EXECUTIVE SUMMARY

Globally, we face significant economic, social, and environmental risks as we confront the challenges associated with climate change. The body of scientific evidence confirms with a high degree of certainty that human activities in the form of increased concentrations of greenhouse gases (GHGs) since the beginning of the Industrial Revolution, changes in land use, and other factors are the primary cause for the warming that the planet has experienced, especially in recent decades.

Is there a debate within the scientific community with regard to observed changes in climate and human activities as the principal causal factor? The short answer here is "no", at least certainly not among climate scientists—that is, those scientists who have actual expertise in the study of climate and climate change. For more than a decade, there has been broad and overwhelming consensus within the climate science community that the human-induced effects on climate change are both very real and very large. The debate in 2014 is restricted to precisely how these changes will play out and what actions we will need to take to adapt to and mitigate the effects of these changes.

The magnitude and rapidity of the projected changes in climate are unprecedented. The implications of these changes for the health of our planet, and the legacy we will leave to our children, our grandchildren and future generations are of vital concern. Therefore, it is imperative that we develop strategies now to adapt to the multitude of changes we are experiencing and will continue to experience in our climate. This process of adaptation must begin at the local level, where these changes are being observed and their impacts felt. However, global agreements on the reduction of GHG emissions are a critical part of the solution in terms of mitigating as much future warming as possible.

The approach taken in this report is to review the voluminous scientific literature on the subject and interpret—given time and resource constraints—our current understanding of the science of climate change and the implications of projections of climate change for Nebraska. The goal of this report is to inform policy makers, natural resource managers, and the public about 1) the state of the science on climate change, 2) current projections for ongoing changes over the twenty-first century, 3) current and potential future impacts, and 4) the management and policy implications of these changes. Hopefully, this report will lead to a higher degree of awareness and the initiation of timely and appropriate strategic actions that enable Nebraskans to prepare for and adapt to current and future changes in our climate.

The Earth's Climate System

Changes to the components of the earth's climate system are caused by changes in forcings, or external factors, that may be either positive (lead to warming) or negative (lead to cooling). Climate forcings can be classified as natural or anthropogenic—that is, human-induced. Examples of natural forcings include solar variability and volcanic eruptions, while anthropogenic forcings include GHG emissions, aerosol production, and land-use changes.

Changes in natural forcings have always occurred and continue today, having produced climate change and variability throughout the earth's history; only recently have anthropogenic forcings become large enough to significantly affect the climate system.

Nearly all the energy driving the climate system comes from the sun. Although solar output varies over time and has led to climate changes during the earth's geologic history, changes in solar radiation cannot account for the warming observed over the past 30 years, during which accurate measurements of solar output have been made. In the absence of solar forcing, the largest climate forcing is due to changes in atmospheric composition, particularly of GHGs and aerosols. Global climate models cannot reproduce the recent observed warming without including anthropogenic forcings (particularly GHG emissions).

Evidence that human activities influence the global climate system continues to accumulate because of an increased understanding of the climate system and its response to natural and anthropogenic factors, more and better observations, and improved climate models. In fact, in their latest assessment report, the Intergovernmental Panel on Climate Change (IPCC) now states with 95% confidence that human influence is the main cause of the observed warming in the atmosphere and oceans and other indicators of climate change and that continued emissions of GHGs will cause further warming and changes in these components of the climate system. Before the large-scale use of fossil fuels for energy (starting during the Industrial Revolution), the concentrations of the major GHGs were remarkably constant during human history. Since then, the concentration of these gases has risen—slowly at first, then more rapidly since the middle of the twentieth century. Furthermore, scientists can say with very high confidence that the rate of increase of these gases is unprecedented in the last 22,000 years—and with high confidence over the last ~800,000 years.

Evidence for a Changing Climate

Multiple lines of evidence show that the earth's climate has changed on global, regional, and local scales. Scientists from around the world have collected this evidence from weather stations, satellites, buoys, and other observational networks. When taken together, the evidence clearly shows that our planet is warming. However, temperature change represents only one aspect of a changing climate. Changes in rainfall, increased melting of snow and ice, rising sea levels, and increasing sea surface temperatures are only a few of the key indicators of a changing climate.

Although the globe as a whole is getting warmer, observations show that changes in climate have not been uniform in space and time. Some areas have cooled while others have warmed, a reflection of normal climate variability and differing controls on regional climate. Likewise, some areas have experienced increased droughts while others have had more floods. Changes in Nebraska's climate are occurring within the context of these global and regional changes.

Past and Projected Changes in Nebraska's Climate

Nebraska has experienced an overall warming of about 1°F since 1895. When this is separated into daytime highs and nighttime lows, we find that the trend in low temperatures is greater than the trend in high temperatures, both of which show an overall warming. These trends are consistent with the changes experienced across the Plains states in general, which show a warming that is highest in winter and spring and a greater warming for the nighttime lows than for daytime highs. By far, the vast majority of this warming has occurred during the winter months, with minimum temperatures rising 2.0-4.0°F per century and maximum temperature increases of 1.0-2.5°F per century. Summer minimum temperatures have shown an increase of 0.5-1.0°F per century at most locations, but maximum temperature trends generally range from -0.5 to +0.5°F per century. Unlike temperature, however, there is no discernable trend in mean annual precipitation in Nebraska. Since 1895, the length of the frost-free season has increased by 5 to 25 days across Nebraska, and on average statewide by more than one week. The length of the frost-free season will continue to increase in future decades.

Projected temperature changes for Nebraska range from an increase of 4-5°F (low emission scenarios) to 8-9°F (high emission scenarios) by the last quarter of the twenty-first century (2071-2099). This range is based on our current understanding of the climate system under a variety of future emissions scenarios. The range of temperature projections emphasizes the fact that the largest uncertainty in projecting climate change beyond the next few decades is the level of heat-trapping gas emissions that will continue to be emitted into the atmosphere and not because of model uncertainty.

Under both low and high emissions scenarios, the number of high temperature stress days over 100°F is projected to increase substantially in Nebraska and the Great Plains region. By mid-century (2041-2070), this increase for Nebraska would equate to experiencing typical summer temperatures equivalent to those experienced during the 2012 drought and heat wave. The number of warm nights, defined as the number of nights with the minimum temperature remaining above 80°F for the southern Plains and above 60°F for the northern Plains, is expected to increase dramatically. For Nebraska, the number of warm nights is expected to increase by an additional 20-25 nights for the low emissions scenario and 25-40 nights for the high emissions scenario.

With the projected increase in global and regional temperatures, there has been an increase in heat wave events occurring around the world. This can be demonstrated by the ratio of maximum temperature records being broken in comparison to the number of minimum temperature records being broken. The current ratio across the United States is approximately 2 to 1, providing further evidence of a significant warming trend.

Current trends for increased precipitation in the northern Great Plains are projected to become even more pronounced, while the southern Great Plains will continue to become drier by mid-century and later. The greatest increases for the northern Great Plains states so far have been in North and South Dakota, eastern Montana, and most of eastern Nebraska. Little change in precipitation in the winter and spring months is expected for Nebraska. Any increases in the summer and fall months are expected to be minimal and precipitation may be reduced during

the summer months in the state. An increase in the percentage of average annual precipitation falling in heavy rainfall events has been observed for portions of the northern Great Plains states, including eastern Nebraska, and the Midwest. This trend is expected to continue in the decades ahead. Flood magnitude has been increasing because of the increase in heavy precipitation events. Soil moisture is projected to decrease by 5-10% by the end of the century, if the high emissions scenario ensues.

A major concern for Nebraska and other central Great Plains states is the current and continued large projected reduction in snowpack for the central and northern Rocky Mountains. This is due to both a reduction in overall precipitation (rain and snow) and warmer conditions, meaning more rain and less snow, even in winter. Flows in the Platte and Missouri rivers during the summer months critically depend on the slow release of water as the snowpack melts. These summer flows could be greatly reduced in coming years.

Human activities local to Nebraska can also be important in terms of how they influence the climate at the microclimatic level. In particular, the advent of large-scale irrigation in Nebraska since the 1960s has kept the summertime climate in Nebraska cooler and wetter than it otherwise would have been. However, if reduced water availability curtails irrigation in the state, then the microclimatic effects of irrigation will be lessened in the future, exacerbating the effects of anthropogenic climate change.

Drought is a critical issue for Nebraska. This was demonstrated clearly during 2012, which was the driest and hottest year for the state based on the climatological record going back to 1895. Although the long-term climatological record does not yet show any trends in drought frequency or severity from a national perspective, there is some evidence of more frequent and severe droughts recently in the western and southwestern United States, respectively. Looking ahead, however, the expectation is that drought frequency and severity in Nebraska would increase—particularly during the summer months—because of the combination of increasing temperatures and the increased seasonal variability in precipitation that is likely to occur. Modeling studies show that drought, as indicated by the commonly used Palmer Drought Severity Index (PDSI), is expected to increase in the future. The PDSI uses temperature and precipitation data to estimate relative dryness. Temperature increases could result in widespread drying over the United States in the latter half of the twenty-first century, with severe drought being the new climate normal in parts of the central and western United States.

Implications of Projected Climate Changes in Nebraska

Current and projected changes in temperature will have positive benefits for some and negative consequences for others, typically referred to as winners and losers. However, the changes in climate currently being observed extend well beyond temperature and include changes in precipitation amounts, seasonal distribution, intensity, and form (snow versus rain). Changes in the observed frequency and intensity of extreme events are of serious concern today and for the future because of the economic, social, and environmental costs associated

with responding to, recovering from, and preparing for these extreme events in the near and longer term.

To address the implications of observed and projected changes in climate on particular sectors, experts with knowledge of, and practical experience in, the principal sectors of importance to Nebraska were invited to prepare commentaries for this report. The basis for these commentaries was the information contained in the recently released National Climate Assessment Report. The key sectors chosen for inclusion in the Nebraska climate change report were water resources; energy supply and use; agriculture; forests; human health; ecosystems; urban systems, infrastructure and vulnerability; and rural communities. An assessment of the importance of observed and projected changes in climate for the insurance industry, both globally and locally, was also completed. These commentaries raise serious concerns about how the projected changes in climate will impact Nebraska, and they provide a starting point for discussions about the actions that we should take to adapt to the changes in each sector.

It is critically important to point out that the implications of and potential impacts associated with observed and projected changes in climate will be closely associated with the management practices employed in these specific sectors. For example, the impacts of projected changes in climate on the productivity of a specific farm will be dependent on the ability of that producer to adapt to these changes as they occur, and the producer's access to new and innovative technologies that facilitate the adaptation process. Early adapters will be better able to cope with changes as they occur.

This report documents many of the key challenges that Nebraska will face as a result of climate change. Imbedded in each of these challenges are opportunities. A key takeaway message from the report is that, with this knowledge in hand, we can identify actions that need to be implemented to avoid or reduce the deleterious effects of climate change in Nebraska. Action now is preferable and more cost effective than reaction later.