructure

Modern, integrated water storage and distribution systems can provide tremendous physical and economic flexibility to address climate transformation and population growth. However, this flexibility is limited by legal, regulatory, or other institutional constraints, which can take longer to address than actually constructing the physical infrastructure[10].

The often slow and cumbersome federal regulatory process is a major obstacle to realization of projects and actions that could enhance Western water supplies. In addition, there exists with agencies a defeatist attitude that no dams or water supply projects will be built. So, there is no commitment to earnestly begin and engage the

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[10] CLIMATE WARMING AND WATER MANAGEMENT ADAPTATION FOR CALIFORNIA, Stacy K. Tanaka et al, Department of Civil and Environmental Engineering, Department of Agricultural and Resource Economics, University of California, Davis 95616

difficult problems described above. The Family Farm Alliance wants to work with Congress, federal agencies and other interested parties to build a consensus for improving the regulatory process.

3. Prioritize Research Needs

Our country has tremendous, but limited, resources available to fix our problems, so we must prioritize. One priority research items should be a comprehensive validation of West-wide changes in climate change-driven streamflow. This should be followed by quantification of the amount of additional reservoir storage, conservation targets, etc required to re-regulate this change in hydrology. This would quickly illustrate to policy makers the need to start modernizing our water infrastructure. This assessment should be accompanied by a comprehensive study of the collective impacts of agricultural land and water changes in western states over the last 10 years, as well as predicted trends. A study of this sort may provide the type of hard findings that may help wake up policy makers on the "big picture" ramifications of this issue.

The potential water impacts associated with use of alternative fuels must also be studied. Throughout the West, we are seeing proposals to build plants to make ethanol, another "answer" that may (or may not) lower greenhouse gas emissions. An April 2007 *Sacramento Bee* editorial provides a reality check on how much water it would take to grow all the corn required to meet California's goal of producing a billion gallons of ethanol a year. According to the *Bee*'s calculations, that's about 2.5 trillion gallons of water for 1 billion gallons of ethanol, which is more than all the water from the Sacramento-San Joaquin Delta that now goes to Southern California and valley farms. Because there is only so much water for agriculture in California and other Western states, this means that some other existing crops will not be grown, thus furthering our dependence on imported food sources.

Another growing demand that will be placed on Western water resources is driven by power requirements. The total water consumed by electric utilities accounts for 20 percent of all the non-farm water consumed in the United States. By 2030, utilities could account for up to 60 percent of the non-farm water, to meet the water needs required for cooling and pollutant scrubbing. This new demand will likely have the most serious impacts in fast-growing regions of the U.S., such as the Southwest. Even without warming climate conditions, continued growth in these regions will put the squeeze on both water and power use. When you throw in climate change considerations, the projections look worse.

Conclusion

Climate change could further strain fresh water supplies in the American West. We must begin to plan for that now, and not wait until we are forced to make decisions during a crisis. Relying on agriculture to be a "shock absorber" to soften or eliminate the impending water shortage is not planning. It is a choice to put our heads in the sand and hope for the best. It is a decision that could worsen the overall impact of climate change on our nation's economy and security.

Millions of acres of barren land have been transformed into the most efficient and productive agricultural system in the world. About 5 percent of the land area of the West is irrigated, and the Bureau of Reclamation provides water to about one-fifth of that acreage. All of this has been done for a total federal investment of $11 billion. A 1998 study found that the economy of the United States receives a greater than 100% return each year on this investment[11].

Now is not the time to retreat from our investment. Now is the time to enact sound policies that encourage continued investment in irrigated agriculture. Allowing water-short cities to absorb farmers' water supplies will significantly diminish domestic food production at exactly the same time global warming is predicted to severely adverse impact food production worldwide.

The U.S. recently became a net importer of food. The U.S., which once fed much of the world, now imports more food than it exports. Food production, like so many of our industries and services, is moving off shore, and a large part of our security is moving with it.

Europeans aggressively protect their farms and food production capability because they still remember the hungry years during and after World War II when they relied on other nations, America in particular, to feed them. The time has come – indeed, it's long overdue – for the United States to similarly adopt an overriding national goal of remaining self-sufficient in food production. Policy decisions on a wide range of issues ranging from taxation to the management of natural resources should then be evaluated to be sure they are consistent with that goal. It's hard to imagine a simpler or more important step to safeguard the American public.

While much of the debate surrounding what to do about climate change has centered on mitigation for greenhouse gas emissions, we believe that climate change policies for irrigated agriculture in the future need to address adaptive approaches that prepare for the worst case scenarios predicted for Western watersheds. We must look to increasing available fresh water supplies through a balanced approach of improved watershed management, water conservation techniques, and increased water storage facilities – both on the surface and in our aquifers. Our infrastructure is aging and we must continue to

[11] That report and associated data was produced by Darryll Olsen, Ph.D. of the Pacific Northwest Project in Kennewick, Washington and Houshmand Ziari, Ph.D. of IRZ Consulting in Hermiston Oregon. The report was prepared for the Family Farm Alliance.

invest in rehabilitation and improvement of our existing facilities. We must look to new technologies, better research and studies, and improved management tools to be prepared for such dire climatic predictions. And, we must work toward more collaborative approaches that protect our irrigated agriculture, our cities and towns, and our environment for future generations to enjoy.

Thank you for the opportunity to testify on this important subject, and I would answer any questions you might have.

Ms. SOLIS [presiding]. Thank you.

Our next witness is Heather Cooley.

Heather Cooley is a senior research associate with the Pacific Institute Water and Sustainability Program. At the institute, her research involves water privatization, California water issues and environmental justice, and climate change.

Prior to the institute, she worked at the Lawrence Berkeley Laboratory, where she studied climate and land-use change in carbon cycling. She has published a book on freshwater resources, ranging on issues from floods and droughts to impacts on businesses and ecosystems, and has testified before the State of California regarding management of freshwater resources.

She holds a bachelor of science in molecular environmental biology, with an emphasis in ecology, from UC-Berkley and an MS in energy and resources from UC-Berkley.

Welcome, and thank you for coming, Ms. Cooley.

STATEMENT OF HEATHER COOLEY, SENIOR RESEARCH ASSOCIATE, PACIFIC INSTITUTE

Ms. COOLEY. Thank you.

Mr. Chairman and members of committee, thank you for inviting me to offer testimony on the growing risk to the Nation from extreme weather events as a result of climatic change. I will limit my discussion here to floods and droughts and how we can adapt to these changes, but my written testimony expands on a broader range of risks and responses.

Floods and droughts have dominated the headlines in papers across the United States in recent months. Floods along the Mississippi River and its tributaries have devastated communities throughout the Midwest. Drought conditions are prevailing across large parts of the United States. And, in California, drought conditions have spawned nearly 2,000 fires since late June in what may turn out to be one of the worst fire seasons on record.

Yet most the discussion about climate change has focused on average conditions. But the Nation is far more vulnerable to extreme events like those we are experiencing throughout the country today. These extreme events have the largest social, economic and environmental impacts. They kill and injure the most people, and they cause the most damage to our economy and environment.

Scientists are increasingly investigating the risks of these extreme events. And, in short, they conclude we are loading the dice in favor of the increase in severe events. And the Nation's water resources appear to be most at risk.

In particular, research now shows that warmer temperatures will intensify the hydrologic cycle, leading to greater climate variability and, unfortunately, an increase in the risk of both floods and droughts.

The idea that both floods and droughts may increase may seem counterintuitive to some. But let me provide an example that is particularly relevant to the West to illustrate this point.

In the West, snowfall and snowmelt are critical for water supply. The research indicates that warmer temperatures will raise the snow line in mountainous regions, causing more precipitation to fall as rain rather than snow, and thereby increasing the likelihood of winter floods. To make matters worse, these higher temperatures will lead to an earlier and faster snowmelt, increasing the likelihood of droughts and water shortages during the summer months when our farms and cities need water the most.

But what can we do about these growing risks? Impacts associated with climate change are now unavoidable, but that doesn't mean we are helpless. Let me touch on a few options that my written testimony describes in much greater detail.

First, smarter flood plain management. In the past, we have relied heavily on levees for flood protection, but these measures can often give a false sense of security, encouraging development and putting more lives and people at risk.

The 1994 Galloway report from General Galloway and the Army Corps of Engineers strongly called for a new approach, one based on, and I quote, "avoiding the risks to the flood plain, minimizing the impact of these risks when they cannot be avoided, mitigating the impacts of damages when they occur, and accomplishing the above in a manner that concurrently protects and enhances the natural environment."

Second, we must develop new alternative supplies. Recycled water, for example, can be used for a wide range of purposes, from agricultural and landscape irrigation to power plant cooling and groundwater recharge. Agencies throughout the West are beginning to pursue recycled water, but we need to encourage this transition.

In addition, better groundwater management would allow us to restore excess surface water, including storm water, and groundwater aquifers during wet years for later use in dry years. In the past, we often looked at storm water as a liability and sought to get it out of our cities as quickly as possible. But now communities are realizing that this is an asset, that we can then recharge our groundwater and use it again when we need it.

And, finally, water conservation and efficiency offers enormous potential for reducing water pressures on water supply and must be central to any effort to adapt to climate change.

We have made some remarkable achievements in the past 25 years, and as the figures on page 11 of my written testimony indicate, total water use in the Nation has actually declined, despite continued economic and population growth.

But much more potential to improve the efficiency of water use remains. Work we have done at the Pacific Institute indicates that the urban sector could reduce its water use by a third at lower cost than new supply. And that is in California, where very already done quite a bit, but there is still a tremendous amount available. There is also potential for the agricultural sector.

These efficiency improvements can also help us reduce the impacts of climate change. Capturing, treating, transporting, and using water require large amounts of energy. In California alone, an estimated 19 percent of the electricity used, 32 percent of the natural gas and 88 million gallons of diesel fuel consumption are water-related. Thus, conservation and efficiency improvements can also save energy, thereby reducing our greenhouse gas emissions.

Furthermore, a recent analysis from the California Energy Commission found that energy can be saved through water conservation at lower cost than through traditional energy-efficiency measures.

In closing, I would like to urge members of the committee to take action now. Waiting another 5 to 10 years will only make solving these problems more difficult and costly. Furthermore, all of the options I discussed—smarter flood plain management, better groundwater management, recycled water, and conservation—makes sense under today's climate conditions and can help reduce current pressures on our water system.

Thank you.

[The statement of Ms. Cooley follows:]

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Research for People and the Planet

Testimony of Heather S. Cooley to the
United States Congress
Select Committee on Energy Independence and Global Warming

For the Hearing on Global Warming Effects on Extreme Weather

July 10, 2008

My testimony today addresses **the rising risk of extreme weather-related events as a result of climatic changes and their impact on water resources, with a focus on the western United States.** In the short time available, let me provide a summary overview. **I have submitted more detailed supplementary materials for your review.**

The United States already faces growing pressures on existing water resources due to increases in population, industrial and agricultural water demand, and rapid development in semi-arid and arid regions. Based on a sizable and growing body of scientific analysis, it now seems highly likely that climate change will vastly increase those pressures. Of special concern is an expected increased risk of extreme events, such as floods, droughts, and heat waves. I will address what we can expect, and what policymakers and the public should begin to do to reduce the risks to life and property that we now expect.

Floods and droughts are among the most common and damaging of all natural hazards and much of the existing water infrastructure in the United States was built to lessen these hazards. Since 1903, floods have killed an average of 93 people annually in the United States, but single extreme events can kill hundreds or even thousands. Droughts also can lead to illnesses and deaths, but are more closely associated with economic damages. Direct economic losses from floods and droughts are high, averaging US$11.5 billion annually in direct losses; again, individual extreme events can be much higher.[1] Hurricane Katrina, for example, is estimated to have led to direct economic losses of

[1] Based on data from the National Weather Service, annual flood losses average $4.5 billion since 1903. Data from FEMA suggests that drought damages total between $6-8 billion annually.

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$100 billion to $150 billion, of which about 30% is attributed to flood losses. If indirect damages and losses associated with floods and droughts, such as loss of business and personal income, reductions in property value, etc., are included, these estimates would increase substantially.

Floods and droughts have dominated headlines in papers across the United States in recent months. Floods along the Mississippi River and its tributaries have devastated communities throughout the Midwest. Drought conditions are prevailing across large parts of the United States. As of July 2008, moderate-to-exceptionally severe droughts are affecting 35% of the western U.S.; 40% of the South; 17% of the High Plains; and 59% of the Southeast. Overall, nearly 30% of the contiguous U.S. is suffering moderate–to-exceptional drought.[2] In California alone, drought conditions have spawned nearly 2000 fires since late June in what may turn out to be one of the worst fire seasons on record.

Floods and droughts are, of course, a natural part of the climate system. Growing and convincing scientific evidence, however, indicates that increases in greenhouse gases are causing large, systemic change to our climate with implications for the intensity and frequency of hydrologic extremes, i.e., floods and droughts. While scientists are reluctant to attribute individual events like those experienced in 2008 specifically to climate change, long-term records and trends increasingly suggest that we are essentially "loading the dice" and increasing the probability that these types of events will increase in frequency and intensity.

Climate Change: What Can We Expect for Floods, Droughts, and Sea-Level Rise

The best climate science notes: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."[3] Atmospheric

[2] Data from the United States Drought Monitor
[3] Bernstein, L. et al. 2007. Summary for Policymakers. Climate Change 2007: Synthesis Report. Intergovernmental Panel on Climate Change Fourth Assessment Report.

climate models indicate that global warming will induce significant changes to global water resources and coastal ocean conditions during the next century; average surface air temperatures are projected to rise by 1.1°C to 6.4°C; sea level is expected to rise at least 18 cm to 59 cm; and average precipitation is expected to increase due to higher evaporation rates caused by warmer temperatures. These changes in averages, however, will also be accompanied by changes in extremes.

As noted in the 2000 National Water Assessment prepared for Congress and the President under the 1990 Global Change Research Act (PL 101-606), "[w]hile many factors of concern are affected by such average conditions, some of the most important impacts will result, not from changes in averages, but from changes in local extremes."

As models have improved in recent years, scientists are increasingly investigating the risks of these extreme events in greater detail. Over the next 100 years, most climate models are in agreement that warmer temperatures will intensify the hydrologic cycle, leading to greater climate variability and an increase in the risk of both floods and droughts. Throughout the northern middle and high latitudes, warmer temperatures are projected to increase summer dryness and winter wetness.[4] Thus the frequency and intensity of both floods and droughts are expected to increase – the worst of all possible worlds. As an example, more frequent or larger extreme events can change what we think of as a 1-in-100-year event (something that has a 1% chance of occurring in any year) could become a 1-in-10-year event (something that has a 10% chance of occurring in any year).

An example of this can be seen in research and observations in the western United States. For nearly two decades now, climate research has pointed to serious changes in regions where snowfall and snowmelt are critical for water supply. Models indicate that warmer

[4] Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper,I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S.,D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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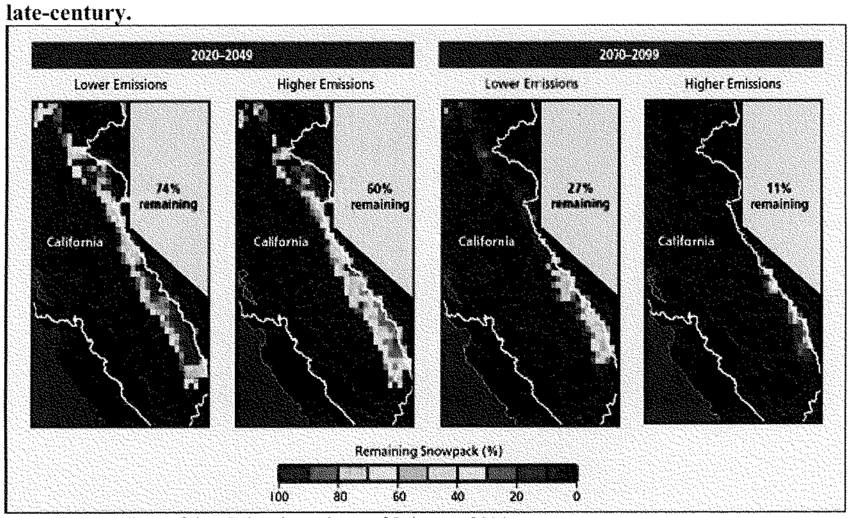
temperatures will raise the snowline in mountainous regions, causing more precipitation to fall as rain rather than snow, thereby increasing the likelihood of winter floods. To make matters worse, the higher temperatures mean that what does fall as snow will melt faster and earlier. Recent observations suggest that these changes are beginning to occur.

What does this mean? Even under optimistic scenarios of climate change, all the climate models suggest that winter runoff will rise – threatening more floods, and summer runoff will decrease – threatening agricultural production and water supply for cities. By the end of this century, scientists forecast that as much as 70% of California's snowpack will be lost due to warming (Figure 1). Similar kinds of changes are likely for the Rocky Mountain States and the Pacific Northwest.

Figure 1. The loss of California snowpack under two climate scenarios by mid- and late-century.



Source: Proceedings of the National Academy of Sciences. 2004.

As the country saw so dramatically with Hurricane Katrina, extreme flooding can also result from storms in coastal areas vulnerable to sea-level rise caused by climate change. Again, all climate models show dramatic increases in sea level over the coming decades, putting lives and property at risk from coastal storms and storm surges. For example, millions of people and hundreds of billions of dollars of property are exposed to these risks along the West coast of the United States.. As sea level rises, storm surges the number of people and property at risk will also rise. California's Bay Conservation and Development Commission recently completed maps showing areas around the San Francisco Bay that are at risk from a 1-meter rise in sea level. As shown in Figure 2, valuable infrastructure, including the Oakland and San Francisco airports, power plants, highways, railroads, industrial sites, and residential property along the margins of the San Francisco Bay are vulnerable to sea level rise. An early 1990 study by Gleick and Maurer, now being updated, suggests that property valued at more than $40 billion was at risk in this area – a figure that is now thought to be much higher.[5]

[5] Gleick, P.H. and E.P. Maurer. 1990. "Assessing the costs of adapting to sea-level rise: A case study of San Francisco Bay." Pacific Institute for Studies in Development, Environment, and Security, Berkeley, California and the Stockholm Environment Institute, Stockholm, Sweden. 57 pp. with 2 maps.

San Francisco Bay Scenarios for Sea Level Rise
Central and South Bay

Figure 2. Maps of Inundated Areas Associated with a 1-Meter Sea Level Rise.
Source: Bay Conservation and Development Commission
Note: These maps show inundated area but do not capture areas at risk of flooding during storms or other high water events. Work currently underway at the Pacific Institute will provide more detailed maps of flood damage along the entire California coast.

Climate Change will Alter Both Water Supply and Quality

Changing climate conditions will also affect the supply of and demand for water resources. The Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report notes that climate change will lead to "changes in all components of the freshwater system." Indeed, all of the IPCC reports conclude that freshwater systems are among the most vulnerable sectors. Climate change will have a significant impact on freshwater resources, affecting availability, timing, reliability, and quality. Below we describe some of the impacts associated specifically with floods and droughts.

One of the most obvious impacts of drought is a reduction in water supply, which is generally a temporary phenomenon but can become permanent. Over-pumping of groundwater, for example, can cause an aquifer to collapse, devastating regions and farms production that rely on groundwater as a primary supply. Drought can also compromise water quality by increasing the salinity and temperature of water bodies and reducing oxygen levels. In addition, drought can lead to higher water-pollution levels, as less water in rivers, streams, and lakes means that there is less water available to dilute wastewater effluent. These water-quality problems can exacerbate water-supply problems.

Flooding can also affect both water supply and quality. It can cause toxic spills and leaks that contaminate riverine systems and expose buried contaminates and redistribute them along the river. More intense precipitation events can increase erosions rates and wash more pollutants and toxins into waterways. Storm surges or levee breaks can induce saltwater intrusion in coastal areas, contaminating freshwater ecosystems. In some areas, such as the Sacramento-San Joaquin Delta in California, saltwater intrusion can contaminate the water supply for a large segment of the population.

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What Can We Do to Reduce the Risks of Extreme Events from Climate Change? Adapting to a Changing World

Impacts associated with climate change are now unavoidable. The Earth's energy system is out of balance and even if we stop emitting greenhouse gases today, the Earth's climate will continue to change. Because we have already committed to a certain degree of climate change and emissions continue unabated, adaptation must be a central element of all climate-change policy. The IPCC defines adaptation as "initiatives and measures to reduce the vulnerability of natural and human systems against actual and expected climate-change effects."

A key element in any climate adaptation strategy is to avoid taking rigid, expensive, and irreversible actions in climate-sensitive areas that worsen our vulnerability and ultimately increase the long-term costs to society. Given remaining uncertainties associated with climate change, some planners support policies that provide social, economic, and environmental benefits regardless of climate change impacts, referred to as "no regret" policies. Some of these "no regret" adaptation options include a greater emphasis on water efficiency, improved weather-monitoring efforts, expanding water supply options, and better planning and preparedness for floods and droughts. Below, I describe some of these "no regret" options.

Smarter Floodplain Management Can Reduce Deaths and Damages

Traditional floodplain management has typically relied upon controlling a river via large-scale structural measures, such as dams, levees, and diversions. Levees and other structural methods, however, have a number of disadvantages as seen in the recent Mississippi floods. In addition to isolating the river and eliminating important ecosystem functions and processes, structural methods tend to increase vulnerability to the hazard by encouraging development in flood-prone areas and giving those who live behind the structure a false sense of security. For this reason, recommendations after flood events now consistently call for less reliance on strict and rigid structures in favor of smarter floodplain management. In addition to structural mitigation measures, traditional flood management has also relied on disaster response such as evacuations and relief aid, which can encourage redevelopment in unsafe locations as well, thereby increasing the long-term risk associated with these events.

The 1994 Galloway report, however, strongly asserts that a new approach is needed; one based on "avoiding the risks of the floodplain; minimizing the impact of those risks when they cannot be avoided; mitigating the impacts of damages when they occur; and accomplishing the above in a manner that concurrently protects and enhances the natural environment."[6] Smart land-use management can effectively reduce the risk of floods. This approach could include armoring existing urban centers whose existence is tied to the river; relocating high-risk businesses and homes; placing parks, wildlife, and recreation areas in flood-prone areas; and providing for upstream flooding to protect downstream areas. In addition, proper land-use management can increase the benefits of floods; floodwaters, and the sediments they contain, providing an important resource for maintaining agricultural productivity. For example, California's Yolo Bypass was established as a flood conveyance channel around communities in the Sacramento River watershed in California. While the Bypass is an effective flood control method, it also provides a number of other benefits, including essential upland and wetland habitat for wildlife, as well as productive agricultural land for a variety of farm uses.

Although not typically considered an element of land-use management, leaving certain elements of the natural environment in place may help reduce the risk of flood. Wetlands, for example, can absorb large volumes of water and release the water after the flood peak has receded. Wetlands, as well as mangroves, can also absorb some of the energy associated with storms and minimize coastal inundation.

[6] Interagency Floodplain Management Review Committee. 1994. Sharing the Challenge: Floodplain Management into the 21st Century. Administration Floodplain Management Task Force.

Water Conservation and Efficiency Offer Enormous Potential for Reducing Pressure on Water Supply

Improving the productivity of water use is a particularly attractive adaptation option. The terms "water conservation and efficiency" refer to actions that permit us to reduce the amount of water needed to do the things we want: to grow food, produce industrial goods and service, clean our cloths or homes, and remove wastes.. While some still think of "conservation" as the same as "deprivation" -- shorter showers, dirty cars, and brown lawns – those kinds of temporary actions are only adopted during a drought or some other water-supply emergency. But comprehensive improvements in the efficiency of water use are permanent and largely cost-effective: they typically result from the application of well-known and widely used technologies, such as digital x-ray machines, drip irrigation systems, modern cooling systems, low-flow toilets, and front-loading clothes washers.

These technologies have already contributed to significant improvements in the efficiency of national water use. Over the past 25 years, total water use has declined while the population and economy have grown (Figure 3), supporting the notion that water conservation and efficiency can reduce water use while helping the economy. As a result of past efforts, per-capita water use has declined from a high of 1,950 gallons per person per day in 1977 to 1,480 gallons per person per day in 2000 (Figure 4). Even in the West, where concerns about water-supply constraints have long been a reality, water use remains wasteful and the potential for further improvements in efficiency is tremendous. The Pacific Institute's 2003 study, "Waste Not, Want Not," provides a comprehensive statewide analysis of the conservation potential in California's urban sector. This study finds that existing, cost-effective technologies and policies can reduce current residential, industrial, and commercial water demand by more than 30 percent.[7] A more recent study, "California Water 2030," concludes that the state as a whole could reduce water use in urban and agricultural sectors by 20% overall with existing technologies, even with a growing population and economy.[8]

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[7] See http://www.pacinst.org/reports/urban_usage/
[8] See http://www.pacinst.org/reports/california_water_2030/index.htm

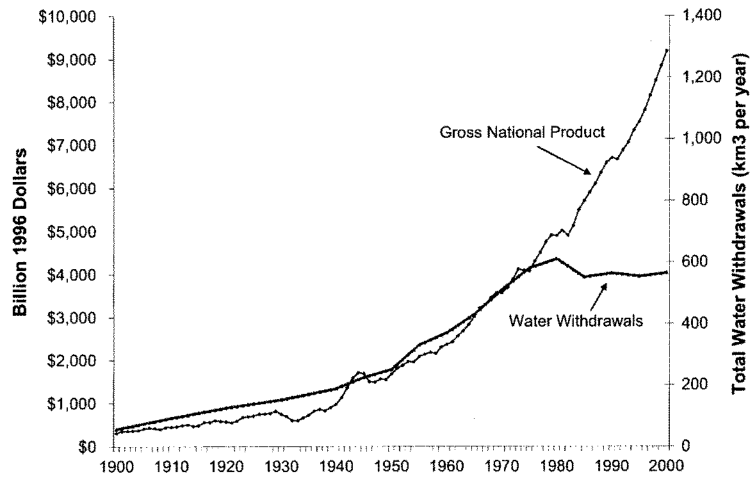

Figure 3. U.S. Total Water Use and Gross National Product, 1900-2000.
Source: Gleick, P.H. 2005. Freshwater and Foreign Policy: New Challenges. Great Decisions. Foreign Policy Association. 2005 Edition. New York. pp. 95-104.

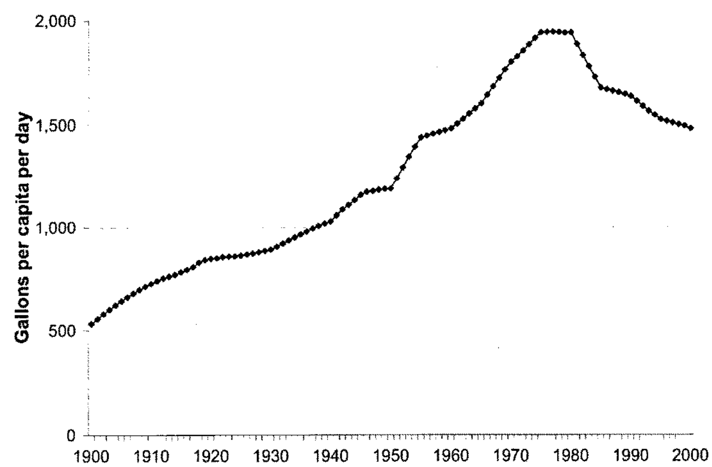

Figure 4. Total Per Capita Water Use in the United States, 1900-2000.
Source: Gleick, P.H. 2003. Water Use. Annual Review of Environment and Resources. Vol. 28, pp. 275-314.

Substantial savings are available from the agricultural sector as well. More than 40% of all crops grown in the western United States are still grown with inefficient flood irrigation systems. Studies have shown that installing efficient irrigation technologies, such as drip system or sprinklers, can reduce water use and increase agricultural yield. Given that the agricultural sector uses, on average, 85% of the West's water supply, even small efficiency improvements can produce tremendous water savings. Additional water savings are possible if farmers continue the trend of moving away from water-intensive crops like cotton, pasture, rice, and alfalfa in favor of more valuable, less water-intensive crops like fruits, vegetables, and nuts.

Recycled Water Offers New Supply for Some Uses

Another new source of water is the collection, treatment, and reuse of wastewater. In California alone, an estimated 500,000 acre-feet (163 billion gallons) of water are recycled and reused each year for a wide range of purposes, from agricultural and landscape irrigation to power-plant cooling and groundwater recharge. Some communities are already beginning to tap this resource. For example, the Irvine Ranch Water District, in Southern California, meets nearly 20% of its total demand with recycled water. A new residential community in Ventura County, California has decided to use recycled water for all of its landscaping needs at costs far below the cost of new surface storage. This suggests that significant opportunities exist to increase recycling and reuse throughout the West, effectively lessening the need to identify and develop new water supplies and reducing our vulnerability to climate change impacts.

Conjunctive Use of Surface and Groundwater Offers New Storage Possibilities

Surface water and groundwater are hydrologically linked. "Conjunctive use" takes advantage of this connection by storing excess surface water, including storm water, in groundwater aquifers for later use in dry years. This option, already being implemented in parts of the West, has a number of important benefits, including reducing the risk of floods, improving water-supply reliability and flexibility, reducing land subsidence, and minimizing the impacts of urban runoff on local streams and the marine environment.

While Adaptation is Critical, There are Also Important Mitigation Options

While we must begin planning to adapt to those climate impacts that are unavoidable, we must also work to try to avoid severe climate impacts to which we cannot adapt. The good news is that the strong connections between water and energy offer us some unique opportunities to both reduce greenhouse gas emissions and to use water more sustainably.

Capturing, treating, transporting, and using water require large amounts of energy. This is particularly true in the West, where water supplies and population centers are often separated by hundreds of miles, requiring a tremendous amount of infrastructure to move water from where it is available to where it is needed. In **California, for example, an estimated 19% of electricity use, 32% of all natural gas consumption, and 88 million gallons of diesel fuel consumption are water-related.**[9] Thus, a key new strategy focused on saving water through conservation and efficiency improvements can also save energy. Furthermore, a recent analysis by the California Energy Commission found that energy can be saved through water conservation at lower cost than through traditional energy efficiency measures.

The production of energy also requires water – often vast amounts of water for cooling traditional fossil fuel and nuclear power plants. When water is in short supply, energy production can be constrained, and there are concerns that climatic changes will threaten energy production because of the increased risk of drought. This is already a reality in parts of the United States (see headlines, below).

- **Drought Could Force Nuke-Plant Shutdowns**
  The Associated Press, January 2008

- **Sinking Water and Rising Tensions**
  EnergyBiz Insider, December 2007

- **Stricter Standards Apply to Coal Plant, Judge Rules; Activists Want Cooling Towers for Oak Creek**
  Milwaukee Journal Sentinel, November 2007

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[9] To put these numbers in perspective, consider that leaving the hot water running for 5 minutes uses as much energy as operating a 60-W light bulb for 14 hours.

- **Journal-Constitution Opposes Coal-Based Plant, Citing Water Shortage**
  The Atlanta Journal-Constitution, October 2007

- **Maryland County Denies Cooling Water to Proposed Power Plant**
  E-Water News Weekly, October 2007

- **Water Woes Loom as Thirsty Generators Face Climate Change.**
  Greenwire, September 2007

But not all energy systems are equally demanding of water: many renewable energy systems require very little water (see Figure 5). As U.S. water supply becomes increasingly scarce as a result of climate change and continued economic and population growth, these low-water-using energy sources will become even more attractive. Thus conversion to renewable energy sources, such as wind and solar, can help reduce our vulnerability to water supply constraints on energy production and reduce greenhouse gas emissions at the same time.

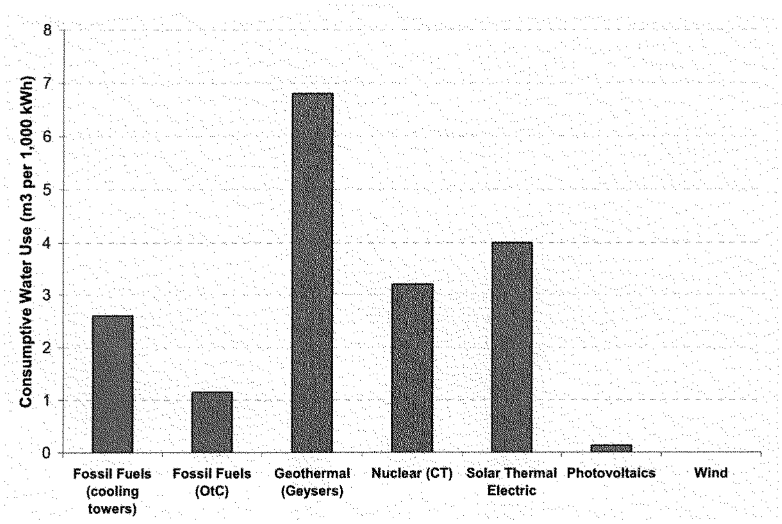

Figure 5. Consumptive Use of Water By Various Energy Technologies.
Source: Gleick, P.H. et al. 2002. The World's Water. (OtC: Once-through-cooling; CT: Cooling towers)

Recommendations

Let me conclude with a set of recommendations, several of which would benefit from legislative action.

- Existing state, federal, and local water systems should be tested under a range of potential future climate conditions to see how they respond and the extent to which they are vulnerable to expected changes. Water managers must re-evaluate engineering designs, reservoir operating rules, contingency plans, and water-allocation policies.

- All new water infrastructure must be designed and built incorporating climate change over the expected life of the project, including levees, reservoirs, and constructed and restored wetlands.

- All water-management decisions must take into account their energy and greenhouse-gas implications, with a focus on identifying actions that can both improve water management and efficiency and reduce energy use and emissions.

- Water agencies should partner with other agencies and authorities to seek combined solutions to water, energy, and greenhouse-gas problems.

- The management of water resources is spread among a number of federal and state agencies. The Environmental Protection Agency, for example, oversees water quality, while the United States Geological Survey monitors water use. Dams are operated by the Army Corps of Engineers in some locations and the Bureau of Reclamation in others. Better coordination is needed among these agencies to ensure effective management of this essential resource.

- The last National Water Assessment of the impacts of climate change on the country was completed in 2000. This assessment should be updated in light of extensive new research on water and climate change.

- A new National Water Commission, as proposed in legislation now pending (HR 135), has the potential to offer new recommendations for better water management in the nation as a whole. The risks of climate change must be included as a factor for this Commission to address.

Mr. HALL [presiding]. Thank you.

Our next witness is from my home State, Ms. Angela Licata, who serves as deputy commissioner for the New York City Department of Environmental Protection and director of the Bureau of Environmental Planning and Analysis.

She has worked in NYCDP for over 20 years. As deputy commissioner, she oversees climate change issues for the agency, the development of a watershed and sewershed program for Jamaica Bay, storm water management planning, natural resource planning, and sewer infrastructure planning as it relates to new growth stimulated by rezoning throughout the city.

She is also an expert in environmental planning assessment and negotiates complex land-use and permitting issues.

Ms. Licata, you are now recognized.

STATEMENT OF ANGELA LICATA, DEPUTY COMMISSIONER, NEW YORK CITY BUREAU OF ENVIRONMENTAL PLANNING AND ANALYSIS, DEPARTMENT OF ENVIRONMENTAL PROTECTION

Ms. LICATA. Good afternoon, members of the committee. I am Angela Licata, deputy commissioner with New York City's Department of Environmental Protection. On behalf of Commissioner Emily Lloyd, thank you for the opportunity to speak before your committee today.

Climate change certainly raises serious challenges to the future of New York City's water supply delivery, storm water management, and wastewater treatment system. In 2007, Mayor Michael Bloomberg released PlaNYC. This is a comprehensive, sustainable urban plan for New York City that includes 127 initiatives to create a greener, more sustainable city.

One of the key challenges addressed by PlaNYC is global climate change. In May of 2008, DEP released the first report of its "Climate Change Assessment and Action Plan," detailing the extensive work that DEP has undertaken to better understand and plan for the potential impacts of climate change on the city's water and sewer systems.

I am submitting the report to the committee for its consideration.

The report outlines specific steps that DEP has taken to, one, refine climate change projections for the city of New York; two, better quantify risks to existing systems; three, integrate climate change data into current design for new projects; four, develop adaptation strategies for critical infrastructure.

Adequate funding for ongoing research in the short term and for capital investments in infrastructure upgrades in the long term is crucial to our ability to adapt to a changing climate.

Customized climate change projections performed for DEP by Columbia University's Center for Climate Systems Research and NASA's Goddard Institute for Space Studies indicates that, by 2050, New York City and its watershed region will experience a 3- to 5-degree Fahrenheit rise in temperature, a 2.5 to 7.5 percent increase in precipitation, and a 6- to 12-inch rise in sea level. It is projected that these conditions will be even more pronounced by the year 2080.

Without proper planning and extensive adaptations, this degree of climate change could have a significant effect on the city's drinking water quality and supply.

Preliminary analysis indicates that rising temperatures could extend the growing season, exaggerate the frequency and severity of droughts, and heat waves will likely change the ecology of our watershed. Rising temperatures, coupled with heavier participation, could wash additional nutrients and particles into water supply reservoirs, thereby increasing turbidity and eutrophication levels, thus compromising the viability of New York City's currently unfiltered drinking water system.

Increased precipitation could also overwhelm storm water drainage systems, wastewater treatment facilities, and sewer infrastructure. Rising seas, coupled with storm surges, pose a threat to our coastal wastewater treatment facilities.

Recently, in fact, an observed increase in the frequency of severe rainfall events, which may be evidence of changing climate conditions, is alarming and unprecedented in the written record. In 2007, for example, on April 15th, 17 inches of rain were recorded in Upper Manhattan, the largest daily accumulation since 1882. On July 18th, 2007, between 3 and 5 inches of rain were recorded at locations across the city within a 4-hour period. In some areas, 3 inches of rain fell in 1 hour. And on August 8th, 2007, between 1.4 and 3.5 inches of rain were recorded within a 2-hour period.

Our current storm water conveyance system is designed only for 1.75 inches of rainfall per hour, given that the rate of return from much larger storms has historically occurred very infrequently.

Climate change is a complex emerging issue. The timing and extent of change are uncertain, and modifying large-scale infrastructure systems is expensive and takes time. But with sufficient support, we can develop and implement strategies that will help ensure the long-term viability of our drinking water and wastewater systems.

Working in concert with PlaNYC, Mayor Bloomberg's comprehensive urban sustainability initiative, DEP is already planning for the diversification of New York City's drinking water supply by increasing the interconnectivity and flexibility of our systems. We are also developing aggressive conservation programs, increasing water supply protection measures through a robust land acquisition program within our watershed, and building new drinking water quality infrastructure.

In another step forward, New York City DEP has also joined with water providers serving seven of the country's major metropolitan areas to form the Water Utility Climate Alliance. Working together, we aim to foster research aimed at advancing climate science and to develop more robust decision support frameworks. This alliance recognizes the importance of Federal partnerships in this endeavor.

DEP's 10-year capital program budget is intended to fund infrastructure investments on a 50-year time scale.

The CHAIRMAN [presiding]. Could you summarize, please?

Ms. LICATA. Yes.

Integrating climate change projections with departmental planning will help ensure that the city's water and wastewater systems are more resilient and better prepared to withstand the volatile conditions of a changing climate.

Once again, I thank you for the opportunity.

[The statement of Ms. Licata follows:]

Statement of Deputy Commissioner Angela Licata
New York City Department of Environmental Protection
before the House Committee on Energy Independence and Global Warming

Cannon House Office Building, Washington, D.C.
Thursday, July 10, 2008

Good afternoon, Chairman Markey, Ranking Member Sensenbrenner and Members of the Committee. I am Angela Licata, Deputy Commissioner with the New York City Department of Environmental Protection (DEP). On behalf of Commissioner Emily Lloyd, thank you for the opportunity to speak on the challenges New York City is facing and the steps we are taking to address the increase in extreme weather events as a result of global warming and to prepare for a changing climate.

Climate change raises serious, important challenges to the future of New York City's water supply and delivery, stormwater management and wastewater treatment systems as well as to the City's overall economic vitality and the health and well-being of our residents.

In 2007, Mayor Michael R. Bloomberg released PlaNYC, a comprehensive sustainability plan for New York City that includes 127 initiatives to create a greener, more sustainable city. One of the key challenges addressed by PlaNYC is global climate change. To mitigate the effects of climate change, PlaNYC calls for a 30 percent reduction of greenhouse gas emissions in New York City by 2030. To enable the city to adapt to the impacts of climate change, many of which we have already begun to experience, PlaNYC calls for the creation of a Climate Change Adaptation Task Force made up of city and state agencies and private companies to protect the city's critical infrastructure, a public outreach campaign to educate at-risk communities, and the development of a citywide strategic planning process to adapt the city to climate change.

In response to these challenges, DEP has released the first report of its *Climate Change Assessment and Action Plan*, detailing the extensive work that DEP has undertaken to better understand and plan for the potential impacts of climate change on the city's water and sewer systems. I am submitting the report to the Committee for its consideration.

The report outlines specific steps that DEP is taking to (1) refine climate change projections for New York City and its watershed region, (2) better quantify risks to existing systems, (3) integrate climate change data into current design for new projects, and (4) develop both short-term and long-term adaptation strategies for critical infrastructure. Adequate funding for ongoing research in the short term and for infrastructure upgrades in the long term is crucial to our ability to adapt to a changing climate.

Customized climate change projections performed for DEP by Columbia University's Center for Climate Systems Research and NASA's Goddard Institute for Space Studies indicate that by 2050, New York City and its watershed region will likely experience a 3 to 5 °F rise in temperature, a 2.5 to 7.5 % increase in precipitation and a 6- to 12-inch rise in sea level. It is projected that these conditions will be even more pronounced by 2080.

Without proper planning and extensive adaptations, this degree of climatic change could have a significant effect on New York City's drinking water quality and delivery, stormwater management and wastewater treatment systems. Preliminary analysis indicates that:

- Rising temperatures could exaggerate the frequency and severity of droughts and heat waves and will likely change the ecology of our watershed by shrinking supply, increasing demand and thus straining drinking water supplies;
- Rising temperatures coupled with heavier precipitation could wash additional nutrients and particles into water supply reservoirs, thereby increasing turbidity and eutrophication levels and compromising the viability of New York City's unfiltered drinking water system;
- Increased precipitation would also overwhelm drainage systems, treatment facilities and sewer infrastructure; and,
- Rising seas coupled with storm surges could pose a similar threat to key in-city infrastructure, particularly coastal wastewater treatment plants.

An observed increase in the frequency of severe rainfall events, which may be evidence of changing climate conditions, is alarming, and unprecedented in the written record. In 2007, for example:

- on April 15, 7" (18 cm) of rain were recorded in upper Manhattan, the largest daily accumulation since 1882
- on July 18, between 3" and 5" (7.6 and 12.7 cm) of rain were recorded at locations across the city within a four-hour period; in some areas, 3" of rain fell in one hour
- on August 8, between 1.4"–3.5" (3.5–8.9 cm) of rain were recorded within a two-hour period

Our current stormwater conveyance system is designed only for 1.75 inches of rainfall per hour.

Climate change is a complex, emerging issue. The timing and extent of change are uncertain, and modifying large-scale infrastructure systems is expensive and takes time; but with sufficient support, we can develop and implement adaptation strategies that will help ensure the long-term viability of our water and sewer systems.

Working in concert with PlaNYC 2030, Mayor Bloomberg's comprehensive urban sustainability initiative, DEP is already planning to diversify New York City's drinking water supply by developing alternative water sources as a backup, should localized conditions cause failure of an existing system. We are also developing more effective conservation programs, increasing watershed protection measures through a robust land acquisition program and building new water quality infrastructure.

DEP has also joined with water providers serving seven of the country's major metropolitan areas to form the Water Utility Climate Alliance. Working together, we aim to foster research advancing our collective understanding of anticipated impacts, develop targeted adaptation strategies and reduce each member's greenhouse gas emissions.

DEP's ten-year capital program budget is intended to fund infrastructure investments on a 50-year timescale. Integrating increasingly refined climate change projections with departmental planning will help ensure that the city's water and sewer systems are more flexible and better prepared to withstand the more volatile conditions of a changing climate. Sufficient funding, lead time and focused research are vital to ensure that new infrastructure investments adequately serve the public need.

Thank you again for the opportunity to address this Committee. I would be glad to answer any questions.

DEP's *Climate Change Assessment and Action Plan, Report 1* is available for download at http://www.nyc.gov/html/dep/pdf/climate/climate_complete.pdf

The CHAIRMAN. Thank you very much.

And Mr. Cleaver will be recognized to introduce our final witness.

Mr. CLEAVER. Thank you, Mr. Chairman.

It is with great pride and pleasure that I introduce Jimmy Adegoke, who was an associate professor in the Department of Geosciences at the University of Missouri in Kansas City, UM-KC, in the city where I reside.

He studied the role that land surfaces play in driving weather and climate change. And Dr. Adegoke's research also looks at linkages and feedback between the processes that impact air quality and heat stress in changing urban environments.

And as a member of the Geosciences Department, he was recently invited to serve on the advisory committee of remote sensing experts to assist the United Nations program in assessing various country-level projects in ecosystem and water management in different African countries.

He has a BS, he has an MS in climatology, he has a Ph.D. in satellite climatology from Penn State, and was awarded the National Oceanic and Atmospheric Administration postdoctoral fellowship in regional climate modeling.

We are very, very proud of him in Kansas City and pleased to have him present to this committee.

The CHAIRMAN. That is great.

Welcome, sir.

STATEMENT OF JIMMY O. ADEGOKE, ASSOCIATE PROFESSOR, UNIVERSITY OF MISSOURI

Mr. ADEGOKE. I would like to thank Chairman Markey and Ranking Member Sensenbrenner and all the members of the select committee for this opportunity to appear before you and address the energy and environmental challenges facing our Nation, climate variability and climate change, in particular focusing on the Midwest region.

I would like to thank Congressman Emanuel Cleaver, who is my representative, for his service on this important select committee and his guidance locally.

The United States Midwest is one of the most agriculturally productive areas or regions in the world. It supports a wide range of agro businesses and industrial manufacturing complexes that are economically vital to the United States.

This region is also susceptible to substantial interannual and interdecadal variations in summer climate. Frequent severe droughts and devastating floods are features of the extreme warm season climate anomalies that affect much of the central U.S. The drought of 1988, for instance, the flood of 1993, resulted in an estimated $52 billion lost in farm and property damage in the Midwest.

The last two summers, 2007 and 2008, have been especially devastating for us for large swaths of the Midwest due to the back-to-back floods that have destroyed thousands of acres of prime farmland in several States and submerged whole communities. The losses sustained from just these two last flood events alone undoubtedly will run into tens of billions of dollars.

The financial impact of the current flood is exacerbated by the fact that many property owners in the worst-hit areas lack flood insurance, because they live in areas deemed "500-year flood plains," where mortgage banks do not require flood insurance. Furthermore, it has been reported that many communities in Wisconsin and Iowa and Missouri either dropped out or never even participated in the federally funded Flood Insurance Program for the same reason. This makes residents in these communities ineligible for Federal aid under the existing rules for the National Flood Insurance Program.

So against this backdrop, the decision of the chairman of this committee to hold this hearing is both timely and highly commendable.

My written testimony, which has been submitted for the record, contains an overview of the evidence that supports the view, the scientific evidence that supports the view that we are indeed in a regime of enhanced climate variability. We are already there. We are not looking for a changing climate anymore. We are in a regime of enhanced climate variability.

That testimony also discusses what are the implications of these current and the future changes that we expect on the Midwest, using what I advocate as a vulnerability framework. And I also offer some thoughts on strategies for mitigating and managing those risks.

This committee has been addressed by several of my colleagues at this table on what the current state is and the fact that evidence has accumulated to show that the climate is changing and will continue to change. Now, the trend in the U.S. follows exactly what we know from global assessments. And the trend in both temperature and precipitation in the Midwest, in particular, they reflect these same national trends with some regional variations.

For example, we know that the northern Midwest has warmed by almost 4 degrees Fahrenheit, while the southern Midwest, especially in the Ohio Valley Region, has cooled by a little less than 1 degree Fahrenheit. Annual precipitation has increased by over 26 percent in some areas, with most of this increase coming from periods of heavy rainfall. So our climate has already changed in the Midwest.

Now, the evidence available to us from climate model projections suggests that these trends will continue and will, in fact, accelerate in a warming world. Higher temperatures will increase the water-holding capacity of the atmosphere and encourage greater evaporation, resulting in conditions that favor increased climate variability. And with more intense precipitation and more droughts, we can also expect increased frequency and severity of heat waves and greater potential for reduced air quality in urban areas.

Now, these projections are a result of——

The CHAIRMAN. Dr. Adegoke, if you could wrap up, please. We will have questions.

Mr. ADEGOKE. Now, these projections are the result of climate models. And our contention is that, while this gives us a direction to go forward, we need to begin to address these issues, in particular from a vulnerability perspective. We are already vulnerable, and we need to think about how specific sectors can be strengthened and new mitigation strategies developed to address our risks and vulnerabilities in these various sectors.

[The statement of Mr. Adegoke follows:]

"Climate Variability and Climate Change in the United States Midwest: Mitigating and Managing Impacts and Risks"

Written Testimony by Dr. Jimmy Adegoke
Associate Professor of Geosciences
Laboratory for Climate Analysis & Modeling
Department of Geosciences, University of Missouri-Kansas City, Kansas City, MO

For the Select Committee on Energy Independence and Global Warming
United States House of Representatives
(Honorable Edward J. Markey, Chairman)

Hearing "Global Warming Effects on Extreme Weather"
July 10, 2008

1. Introduction

I would like to thank Chairman Markey and Ranking Member Sensenbrenner and all of the Members of the Select Committee for this opportunity to appear before you and address the energy and environmental challenges facing our nation climate variability and climate change in the our nation's Midwest region and how we can mitigate and manage both the impacts and the risks. I would also like to thank Congressman Emanuel Cleaver, who is my representative, for his service on this important Select Committee and his and guidance locally.

The United States Midwest is one of the most agriculturally productive areas in the world and supports a wide range of agro-businesses and industrial-manufacturing complexes that are economically vital to the United States. The region encompasses the headwaters and upper basin of the Mississippi River and most of the lengths of the Missouri and Ohio rivers, all critical water sources for agriculture, municipal water supply and hydro-electric power generation. This economically vital agricultural and manufacturing region is susceptible to substantial inter-annual and interdecadal variations in summer climate. Frequent severe droughts and devastating floods are features of the extreme warm season climate anomalies that affect much of the Central U. S. The drought of 1988 and flood of 1993 resulted in an estimated $52 billion in farm losses and property damage in the Midwest (Lott, 1993). The last two summers (2007 and 2008) have been especially devastating for large swaths of the Midwest due to back-to-back floods that destroyed thousands of acres of prime farmland in several states and submerged whole communities. The losses sustained from just these last two flood events undoubtedly run into tens of billions of dollars.

The financial impact of the current flood is exacerbated by the fact that many property owners in the worst-hit areas lack flood insurance because they live in areas deemed "500 year flood plains" where mortgage banks do not require flood insurance. Furthermore, it has been reported that many communities in Wisconsin, Iowa and Missouri either dropped out of or have never participated in the federally-sponsored flood insurance program for the same reason. This makes residents of those communities ineligible for federal aid under the existing rules of the National Flood Insurance Program (NFIP). Against this backdrop, the decision of the Chairman of the House Select Committee on Energy Independence and Global Warning, Honorable Edward J. Markey, to hold this hearing on "Global Warming Effects on Extreme Weather" is both timely and highly commendable. My testimony will begin with an overview of the evidence that supports the view that we are indeed in a regime of enhanced climate variability and the changes that we can expect in the future. I will discuss the implications of these current and future changes on the Midwest using a framework that integrates notions of risk and vulnerability and offer some thoughts on strategies for mitigating and managing those risks.

2. Our Changing Climate System

The material included in this section is primarily a summary of relevant sections of the recently released synthesis report of the Committee on Environment and Natural Resources of the National Science and Technology Council titled "Scientific Assessment of the Effects of Global Change on the US."

2.1. Evidence of a Changing Climate Regime: Temperature Trends

Numerous lines of evidence robustly lead to the conclusion that the climate system is warming. The Intergovernmental Panel on Climate Change (IPCC) in its 4th Assessment Report stated "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Analyses of quality-controlled data from thousands of worldwide observation sites show that global mean surface temperatures have risen over the last 100 years by 0.74 ± 0.18 °C with the rate of warming over the last 50 years almost double for the past 100 years (Trenberth et al., 2007). Globally the warmest combined land and ocean years in the instrumental record surface temperatures on record (since the mid-19th century) have mainly occurred in the past 12 years. Out of the 8 warmest years on record, 7 have occurred since 2001, and the 10 warmest years have all occurred since 1995. Additionally, widespread changes in extreme temperatures have been observed in the last 50 years around the world, and these changes in temperature extremes are consistent with the general warming (Solomon et al., 2007). Cold days, cold nights, and frost have generally become less frequent, globally while hot days, hot nights, and heat waves have become more frequent (IPCC, 2007d). A widespread reduction in the number of frost days in mid-latitude regions, an increase in the number of warm extremes, and a decline in the number of daily cold extremes are observed in 70 to 75% of the land regions where data is available. New analyses also shows that since 1950, heat waves have increased in duration (Solomon et al., 2007).

Similar to the global trend, U.S. temperatures also warmed during the 20th and into the 21^{st} century. The U.S. average annual temperature is now approximately 0.6 °C warmer than at the start of the 20^{th} century, according to NOAA (2008a), with an increased rate of warming over the past 30 years. There is some disagreement about which year was the warmest on record due differences in data sets, processing and analyses (NASA found 1934 while NOAA data shows 1998). The year 2007 was the 10th warmest year for the contiguous United States since national records began in 1895, according to preliminary data from the NOAA National Climatic Data Center (NOAA, 2008a). Additionally, the past 9 years have all been among the 25 warmest years on record for the contiguous United States, a streak that is unprecedented in the historical record, and the last nine 5-year periods were the warmest 5-year periods in the last 113 years of national records, illustrating the anomalous warmth of the last decade.

Regional data for North America confirms that warming has occurred throughout most of the United States. The U.S. Historical Climate Network of NOAA's National Climatic Data Center found that for all but 3 of the 11 climate regions, the average temperature increased more than 0.6 °C between 1901 and 2005 (NOAA, 2007b). Furthermore, North American regional studies consistently show patterns of changes in temperature extremes consistent with a general warming (Trenberth et al., 2007), including intense warming of the lowest daily minimum temperatures over western and central North America (Robeson, 2004 in Trenberth et al., 2007). The U.S. Climate Change Science Program (CCSP) Synthesis and Assessment Report 3.3 (SAP 3.3.), Weather and Climate Extremes in a Changing Climate (Karl et. Al., 2008) concluded that in the United States there has been a shift towards a warmer climate with an increase in extreme high temperatures and a reduction in extreme low temperatures:

> • Since the record hot year of 1998, 6 of the last 10 years (1998–2007) have had annual average temperatures that fall in the hottest 10% of all years on record for the United States. The number of heat waves (extended periods of extremely hot weather) also has been increasing since 1950. However, the heat waves of the 1930s remain the most severe in the U.S. historical record.
>
> • There have been fewer unusually cold days in the United States during the last few decades and the last 10 years have had fewer severe cold waves than any other 10-year period in the historical record, which dates back to 1895. There has been a decrease in frost days and a lengthening of the frost-free season over the past century. For the United States as a whole, the average length of the frost-free season over the 1895 to 2000 period has increased by almost two weeks.

2.2. Evidence of a Changing Climate Regime: Precipitation Trends

As surface temperatures rise, the evaporation of water vapor increases from oceans and other moist surfaces. Increased evaporation is leading to higher concentrations of water vapor in the atmosphere. Increased atmospheric water vapor tends to produce weather systems that lead to increased precipitation in some areas. At the same time, increased evaporation and evapotranspiration from warming can lead to increased land surface drying and, therefore, increased potential incidence and severity of droughts in other areas. Unlike temperature, precipitation is highly variable spatially and temporally which makes the task of establishing robust long-term trend difficult in some regions, especially the data sparse areas of the world. Nonetheless, the conclusion from the IPCC report is that long-term trends from 1900 to 2005 have shown significant increases in precipitation over many large regions (e.g., North and South America) and drying in others (e.g., the Sahel). Additionally, more intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.

Over the contiguous United States, annual precipitation totals have increased at an average rate of 6% per century from 1901 to 2005, according to an analysis of data from the NOAA National Climatic Data Center's U.S. Historical Climate Network (Version 1; NOAA, n.d.). There has been significant variability in U.S. regional precipitation patterns over time and space. Despite the overall national trend towards wetter conditions, severe droughts have affected several parts of the U.S. in the last two decades, including the 1988 drought that affected the Midwest, the long running drought in the southwestern United States from 1999 through 2007, and more recently the severe drought experienced in the southeastern United States (NWS CPC, 2008).

The IPCC (Solomon et al., 2007) reports that it is *likely* that there have been increases in the number of heavy precipitation events within many land regions, even in those regions where there has been a reduction in total precipitation amount; this is consistent with a warming climate and observed increases in the amount of water vapor in the atmosphere, which have been significant. Increases have also been reported for rarer (1 in 50 year return period) precipitation events, but only a few regions have sufficient data to reliably assess such trends (Trenberth et al., 2007). Observations over the contiguous United States show statistically significant increases in heavy precipitation (the heaviest 5%) and very heavy precipitation (the heaviest 1%) of 14% and 20%, respectively, primarily during the last three decades of the 20th century (Kunkel et al., 2003 in Trenberth et al., 2007 and Groisman et al., 2004 in Trenberth et al., 2007). This increase is most apparent over the eastern parts of the country. Some evidence suggests that the relative increase in precipitation extremes is larger than the increase in mean precipitation (Trenberth et al., 2007). CCSP SAP 3.3 (Karl et al., 2008) concluded that very heavy precipitation (the heaviest 1%) in the continental United States increased by 20% over the past century, while total precipitation increased by 7%. Additionally, the monsoon season is beginning about 10 days later than usual in Mexico and in general, for the summer monsoon in southwestern North America, there are fewer rain events, but the events are more intense (Karl et al., 2008).

The trends in both temperature and precipitation in the Midwest reflect these national trends but with some regional variations. For example, the National Assessment of Climate Change Impacts on the United States conducted under the auspices of the US Global Change Research Program concluded that during the last 100 years, Midwestern temperatures have increased substantially across the region. The northern Midwest has warmed by almost 2 °C while the southern Midwest, especially along the Ohio River valley has cooled by a little less than 1 °C. Annual precipitation has increased by up to 20% in some areas with most of this increase coming from periods of heavy rainfall.

3. Future Projections: A "Bottom-Up" vulnerability Perspective

Climate models are the primary tools used by the climate science community to project future changes in the climate system, including temperature, precipitation, and sea level at global and regional scales. Confidence in changes projected by global models decreases at smaller spatial and temporal scales because many important small-scale processes, in particular clouds, cannot be represented explicitly in models, and so must be included in approximate form as they interact with largerscale features (Randall et al., 2007). On these scales, natural climate variability is relatively larger. In addition, uncertainties in local forcings and feedbacks also make it difficult to estimate the contribution of greenhouse gas increases to observed small-scale changes (IPCC, 2007d). According to the IPCC (Meehl et al., 2007):

> Confidence in models comes from their physical basis, and their skill in representing observed climate and past climate changes. Models have proven to be extremely important tools for simulating and understanding climate, and there is considerable confidence that they are able to provide credible quantitative estimates of future climate change, particularly at larger scales. Models continue to have significant limitations, such as in their representation of clouds, which lead to uncertainties in the magnitude and timing, as well as regional details, of predicted climate change. Nevertheless, over several decades of model development, they have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.

From the foregoing, it is clear that existing model simulations that have been used to predict the future climate (Houghton et al., 2001 ; US National Assessment) have used models with only subsets of climate forcings and feedbacks. To apply these results to predict the future climate changes at regional or local scales and for economic activities such as Midwestern agriculture will at best only provide minimal insight. Rather than focus on the perspective driven by global model predictions that are downscaled to agricultural impacts (*a top-down approach*) a more useful perspective would be to focus on the view of the affected party (*a bottom-up approach*) by assessing key societal and environmental vulnerabilities to range stressors (Sarewitz et al., 2000; Pielke and Guenni, 2004; Steffen et al., 2004; Sarewitz and Pielke Jr., 2005, Pielke et al., 2007). The strength of this vulnerability paradigm is that it frees climate change policy studies from the requirement to focus on global mean surface temperature change as the metric to link to economic impact due to anthropogenic changes in atmospheric composition (Houghton et al., 2001) and allows a more rigorous assessment that extends far beyond global mean temperatures and include other anthropogenic climate forcings such as land-use change (e.g., Pielke Sr., 2001, Marland et al., 2003, Adegoke, 2003, Adegoke et al. 2007), the multiple forcings associated with aerosols (e.g., Andreae et al., 2004; Niyogi et al., 2004) as well as complex feedbacks (National Research Council, 2003).

The framework for vulnerability assessments is place-based and has a bottom-up perspective, in contrast to the GCM-focus which is a top-down approach from a global perspective. The vulnerability focus is on the resource of interest, agricultural production, water resources, health impacts etc. The challenge is to use resource specific models and observations to determine thresholds at which negative effects associated with this resource occur. Changes in the climate *represent only one threat*; the climate itself may also be significantly altered by changes in agricultural practices and of other land management, and there are multiple, nonlinear interactions between the forcings. The GCM models, even if they were skilful predictions, still only capture a portion of the threat to a specific sector, such as energy or agriculture.
Take the case of agriculture for instance, in CCCP SAP 4.3, Harfield et al. (2008) showed that agricultural systems in the U.S. are highly diverse and distributed over a variety of climates, regions, and soils. However, regardless of where they are grown, crops and livestock are affected

by temperature, precipitation, carbon dioxide, and water availability. Indeed, variability in yield from year to year is mostly (and strongly) related to weather effects during the growing season (Hatfield et al., 2008). The agricultural sector within the United States is sensitive to both short term climate variability and long-term climate change. Productivity is driven by the interaction of a variety of variables including temperature, radiation, precipitation, humidity, and wind speed (Easterling et al., 2007). Vulnerability of the U.S. agricultural sector to climate change is a function of many interacting factors including pre-existing climatic and soil conditions, changes in pest competition, water availability, and the sector's capacity to cope and adapt through management practices, seed and cultivar technology, and changes in economic competition among regions. The IPCC (Easterling et al., 2007) found that the growth, development, and yield of crops are dependent upon their responses to their climatic environment (Porter and Semenov, 2005). Particular crops are suited to a particular range of conditions, thus production is reduced and damage can occur when thresholds are exceeded, even for short periods in some cases (Wheeler et al., 2000; Wollenweber et al., 2003 in Easterling et al., 2007).

The productivity of most agricultural enterprises has increased dramatically over recent decades due to cumulative effects from technology, fertilizers, innovations in seed stocks and management techniques, and changing climate influences. Given the interaction of these various factors, it is difficult to identify the specific impact from any one factor on specific yield changes. The largest changes are probably due to technological innovations (Hatfield et al., 2008). However, weather events are a major factor in annual crop yield variation. Yields of major commodity crops in the United States have increased consistently over the last century, typically at rates of 1 to 2% per year (Troyer, 2004), with significant variations across regions and between years. In the midwestern United States from 1970 to 2000, corn yield increased

58% and soybean yield increased 20%, with annual weather fluctuations resulting in year-to-year variability (Hicke and Lobell, 2004).

Research reported in Hatfield et al. (2008) found variable reductions in maize yields. One study found a 17% reduction per 1 °C increase across the United States (although this study did not include effects of water availability) (Lobell and Asner, 2003). Another study found that the response of global maize production to both temperature and rainfall over the period 1961 to 2002 was reduced 8.3% per 1°C warming (Lobell and Field, 2007). Soybean has cardinal temperatures that are somewhat lower than those of maize. Responses to increasing temperatures are regionally dependent. Yield may actually increase 2.5% with a 1.2 °C rise in the upper Midwest, but would decrease 3.5% for 1.2 °C increase in the South (Boote et al., 1996, 1997). Lobell and Field (2007) reported a 1.3% decline in soybean yield per 1 °C increase in temperature, taken from global production against global average temperature during July to August, weighted by production area. Reviewing the literature for North America, the IPCC (Field et al., 2007) found that in the Corn and Wheat Belts of the United States, yields of corn and soybeans from 1982 to 1998 were negatively affected by warm temperatures, decreasing 17% for each 1 °C of warm-temperature anomaly (Lobell and Asner, 2003).

As with their responses to temperature, crops respond differently to increasing CO_2 concentrations. The evidence for maize response to CO_2 is sparse and questionable (Hatfield et al., 2008). On its own, the expected increment of CO_2 increase over the next 30 years is anticipated to have a negligible effect (i.e., 1%) on maize production (Leakey et al., 2006). In contrast, based on the metadata summarized by Ainsworth et al. (2002), a doubling of atmospheric CO_2 concentrations is expected to yield a 38% increase in soybean yield. In the midwestern United States, an atmospheric CO_2 increase from 380 to 440 ppm is projected to increase yield by 7.4%. For wheat, a cool-season cereal, doubling atmospheric CO_2 concentrations (350 to 700 ppm) increased grain yield by about 31%, averaged over many data sets (Amthor, 2001). For rice, doubling atmospheric CO_2concentrations (330 to 660 ppm) increased grain yield by about 30% (Horie et al., 2000).

Clearly, the vulnerability of North American agriculture to climatic change is multi-dimensional and is determined by interactions among pre-existing conditions, stresses stemming from climate change (e.g., changes in pest competition and water availability), and the sector's capacity to cope with multiple, interacting factors, including economic competition from other regions as well as advances in crop cultivars and farm management (Parson et al., 2003 in Field et al., 2007). Water access is the major factor limiting agriculture in southeast Arizona, but farmers in the region perceive that technologies and adaptations such as crop insurance have recently decreased vulnerability (Vasquez-Leon et al., 2002 in Field et al., 2007). Areas with marginal financial and resource endowments (e.g., the U.S. northern plains) are especially vulnerable to climate change (Antle et al., 2004 in Field et al., 2007). Unsustainable land use practices will tend to increase the vulnerability of agriculture in the U.S. Great Plains to climate change (Polsky and Easterling, 2001 in Field et al., 2007).

4. Managing and Mitigating Climate Induced Risk

Climate change contains elements of both risk and uncertainty. Risk is often defined as more short-term in nature, more measurable, and predictable. Uncertainty arises from the unknown, is often more long term, and typically is difficult to quantify. Climate change and weather-related events contain elements of both risk and uncertainty. Uncertainties in projections of global surface warming derive almost equally from uncertain emissions and incomplete knowledge about some of the forcing factors. Moreover, non-trivial challenges persist in quantifying projections because existing model simulations that have been used to predict the future climate have used models with only subsets of the climate forcings and feedbacks. Addressing these challenges requires a greater focus, as discussed in the preceding section, on assessing key societal and environmental vulnerabilities. While this paradigm is firmly established in fields such as Biology and Political Ecology, only recently have the climate community began exploring it as a basis for understanding the functioning, resilience and vulnerabilities of coupled socio-economic and biophysical systems at policy-relevant time and space scales. This vulnerability paradigm can help refine knowledge about place-based sector-specific risk and uncertainty, so decision-makers will better understand the causes and ramifications of change and improve their ability to understand the consequences of policy, strategy, and operational changes. This model can be applied, for example, to address climate risk management in the energy and agricultural sectors by posing the question: "How should Midwestern energy and agribusinesses respond to climatic uncertainties that are not likely to be relieved in the near future?" Each of these sectors faces uncertainties that are primary or derivative in nature.

Primary uncertainties are those that are a direct effect of climate change. These are industries that experience direct damage as a result of climate change or weather-related events. Examples include the insurance industry needing to payout larger amounts as a result of claims stemming from natural disasters, and agriculture, an industry which may have negative impacts upon crop yield as a result of changing climate.

Derivative uncertainty for a business stems from the political response to climatic uncertainty. The energy business is the best example. Among the issues currently being considered are: Will the political authorities respond to climate uncertainty with new regulations that require local utility companies to replace fossil fuel generation with something else? What else? What response right now best protects the interests of shareholders and serves the companies' public responsibility?

In the Greater Kansas City metro area, where I live, significant local actions are underway to address climate risk and mitigation using the "bottom-up" model that we have advocated here. Working with community leaders and more than 100 volunteers representing a broad range of stakeholders, the City of Kansas City, Missouri has developed an ambitious Climate Protection Plan that will be submitted to the Kansas City Mayor, Mark Funkhouser, and the City Council in July, 2008 for their consideration and adoption. It includes goals and actions to reduce municipal and community-wide greenhouse gas (GHG) emissions by 30% below year 2000 levels by 2020 and an aspirational goal to reduce community emissions 80% by 2050. An additional 19 metro mayors from across the metro area in Kansas and Missouri have signed the U.S. Conference of Mayors Climate Protection Agreement and will be working together to make GHG emission reductions a regional effort in the Greater Kansas City area.

The local business community has also taken an active role in climate protection. The Greater Kansas City Chamber of Commerce has created a Climate Protection Partnership Program for metro area employers (businesses, institutions, not-for-profit organizations, and government entities) to commit to assessing their carbon footprint and implementing GHG reduction measures. To date, 150 metro area employers representing more than 100,000 employees have signed on to the partnership. Additionally, Kansas City Power & Light, the largest local energy provider in the Kansas City area has committed to offsetting 6 million tons per year of GHG emissions by 2012 through additional wind energy generation projects and the aggressive implementation of energy efficiency initiatives. Cities, businesses, and citizens across the Midwest are looking to Congress for leadership and guidance to help strengthen and sustain home grown efforts to mitigate risk and reduce the vulnerability of their systems and infrastructure to the current and potential impacts of climate change.

The CHAIRMAN. Thank you, Dr. Adegoke. We much appreciate it.

There are four roll-calls that are going to be conducted out on the House floor. There are 11 minutes to go before that roll-call. What I thought I could do is recognize the gentleman from Washington State for a round of questions. And then if Mr. Inslee would do that, recognize then Mr. Shadegg, so that we can have a bipartisan questioning. And then we will come back and continue to question.

Mr. INSLEE. Thank you.

Mr. Keppen, I used to live in Yakima, Washington, have a lot of experience with the irrigation community and, I think, know the stresses that you are under.

Has your group taken a look at the issue of a cap-and-trade system to try to actually limit the amount of warming that we experience and climatic change that we experience?

Mr. KEPPEN. Basically our mission statement is focused completely on, you know, water and water issues. And so, as a board, we have not dealt with that.

Personally, I am on Governor Kulongoski's Climate Change Integration Group in Oregon, and that is an issue that is being discussed there.

I think agriculture definitely needs to be involved, from a personal standpoint. But, as an organization, we haven't taken a position.

Mr. INSLEE. Well, I would encourage you to think about that and become engaged in that discussion. And the reason I say that is that ag, I think, has probably got as much at risk as any other sector of our community. And knowing how fragile our irrigation system is in eastern Oregon and eastern Washington, how we are always on the edge—it could be pushed over by reductions in our snow pack and just dry years—we need your leadership and we need your engagement in this issue as a community.

So I hope that your organization will think not just about adaptation and accepting this change, but, in fact, trying to slow it down. And there is a whole variety of ways to do that, through research of new clean energy technology, some of which is going to benefit ag, a cap-and-trade system.

I just hope your organization will look at some of these issues and help us design an effort to slow down global warming as well as adapt to it.

Mr. KEPPEN. Well, thanks for that input. I will pass it on to my board.

Mr. INSLEE. We would love to hear from you.

And that is my only comment. Thank you very much.

The CHAIRMAN. Great.

The gentleman from Arizona, Mr. Shadegg.

Mr. SHADEGG. Thank you, Mr. Chairman.

Ms. Cooley, I want to begin with you. I strongly share your interest in water and in conserving water. In Arizona, we began a very aggressive program toward groundwater storage and restricting the use of groundwater but also recharging our water table. I guess I am interested in some innovative ideas from you briefly on that topic.

But also, I recently built a home, and I very seriously considered a gray-water system. I didn't put it in, and I now regret that. I am interested in your thoughts on how widespread that technology is for the use. Should we be splitting wastewater, as it comes out of our houses, into a gray-water/black-water dichotomy? And how soon can we do that and have it reduce our reliance on water?

And then I have some questions for Dr. Golden.

Ms. COOLEY. Your first question was on groundwater banking and what actions we can do to encourage and incentivize that, is that correct?

Mr. SHADEGG. Yes.

Ms. COOLEY. There are number of things we can do.

One of the additional benefits which I didn't talk a bit about was on the issue of storm water. Much of the storm water runoff is really what is polluting our rivers and streams. And so, capturing that and finding ways and developing ways in which we encourage and basically pursue low-impact development to encourage infiltration of that water can also provide not only a water-supply but a water-quality benefit.

And so, in terms of actions that can be done, ensuring that all new development does integrate those principles I think is one of the first things we need to do, and also encourage that development doesn't occur on some of our most important recharge areas.

Mr. SHADEGG. In the Southwest, we have huge, sudden storms, and we lose all that water. And it is tragic. I don't think we can go on doing that.

What about gray-water systems?

Ms. COOLEY. Gray-water systems, I always get asked about that. It is a very interesting topic. Some areas in some regions have regulations against it, and that is something that we need to, kind of, standardize and systemize so that there is some consistency, even within a given State.

I think in new development it makes a lot of sense. Retrofitting existing developments can be expensive. And then there are other things that we could do at lower costs, such as taking out turf and putting in low-water-use landscapes and those kinds of things. There is plenty of beautiful landscape that is well-adapted to the desert that not only reduces water use, also reduces fertilizers, pesticide, and provides habitat for local species.

Mr. SHADEGG. Yeah, but some of us, though, believe that all that green grass reduces the temperature where we live. I happen to live where there is a lot of green grass, and I can show you the drop in the thermometer in my car as I drive into my neighborhood. So I would rather clean my gray water and water my grass, if I could. But I would want to clean my gray water.

Dr. Golden, I would like to ask you two questions in the limited time I have. One is, I am interested in your testimony on the point that the average temperature, I believe you testified, in the Phoenix area had come down 3.1 degrees, but in the urban portion of the metropolitan area, or of the county—I am sorry, it had gone up 3.1 degrees, but in the urban area it had gone up by 7.6 degrees.

Can you explain that and maybe, at the same time, give us some examples of the practical application of your research and perhaps also of the kinds of materials we might be able to be using in the future that would be more advantageous than materials we have been using in the past without thinking about the issues?

Mr. GOLDEN. Certainly. So, Congressman, if we had a graph of the tremendous population increase in Maricopa County, Phoenix now being the fourth-largest city in the United States and the suburb of Mesa larger than most cities in the United States, we would track the same type of delta-T, the temperature difference between the urban and rural area.

And while it is true that the temperature has gone up 7.6 degrees Fahrenheit, if we look at the temperature difference between an unchanged—and it is very easy to do in Arizona at Casa Grande National Monument—in comparison to where Phoenix temperature recordings have been done, we are now almost 14 degrees Fahrenheit warmer at night than our rural counterparts.

And as we see the population increase, we see that temperature difference increase. Basically, we remove our native vegetation, whether it is cactus or trees or other grass, and we replace that with engineered materials—buildings, concrete, asphalt. And those have a different thermodynamic process. In short, they are darker, they absorb the heat. And, high school physics, when you cover these buildings, you can't reradiate, long-wave radiation, so they don't cool off quickly. And so we have this urban heat island effect.

So, for cities, there are quite a few things they could look at and we are looking at. If we were fortunate enough to fly in the Goodyear Blimp, we would look down at Phoenix and we would see about 40 percent, the largest component for most western State cities, is comprised of paved services—driveways, parking lots, et cetera.

The idea of incorporating smart water, wastewater issues, pervious concrete, pervious asphalt, on paved services that can retain the storm water and use it for beneficial reuse to sustain trees, which, as we know, are a lot cooler, can help mitigate the urban heat island effect, and also offset carbon emissions, as well, by sequestration.

A new generation of surface treatments that can reflect while you still can have the same colors. There is a new generation of building materials. In certain climates, green roofs are appropriate. So there are quite a few things that can be done.

I would mention that the U.S. EPA Heat Island Reduction Initiative does provide a clearinghouse for a lot of these initiatives.

Mr. SHADEGG. I noticed that you have been a consultant to our mayor, and our mayor and our local paper have talked a lot about the fact that we have cut down all the trees in the city of Phoenix and there are very few shaded areas. And if you don't have shade and you are outside in the summer in Arizona, you are in trouble.

We passed legislation at the State legislative level to repaint the tops of all of our buses white. So we are thinking about this stuff a little bit, but we are thinking about it late. It seems to me it is something we have to incorporate into our thinking.

It is pretty clear that the building materials we are using are retaining heat, and some of the concepts that you mentioned—they are not retaining water. I think there is a lot of progress we can make here to try to diminish the impact of urbanization upon the environment in which we leave and improve that environment dramatically.

So I guess I am alone, and you will await our return.

I am to declare that the select committee is in recess until the votes on the floor are concluded in about 20 minutes.

Thank you.

[Recess.]

The CHAIRMAN. We welcome everybody back. And I think we will be able to reconvene for about 15, 20 minutes. We thank you so much for your attendance.

Let me ask the panel, our televisions have been filled with weather-related disasters from the floods in Wisconsin down through Iowa and Missouri, the drought-fueled forest fires in California. As a Nation, we need to increase our resilience to these events, especially as global warming makes them more intense and frequent. To plan effectively for the future, it is essential that regional-scale information is available. Does that information exist today? Dr. Golden?

Mr. GOLDEN. Chairman, as I indicated in the oral testimony and what I submitted as written testimony, there is a variety of Federal agencies, NGOs and local and regional governments that do compile regional data that is imperative for a more refined understanding of what is occurring and what we will be able to predict in the future.

What I also indicated, though, are two glaring issues, the first being that there is not a centralized mission agency that can take all of this data and be able to provide back to other agencies as well as local, regional and government a most refined understanding of what is occurring on the regional level.

Secondly is someone who tries to understand what is occurring and what will occur in the future and provide that to local and regional governments. We rely heavily not only on local climate and meteorological stations but on remote sensing, that being satellite images; and, as I indicated, a variety of our satellites are due to expire. We do not have a dedicated urban system; and the refinements by that, the detail that is provided in these images is somewhat coarse right now and the technology provides for much greater refinement.

The CHAIRMAN. Let me ask then other members of the panel who would like to respond, what roles should the Federal Government play in supporting and enhancing our understanding by planning for the regional impacts of global warming? Give us a recommendation for the Federal Government's role. Ms. Cooley.

Ms. COOLEY. Thank you, Chairman.

One of the things that I would like to draw attention to is that there has been a substantial amount of cut in the funding for many of the monitoring programs. For example, for the USGS, many of the stream gauge stations have been shut down and that data is no longer being maintained. So increasing funding for those programs so that we can actually look at trends and see what is happening I think is critical.

In addition, looking at projections, climate projections and then down-scaling them to local and regional levels so that water utilities can make use of that information and use that in their planning. In California, there is a very comprehensive effort to do that. At the State level, it is a program done by the California Energy Commission; and they have pulled together a team of researchers using the same climate models, the same emissions scenarios and are looking at impacts associated with that. So doing those types of activities regionally in other States I think it is critical.

The CHAIRMAN. Thank you.

Ms. Licata, you sought recognition.

Ms. LICATA. One of the reasons that we joined together with other metropolitan cities that are searching for good research with respect to climate change signs is exactly for the reason that we have many institutions sort of foraging out and working on these issues independently, and we feel that the Federal Government certainly has a role to provide us with unified research on this front. It is extremely important to water managers to have good data on precipitation and precipitation trends. So I echo, you know, the comments made earlier by the members of the panel, but it is extremely important for the Federal research to take on this role of looking at the questions that the water managers are asking and to have focused research on some of those ideas and questions and particularly with respect to precipitation, which is something that we are all struggling with at this point.

The CHAIRMAN. And you are dependent upon the Federal Government for the information.

Ms. LICATA. We are dependent on the Federal Government as well as on the academic institutions.

The CHAIRMAN. Well, that goes to you, Dr. Adegoke. You are an academic representative here on the panel.

Mr. ADEGOKE. My view on this is that the Federal Government has an important role, a major role to play, but that role really is in enhancing capacity at the local level to—climate change and climate variability presents various levels of risks and vulnerabilities to various sectors. You think about agriculture, you think about whatever sector you pick up, you know, or even our city systems. If we look at our cities across the country, you know, we are vulnerable at various points and in various ways; and those vulnerabilities are best assessed at the local level. But what we do need, what we do need is an enabling environment in times of policy that provides the kind of support both in times of leadership and in times of funding to——

The CHAIRMAN. Are you talking in terms of the National Weather Service receiving more funding that then could provide you with the more targeted information that you need on a regional basis in order to make these decisions? Tell us specifically how much money you think would be needed and which agency should get it and what are the responsibilities that we should give them in order to provide the regional information.

Mr. ADEGOKE. Well, every agency that has a responsibility for some sector of the environment. So we are talking about—we are talking about NOAA, for instance, for weather. We are talking about—we are talking about USGS for—we are talking about all our national agencies that have a responsibility for managing our environment need significantly more funding, you know, to enhance observational capacity at the local level.

The CHAIRMAN. So which agency, Dr. Adegoke, is the lead agency in your mind? Who would we put the coordinating responsibilities with to ensure that our package is then sent to a region? How would you construct that Federal Government responsibility so that it was coordinated there and it didn't come in from five different locations? Which agency should be the lead agency?

Ms. Licata.

Ms. LICATA. There is the Climate Change Science Program, and that is currently the Federal organization that is supposed to centralize all of the activities of the agencies, and there are multiple amounts of agencies engaged in the climate change research and science. So that is the Climate Change Science Program, and I believe they are based out of NOAA. I believe it is out of NOAA. But its intended purpose is to coordinate among all of the Federal agencies working in this field.

The CHAIRMAN. So you would make NOAA the lead agency?

Ms. LICATA. It seems as though there is already a seed organization within NOAA. So it would make sense to me.

And because I do believe that the data and research regarding the weather trends, precipitation, the rain gauges is really very important, I would suggest that that would be the right way to proceed.

The CHAIRMAN. Dr. Golden, do you think NOAA should be the lead agency?

Mr. GOLDEN. I think it depends on exactly what we are talking about. If I look in the arena of protecting human health and the environment, that itself is the mission statement of the U.S. EPA. And the U.S. EPA, as do other agencies—and I work with NOAA and CDC and EPA—also does coordinating. So I am not focusing just on them, but it would seem by their mission statement to——

The CHAIRMAN [continuing]. Put it in EPA?

Mr. GOLDEN. Yeah.

The CHAIRMAN. Let's have some other votes out there.

Mr. Keppen, where would you put it?

Mr. KEPPEN. Mr. Chairman, thanks.

Going back to your first question, what can Congress do? What can the Federal Government do? I mentioned in my earlier testimony a bill that was introduced on the Senate side by Senator Bingaman and Senator Domenici called the Secure Water Act. It has got some great ideas in there about how to coordinate with all these various agencies, kind of bring them all together at one table.

The CHAIRMAN. Who is the lead in that bill?

Mr. KEPPEN. I can't recall. It might be the Interior Department Secretary or it might be the Commerce Department Secretary. I can't quite recall which one. But it does talk about bringing these various entities together that are dealing with climate change.

The CHAIRMAN. What about Dr. Golden's idea, that it should be the EPA?

Mr. KEPPEN. Well, there is merit there. I have to say I can't argue with what he is saying. I think just as long as all these parties have a fair say and there is some coordination going on so people know what other agencies are doing, I think that would be helpful.

And I would also say that bill, the Secure Water Act, contains provisions that provide funding for additional monitoring and testing and more stream gauges and coordinating between entities in that way.

The CHAIRMAN. Do you think NOAA, though—NOAA is inside of Commerce. Is NOAA really the best agency in your opinion on this, Dr. Keppen?

Mr. KEPPEN. Well, it sure seems like they have a lot of expertise. I see they are a little bit less——

The CHAIRMAN. When we have this hearing in 2 or 3 more years and there has been a complete mess and the Federal Government hasn't passed on the timely information to the regions about something that was anticipatable if it had been put together—well, who is sitting in Dr. Golden's seat? Who do you want sitting there? Do you want EPA? Do you want NOAA? Who do should we be yelling at, screaming at on that day?

Mr. KEPPEN. So you are saying the agency that I dislike the most.

The CHAIRMAN. They will be sitting here going, well, we handed it all over.

Mr. KEPPEN. Does Fish and Wildlife fit into this?

The CHAIRMAN. Who is putting it all together?

Mr. ADEGOKE. I think what I can add to that is, several of the agencies in the last year or two alone, they have all articulated very strong climate change initiatives, whether it is the——

The CHAIRMAN. If it is everybody's job, it is nobody's job.

Mr. ADEGOKE. The lead agency in the U.S., the lead agency for climate change has to be NOAA.

The CHAIRMAN. Has to be NOAA.

Mr. ADEGOKE. It has to be NOAA in the U.S.

The CHAIRMAN. Ms. Cooley, you have the final vote here.

Ms. COOLEY. Thank you.

Well I think there is a difference, too. Are we just talking about monitoring and looking at what is projected under climate change? Or are we then looking at impacts? Because if we are talking about impacts, there is going to be a lot of different agencies that are involved in that. And I would agree with Ms. Licata that, you know, perhaps the climate research team would be a good place for that in terms of bringing all these agencies——

The CHAIRMAN. Who is in charge of the climate research team right now, Ms. Cooley?

Ms. COOLEY. I do not know.

The CHAIRMAN. Ah, see, that is not good.

The thing is, we know the name of the Secretary of Commerce. He will be sitting where Dr. Golden is. We know the head of EPA will be sitting there. But we need somebody that we can actually say, we gave you the power. Right? So it has got to be something that has real accountability and people really feel, oh, this is important.

We have a rising storm here in the community. So we have to do it in a way that not only has accountability but that you all know their name. You know? Of course. Like the equivalent of FEMA, right? That you know the name of the person, you know, in case there is a mess heading your way.

That is after the fact, though, right? I am talking about before the fact here. And FEMA is now over in Homeland Security. But, in a way, this is homeland security as well. But we need to raise the accountability because it is reasonably anticipatable that there is going to be some really tragic events that occur.

I see pretty much a split decision here. We are leaning towards NOAA, I would say.

Dr. Adegoke, you mentioned taking a bottom-up vulnerability perspective and researching the impacts of climate change. Can you describe what is needed for this research and how the future scientific assessments such as the one recently released by the United States Climate Change Science Program should incorporate a bottom-up analysis?

Mr. ADEGOKE. Yes. Thank you very much, Mr. Chairman.

That assessment that you have just referred to is—it integrates the best of what we know currently. But it is still a translation, a down-scaling of the information that we have from general circulation models in terms of future predictions.

I do climate modelling. I do climate research. I run a climate modelling laboratory. But I know that when you are looking at regional and local impacts, what we have, the projections and the down-scaled information that we get from these models do not sufficiently capture, okay, the understanding that we need to begin to address the question of risk and vulnerability.

What we need, okay, is to take a sectoral approach. We have to do a sectoral approach. We have to look at specific sectors, look at water systems, say, for instance, in small communities. We will look at health across the spectrum. You know, we will look at agricultural systems, you know, and then do an assessment of risk for each of the sectors.

So this, I think, connects back to your earlier question about who should be a lead agency. We do need a lead agency, yes, to give direction. Okay. But this work has—what I think we really need is a U.S. Government that is going to say, everything that we do as a government, everybody that we fund as a government needs to look at this question of how are we as a society vulnerable, where are our risks? Use some of the money that we are giving you. We are going to increase some of your funding to address this issue but address it at policy relevant scales. And that policy relevant scale I believe it would be at the local level.

The CHAIRMAN. Okay. Thank you, Doctor, very much.

Let me throw out this question. Many of you today have highlighted the amount of water consumed by our fossil fuel and nuclear energy sources.

Mr. Keppen, in your testimony, I was struck by the statistics that, by 2030, utilities could account for up to 60 percent of the nonfarm water consumed in the entire United States. That is a staggering amount of water just to be consumed by the fossil fuel and nuclear energy industries.

Ms. Cooley, you testified that wind and photo-voltaic technologies require none to very little water for energy production. This connection between water use and energy production is one that is little understood by the public or even Members of Congress. How do the witnesses on our panel today suggest that, as Congress considers energy policy, we incorporate this water issue? Ms. Cooley.

Ms. COOLEY. Thank you, Chairman.

One way to do that is to really integrate water and energy issues and planning so that if we are looking at water supply we also look at what the energy implications are of those water supply options.

Another way would be through, as I testified, water conservation and efficiency, that that is an important way to not only reduce water use but to reduce energy use. And doing so is cost effective. So including measures that not only save water but saving energy. Perhaps setting Federal standards for clothes washers, for example. Both consume tremendous amount of water and energy, and some of the newer versions that are on the market reduce that use considerably.

Also, when considering energy technologies, to look at what the water uses are and to consider whether that is an appropriate use of our water resources in the areas that they are being considered.

The CHAIRMAN. But if 60 percent of the water that is non-farmed is in the utility sector, does that not call for a solar and wind revolution in America? Is that basically what we need to have by 2030 in order to prevent this incredible consumption of water by a very narrow part of the total American economy?

Ms. COOLEY. Well, it does suggest some opportunities and some additional benefits that wind and solar can provide. So not only reducing our greenhouse gas emissions but reducing our vulnerability to water supply constraints.

In my written testimony, I have provided a couple of newspaper headlines that talk about how water availability affects energy production and as we look into the future with an increased incidence of drought, as we know, that we are going to have constraints on both energy and water.

The CHAIRMAN. So I think it was your testimony, Dr. Golden, that made a reference to the additional amount of electrical generating capacity we were going to need in the year 2030 in the United States to make up for the increased demand plus the retirement of older plants. Could you tell me again how much new electricity generation in megawatts do you think we need by 2030?

Mr. GOLDEN. About 281,000 megawatts of new power generation capacity will be needed by 2025, which is equivalent to about 950 new power plants at 300 megawatts.

The CHAIRMAN. So 281,000 new megawatts of electricity by 2025 will be needed in the United States. So if a high percentage of them are nuclear or coal, then we are going to see huge consumption of water. We will hit that 60 percent target for nonfarm water consumption in the utilities sector.

Mr. GOLDEN. Well, I would add one other factoid to this. As the USGS in their reports have indicated that it is not agriculture, it is not municipal water. In fact, thermal electric power is the largest use of water withdrawals, not consumption, water withdrawals in the United States; and that does not go without impacts to our environment and ecological systems as we heat the water, use the water through cooling towers and then send it back out.

The CHAIRMAN. So what if we adopted a strategy? Let's just say, 281,000. Where did you get that number from in terms of the needed additional electricity?

Mr. GOLDEN. EIA, DOE.

The CHAIRMAN. Okay. And let's just assume that is the worst-case scenario and the Department of Energy hasn't factored in increased efficiency in appliances and air conditioning and other devices, and we know for the first 6 years of the Bush administration they missed all 35 deadlines. But let's assume that no President for the next 18 years meets any deadlines and we have the worst-case scenario, which I am assuming that that is what the Department of Energy must be talking about.

This year, there is an estimation that 7,000 new megawatts of wind will be constructed in the United States. So if you go between now and 2018 and you are very conservative and it is just 7,000 new megawatts of wind per year and you multiply that by 18, that might come out to—that would be 126,000 megawatts of the needed 281 under your scenario, huh? Which would really put a dent in that big number.

And if we made an assumption that solar, let's just say, was only producing 50,000 megawatts by then, then you might be up to 180,000 or so of the 280,000 megawatts that you need. In other words, a lot of this is avoidable if you move over to the renewable sources for electrical generation and—could you tell me, does gas-fired electrical plants consume as much water as coal-fired?

Mr. GOLDEN. No.

The CHAIRMAN. No. Do you know what the factor is there in terms of the equation?

Mr. GOLDEN. No, not off the top of my head. I can get that back to you.

The CHAIRMAN. It is substantially less, though, natural gas as opposed to coal.

Mr. GOLDEN. The new natural gas plants are actually dry natural gas plants. Many of the new natural gas plants are considered dry natural gas plants.

The CHAIRMAN. Dry, dry natural gas. Is there such a thing for coal, dry coal?

Mr. GOLDEN. No.

The CHAIRMAN. Ms. Cooley, do you know the answer to this question?

Ms. COOLEY. I also do not have those numbers off the top of my head, but I would be happy to send those numbers to you and your staff members.

The CHAIRMAN. So if we put in place a program of moving to wind and solar, perhaps geothermal plus natural gas, we could probably drive down dramatically the amount of water by 2025 that is being consumed in the electrical generating sector. Do you agree with that?

Mr. GOLDEN. I would. But I would caution one caveat. When we talk about electrical generation we need to think about base versus peak. So as an advocate of renewable energy, I concur with your statements. My only caution is that we need to ensure that this is a base load and we can also meet our peak.

The CHAIRMAN. Well, a lot of people are saying that because of the high price now for oil that it is driving up the price of natural gas. And, as a result, we are discovering a lot more natural gas in the United States. So if we used the natural gas as the base load and then we built our wind and solar around it as planned, so that you still had the base load capacity and natural gas and whatever, you know, is the remainder of coal, is that a strategy for reducing water consumption while still maintaining the base load capacity?

Mr. GOLDEN. Yes.

The CHAIRMAN. So we need a plan for America going forward towards 2025. Because what you have laid out here is pretty catastrophic in terms of the amount of water being consumed and what the impact then is on all the other needs that we have in our society.

So at this point my time has been consumed. The gentleman from Oregon, Mr. Blumenauer, has arrived; and I will recognize him to ask questions.

Mr. BLUMENAUER. Thank you very much, Mr. Chairman.

And I must confess I am quite frustrated. I had two other committee meetings that kept me from this. But I have had a chance to review the testimony, and it is just really outstanding.

The CHAIRMAN. Yeah. You have saved the best hearing for last, like the wedding feast at Cana. I appreciate it.

Mr. BLUMENAUER. This is terrific stuff. And I am particularly interested—but time doesn't permit. We are being called to another vote. But I am hopeful that there would be a chance for us to explore with you in greater depth what the Federal Government can do in terms of promoting reasonable land use as a way to help reduce the impacts from flooding.

And the Federal Government, part of something that has frustrated me for years, how hard it worked to get the most minimal reforms in the flood insurance program, where we kept putting people back in harm's way. I would particularly appreciate it if you would have a chance to review the legislation that is currently wending its way through dealing with flood insurance for a way that we might be able to tweak that for the Federal Government to do a better job to reduce that. And I think I have time, though, to maybe get an answer.

Mr. Keppen, just dealing with issues that relate to the promotion of farm policies on the part of the Federal Government—we lost—sorry—policies that relate to the promotion—the things going forward we can do with Federal agricultural policy to try and take advantage of preserving key lands, using it to preserve and protect communities and be able to strengthen the agriculture. Even though we missed the boat with the Farm Bill, literally and figuratively, I wonder if you had other thoughts and observations about what we could and should be doing at this point.

Mr. KEPPEN. Well, one of the—I guess you brought up an observation earlier about land use and how the government can work on that, and it sounds like your comments were targeted towards flood insurance.

In the West, our watershed areas are almost all owned by the Federal Government; and they are in bad shape. I don't know if you have been to northern Colorado or southern Wyoming lately, but those watersheds are dying. The trees are dying. Even around where I live, Klamath Falls, we have got lots of areas where beetle kills, taken out trees——

We have got to get back and get serious about watershed management, and that has benefits not just for timber and wildlife and economies but also flood control. Because most of your areas draining downstream start in Federal lands in the West.

All I can say, as far as looking for ways to protect the farmland and that sort of thing, my organization—you know, we are even catching some heat for it, trying to get out and develop partnerships with conservation groups. We worked with conservation groups on the Farm Bill to try to come up with some programs that would help water supplies in rural areas. It is getting to the point right now where that is going to be the way of doing business just for farmers to survive.

I talked to the president of my board, a Wyoming rancher, yesterday. He is spending $2,000 per vehicle per week on gasoline alone just getting around on his ranch; and he said he is going to go broke. He can't make it.

So the economics are forcing agriculture I think to start to be a little bit more innovative and maybe creating partnerships with groups that we have been adversaries with in the past. So those are some of the things that we are working on.

Mr. BLUMENAUER. Mr. Chairman, I would just leave as an open-ended request for suggestions about specific policies. It seems to me that we have a new transportation bill that is coming forward. We are going to be looking at energy. The cap and trade is going to be likely, no matter who is president, and being able to use a small portion of this resource to be able to help people to be able to cope with the disasters, particularly as it relates to water. Policies on Federal land itself that should be adjusted, flood insurance. So the sense of priority that you have for things that we are going to have walking through the Capitol over the course of the next 30 months for specifics would be of great interest to me.

Thank you, Mr. Chairman.

The CHAIRMAN. I thank the gentleman.

We just have time to give 5 minutes to the gentleman from New York, and then we will have to adjourn.

Mr. HALL. Thank you, Mr. Chairman.

Thank you all for your testimony.

I will ask my questions primarily to Ms. Licata, since we are fortunate enough to have her here today.

In the Northeast, we have the country's oldest wastewater infrastructure, which means that we are heavily reliant on CSOs and SSOs, which are already frequently overwhelmed. If we are looking at severe increases in participation, isn't it fair to assume that the pollution when these old systems overflow could lead to a serious regression as far as water quality standards are concerned?

Ms. LICATA. That is certainly a possibility; and, for that reason, we are starting to explore new strategies.

The New York City system is 70 percent combined sewer overflows, and one of the opportunities that we may have is to start to look at more source control. So the way in which that we have dealt with the CSOs in the past has been to rid our city of storm water as quickly as possible and to send that to our water treatment plants and, when they are overwhelmed, to discharge the untreated but heavily diluted wastewater. Now what we are looking at is can we have—and do we have—opportunities within public rights of way and on public land to do some type of storm water management?

We are also looking very closely at what can you do on individual development lots? One of the strategies you have heard, I am sure, about our green roofs. But what the city of New York is currently looking at are what are known as blue roofs. And they are not really picturesque. It is really a tank on a roof, but what it does is it has the effect of detaining storm water.

Mr. HALL. Thank you very much, and I compliment you on your work and the Mayor for his leadership in this regard.

How can Congress help local communities best address this particular threat?

Ms. LICATA. One of the very significant challenges that New York has is really the age of its infrastructure system and what we need sorely is to build out the remainder of infrastructure. So we have these two problems: One, we have not kept pace with development pressures in the outer boroughs. So we have a lot of infrastructure that still has yet to be built. And, two, we really need to resize and rethink infrastructure that was built, say, in the early 1920s and before we saw major growth after World War II. So those are two major sources of funding that the city is lacking.

Mr. HALL. Thank you.

The city has a number of reservoirs and, of course, the aqueduct system which runs through my district and several reservoirs in my district and other upstate districts. In the 19th District of New York we have had three 50-year floods in the last 5 years, some of the extreme weather events that the doctor and the rest of the panel have been talking about. And I am curious, in terms of the Delaware watershed, which has experienced, in particular, April 29th of last year, the nor'easter that flooded Port Jervis and other communities in Orange County and also my hometown of Dover Plains in Dutchess County, where the Ten Mile was flooding again for the third 50-year time in a 5-year period. There has been talk about whether the New York City reservoir system could be used if we knew in advance that an extreme rain event was about to happen and whether there is a possibility of letting some water out in advance so that then it can be—some of the rain can be retained.

I understand it is a complicated question, and it requires maybe better science than we have. But do you have any thoughts about those?

Ms. LICATA. It is a very complicated question to answer in a very short amount of time. But what I will say is that the Department has implemented a flexible flow management program, and what that allows us to do is to maintain a certain void within those reservoirs on the Delaware system. However, that void can only be maintained when we have a certain or a more certain probability of refill. So once we get past June 1, it is very difficult for us to maintain a void because we won't have the—well, at least by hindcasting, we won't have precipitation events that we can be certain of.

So one of the other strategies that we can use is to look to make our Croton system more robust. We are bringing our filtration plans online there and to be able to develop aqueducts that will allow further interconnectivity between the Delaware system and the Catskill system. And these are all strategies that the Department is analyzing, but these are very long-term strategies.

Mr. HALL. Thank you very much.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

We have time for each of you to give us your concluding 20 seconds. That is all you have.

What do you want us to remember for the final 20 seconds, Ms. Cooley?

Ms. COOLEY. Thank you, Chairman. Thank you again for inviting me here today to speak.

I think the things I would like you to remember today is that we are faced with challenges both from climate change as it is related to floods and droughts and from continued population growth. The good news is that we have a number of options available that are not only effective today but are effective in the future; and so I would encourage the government and the legislature to go ahead and move forward and pursue these options, including—and I will restate—smart flood plain management, developing alternative supplies——

The CHAIRMAN. Twenty seconds. Thank you.

Mr. Keppen.

Mr. KEPPEN. I will say, in a nutshell, we are looking at competition for water in the West, limited supplies. Right now, agriculture is the default reservoir to meet a lot of these new demands. We need to be thinking about our ability as a country to be self-sufficient, and somehow that needs to find its way into the highest levels of the national policy.

The CHAIRMAN. Twenty seconds. Thank you, Mr. Keppen.

Dr. Golden.

Mr. GOLDEN. Our communities are at risk. We have a variety of Federal agencies that are doing great work, but we need leadership to bring that great work to bear back to the local and regional governments.

The CHAIRMAN. Thank you. You did that in 9 seconds.

Ms. Licata.

Ms. LICATA. We need to update floodplain maps within the city of New York. And, two, I believe we need Federal partnerships to go ahead about the business of down-scaling those global—I should say general circulation models into more regionally specific models.

The CHAIRMAN. Floodplain maps in New York. It is like a movie, huh? It is like a preview of coming attractions.

Dr. Adegoke.

Mr. ADEGOKE. We need to strengthen the research capacity that we have in this country to begin to address the questions of risk and vulnerability that we are facing as a society.

The CHAIRMAN. Thank you, Dr. Adegoke, very much.

We have a roll call on the floor that will begin in a minute and 22 seconds. Mr. Hall and I would like to take a picture with you, and then the hearing is adjourned. Thank you.

[Whereupon, at 3:26 p.m., the committee was adjourned.]

Follow-up Questions for the Record
Select Committee on Energy Independence and Global Warming
Oversight Hearing
July 10, 2008

Dan Keppen
Executive Director
Family Farm Alliance

1. **Assuredly, there will be environmental concerns associated with any new surface water storage projects. In your opinion, is it possible to address those issues and move forward with storage projects that will ultimately have broad support from a number of different stakeholders?**

Response: Yes. Individual surface storage proposals must be evaluated and the associated benefits and risks must be viewed in a net, comprehensive manner. While some environmental groups focus on perceived negative impacts associated with new facility construction (e.g. loss of habitat, disruption of "natural" stream flow patterns, and potential evaporative losses), these perceived impacts must also be compared to the wide range of multi-purpose benefits that storage projects can provide. Properly designed and constructed surface storage projects provide additional water management flexibility to better meet downstream urban, industrial and agricultural water needs, improve flood control, generate clean hydropower, provide recreation opportunities, and – yes, create additional flows that can benefit downstream fish and wildlife species.

Some people and organization oppose dams as a matter of dogma. They have no flexibility when it comes to surface storage. But experience teaches us that solving complex problems requires a great deal of flexibility. It also requires the collective efforts of reasonable, well intentioned people who may come at the problem from entirely difference perspectives. Surface storage isn't the solution in all cases, but dismissing it out of hand serves no good purpose.

Creative, successful solutions can be found by motivated, unthreatened parties. Incentives that create reasons to succeed will do more good for the environment in a shorter period of time than actions that rely on threats of government intervention.

2. **Have conservation efforts been effective in reducing water demand or have increases in population in the West negated the savings from conservation?**

Response: Conservation efforts have been effective, but it strains credibility to believe that conservation alone will supply enough water for the tens of millions of new residents expected to arrive in Western cities during the coming decades. Also, conservation does not work in many cases, especially where the desire is to increase in-stream flow. Water that is conserved tends to be used by the next junior downstream appropriator and the flow remains the same.

The report[1] I submitted for the record at the July 10 hearing provides several examples from throughout the West, where creative measures have been taken to develop and efficiently manage water resources for irrigation. These examples represent just a handful of the creative water management programs that Western irrigators are working on. Efforts to conserve water in urban areas have also been impressive, particularly in the Southwest.

In Las Vegas, description of a specific experience may provide the best response to this question. The Southern Nevada Water Authority (Authority) has imposed dramatic conservation measures in the urban areas around Las Vegas. Consider the following:

- As of March 2006, a program developed to pay customers $1 per square foot to remove lawns had already spent $56 million.
- New restrictions were imposed on landscaping.
- Use of recycled water was stepped up dramatically.
- Casino-hotels along the Las Vegas Strip have made significant investments in water features, capturing and treating grey water and using recycled water.
- A stiff four-tier rate structure was imposed, as were high connection charges.

With conservation measures in place, southern Nevada reduced water use by 65,000 acre-feet in two years. However, despite these aggressive conservation actions, the Authority is moving with equal determination to develop new water supplies in other parts of the region, since probabilities of shortages on the Colorado River are likely going to increase over time. As noted in our written testimony, the Authority is already planning to take groundwater out of aquifers under the Utah-Nevada state line and pipe it to Las Vegas.

So, this particular example – which describes some of the most innovative and aggressive conservation measures undertaken in the West – suggests that even the highest level of conservation is insufficient to keep up with new demands caused by new residents moving to Las Vegas.

3. **How do you see technology assisting adaptation efforts to climate change? For example, are you aware of any projects being developed right now that will help manage water supply and increase crop resiliency?**

Response: Technology has and will continue to play a role in assisting adaptation efforts to climate change. Recent advances in water measuring technology, weather modification and the use of GIS to better manage complex water systems are three such examples. I will elaborate on one other important area where technology is already impacting crop resiliency.

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[1] "Water Supply in a Changing Climate: The Perspective of Family Farmers and Ranchers in the Irrigated West", Family Farm Alliance, September 2007

Of the inputs crucial to growing a healthy crop, water is among the most important. Plants improved through today's biotechnology traits are already providing environmental mitigation benefits. Research is honing the next-generation of biotechnology traits aimed directly at improved drought stress tolerance. Such biotech benefits --potentially available in corn, cotton and oilseeds -- may boost yields under reduced moisture levels or allow increased performance with additional water application, helping to alleviate pressure on limited water supplies.

Unfortunately, the environmental movement has been very proactive and creative in its opposition to the genetic modification of food. It successfully made the erroneous connection in the public's mind between genetically engineered foods and chemical manipulation, even though genetic engineering has nothing to do with chemicals and is in fact an organic science that uses the same processes that nature uses to evolve species. Genetic engineering of foods is about improving nutrition, increasing productivity of farms to reduce conversion of native lands, improving health benefits of food, and reducing the use of chemical pesticides.

4. **Do you agree that any mandatory cap on greenhouse gas emissions must include rapidly developing countries, specifically China and India?**

Response: The Family Farm Alliance focuses on water issues directly associated with Western irrigated agriculture, and we have not taken a formal policy position on this matter. Other witnesses who testified at the July 10 hearing may be better qualified to respond to this question.

5. **Do you support nuclear energy as a source of carbon-free electrical generation?**

Response: Please see response to #4, above.

6. **What can my home state of Missouri and the Midwest in general look forward to (in regards to extreme weather) in the coming decades as a result of increased temperatures due to climate change?**

Response: Please see response to #4, above. The Family Farm Alliance membership spans 17 Western states. Unfortunately, our membership does not include water users in Missouri or other Midwest states. Our 2007 climate change report did identify likely impacts to hydrology in Western states, and those impacts are summarized in my written testimony.

7. **We have all seen the devastation caused by Hurricane Katrina in New Orleans. Sometimes urban areas are more vulnerable to extreme weather events, due to the high density of people and structures. What can cities expect in terms of extreme weather?**

Response: In our work on climate change in the West, we have not focused specifically on cities, but rather, the agricultural sector. However, in general, as noted in our testimony, we can expect to see the following general effects and impacts caused by warming future temperatures in the Western U.S.:

- Smaller snow packs and earlier snowmelt will affect reservoir storage and demand for water and impact productivity and value of hydroelectric generation;
- More rain than snow is likely, with uncertain projected impacts to overall precipitation amounts in specific areas;
- Extreme flood events could be more common and larger, posing a potentially greater threat to urbanized areas.
- Droughts and higher temperatures would be more intense, frequent and last longer, which would increase stream and reservoir evaporation, diminish surface water supplies, and stress groundwater supplies and water quality.

Despite the highly variable and uncertain nature inherent with climate change predictions, it can safely be concluded that, in the West, with a warming climate, there will be less water stored in our biggest reservoir...the snow pack.

8. How can cities – like my hometown of Kansas City, Missouri – prepare for an extreme weather event, in terms of evacuation plans and emergency shelters?

Response: Please see response to #4, above. The Family Farm Alliance membership spans 17 Western states. Unfortunately, our membership does not include water users in Kansas City, and thus, we are not prepared to address extreme weather events associated with that locale. We also generally focus on water supply, rather than flood control, matters. We support a general philosophy that the best decisions on water issues are made at the local level.

9. Since climate change has been linked to intense weather events, how can cities help to avoid incidents of extreme weather?

Response: Please see response to #4, above. Our involvement with climate change issues has not delved into impacts on cities, since our membership consists of agricultural water users.

10. Would the increased farming – like the recent increase of biofuels – in this country have any effect on extreme weather events?

Response: We are unaware of any information or study that directly links increased farming with extreme weather events. On the contrary, our 2007 report cites new research that suggests Western irrigation has kept croplands cool, essentially countering rising temperatures caused by greenhouse gas emissions over the last half century[2]. That impact may be compounded by the predicted decreases in water available for agriculture in the future due to climate change. This, in turn, would cause more reductions in water supply, which would further restrict irrigation.

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[2] Kueppers, L. M., M. A. Snyder, and L. C. Sloan (2007), Irrigation cooling effect: Regional climate forcing by land-use change, Geophys. Res. Lett., 34, L03703, doi:10.1029/2006GL028679.

11. **What can Congress do to mitigate the effects of global warming, in an attempt to reduce the chances of extreme weather events?**

Response: We recommend an adaptive approach to dealing with the uncertainties of climate change. Even if current efforts to mitigate for greenhouse gas emissions are successful, the climate is still predicted to warm considerably over the next several decades, which will have impacts on water supplies and water users.

Family Farm Alliance President Patrick O'Toole of Wyoming last year testified before the Senate Energy and Natural Resources Committee on S. 2156, the SECURE Water Act, sponsored by Senators Bingaman and Domenici. This legislation includes water science initiatives; water efficiency programs; and additional actions that will help us adapt to the water-related impacts of global climate change. These provisions closely match similar recommendations in our 2007 report. While there is not currently a companion bill introduced in the House, the Alliance would encourage the House to take up a similar bill to help speed its enactment into law.

12. **Could you clarify your point with specific examples regarding the vulnerability of Midwest farming households to the variations in climate that you described in your testimony?**

Response: Our written testimony did not mention vulnerability of Midwest farming households to the variations in climate, since our membership spans the 17 Western states. As noted above, however, we can expect to see the following general effects and impacts caused by warming future temperatures in the Western U.S.:

- Smaller snow packs and earlier snowmelt;
- More rain than snow;
- Extreme flood events; and
- Droughts and higher temperatures.

Our report summarizes how these general impacts are projected by certain studies to be manifested in specific regions of the Western United States. In Western areas that rely on melting snowpack from mountainous areas, in general, more water in the form of rainfall and runoff will come at farmers and ranchers sooner in the season, when it may not be useful and may even present a threat.

For example, snowpack in the Cascade Range holds two-thirds of the region's stored water. As it melts during the dry summer months, it fills rivers, generates hydropower, and helps meet the water needs of irrigation, fish, recreation and growing urban areas. But, some experts say that Cascade snowpack has diminished in the past fifty years and is expected to further shrink. If this is the case, projected warmer winter temperatures could cause snowpack to melt earlier in the spring, which could exacerbate both spring-time flooding and late-summer drought conditions.

13. **In a warming world, we have been told that the conditions that favor summer heat waves will become more frequent. What are your thoughts on what we can do to protect those in our inner cities who are least capable of protecting themselves and are therefore more vulnerable to these types of conditions?**

Response: Please see response to #4, above. Our involvement with climate change issues has not delved into impacts on cities, since our membership consists of agricultural water users.

14. **Are there currently any options available to expand hydropower and water storage?**

Response: Yes. Two recent studies support this answer.

The Board of Directors of the Family Farm Alliance in 2005 launched a project that pulled together a master data base of potential Western water supply enhancement projects. Our goal was to gather together ideas from around the West and put them into one master data base.

The types of projects contained in the resulting *Western Water Supply Enhancement Study* database are not monstrous dams like China's Three Gorges project. Instead, they are supply enhancement projects that range from canal lining and piping, to reconstruction of existing dams, to integrated resource management plans. There are also some very feasible new surface storage projects. The benefits from these projects include providing certainty for rural family farms and ranches, additional flows and habitat for fish, and cleaner water. There are over 100 projects included in our data base.

Shortly after the Alliance's data base was released (and submitted to the Congressional record in April 2005), the Bureau of Reclamation seven months later submitted a report to Congress that identified nearly one thousand potential hydroelectric and water supply projects in the Western United States that have been studied, but not constructed. The report was required by the Energy Act of 2005.

The 2005 Alliance and Reclamation efforts show that, in most areas of the West, water resources are available to be developed. Environmentally-safe and cost-effective projects exist. They await the vision and leadership needed to move them to implementation.

What can be done to counteract smaller snow packs and less spring runoff?

Response: A recent Western Governor's Association report and other studies suggest that more spring runoff, coming off the mountains in a shorter time period, is the general predicted impact associated with climate change. Water resources experts throughout the West realize that new surface water storage projects may be necessary to capture more rapidly melting snowmelt or water from other sources.

There are several reports that suggest existing reservoirs will not be capable of safely accepting the earlier, more intense snowmelt. A report released two years ago by the State of California predicts that climate change will result in a drastic drop in the state's drinking and farm water supplies, as well as more frequent winter flooding. The report suggests that warmer temperatures will raise the snow level in California mountains, producing a smaller snowpack and more winter runoff. This means more floodwaters to manage in winter, followed by less snowmelt to store behind dams for cities, agriculture, and fish.

Some Western water managers believe there will likely be a "rush" to re-operate existing multi-purpose projects to restore some of the lost flood protection resulting from the changed hydrology associated with climate change. These projects were designed to provide a certain level of flood protection benefits that will be reduced because of more "rain flood"- type of events. There will be a call to reduce carryover storage and to operate the reservoirs with more flood control space and less conservation space. If this is done, it will even further reduce the availability and reliability of agricultural water supplies.

Further, many water users are located upstream of existing reservoirs. These users must then rely on direct or natural that is primarily fueled by snowmelt. In the Rocky Mountain West, snowmelt traditionally occurs during the onset of the irrigation season. Since conveyance systems are never 100% efficient, water is diverted, conveyed and spread on the land in excess of the net irrigation demand. This surplus returns to the stream and recharges groundwater aquifers, which augments water supplies for all users located downstream from the original diversion. If more runoff were to occur during warm cycles in winter before the onset of the irrigation season, this would impact the utility associated with these return flows.

15. How is per capital water usage trending in the West?

We do not have "per capita" water use information at hand. "Per capita" is a term that is generally used when discussing domestic water use, since it provides a sense of the average amount of water an individual would use per day. Agricultural water use – which is the focus of the Family Farm Alliance – is addressed in terms of "acre-feet" of water used per acre of irrigated farmland, number of acres irrigated, etc.

"Per capita" water usage trends have varied throughout the West, as well as throughout the rest of the country, according to location. The Water Resources Division of the U.S. Geological Survey (USGS) is the lead office for this type of information. The USGS publishes a report, *Estimated Use of Water in the United States*, every five years which contains this information. The USGS first conducted the water-use compilations for 1950 and has published them every 5 years since.

To provide a quick sense of how recent USGS reports have characterized irrigation water trends, consider the following. Since 1985, when USGS first collected data on irrigated acres by system type, more acres were irrigated using sprinkler and microirrigation systems than were irrigated with flood systems. The proportion of total acres irrigated using sprinkler and microirrigation systems increased from less than 40 percent in 1985 to 52 percent for 2000. The average irrigation application rate declined about 30 percent, from 3.55 acre-feet per acre during 1950 to 2.48 acre-feet per acre during 2000. The largest declines in application rates occurred after 1980.

For domestic, industrial and other types of water uses, the USGS report contains a multitude of data presented in a myriad of ways. We recommend that you review this report to assess the exact information you are looking for.

16. What options should be on the table to balance the need for water to go to urban settings against the need for agricultural use of water?

Response: We believe that it is possible to meet the needs of cities and the environment in a changing climate without sacrificing Western irrigated agriculture. To achieve that goal, we must expand the water supply in the West. There must be more water stored and available to farms and cities. Maintaining the status quo simply isn't sustainable in the face of unstoppable population growth, diminishing snow pack, increased water consumption to support domestic energy, and increased environmental demands. Conservation measures must continue to be included in the suite of solutions, but it strains credibility to believe that conservation alone will supply enough water for the tens of millions of new residents expected to arrive in Western cities during the coming decades. Water reuse, desalination and temporary water transfer mechanisms should also continue to be employed, but they, too, are not sole "silver bullet" solutions.

A multitude of unique solutions exist for Western communities wrestling with growing urban water use. Unique solutions exist for unique locations. The Northern Colorado Water Conservation District is currently seeking to develop new offstream storage to protect agriculture as urbanization sweeps into Northern's traditional service area. Farmers in the Klamath Irrigation Project (CALIFORNIA / OREGON) are paid through an environmental water bank to temporarily fallow land or pump groundwater in place of using Klamath River water. On the other hand, unsuccessful implementation of Central Valley Project Improvement Act water transfer provisions in California suggests that water markets cannot be legislated.

There is growing recognition that states and local governments must consider the impacts of continued growth that relies on transfers from agriculture and rural areas and to identify feasible alternatives to those transfers. For example, a 2006 report released by the Western States Water Council (WSWC) and Governors Association (WGA) states "there is understandable support for the notion of allowing markets to operate to facilitate transfers from agricultural to municipal and urban use as a means to accommodate the needs of a growing population. While such transfers have much to commend them, third party impacts should be taken into account, including adverse effects on rural communities and environmental values. Alternatives that could reasonably avoid such adverse impacts should be identified."

The Family Farm Alliance is working with WSWC to develop a report on successful and unsuccessful agricultural-to-urban water transfers to determine how transfers can be accomplished in a manner that avoids or at least mitigates damage to agricultural economies and environmental values, while at the same time avoiding infringement on private property rights. We would be happy to share that report with your committee when it is complete.

17. How much investment do you think is necessary to upgrade irrigation infrastructure to accommodate future water management issues?

Response: According to information provided at an April 2008 hearing conducted by the Senate Water & Power Subcommittee, since 1902, Reclamation constructed a large majority of the water infrastructure that now exists in the 17 Western states. Much of this infrastructure is now 50-100 years old, approaching the end of its design life and in need of substantial rehabilitation or replacement. The original development cost of this infrastructure was over $20 billion. Reclamation estimates that the replacement value of its water infrastructure is over $100 billion.

The problem with fixing aging public infrastructure is there are not enough federal dollars to go around for burgeoning repair needs. Yet, in the case of Reclamation water facilities, most of the rebuilding of this federal water infrastructure is paid for by the end users who contract with Reclamation for their water supplies. Reclamation estimates that $3 billion will be needed from project users in the near-term to provide for essential repairs and rehabilitation of facilities. These costs do not reflect the costs associated with developing new storage facilities and expanded delivery systems to accommodate the growing population, increased environmental water demands, expanding energy water requirements, and climate change. Also – these costs relate only to Reclamation facilities and do not reflect costs of non-Reclamation water users, including private water rights holders, which are numerous.

18. Have you done any work with farmers around the world who currently work with a similar water supply as what you anticipate Western farmers will see?

Response: As an organization, the Family Farm Alliance has not formally interacted with farmers around the world who currently work with a similar water supply as what we expect Western farmers will see. However, many of our individual members have worked with agricultural interests from other countries, particularly Israel. I personally have worked with water managers from Russia and Australia on water conservation and water marketing issues.

19. What policies can the Federal government implement to help preserve farmland?

Response: In the big picture, "preserving farmland" equates to "preserving farmers", which means we must find ways to keep farmers and ranchers doing what they do best, and to further encourage young farmers to follow in their footsteps.

Federal funds and other money should be authorized to help local governments protect farmland, analyze ways to keep farmland in production, set up grant programs for local governments and provide technical assistance to farmers. Congress should consider the option to encourage states to lease development rights from farmers to buffer their farmland.

Legislation could also make it easier for aging parents to deed their farms to relatives without paying heavy inheritance taxes.

To achieve these objectives, the U.S. should adopt an overriding national goal of remaining self-sufficient in food production. Policy decisions on a wide range of issues ranging from taxation to the management of natural resources should then be evaluated to be sure they are consistent with that goal.

Are there already some programs available?

Response: Yes. The U.S. Department of Agriculture, Natural Resource Conservation Service has many manuals describing all facets of its programs. Title 440 – Programs, Part 519 - Farm and Ranch Lands Protection Program – is a good place to start to get a sense of current federal programs. The American Farmland Trust has further information on state and local programs in place, intended to protect and preserve American farmland. For example, the state of Pennsylvania already spends about $30 million a year to buy up development rights from farmers "in perpetuity," so the land will stay agricultural even if it changes ownership. So far, 2,600 farms, with more than 300,000 acres, have been included in the preservation program, but there is a long backlog of farmers who want to join but can't because the state doesn't have enough money. Pennsylvania has also studied the possibility of having the state pay the tab for a farmer's property taxes. These taxes are often onerous and can lead farmers to sell their land for housing or shopping malls. By paying property taxes over a number of years, the state would need less upfront money than the current program of giving a farmer a lump sum for land preservation. That way, more farms could be included.

20. **You note the importance of a stable domestic food supply to the United States' national security interests. How diversified is our domestic crop? Are farmers harvesting a broad enough range of crops that we actually have a stable domestic food supply?**

Response: The World Agricultural Supply and Demand Estimates (WASDE) report prepared by the Agricultural Marketing Service Economic Research Service and the Farm Service Agency Foreign Agricultural Service provides the data and analysis that would best form a response to this question. These monthly reports estimate supply and demand for wheat, rice, feed grains, oilseeds, cotton, sugar, meat animals, poultry and dairy commodities. The WASDE report can be downloaded at: http://usda.mannlib.cornell.edu/. A free e-mail subscription to the WASDE and other USDA crop reports can be obtained at this same address. For print subscriptions, you can call the National Technical Information Service (NTIS) at 1-800-999-6779 or 703-605-6220. For the remainder of 2008, the WASDE report will be released on September 12, October 10, November 10 and December 11.

21. What sort of role do you believe agriculture should take in a carbon offset market?

Response: The Family Farm Alliance focuses on water issues directly associated with Western irrigated agriculture, and we have not taken a formal policy position on this matter. However, many of our individual members have expressed concern that agricultural representatives become actively engaged on this matter, since there are enormous potential risks and opportunities to agriculture stemming from future policy development in this area.

22. How would streamlining regulatory hurdles assist in developing water management policy? How much do regulations add to the cost of developing infrastructure?

Response: The federal government should adopt a policy of supporting new efforts to enhance water supplies and encouraging state and local interests to take the lead in the formulation of those efforts. The existing regulatory procedures for developing additional supplies should also be revised to make project approval less burdensome. By the time project applicants approach federal agencies for authorization to construct multi-million dollar projects, they have already invested extensive resources toward analyzing project alternatives to determine which project is best suited to their budgetary constraints. However, current procedure dictates that federal agencies formulate another list of project alternatives which the applicant must assess, comparing potential impacts with the preferred alternative. These alternatives often conflict with state law. Opportunities should be explored to expedite this process and reduce the costs to the project applicant.

The example of the permitting history of the Little Snake River Irrigation Water Supply Project, High Savery Dam and Reservoir (Attachment 1) best illustrates this matter.

In addition, the current mitigation procedure for federal agencies should be reviewed to determine the feasibility of clarifying and standardizing mitigation requirements. Currently, requirements for one project become the standard for all subsequent projects. Since no two projects are the same, federal agencies tend to impose increasingly severe mitigation requirements on new projects. The end result is that applicants end up spending tremendous amounts of money for potentially uncertain mitigation.

The example of the city of Buffalo, Wyoming (Attachment 2) illustrates the point. For 8.8 acres of wetlands impacts, the cost of mitigation amounted to approximately $1 million. This is in excess of $100,000 per acre. The primary reason for these costs was that the United States Army Corps of Engineers required a 5:1 ratio for wetland mitigation. The 5:1 ratio is not a scientifically based figure, but rather an arbitrary figure developed by the agency. After 3 years and significant expense, the city finally was forced to accept this ratio in order to proceed with the project.

23. Can you provide some specific examples of the water supply enhancement projects that the Family Farm Alliance has looked at to make up for streamflow losses?

Response: Yes. As noted above, the Western Water Supply Enhancement Study we released in 2005 was transmitted in the form of a CD-ROM. The database that was generated from the compilation of our survey has a Global Information System (GIS) element and includes pictures, maps and a description of up to 500 words for each project or proposal. New GIS format technology is embedded that permits viewers to see a map of 17 Western states and then "drill down" to see map details of a project area.

There are over 100 projects included in our data base. Some specific projects include:

- **Atterberry Irrigation Reservoir (Washington)** is a small proposed project that involves construction of an irrigation water reservoir (500 acre-feet) which would reduce irrigation water withdrawal from the Dungeness River during periods of low streamflow. The project will provide substantial increases in available side channel spawning/rearing habitat as well as reduced water temperature benefits.

- **Plateau Reservoir (Colorado)** would be operated in conjunction with McPhee Reservoir to improve downstream fishery habitat. The Dolores Water Conservancy District (DWCD), Bureau of Reclamation, State of Colorado and Federal fishery agencies have identified the need to provide at least 3,300 acre-feet per year of additional water for the fishery flow downstream of McPhee Reservoir. McPhee Reservoir and related delivery facilities are part of the Dolores Project, a multi-purpose water storage project that supplies water for irrigation, municipal, fishery below the dam, and other uses. The fishery downstream of McPhee Dam is an excellent cold water trout fishery. DWCD has been studying methods to provide the additional fishery water and has identified the construction of Plateau Reservoir as an option to supply additional fishery water.

- **Viva Naughton Reservoir (Wyoming)** is one of several alternative storage sites under investigation on the Hams Fork River above Kemmerer. The recent drought has greatly changed the water agreement between downstream irrigators and PacifiCorp, the owner of Viva Naughton Reservoir. Investigations completed for the Green River Groundwater Recharge and Alternate Storage Study published in late 2001 indicate enlarging Viva Naughton Reservoir is one of the more efficient water development projects in the state. The permitted enlargement of Viva Naughton Reservoir would provide a much needed source of late season water for users below the dam.

- **Sites Reservoir (California)** has been identified by the Department of Water Resources and the CALFED Program as one of the most cost-effective and environmentally beneficial new facilities under consideration in California. The Sites project would enhance water supply reliability for environmental, urban and agricultural uses throughout the state. It would provide water supplies in average and dry years for urban, agricultural and environmental purposes, increase San Francisco Bay-Sacramento / San Joaquin Delta outflows during critical times, improve flood control, enhance groundwater recharge, bolster fish flows, and improve flexibility for existing projects, such as Shasta Reservoir. Sites reservoir can greatly increase reliability of water supplies by reducing water diversions on the Sacramento River during critical fish migration periods.

- **Strawberry Valley Rehabilitation and Betterment Projects (Utah)** are proposed to decrease the water seepage and losses in the Strawberry Valley Project, as well as provide gravity pressure for the continued migration toward sprinkler irrigation systems, which would then provide additional water savings. These projects could save approximately 15,000 to 20,000 acre-feet of water per year in an agricultural area that is rapidly urbanizing.

- **Temperance Flat Dam (California)** would be a new structure constructed on the San Joaquin River, above Friant Dam, which would provide much needed water supplies and hydroelectric power. The Upper San Joaquin River Basin Storage Investigation was completed by the U.S. Bureau of Reclamation, in cooperation with the California Department of Water Resources, consistent with recommendations in the CALFED Bay Delta Program Record of Decision.

- **Teton Dam Re-Construction (Idaho)** would replace Teton Dam, which failed in 1976 just as it was completed, causing massive flooding in the Rexburg, Idaho, area. Fremont-Madison Irrigation District is considering participating in a reconstruction of this dam, which, in 1990, was estimated to cost \$168 - \$265 million. The project would yield 41,000 acre-feet of water to benefit the fishery, 24,000 acre-feet for trumpeter swans, and 20,000 acre-feet for irrigation.

- **Water for Irrigation, Streams, and Economy Project (WISE - Oregon),** is a collaborative effort in Oregon to improve the health of the Little Butte Creek and Bear Creek systems and increase the effectiveness and efficiency of local irrigation districts. The WISE Project utilizes a combination of strategies including: piping and lining canals, increasing the storage capacity of selected reservoirs, and installing a pumping system that will provide access to water that has been allocated for agricultural purposes. Collectively, more water will be available for management for irrigation and environmental instream purposes.

24. In addition to streamflow losses, increasing temperatures and a drying climate will likely dry rangelands and have other negative impacts to agriculture. This industry

is already stressed. What is your sense of the future of agriculture in the West – do the opportunities outweigh the challenges or do you have concerns about the long-term viability of family farms?

Response: As the West has grown, water issues have become increasingly polarized. We face a number of challenges in the Western water arena, but they can be addressed by thoughtful, motivated and reasonable parties. Growing urbanization in the West has placed heavy demands on water, the key ingredient in the production of agricultural products.

This conflict can be characterized in simple terms. Some argue that irrigated agriculture in the West uses too much water; that our rivers are over-committed; and that the environment is suffering. Others insist that a healthy rural economy is driven by farmers and their production of food. Taking water from farms and giving it to cities and the environment will do harm to the fabric of the rural West.

Inaction in this regard really is action. By not seeking creative ways to streamline the regulatory process associated with repairing existing and creating new water infrastructure, the action that will follow is a continuation of the status quo. That action will push water-short cities and new environmental water demands to pursue water supplies from agriculture. In addition to adverse socio-economic impacts for rural communities, that action will significantly diminish domestic food production at exactly the same time global warming is predicted to severely adverse impact food production worldwide.

We must begin to plan for that now, and not wait until we are forced to make decisions during a crisis.

The Family Farm Alliance believes that it possible for the West to find balanced solutions to these conflicts. The solutions will not come easily. They will require visionary leadership and a firm commitment to a balanced, workable policy. But opportunities exist, if we are prepared to seize them, conflict will be reduced and certainty increased.

Attachment 1: Permitting History
of the Little Snake River Irrigation Water Supply Project
High Savery Dam and Reservoir

Introduction

Permitting is a major step in any project that requires federal agency action; it can be the most perplexing and confusing step in project development. Projects requiring federal actions must go through the National Environmental Policy Act (NEPA) assessment process, which in itself is not a permitting process but is of utmost importance concerning whether required permits will eventually be issued. Due to extensive/thorough NEPA screening requirements and alternative evaluations, projects often lose direction and focus during this process.

NEPA was enacted in 1969 to promote informed decisions and public disclosure of federal actions. Through NEPA assessments other laws such as the Endangered Species Act, Clean Water Act, Fish and Wildlife Coordination Act, and the National Historic Preservation Act come into play. These laws and acts require permits or clearances from a number of agencies, and make coordination of the NEPA process the driving force for project permitting. This was especially true for the Little Snake River Irrigation Supplemental Water Supply Project.

The following sections discuss major events that occurred during permitting of the Little Snake River Irrigation Water Supply Project and present conclusions and lessons learned from this process. The history and conclusions presented are a compilation of information from legislative reports, project studies and personal recollections.

History

The Little Snake Irrigation Water Supply Project began as the Sandstone Dam Project and now is commonly referred to as the High Savery Dam and Reservoir Project. The Sandstone Dam Project began as mitigation for the Cheyenne Stage I, II and III projects and to provide additional water storage for industrial development. The Wyoming Legislature authorized the Cheyenne Stage I and II projects in 1979 and 1980 and also instructed the Wyoming Water Development Commission (WWDC) to look at the feasibility of developing storage in the Little Snake River Basin to address in-basin agricultural, recreational and municipal needs.

Studies were initiated to evaluate dam and reservoir sites in the basin and the Sandstone site was selected as the preferred site. In 1984, the legislature authorized a project in the Little Snake River Basin to mitigate and alleviate any water supply shortages caused by the Cheyenne Stage I and II projects. Sandstone Dam was to impound 52,000 acre-feet of water behind a 200-foot high structure. The reservoir would have had a 32,000 acre-foot annual yield with 12,000 acre-feet allocated for irrigation and 20,000 acre-feet allocated for future industrial development.

After several years of study, the permitting process for the Sandstone Project was initiated in 1986. An application for a Clean Water Act, Section 404 Permit (404 Permit) was filed with the U.S. Army Corps of Engineers (Corps), which initiated the NEPA assessment process. The project was of a scale that an environmental impact statement (EIS) was necessary; the Corps was the lead agency for the NEPA review and for preparation of the EIS. The draft EIS and biological assessment (for assessment of impacts to endangered species) were published in January 1988. Six action alternatives and the no action alternative were evaluated. The six action alternatives included four reservoirs, a ground water development alternative and a water conservation alternative. The preferred alternative, for the state and the sponsor, was the Sandstone Dam and Reservoir Project. All of the alternatives were sized to allow storage of 12,000 acre-feet of irrigation water and 20,000 acre-feet for future industrial development. A supplement to the Draft EIS was published in April 1989 to support need for storage of 20,000 acre-feet for future industrial use. Work continued on the EIS process during 1989 and 1990.

On December 14, 1990, the WWDC received notice from the Corps' Omaha District Office that they were recommending denial of the 404 Permit for the Sandstone Project. Their denial was based upon the lack of an acceptable federal "purpose and need" for the 20,000 acre-feet of water reserved for industrial purposes. The WWDC and then Governor Sullivan disagreed with the decision and requested that the permit be issued. The decision was elevated to the Corps Division Engineer. In 1991, the WWDC was notified that the Division Engineer upheld the District Engineer's recommendation that the 404 Permit be denied for the 52,000 acre-foot project. However, the Corps noted that it would be prepared to reopen consideration of the application if use of the reservoir yield could be clearly defined.

During 1991, the Little Snake River Basin Planning Study was authorized by the WWDC and legislature. This study was completed in October 1992. One task of the study was to evaluate potential reservoir sites to determine whether any were capable of meeting the supplemental irrigation water needs in the Little Snake River Basin. At the request of the Savery-Little Snake Water Conservancy District (District), a downsized version of the Sandstone Project was included among the alternatives.

The Commission recommended construction funding for a smaller Sandstone Dam and Reservoir project; this downsized version would possess a water storage capacity of 23,000 acre-feet, which would yield 12,000 acre-feet per year of supplemental irrigation water. Legislation was approved during the 1993 session to provide $30,000,000 to construct the project. The project purpose, as defined by the legislature, was to serve as an agricultural, municipal and domestic water supply; the project was to also increase recreational opportunities, provide environmental enhancements, and serve as mitigation water for shortages caused by the Cheyenne Stage I, II, and III trans-basin diversion water supply projects.

Additional studies were conducted in 1993 to determine the suitability of the Sandstone site. The report concluded dam construction at the Sandstone site was technically feasible. In 1994, the WWDC began the permitting process for construction of a smaller project, including a downsized Sandstone Dam and Reservoir project and several other potential alternatives. The downsized Sandstone Dam was the preferred alternative. Since the scope of the project had changed, the results of the draft EIS published in 1988 could not be used. The WWDC entered into an agreement with the Corps and contracted with Burns and McDonnell to complete a new third party EIS.

The Corps advised the WWDC, District and valley residents in January 1995 that a 404 Permit could be issued only for the least environmentally damaging alternative. That summer the Corps indicated that the least damaging practicable alternative was a combination of two alternative reservoirs (Dutch Joe and Big Gulch); therefore, a 404 Permit would not be issued for the Sandstone Dam alternative. The Corps had narrowly defined the purpose and need for the project as supplemental late season irrigation water supply. The Corps' definition conflicted with the Wyoming legislation that authorized funding for the project; the Wyoming Legislature stipulated that recreation, environmental enhancement, municipal water supply, supplemental irrigation, and mitigation for past and future trans-basin water projects were all legitimate purposes for the project.

In August 1995, the WWDC director and project manager explained to the WWDC and Select Water Committee of the Wyoming Legislature reasons why the EIS was stalled, which was largely attributable to the lack of support for alternatives other than the Sandstone site. The WWDC and the Select Water Committee concluded that alternatives to the Sandstone Dam and Reservoir should be considered if there was a clear consensus of support for other alternatives. Public meetings were held in the Little Snake Valley in August, October and December 1995 for the purposes of discussing project alternatives. It was apparent that a majority of those attending the meetings preferred the construction of Sandstone Dam, since they believed that the Sandstone site would provide more multiple use benefits than the other alternatives. This majority also disagreed with the Corps decision not to include other project purposes, which were mandated by the legislature, within the Corps' purpose and need analysis.

The WWDC supported the position expressed by a majority of the Little Snake Valley residents and directed the WWDC staff to further pursue changing the purpose and need section of the EIS to include state legislature's mandated purposes, particularly recreation. The lack of agreement between the state and the Corps, concerning the project's purpose and need, resulted in further delay of the project.

In 1996, The WWDC contracted with Burns and McDonnell to complete an analysis of need for additional flat-water recreation in the Baggs, Wyoming area. The study concluded that there wasn't a need for additional flat-water recreation in the area. Other studies were commissioned to keep the project moving forward; but study results also did not support the Sandstone alternative. The Corps reaffirmed their position that the project purpose could only be for supplemental irrigation water supply. Further, the Corps indicated verbally and in writing that the project should provide 12,000 acre-feet of water on a firm basis 8 out of 10 years. The

Savery-Little Snake River Water Conservancy District had requested a firm 12,000 acre-foot yield 10 out of 10 years.

Adding to other problems, the Sandstone Dam alternative was the most costly project (about $48 million). The Dutch Joe alternative was nearly $10 million less costly. The High Savery alternative was the least costly at about $30 million. Environmental impacts were greatest at Sandstone but appeared to be significant at the Dutch Joe and High Savery sites as well. A meeting to discuss the project, attended by representatives of the Corps, other federal agencies, several state agencies, the Governors office, representatives from the District, other representatives from Carbon County, the WWDC, and the Select Water Committee, was held on November 19, 1996. The Corps stated that given the available data, the Sandstone site could not be permitted because the Dutch Joe site was the least environmentally damaging alternative. They indicated that the High Savery Project might be permitted if it could be shown that impacts to big game winter range at Dutch Joe were more environmentally damaging than the wetland and stream channel impacts at High Savery. A meeting was held in Baggs on December 5, 1996 and the irrigators and Little Snake Valley residents supported a motion to change the project name from Sandstone to the Little Snake Water Supply Project. Work completed in 1995 and 1996 resulted in a delay to the project but set the stage for the eventual construction of the High Savery Dam and Reservoir alternative.

The permitting process was put back on track in 1997 and three alternatives were selected that would meet the specified need for the project, which was to supply 12,000 acre-feet of supplemental irrigation water to the users in the Little Snake River Valley 8 out of 10 years. The alternatives studied were a downsized Sandstone Dam and Reservoir, Dutch Joe Dam and Reservoir, and High Savery Dam and Reservoir. High Savery became the preferred alternative. The final studies were completed during 1997 and 1998 and the Draft EIS was published in August 1998. The Fish and Wildlife Coordination Act report was also released in August 1998.

Public meetings were held and comments were taken on the draft EIS in the fall of 1998. Disagreements between the WWDC, the WGFD, the U.S. Fish and Wildlife Service and the Corps on how best to address the DEIS comments delayed the completion of the Final EIS until October 1999. The U.S. Fish and Wildlife Service issued the Biological Opinion in July 1999 to satisfy the consultation requirements of Section 7 of the Endangered Species Act. In order that a Record of Decision (ROD) could be issued, work began in earnest in 1999 to mitigate the project's adverse environmental impacts. Numerous meetings were held with the Wyoming Game and Fish Department, WWDC, USFWS, Savery-Little Snake Water Conservancy District and Corps to resolve differences and finalize the plan.

The Final EIS, completed in October 1999, identified the High Savery Project as the preferred alternative. Several comments were received but none were significant. These few comments were eventually addressed in the Corps' Record of Decision (ROD). However, the project was further delayed because the Corps was concerned about issuing the ROD and 404 Permit before cultural resource preservation and management issues were resolved.

Efforts to comply with the National Historic Preservation Act, which protects cultural resources, were also underway at this time. A number of site visits, conference calls, and meetings were conducted to discuss cultural resource issues with interested Native American Tribes, the Wyoming State Historic Preservation Office (SHPO), WWDC and the Corps. There were a variety of tasks undertaken to satisfy the requirements of the Tribes and SHPO. Several cultural sites had to be evaluated and protection plans developed. One site required excavation and interpretation. This work was conducted during 1999 and 2000. A final Programmatic Agreement to protect and manage cultural resources on the High Savery Site, which took over a year to negotiate, was eventually signed in early December 2000.

The plan to mitigate the adverse impacts to wetlands, uplands and riparian areas proved to be extremely controversial, which further delayed the project. Three drafts of the plan were completed and debated by all parties involved. In October 2000 a final draft plan was presented to the Corps by WWDC. This plan was finally approved in December 2000 after a meeting with the Corps at their District headquarters in Omaha, Nebraska.

The ROD was issued December 14, 2000, approximately one-year and two months after the final EIS was released. The 404 Permit for High Savery Dam and Reservoir was signed December 20, 2000. These steps completed the permitting portion of the project and advanced the High Savery Project toward construction.

Conclusions and Lessons Learned

It could be concluded from the Little Snake Supplemental Irrigation Supply Project (High Savery Project) history that 14 or more years might be required for permitting reservoir projects. However, that may not be correct. During the time the High Savery Project was being permitted several other reservoir projects within Wyoming were designed, permitted and constructed. Sulfur Creek Reservoir Enlargement near Evanston was initiated in 1984 and constructed in 1986. Design of the Twin Lakes Enlargement for the Sheridan water supply was started in 1988, permitting was begun in 1992, and construction started in 1996 and was completed in 1998. A 404 Permit application was submitted for the Tie Hack Dam and Reservoir Project above Buffalo in February 1994, the permit was issued in March 1996 and the project was completed in 1997. A 404 Permit application was filed in November 1996 for the Greybull Valley Dam and Reservoir. The permit was issued in June 1998 and the project was completed in 2000.

We often learn more from mistakes than we do from successes; in this regard there are a number of lessons that can be gained from the Sandstone/Little Snake Supplemental Irrigation Water Supply Project/High Savery Dam and Reservoir permitting process. The determination of purpose and need under federal guidelines restricts planning opportunities and purposes for which a project may be permitted. The state's acceptance of a project that yields less than a firm supply should be questioned. This acceptance results in less utility for the state and for the project's beneficiaries. A better approach would be to maximize the basin's available hydrology or at least meet the firm-yield requirements of the sponsor. If the basin hydrology cannot provide the firm yield, the decision to construct the project should rest with the state and sponsor and should not become a reason for permit denial by the Corps. Further, the state should encourage its Congressional delegation to sponsor legislation that would allow the state's legislative and planning process to be considered in establishing purpose and need for construction of dam and reservoir projects.

If Congress is unwilling to expand the state's role in establishing the purpose or need for a project, the project sponsor and the state must work within existing guidelines to maximize opportunities. Working within either existing or expanded federal guidelines would facilitate the NEPA analysis, from which all other permitting processes will tier. The 20,000 acre-feet of water storage for future industrial development that couldn't be definitively described in the early Sandstone Project was a permitting problem. There was no specific purpose or need described for the 20,000 acre-feet of industrial water. Therefore, the Corps felt that justification for building a reservoir having this extra capacity and additional adverse environmental impact was unwarranted. However, it is incumbent on the state and potential project sponsors not to lose sight of future demands for water that may only be addressed by constructing new dam and reservoir projects. The challenge will be to convince regulators, during the permitting process, that the benefits of constructing a proposed future project outweigh the adversities; consequently, there is a justifiable "purpose and need" for the project.

Developing a reasonable range of alternatives is also very important in project planning and the NEPA process. Alternatives must meet the need and purpose for the project and must be capable of being implemented. It is important to use the NEPA process to help determine the most appropriate alternative from the set of reasonable alternatives. Although the Sandstone Project started with a set of alternatives the one seriously considered was the Sandstone Dam and Reservoir alternative. When the Corps determined that the Sandstone alternative could not be permitted, the permitting process stalled because other alternatives had not been seriously considered. Even after the project was downsized to match the need, the State, District, and valley residents wanted to maintain the Sandstone alternative as the preferred alternative. This caused permitting delays.

The permitting process did not proceed until a reasonable range of alternatives was developed. Once a reasonable range of alternatives, including the High Savery alternative, was developed, the project moved forward to a conclusion within an acceptable timeframe. In other words, the alternative site and project evaluations undertaken in 1996 put permitting back on track in 1997. The state successfully secured the permit to construct High Savery in December 2000.

Cooperative efforts are important for moving projects through the NEPA and permitting processes. The WWDC and local sponsors should become cooperating agencies in the NEPA process if possible and if not, should be allowed to serve on the project EIS interdisciplinary team. The Corps wasted a great deal of time making decisions on the project and at times seemed unable to make decisions. These delays not only postponed the project, they resulted in wasted money. Disagreements at the state and local level also contributed to delays, and led to additional costly studies and analyses.

Establishing working relationships with the agencies involved in the NEPA process and permitting is important to keep the project on schedule and to avoid costly delays and disagreements. It is impossible to eliminate all problems associated with permitting dam and reservoir projects, but good cooperation and communications between agencies and groups, with an understanding of each participant's expectations, will help in problem resolution.

Dam and reservoir projects are complex and often controversial, a dedicated local sponsor or project proponent and a documented "purpose and need" are minimum requirements for success. The primary reason the High Savery Dam was permitted and constructed is the persistence and perseverance of the Savery-Little Snake Water Conservancy District and the residents of the valley. The sponsor's and the state's staying power prevailed in the end.

Attachment 2: City of Buffalo, Wyoming Case Study

The example of the city of Buffalo illustrates the enormous difficulties and expense associated with obtaining federal regulatory clearance requisite for constructing even small and non-controversial water projects. The mitigation associated with this project illustrates the unreasonable approaches being taken by federal agencies as a condition of obtaining needed federal permits. Within Wyoming there are rarely two projects which have the same or equivalent mitigation imposed on them. Rather, it appears that as time passes, each new project has more severe mitigation imposed on it that then becomes the standard for all subsequent projects. This mitigation "ratcheting" creates enormous costs and tremendous uncertainty as has been the city of Buffalo's experience.

The Buffalo Municipal Reservoir Project is developing a small municipal supply storage reservoir in the Clear Creek Basin west of Buffalo. Buffalo's existing water supply is diverted from Clear Creek about 6 miles west of the city. After project completion, releases from the reservoir will supplement Clear Creek flow when the direct flow cannot fulfill Buffalo's water supply requirements. The project is being funded in part by the Wyoming Water Development Commission, a state agency.

A Level 11 - Phase I report was completed in March 1989. The report concluded that the preferred development option included a dam and reservoir at the Lower Tie Hack site on South Clear Creek, a tributary of Clear Creek. The recommended reservoir size is 2,425 acre- feet and the estimated cost of the dam and reservoir is $10,650,000. The reservoir will inundate approximately 60 acres in total, including 8.8 acres of wetlands. In addition, the report indicated that installation of a $975.000 hydropower generation unit at the downstream end of the city's water supply pipeline could be economically advantageous. The hydropower unit is addressed as a separate project, but construction of both components is required if the total project is to be economically feasible. The report also noted that the feasibility of the project would depend on the successful transfer of Buffalo's existing 1933 water right filing for 1,640 acre-feet from Little Sourdough Creek to the dam site. This transfer was accomplished in 1990.

The process of permitting this facility began in the early summer of 1992. The arduous and expensive process of obtaining final permits was not completed for nearly 4 years. The Forest Service special use permit was issued on February 23, 1996, and the U.S. Army Corps of Engineers Section 404 permit was issued on March 5, 1996. During the course of the nearly 4-year long ordeal, nearly $1 million was spent in efforts directly related to obtaining the necessary federal permits.

The mitigation for the 8.8 acres of wetlands has cost in excess of $1 million. The primary reason the costs for mitigation to the City of Buffalo were so high is that the US Army Corps of Engineers required a 5:1 ratio for wetland mitigation. The 5:1 ratio is not a scientifically based figure, but rather an arbitrary figure developed by an individual within the agency. The City agreed to accept the ratio so that they might proceed with their project.

PACIFIC INSTITUTE

Research for People and the Planet

August 27, 2008

Honorable Members of the Select Committee on Energy Independence and Global Warming,

Thank you for the opportunity to testify about climate change and extreme events. Below, I have provided brief responses to your questions. If you would like additional information, please do not hesitate to contact me.

Thank you,
Heather

1. Assuredly, there will be environmental concerns associated with any new surface water storage projects. In your opinion, is it possible to address those issues and move forward with storage projects that will ultimately have broad support from a number of different stakeholders?

Yes, some new surface storage may ultimately prove to be cost-effective, environmentally acceptable, and politically feasible. However, it is important to examine all water supply and conservation options to choose those projects that provide the greatest benefits with the least social, economic, and environmental cost.

2. Have conservation efforts been effective in reducing water demand or have increases in population in the West negated the savings from conservation?

Conservation and efficiency improvements have led to a very large drop in total water use and in water use per person in the United States. In a few rapidly growing regions, population growth has absorbed much or all of the savings, but these savings have still mitigated the need for new more expensive supply.

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3. How do you see technology assisting adaptation efforts to climate change? For example, are you aware of any projects being developed right now that will help manage water supply and increase crop resiliency?

Many technologies offer advantages in both water savings and in climate adaptation. For example, better weather forecasting capability will allow water managers to adjust reservoir operations in response to changing weather conditions. Efficient irrigation methods can reduce evaporative losses (which will grow as the temperatures rise) and also help manage water scarcity overall. Many of these technologies make sense with or without climate change because of their economic and water savings potential.

4. Do you agree that any mandatory cap on greenhouse gas emissions must include rapidly developing countries, specifically China and India?

Any climate policy, to be effective in the long term, must ultimately include all carbon emitters, especially large ones. How to implement these is the subject of much policy, technical, and economic debate and we (the Pacific Institute) have no position on specific greenhouse gas reduction strategies or legislation.

5. Do you support nuclear energy as a source of carbon-free electrical generation?

All energy sources, including nuclear, must be considered in a comprehensive energy strategy aimed at reducing carbon. But nuclear has no special characteristics that should result in it receiving special subsidies or preferences over other non-carbon sources – thus, the decision about nuclear expansion must rely on economic, environmental, social, and political factors as well.

6. What can my home state of Missouri and the Midwest in general look forward to (in regards to extreme weather) in the coming decades as a result of increased temperatures due to climate change?

In general, climate change projections suggest that the Midwest can expect more extreme heat days. Changes in precipitation patterns remain uncertain, but there is potentially a greater risk of flooding along the Mississippi and Missouri Rivers. The Midwest is an important agricultural producer and changes in temperature and precipitation are projected to result in greater variability in crop production due to drought and heat stress. Please see Chapter 6 of the National Assessment Synthesis Team's report on climate change, "Potential Consequences of Climate Variability and Change for the Midwestern United States for more detailed information. Note that this report was completed in 2000 and should be updated to reflect the best available information. (http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewmidwest.htm).

7. We have all seen the devastation caused by Hurricane Katrina in New Orleans. Sometimes urban areas are more vulnerable to extreme weather events, due to the high density of people and structures. What can cities expect in terms of extreme weather?

One of the greatest concerns is a very significant increase in extreme heat events and heat-related illness and mortality in cities. As suggested by Hurricane Katrina and floods along the Mississippi R. and its tributaries in 2008, flooding remains a major concern as well.

8. How can cities – like my hometown of Kansas City, Missouri – prepare for an extreme weather event, in terms of evacuation plans and emergency shelters?

Make sure emergency planners and services stay current on climate science (perhaps through FEMA or NOAA) and on the kinds of risks that may result. In general, no new kinds of events are expected; rather, there is more likely to be an increase in the number and severity of emergencies that cities already plan for.

9. Since climate change has been linked to intense weather events, how can cities help to avoid incidents of extreme weather?

Avoiding extreme weather events requires reducing the risk of climate change through comprehensive greenhouse gas reductions worldwide. By reducing GHG emissions, cities can help mitigate climate change and thus reduce the likelihood and intensity of extreme events. Given that we have already committed to a certain degree of climate change as a result of past greenhouse gas emissions, some impacts will be unavoidable. To reduce the potential damage, cities must be prepared to deal with the potential impacts.

10. Would the increased farming – like the recent increase of biofuels – in this country have any effect on extreme weather events?

An increase in farming could alter the land surface characteristics, including the reflectance and evaporation. These changes could affect the energy balance and affect the local climate. The production of biofuels may have an indirect effect on extreme events through the reduction of fossil-based greenhouse gas emissions and subsequent mitigation of climate change.

11. What can Congress do to mitigate the effects of global warming, in an attempt to reduce the chances of extreme weather events?

In order to reduce the chances of extreme events, Congress should work to reduce greenhouse gas emissions.

12. Could you clarify your point with specific examples regarding the vulnerability of Midwest farming households to the variations in climate that you described in your testimony?

The Midwest is an important agricultural producer and changes in temperature and precipitation are projected to result in greater variability in crop production due to drought and heat stress. Please see Chapter 6 of the National Assessment Synthesis Team's report on climate change, "Potential Consequences of Climate Variability and Change for the Midwestern United States for more detailed information. Note that this report was completed in 2000 and should be updated to reflect the best available information. (http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewmidwest.htm).

13. In a warming world, we have been told that the conditions that favor summer heat waves will become more frequent. What are your thoughts on what we can do to protect those in our inner cities who are least capable of protecting themselves and are therefore more vulnerable to these type of conditions?

There are a number of ways to protect those in inner cities, particularly the most vulnerable. Cities could offer "cooling centers" for extreme heat events in community centers. They could also institute systematic warning systems for elderly and other populations at risk.

14. How much of the economic loss due to natural disasters is a result of extensive development on our coasts, such as Miami or New Orleans, and in other vulnerable regions?

This is an interesting question. It is unclear how much of the economic losses are related to where we build. But we do know that it is a combination of where we build, and how much we build there.

15. Do you support expanding dams as a way to store water? What can be done to counteract smaller snow packs and less spring runoff?

New or expanded dams may be necessary. But it is important to examine the reoperation of our existing systems first. Changing how we operate these systems - that is when we

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decide to fill and empty them - may provide the flexibility we need to adapt to climate change. In addition to dams, there are a number of other ways to adapt to a smaller snow pack and less spring runoff, such as developing recycled water projects, capturing storm water, recharging groundwater aquifers with excess flows, and implementing water conservation and efficiency improvements. It is important to examine all alternatives and implement the most cost-effective options first.

16. How do you propose that Congress prevent natural habitats from being developed? Are there already programs in place with this intention?

This is an interesting question but does not fall within the Institute's area of expertise.

17. Would your water conservation and efficiency recommendations be able to accommodate the rapid population growth that has been occurring in the West?

Yes, water conservation and efficiency efforts have allowed communities throughout the U.S., particularly in the West, to meet the needs of a growing population. But more needs to be done in all sectors (residential, commercial, industrial, and agriculture).

18. How do demographic changes, such as more or less people per household or whether dwellings are single family homes or apartment complexes, affect per capita water usage?

Great question. Increasing the number of people in a household would likely increase household use but reduce water use per person. Indoor water use is relatively linear per person, i.e., doubling the number of people would double the indoor water use. But outdoor use is independent of household size. So if two people live in a home and indoor water use averages 50 gallons per person, then the household indoor water use is 100 gallons per day. If outdoor water use is 100 gallons per day, then the total household water use is 200 gallons per day, with each person using 100 gallons per day. If we double the number of people, then indoor water use would be 200 gallons per day and outdoor water use would remain at about 100 gallons per day. With four people, total

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household water use would be 300 gallons per day, or about 75 gallons per person per day.

Multi-family and high-density SF homes tend to have lower water use per person because outdoor water use tends to be lower.

19. Have more households begun to incorporate grey-water systems? What is the largest barrier to increasing the number of systems?

Grey-water systems have become more common, but they remain a very small component of the water supply portfolio. While there are a number of barriers, the largest barrier is that many local ordinances prohibit the use of grey-water systems.

20. Do you support increasing the use of desalination water plants for the West Coast?

Seawater desalination provides a number of important benefits. It provides a reliable, high-quality water source that is independent of weather conditions. However, it remains among the most expensive supply sources. While the cost has fallen in recent years, a countertrend is emerging. Many of the bids on the newest plants are more expensive than those bid just a few years ago because of rising capital and energy costs. Seawater desalination is also among the most energy intensive options available, which results in greenhouse gas emissions and makes the cost vulnerable to short- and long-term energy price trends. Additionally, the intake of large quantities of seawater and discharge of super-salty brine may pose environmental damage on the marine ecosystem. Seawater desalination should be compared with all other water-supply and demand management options to identify those projects that achieve the greatest benefit at the lowest social, economic, and environmental cost. The Pacific Institute has completed a comprehensive analysis on seawater desalination that can be downloaded from our website at http://www.pacinst.org/reports/desalination/index.htm.

21. How many entities, such as cities or water districts, currently use "conjunctive use" water management?

Surface water and groundwater are hydrologically linked. "Conjunctive use" takes advantage of this connection by storing excess surface water, including storm water and recycled water, in groundwater aquifers for later use. This option, already being implemented in parts of the West, has a number of important benefits, including reducing the risk of floods, improving water-supply reliability and flexibility, reducing land subsidence, and minimizing the impacts of urban runoff on local streams and the marine environment. I have not seen an analysis of the number of entities currently using this approach but its use is expanding. In Orange County, California, for example, the water district is recharging the groundwater aquifer with highly treated recycled water. Water agencies in In Kern County, located in the southern part of the San Joaquin Valley, have built large spreading basins to recharge groundwater with water during wet years.

22. How much energy is saved by implementing "conjunctive use" water management?

That is difficult to say without examining a specific system. In some cases, energy use may increase whereas in others in may decrease. It largely depends on what sources are being replaced.

23. Does "conjunctive use" water management actually improve the water quality of aquifers?

It can. Orange County is explicitly improving water quality in the aquifer by recharging it with highly-treated recycled water.

24. How would streamlining regulatory hurdles assist in developing water management policy? How much do regulations add to the cost of developing infrastructure?

Biggest barriers to water infrastructure is not regulation, it is cost and public opinion.

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THE SELECT COMMITTEE ON
ENERGY INDEPENDENCE AND GLOBAL WARMING

Dear Ms. Licata:
Following your appearance in front of the Select Committee on Energy Independence and Global Warming, members of the committee submitted additional questions for your attention. I have attached the document with those questions to this email. Please respond at your earliest convenience, or within 2 weeks. Responses may be submitted in electronic form, at aliya.brodsky@mail.house.gov. Please call with any questions or concerns.

Thank you,
Ali Brodsky

Ali Brodsky
Chief Clerk
Select Committee on Energy Independence and Global Warming
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1. Assuredly, there will be environmental concerns associated with any new surface water storage projects. In your opinion, is it possible to address those issues and move forward with storage projects that will ultimately have broad support from a number of different stakeholders?

   New storage infrastructure that adequately meets demand will ultimately enjoy broad public support. However, environmental concerns will need to be fully addressed before any proposed infrastructure can be built. Additionally, building new infrastructure will require significant lead time for planning, environmental review and permitting.

2. Have conservation efforts been effective in reducing water demand or have increases in population in the West negated the savings from conservation?

   New York City's water conservation program has yielded a decline in aggregate annual water consumption even as our population has grown. However, current conservation strategies will likely require revision in order to address more severe heatwaves and droughts.

   In the western United States, a diminishing water supply will compound the challenge of population growth. In many western cities, population growth has abrogated savings from conservation measures; in some instances, current supplies are only just keeping pace with demand. However, in other instances, conservation strategies have bought time for exploration of both more intensive conservation programs and the development of non-potable sources.

3. How do you see technology assisting adaptation efforts to climate change? For example, are you aware of any projects being developed right now that will help manage water supply and increase crop resiliency?

Managing scarce water resources will require broader application of existing water conservation and reuse methodologies, as well as emerging technologies such as graywater harvesting and potable reuse. In January, California's Orange County Water District opened an innovative potable reuse facility that purifies wastewater for re-introduction to the region's supply aquifer. In 2010, the City of Aurora, CO, will open a water purification facility drawing drinking water from the South Platte river just downstream from the Denver Metro Wastewater Reclamation District's plant.

Advances in genetic engineering may hold the key to developing crops that are resistant to drought, pests and disease. A research team at University of California-Davis is currently field testing a number of crops that have been genetically modified to survive drought events.

4. Do you agree that any mandatory cap on greenhouse gas emissions must include rapidly developing countries, specifically China and India?

If greenhouse gas emission reduction efforts are to be effective, the United States and other developed nations must be wholly committed, and rapidly growing economies must be fully engaged.

5. Do you support nuclear energy as a source of carbon-free electrical generation?

Although nuclear power generation produces no CO_2 emissions, the mining and transportation of nuclear fuel has a measurable carbon footprint. It would also require years for prospective plant operators to successfully navigate the current permitting and review process. Lastly, the hazards posed by radioactive waste products, their extremely long lifetime, and the continuing absence of a broadly accepted disposal methodology make nuclear power prohibitive as a source of new energy.

6. What can my home state of Missouri and the Midwest in general look forward to (in regards to extreme weather) in the coming decades as a result of increased temperatures due to climate change?

Findings released by the United States Global Change Research Program indicate that Midwest states can expect climate conditions similar to those observed in the southern central plains today.

7. We have all seen the devastation caused by Hurricane Katrina in New Orleans. Sometimes urban areas are more vulnerable to extreme weather events, due to the high density of people and structures. What can cities expect in terms of extreme weather?

Cities across the country can expect an increased incidence of heatwaves. Additionally, as warmer temperatures increase evaporation of surface water, cities and regions can expect both more severe drought events and more frequent and more intense rainfall and flooding. Finally, cities on the Gulf coast and on the eastern seaboard should expect an increased incidence of tropical storms.

8. How can cities – like my hometown of Kansas City, Missouri – prepare for an extreme weather event, in terms of evacuation plans and emergency shelters?

Generally, cities should develop tiered evacuation plans tailored to event severity, and ensure that shelters are adequate and located outside of floodplains. Cities must also make 'cooling centers' available to adequately meet the needs of low-income and elderly citizens during heatwaves.

9. Since climate change has been linked to intense weather events, how can cities help to avoid incidents of extreme weather?

Climate change can no longer be avoided, and cities must take steps to prepare for the full range of projected impacts. The only means toward reducing the severity of those impacts is to work for the reduction of greenhouse gas emissions at the local, national and global level. Beyond reducing their own greenhouse gas emissions, cities must advocate for effective emissions reduction policies both nationally and internationally.

10. Would the increased farming – like the recent increase of biofuels – in this country have any effect on extreme weather events?

Increased agricultural demand for water resources may worsen the strain on limited water supplies during drought events.

11. What can Congress do to mitigate the effects of global warming, in an attempt to reduce the chances of extreme weather events?

Congress must pass legislation to reduce the national aggregate carbon output, and support the adoption of strict emissions criteria at the international level. Congress must also pass legislation to incentivize the large-scale implementation of zero-carbon electric power generation technologies, such as wind and solar.

12. Could you clarify your point with specific examples regarding the vulnerability of Midwest farming households to the variations in climate that you described in your testimony?

I believe this question addresses the testimony delivered by Family Farm Alliance Executive Director Dan Keppen,

13. In a warming world, we have been told that the conditions that favor summer heat waves will become more frequent. What are your thoughts on what we can do to protect those in our inner cities who are least capable of protecting themselves and are therefore more vulnerable to these type of conditions?

Heatwaves pose a particular challenge to cities due to the 'urban heat-island effect,' in which building materials trap solar heating and prevent it from dissipating. During heat emergencies, 'cooling centers' setup in schools and other air-conditioned public buildings represent the sole source of relief for many city residents. From a planning perspective, the large-scale implementation of urban 'green roofs,' similar to the roof installation atop Chicago's City Hall, may serve to mitigate the urban heat island effect. However, increased outreach to affected populations will remain essential to reducing the incidence of heat-related fatalities.

14. Currently, where does New York City get their water supply from? You say in your testimony that New York City's unfiltered drinking water system is threatened by global warming. In a worst case scenario, do your adaptation plans include building water filtration plants for New York City's future water supply?

90% of New York City's water supply is sourced from our upstate watersheds and currently requires no filtration. However, an increased incidence of intense rainfall events will lead to increased runoff and increased reservoir turbidity. NYCDEP is currently building a filtration plant to process water sourced from our downstate watershed, but filtering the remaining 90% of our water supply would be extremely costly, as well as energy intensive.

15. Have you encountered any difficulties with the state legislature in the city's attempt to implement PlaNYC?

The state legislature has not to this point been involved in implementing those aspects of PlaNYC 2030 that relate to water supply and stormwater management.

16. You note the need for "adequate funding for ongoing research in the short term." What projects is this research focusing on and how much funding is the city appropriating? Do you anticipate receiving federal funding for these projects?

There is currently a great deal of information available on the potential effects of climate change on water resources, but very little in the way of quantified impact assessments for water resources infrastructure and operations. This type of data is essential for effective water resource modeling and planning.

This month, New York City received a grant of $350,000 from the Rockefeller Foundation supporting the participation of Columbia University's Center for Climate Research (CCSR) in the City's new Climate Change Adaptation Task Force. NYCDEP is also working with our partners in the Water Utility Climate Alliance to develop a funding strategy for our own research programs. Our first project will assess existing methodologies that support decision-making under uncertainty.

We believe that adequate federal funding will be integral to the development of more refined estimates of key indicator variables, particularly at the regional level. There are a number of research teams focusing on this challenge that are currently funded under the NOAA Regional Integrated Science and Assessment program, but the program must be expanded to fund teams in the Northeast and Midwest. Funding will also be necessary to support basic data collection and maintenance. In particular, funding cuts to stream gauging, weather stations, snow-tel sites, and ocean monitoring programs must be restored.

17. What partnerships has New York City developed with upstate New York to properly manage water supplies?

NYCDEP has established relationships with a number of upstate governments and non-governmental organizations including the Watershed Agricultural Council and the Catskill Watershed Corporation that promote sustainable farming and conservation practices. We have also worked with the multi-state Delaware River Basin Commission to fund research evaluating a number of proposed reservoir release programs.

18. Is the city already constructing more resilient infrastructure? If you are, is this directly due to possible threats from a changing climate or is this simply a good practice policy that the city follows?

New York City's new Climate Change Adaptation Task Force constitutes a comprehensive infrastructure assessment and adaptation initiative that will help city departments to develop tailored adaptation strategies. We at NYCDEP are also currently reviewing our capital program budget with the aim of prioritizing capital projects that advance climate change adaptation goals.

19. In your testimony you speak a great deal regarding adaptation strategies. Are you suggesting that adaptation strategies are a more cost effective option than mitigation strategies? Does the city conduct cost-benefit analysis when considering policies with broad implications?

Although mitigation remains essential to ameliorating the anticipated impacts of climate change, these impacts can no longer be avoided altogether. It is therefore essential that water providers serving large metropolitan regions have detailed adaptation strategies in-place. The research project we are currently sponsoring with our partners in the Water Utility Climate Alliance will help us to identify the most cost-effective means toward ensuring no-regret outcomes.