Nebraska's Natural Resources Districts:

An Assessment of a Large-Scale Locally Controlled Water Governance Framework

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March 2015

Water for Food
ROBERT B. DAUGHERTY INSTITUTE
at the University of Nebraska

Policy Report 1 of the Robert B. Daugherty Water for Food Institute

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Robert B. Daugherty Water for Food Institute

The University of Nebraska founded the Robert B. Daugherty Water for Food Institute (DWFI) in 2010 to address the global challenge of achieving food security with less stress on water resources through improved water management in agricultural and food systems. The institute is committed to ensuring a water- and food-secure world while maintaining the use of water for other vital human and environmental needs.

The institute's approach is to extend the University of Nebraska's expertise through strong partnerships with other universities and public and private sector organizations. The DWFI develops research, education and engagement programs in a focused effort to increase food security while ensuring the sustainability of water resources and agricultural systems. The institute works locally and internationally, bridging the water and agriculture communities and worlds of small- and large-holder farmers to deliver innovative solutions to this complex global challenge.

See the DWFI website for more information at http://waterforfood.nebraska.edu/ and stay informed through the institute's Facebook page at facebook.com/waterforfoodinstitute, and on Twitter @water4food.

DWFI Policy and Technical Report Series

This policy report is a product of the institute's efforts to share scientific and policy research with stakeholders (researchers, students, farmers, ranchers, allied organizations, policy makers and other leaders) to further the institute's mission to have a lasting and significant impact on improving food security with less stress on water resources. It is the inaugural publication in a series that will provide an in-depth, peer-reviewed report of issues involved in water and food security, including closing water and agricultural productivity gaps, ground water management, irrigated agriculture, freshwater and agricultural ecosystems, and public health.

Dedication

This work is dedicated to all the current and past members of the local Natural Resources District boards and irrigation district boards. Without the dedication of these men and women, who donate their time and talents, there would be no hope for the success of the local control of water governance in Nebraska. In particular, the authors acknowledge Dean Rasmussen, Dick Mercer, Don Kavan, Jim Nelson and Ron Sabatka, who have served as NRD board members since the NRDs were founded.

Acknowledgments

The authors thank Robert Diffendal for his meticulous editing of the manuscript, and Les Howard for his creation and revisions of figures originally published in other reports by the University of Nebraska-Lincoln, Conservation and Survey Divisions. Without the work of the many scientists from the Conservation and Survey Division, this report, as well as much of the work accomplished by Nebraska's Natural Resources Districts, would not have been possible. The authors also thank Jim Barr and his team of interviewers for creating the Natural Resources District History Project. The advice and helpful discussion from Jim Cook, Marty Link and Karen Griffin are also greatly appreciated.
Jennifer Swanson and Dean Edson from the Nebraska Association of Natural Resources Districts, as well as all the managers from the Natural Resources Districts across the state, were essential for the development of Tables 3 and 4, summarizing the rules of all the Natural Resources Districts across the state. A special thanks is also given to John Turnbull and Rod DeBuhr, from the Upper Big Blue Natural Resources District; to Ron Bishop, Duane Woodward, Lyndon Vogt and Sandy Noecker from the Central Platte Natural Resources District; and to Glenn Johnson and Paul Zillig from the Lower Platte South Natural Resources District, all of whom were critical to the development of the descriptions and figures in the Appendices.

The authors extend their appreciation to those who have reviewed the manuscript and particularly to Nick Brozović and Molly Nance from the Robert B. Daugherty Water for Food Institute at the University of Nebraska who were essential to finalizing the edits and preparing the document for final publication.

Foreword

The use of groundwater for agricultural purposes has increased significantly around the world in recent years, bringing with it important gains in yields and incomes. At the same time, however, this growth has led to rising concerns about the long-term sustainability of the resource. Water tables are dropping in many locations, largely as a result of inadequate governance that fails to ensure that groundwater withdrawals are below rates of aquifer recharge.

Against this background, good groundwater governance increasingly is being recognized as vital to ensure that the quantity and quality of the resource continues to be available to sustain agricultural systems for future generations. If properly managed, groundwater resources can play a key role in ensuring food and water security, especially in the context of a changing climate. But without good institutions, it is unlikely that societies will be able to maintain the groundwater supplies needed to meet human and environmental needs over the long-term.

Despite the recognized need for good groundwater governance, there are few real success stories in this area, particularly of effective governance frameworks covering large areas. In this context, the system of Natural Resources Districts (NRDs) in Nebraska is of significant interest. The NRD governance system is unique. The State's 23 NRDs, organized around river basin boundaries, are locally elected governing boards with taxing powers and authority over the regulation and management of a wide range of natural resources, including groundwater. Established in 1972, about the same time as rapid expansion of irrigation in the state, they have had the major responsibility of governing the vast groundwater resources that are so vital to Nebraska's economy. As this report shows, the NRD governance framework has most of the characteristics that current research is indicating are key to successful water governance today and that will be needed to meet the challenges of tomorrow.

The significance of the governing role of the NRDs is hard to overstate. The NRD framework operates at the center of one of the world's most important food producing regions and at a significant scale, in both land and water resource terms. There is more irrigated agriculture in Nebraska than in any other U.S. state, and more than most of the world's countries. And the volume of water resources held in storage in the aquifer in Nebraska is vast – about twenty times the amount that Egypt's Aswan Dam can store at full capacity.

Most of Nebraska's groundwater comes from the expansive High Plains aquifer system, which includes the Ogallala Aquifer and covers several states from Nebraska though Texas. As is well known, the southern portions of the aquifer have seen significant drops in the water table since intensive irrigation began over 70 years ago. Less well known is the fact that, on average, during this period Nebraska has lost less than 0.5 percent of its historic water levels, even in the face of significant increases in total area irrigated. And although groundwater has declined in some parts of the state, Nebraska has been able to slow or even reverse these declines. While many factors have contributed to these positive outcomes, including the fact that there is plentiful recharge of the aquifer in the sandy soils of Nebraska's Sandhills, there is little doubt that Nebraska's decision in 1972 to establish the NRDs has played a major role. The value of Nebraska's ability to conserve its groundwater resources and thus to irrigate effectively even when rainfall and surface waters are in short supply became clear when Nebraska was able to draw on its groundwater reserves to achieve significant agricultural production in 2012 despite that year's severe drought, the worst in almost 50 years.

However, despite the obvious significance of the NRDs, there is little existing literature on the NRDs and few detailed critiques of the NRDs available to international audiences. This is particularly surprising given the extensive literature on other models of water governance, such as the Murray

Darling River Basin Authority in Australia or the Water Tribunals of the Valencia region of Spain (both of which are of a smaller scale in terms of irrigated area and economic impact). Moreover, the NRD governance system has the characteristics that many believe will be necessary to provide the flexibility and adaptive capacity needed to meet the challenges of global climate change and other uncertainties that the world faces in the 21st century.

It is against this background that the Robert B. Daugherty Water for Food Institute (DWFI) at the University of Nebraska has decided to focus its first policy report on the development and characteristics of the Nebraska Natural Resources Districts. The authors, Ann Bleed and Christina Hoffman Babbitt, are uniquely qualified to take on this challenge and bring an important perspective to bear on the subject. Bleed, an adjunct professor at the University of Nebraska-Lincoln and Faculty Fellow of the DWFI, is a board director of one of the NRDs and served the Nebraska Department of Natural Resources from 1988 and 2008 as the state hydrologist and finally as director of the department, during which period she worked very closely with all of the NRDs. Hoffman Babbitt has analyzed the NRDs in great detail as part of her doctoral dissertation, gaining an in-depth understanding of how Nebraska's water management system works in practice. We are grateful to Drs. Bleed and Hoffman Babbitt for their diligence and hard work in preparing this report. We also wish to acknowledge with thanks the very helpful report reviews received from Professor J. David Aiken of the Department of Agricultural Economics at the University of Nebraska-Lincoln, and Professor Peter Rogers, a faculty member at the School of Engineering and Applied Sciences at Harvard University and a member of the Daugherty Institute's International Advisory Panel.

To make the information contained in this policy report more readily available to policy makers, the DWFI will issue a complementary policy brief as a summary on the Nebraska NRD system. We are

further working with the Nebraska State Historical Society and the Nebraska Association of Resources Districts on an NRD oral history project, which includes more than eighty 45-minute oral histories – spanning former and current staff and leadership of all 23 NRDs, creating the most comprehensive source of information on the formation and early years of the NRDs. This report includes several references to the oral history project, which will be accessible to readers later this year online, providing an easy-to-navigate and visually appealing interface to the oral histories and related content.

This policy brief focuses narrowly on the NRDs and does not attempt to address the broader question of where else a governance system similar to that of the NRDs might be applicable. Our view, however, is that the NRD governance model is clearly relevant to other parts of the world, and we hope this report will stimulate further research and analysis on this hugely important topic. While the exact details of the NRD framework are unlikely to be replicable elsewhere, especially in those parts of the world with vastly different traditions of civic participation and/or levels of production and income, there are undoubtedly many principles embodied in the NRDs that would be applicable elsewhere.

Moreover, an understanding of how the Nebraska system works and how it came about will surely provide some guidance on ways to establish good groundwater governance in other contexts. By outlining Nebraska's overall legal and institutional framework, as well as the historical evolution of the NRDs, we hope the report will help other regions in the world find a way to evolve water governance systems that work in their own contexts.

The DWFI carries out research and policy analysis on food and water security in Nebraska and other parts of the world, with a focus on subject areas, such as groundwater governance, that are significant both locally and globally. This is the first in a series of reports we intend to produce to facilitate a better worldwide understanding water for food policy issues for scholars, researchers, policy makers and others. The report content is dynamic and we welcome your feedback to help us shape future revisions.

Nicholas Brozović
Director of Policy

Roberto Lenton
Founding Executive Director and
Robert B. Daugherty Chair

Preface

In 1972 the State of Nebraska created the Natural Resources Districts (NRDs) to consolidate a multitude of single-purpose local natural resource districts into a more comprehensive, holistic, and efficient natural resources governance system. While consolidation and efficiency was important, so was the concept of maintaining local control. Thus, Nebraska rejected the governance framework of a single top-down state agency, preferring to create NRDs that are each governed by a locally elected board.

The locally elected governing boards of the NRDs were given broad authorities over many of the state's natural resources, including groundwater. Such a governance structure was, and to a large extent still is, experimental and unique.

Giving the authority to manage and regulate groundwater to locally elected boards was not an insignificant decision. Today 85% of Nebraska's irrigated acres are irrigated with groundwater. The state has more irrigated acres than any other state in the United States and, by far, the most irrigated acres per capita in the world. Has this experiment been successful? Is this governance system robust? Will Nebraska's NRDs be able to meet the challenges of the future, including the uncertainties of climate change? This report tries to provide some answers to these questions.

Ann Bleed
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I. Introduction

A. Background and Purposes of the Report

"It was the hope and dream of many individuals and groups that someday Nebraska would have a functional vehicle at the local level with not only the authority, but also the ability, to achieve the coordination and comprehensive management of the state's land and water resources. This dream has now become a reality…The Natural Resources District Concept." — Hazel Jenkins, Nebraska Natural Resources Commission, 1975.

Hazel Jenkins[1], who started her long career with the Nebraska Soil and Water Commission (which later became the Nebraska Natural Resources Commission) in 1949, expressed the above sentiment in 1975, shortly after Nebraska's Natural Resources Districts (NRDs) were established (Figure 1). The dream was big, comprehensive, risky and controversial. No other state in the U.S. had delegated so much authority over a state's natural resources to locally controlled governance. Today, the NRD system is still unique, the only such system in the U.S. (Edson, 2005), and perhaps the world. Has this experiment with a large-scale local-control water governance system achieved the dreams of its founders? Could this unique governance framework be considered a possible robust model of water governance in other settings? Can Nebraska's NRD water governance model provide the flexibility and resilience that Nebraska's citizens will need to meet the state's water demands in the 21st century? With more than 40 years of NRD experience, it is time for researchers to try to answer some of these questions.

[1] Hazel Jenkins was a secretary and stenographer for the Soil Conservation Committee, which organized the State's Soil Conservation Districts in the 1950s. For more than 40 years she continued this work, as the committee became the Nebraska Soil and Water Commission, and later the Nebraska Natural Resources Commission. Hazel Jenkins was not only a very skilled secretary and stenographer, but she also acted as an administrative assistant and traveled extensively throughout Nebraska as she worked with more than 80 Soil and Water Conservation District offices. She was very familiar with the commission's programs and the activities that resulted in the legislation that created the NRDs.

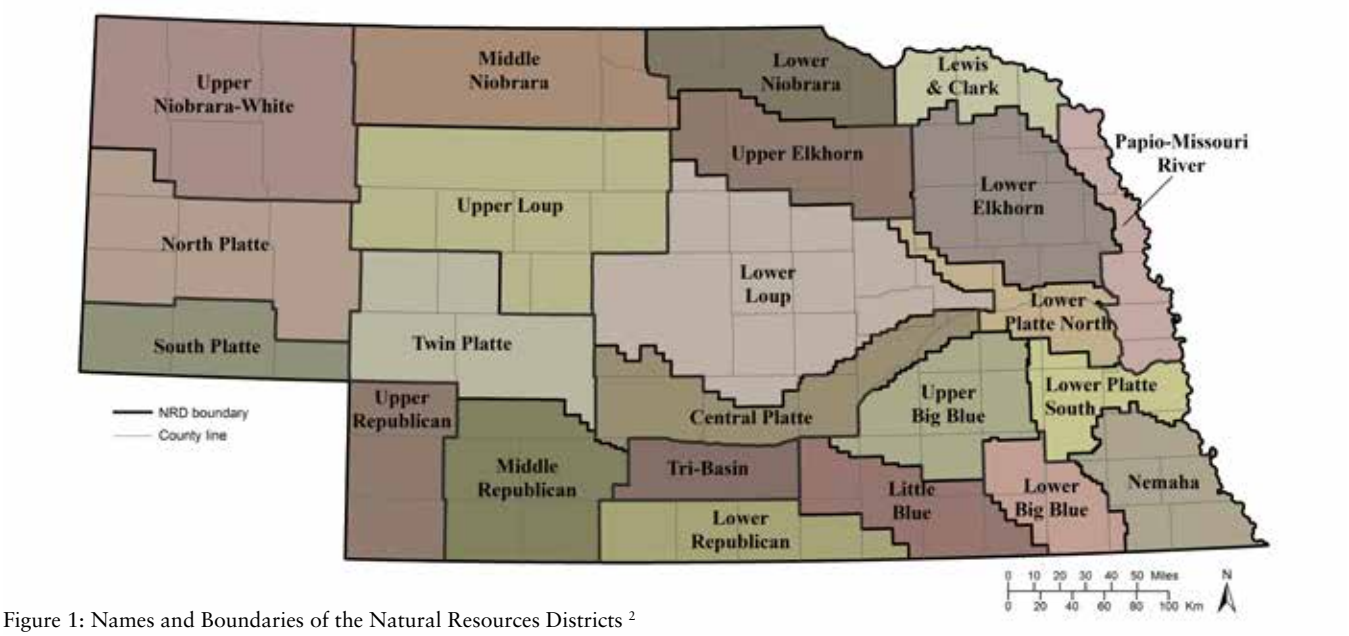

Figure 1: Names and Boundaries of the Natural Resources Districts [2]

The question of how to govern the management and use of the earth's water supplies is critically important, especially as the 21st century matures. As we struggle to meet the world's growing demands for food, we have come to realize the importance of maintaining the availability of a good quality water supply for food production, as well as for domestic and industrial uses, energy production, and maintaining ecosystems that provide other important services upon which human society depends. However, demands for water already exceed the available supplies and have created water stress and scarcity for large segments of the world's populations. As population growth and demands for more water and energy increase, water scarcity will also increase, which could put us beyond the limits for sustaining life on earth as we know it (Vorosmarty et al. 2000, Rockstrom 2009, Rockstrom et al. 2009, Iceland 2013).

We have also realized that the very nature of water as a natural resource, particularly the nature of groundwater, makes water a particularly difficult resource to manage. In addition, agriculture as we know it today developed during the Holocene, the relatively stable climatic period of the last 10,000 years (Hansen, 2009). Today, however, we face the specter of rapid climate changes, and can no longer assume that the water supplies we have relied on in the past will be available in the future (Milly et al. 2008; Mellilo et al. 2014). Finally, we have learned that without good water governance, new management practices and technology that would be helpful may not be adopted, or if adopted initially, may not be maintained. Development of good water governance institutions is imperative to equitably manage the demand for water resources.

Nebraska's NRD system provides a good test case of a large-scale, locally controlled water governance system. The singularity of Nebraska's experiment with local control is particularly noticeable in the area of water governance, because it is the locally elected NRD boards, not the state, which hold the major responsibility and authority for the management and regulation of the state's groundwater. Nebraska has more irrigated crop and pasture land than any other state in the U.S., over 8.5 million acres [3.44 million hectares], and is among the top dozen countries in the world

[2] Copied from Korus et al. 2013 with Permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

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for irrigated land. (Table 1). Furthermore, 83% of Nebraska's irrigated land is irrigated with groundwater (Gollehon and Winston, 2013).

Table 1: Comparison of the Size of Nebraska's Irrigated Area with that of Other Countries and Areas*

Country/Area	Hectares of Irrigated Land
India	66,334
China	62,938
United States	26,644
Pakistan	19,270
Iran	8700
Indonesia	6722
Mexico	6460
Thailand	6415
Brazil	5400
Turkey	5340
Bangladesh	5050
Nebraska	3440
Egypt	3422
Spain	3045
Australia	2546
Japan	2500
Russian Federation	2375
Ukraine	2175

*For all countries the data are the most up-to-date data from the Food and Agricultural Organization of the United Nations and represent the area equipped for irrigation (FAO, 2014 and Eurostat 2012).

In large part because of its groundwater supply, in 2014 Nebraska ranked first in the U.S. for red meat production, second for pinto bean production, third for corn for grain production, and in 2013 cash receipts from farm marketing contributed over $23 billion to Nebraska's economy, which was 5.9% of the U.S. total (Nebraska Department of Agriculture, 2015). Clearly, the decisions of these locally elected boards have a large impact on the water resources and economy in Nebraska, and a significant impact on the U.S.

However, Nebraska's NRD system offers a valuable case study, not only because it is an example of a large-scale, locally controlled governance system over groundwater, but also because it provides a unique example of large-scale governance over a wide range of natural resources beyond water. Since their creation, Nebraska's NRDs have been actively involved in promoting the conservation of soils, preventing soil runoff into streams, mitigating drainage problems, controlling floods, developing wildlife habitat, and providing opportunities for outdoor recreation. They also provide many public information programs to further promote natural resource conservation. Their active involvement in many aspects of natural resource management, not just the management of groundwater, has allowed them to adopt a more holistic approach to both water and natural resource management that would not be possible if they were simply a water management district.

The NRD system is also worth studying because the resource these locally controlled entities are governing is highly interconnected and extends beyond the borders of any individual NRD. Unlike many locally controlled water management districts, most of which manage a fairly contained system, the impacts of water management by one NRD, can and usually does, affect both surface water and groundwater at locations beyond the borders of the governing NRD. Given these widespread impacts, the general inclination is to place the responsibility for governance at a higher state level that would encompasses the entire water system. Yet, Nebraska gave the responsibility to locally elected boards. For all these reasons, Nebraska's NRD governance system provides a good test case of a large scale, locally controlled water governance system.

To assess Nebraska's NRD governance system in the Introduction, we first define what we mean by a successful water governance system and why the governance of water, and in particular the governance of groundwater, creates significant and somewhat unique challenges. To provide a context for the NRD case, we then provide a brief overview of Nebraska's climate and hydrology, a synopsis of the administrative and legal framework of Nebraska's NRD governance system, and a description of the creation and evolution of Nebraska's NRDs. In the fourth section, an Assessment of Nebraska's Local Natural Resources District Governance System, we list and explain the assessment criteria and use each to evaluate the success of Nebraska's water governance system. Then, we develop and apply a set of criteria to assess the likelihood that Nebraska's water governance system will be able to successfully meet the challenges and increased uncertainty of the 21st century.

There is no one magic form of water governance that will work in every situation (Meinzen-Dick, 2007; Ostrom et al. 2007). Furthermore, Nebraska's water governance system still is evolving. Nevertheless, we hope this report will help others evaluate the potential utility and applicability of Nebraska's water governance system in solving their own water governance problems today and into the future.

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B. Definition of Successful Water Governance

For this report we define governance as the structures and processes by which societies share power and shape individual and collective actions. Governance includes laws, regulations, discursive debates, negotiation, mediation, conflict resolution, and elections of the many public and private sector actors (Lebel et al. 2006).

We define a successful water governance system as one that is able to sustain, both for current and future human populations, the benefits derived from a water resource that society requires and ideally desires. Thus, a good water governance system must prevent the water system from developing characteristics that cannot support the human population, as well as prevent the system from transitioning into another state that causes long-term human suffering (Anderies et al. 2004). There are three basic components imbedded in this definition: 1) the resource that provides the required and desired benefits must be maintained; 2) the governance institution itself must be maintained; and 3) both the resource benefits and the governance structure must be able to respond to the stresses and changes of the future. This definition requires consideration of both the physical and ecological components of the system, and the social-economic components of system, a combination that is often referred to as the socio-ecological system (Anderies et al. 2006; Ostrom, 2009a).

In other words, a successful socio-ecological system must not only be resilient, but must also be robust. The concept of resilience was first developed by Holling (1973) to describe the fact that ecosystems exist in more than one alternative state. Resilience measures the amount of change or disruption that is required to transform the maintenance of a system from one set of mutually reinforcing processes and structures to a different set of processes and structures. A system has high resilience if it tends to maintain the existing system processes and functions when impacted by either internal

or external stresses. If a system is vulnerable to perturbation, when a critical threshold is crossed, it will self-reorganize into a new state. Depending on whether the system does or does not provide benefits to human society, resilience may be a desirable or an undesirable characteristic (Anderies et al. 2004; Lebel et al. 2006; Folke et al. 2007; Zelmer & Gunderson, 2009).

Robustness, on the other hand, focuses on the maintenance of characteristics that are of benefit to human society (Carlson & Doyle, 2002; Anderies et al. 2004). For example a socio-ecological system that maintains a valuable irrigated agricultural economy would be considered to be robust, but a socio-ecological system that produces a highly stable contaminated aquifer system, though resilient, would not be considered as robust. It should be noted that in the short term, a robust system will typically not perform as efficiently with respect to a chosen set of criteria as its non-robust counterpart. However, the robust system's performance will not drop off as rapidly as its non-robust counterpart when confronted with external disturbance or internal stresses (Anderies et al. 2004). In a stable environment the better strategy may be to optimize the efficiency of the system, but in an unstable environment, strategies to maintain robustness are more likely to sustain the desired benefits of the resource for the long term (Anderies et al. 2004). In sum, robustness, in contrast to resilience, emphasizes the cost-benefit trade-offs associated with socio-ecologic systems designed to cope with uncertainty (Anderies et al. 2004). Understanding critical thresholds and taking proactive steps to avoid reaching those thresholds when a socio-ecological system is providing beneficial services is, therefore, an important aspect of water governance (Allen et al. 2011; Wiek and Larson, 2012).

C. Why Water Presents Unique Governance Challenges

Arguably water, particularly groundwater, is the most difficult natural resource to govern. Water is highly valued, because it is vital for life itself, as well as essential for growing the food we eat, producing the energy our economies demand, and maintaining ecosystems that provide a whole host of other ecosystem services indispensable to humankind. Water is also sufficiently vast and mobile, making it costly to devise physical or legal boundaries that can exclude potential users. However, it is often necessary to be able to exclude users, because each unit of water consumed by one user results in less being available for other potential consumers (Ostrom, 1990). When exclusion is difficult, consumption is subtractive, and it is difficult to exclude users who do not pay or take responsibility to maintain the resource, resource users face incentives to overharvest, to free-ride on the provisional infrastructure, and shirk maintenance (Ostrom, 1990). Thus, the governance of water poses many challenges to governance systems seeking to prevent over-harvesting and conflict among potential users.

In addition, both the quantity and quality of water can be impacted by a wide variety of factors that often are not directly related to the use of the water supply itself. For example, land uses and air pollution, sometimes from distant localities, can contaminate water, making it useless for many important functions. Water is also very mobile so the use of water in one locale can adversely impact water users and ecosystem services in very distant locales. Thus, the issues of scale and division of authorities over the many factors that impact water are not easily resolved when establishing a system to govern water management and use.

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To address some of these issues, John Wesley Powell in 1890 advocated that governmental boundaries should be established in the western U.S. along surface watershed boundaries. Of interest here, he also said regarding who should control these districts, "I say to the government: hands off! Furnish the people with institutions of justice and let them do the work for themselves." (Powell, J.W. 1890, as cited in Webb, 1931, p. 356). Powell's recommendation was not followed. Today in the U.S. the boundaries of governing institutions rarely align with watershed boundaries. Even in those instances where watershed boundaries were considered, for example in international or interstate water treaties and compacts, there can still be problems. At the time of agreement on most of the interstate compacts in the U.S., surface water provided the bulk of the water for most users. Thus, the compacts were established along surface watershed boundaries. Today, with the significant increase in groundwater use, especially where groundwater and surface water are hydrologically connected, groundwater reservoir boundaries must also be considered. Unfortunately, groundwater reservoir boundaries often do not coincide with surface watershed boundaries.

Finally, the very nature of groundwater increases the challenges exponentially. Some of these challenges are listed below:

- Groundwater is underground and, therefore, difficult to observe. When a stream dries up, the decrease in flow is easily noted and the need for water administration is fairly well accepted. However, depletions to groundwater are often not observed until the wells are already dry, making it easy to ignore the need for restricting water uses until it is too late.
- Groundwater and surface water are often hydrologically connected so the use of one impacts the availability of the other, but this connection is not readily observed. For many years in Nebraska, the general public believed that surface water and groundwater were two

separate bodies of water, and even the state laws treated them as such. This belief was expedient because it greatly simplified the administration and governance of the state's water supplies. Gradually, as streams dried up in areas where groundwater tables dropped, laypeople finally began to believe what hydrologists had been saying for many years: in many instances surface water and groundwater are hydrologically connected.

- Groundwater and the impacts of groundwater use move very slowly. The impact of surface water use or water pollution on distant downstream users is usually observed within days or only a few weeks. In contrast the impacts of groundwater use and pollution on distant users of both surface water and groundwater may not be observed for months, years, decades or even centuries. Even within the immediate area, it may take years for contamination to move from the land surface to a deep groundwater reservoir. In such cases, the recognition of a contaminated water supply may not come in time to prevent the adverse impacts of the contamination.
- The impacts of groundwater use can be very long lasting. Even though a well stops pumping today, the impacts of previous years of pumping or of groundwater contamination may last for many years. Thus the challenge to achieving robust water governance is to convince water users that restrictions are necessary today to ensure sufficient quantities of good quality groundwater will be available to their descendants in the future, or harder yet, to ensure that water will be available for future generations in other parts of the watershed. It is no wonder that elected officials who set water policy often find it politically expedient to ignore the consequences of their decisions, especially if the adverse impacts are on people who live outside their district or people who are not yet born.
- Even scientists are challenged by the inability to directly observe groundwater. To understand and predict the behavior of groundwater, scientists must rely on data that are usually costly to collect, and on complex models with results that are difficult to validate in the near term. In addition, when actual data are lacking, which is usually the case for at least some model input parameters, the modelers must rely on estimates, which are subject to debate. As a result, groundwater modelers themselves often proclaim "all models are wrong, some models are useful."
- With these problems and statements by the modelers themselves, it is no wonder that nonscientists and the general public are skeptical of the results and predictions of a groundwater model. This problem is exacerbated by the fact that most groundwater models are simplifications of the real world, and, while often accurate, may lack precision. For example, a model may accurately portray the average water level for a large area, but this water level may not precisely match the water level observed by a water user in the specific well. When the model's well-level prediction and the actual water level in a well do not compare adequately, the model results are likely to be discounted by skeptical well owners. On the other hand, if one builds a precise model that captures the details on a small scale, the results cannot be used to explain the behavior of groundwater in a larger area.

In sum, the fact that water is a very highly valued and extremely mobile, and its quality can be affected by many factors unrelated to the water use itself, makes the governance of water difficult. The nature of groundwater, which is not easily observed and has long lag times before the impacts of water use can be observed, further exacerbates the challenge for good governance.

II. Climate and Hydrology

Nebraska (Figure 2) became the 37th state of the United States on March 1, 1867. With 77,358 square miles, it is the 16th largest state in the country (Heltzel, 2015). Farming is Nebraska's largest industry; Nebraska ranks third in corn production and in cash receipts from all commodities in the U.S. and fourth in total livestock receipts (Nebraska Department of Agriculture, 2015). Corn is Nebraska's predominant crop, most of it going to feed cattle and hogs. Nebraska has a varied climate, topography, and geology, which creates many challenges for the governance of its water supplies and other natural resources. For the purposes of this study, however, these variations and challenge are positive, because they add an additional test for the effectiveness of the NRD governance system.

Nebraska is where the sub-humid east meets the semi-arid west. In 1878, J. W. Powell, then in charge of the Geographical and Geological Survey of the Rocky Mountain region, made his Report on the Lands of the Arid Region of the United States. In that report Powell stated that 20 inches of rainfall was the limit of successful unirrigated agriculture, and that this line roughly corresponds to the 100th meridian (Webb, 1931). The 100th meridian essentially divides Nebraska in half (Appendix E: Figure 10).

In Nebraska, the tall grass prairies of the east change to mixed prairies and short grass prairies more typical of the west. Appendix E: Figure 11 depicts the vegetation as it was in the 1860s, before Europeans arrived.

The most stunning example of the east meeting the west is in north-central Nebraska, along the Niobrara River valley. Here humid eastern and dry western air masses collide, creating a unique mixing zone for several species of plants and animals. Six major ecosystem types converge in the valley,

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including northern boreal forest, western forest, eastern deciduous forest, tall-grass prairie, mixed-grass prairie and short-grass prairie. Approximately 160 plant and animal species are found at the edge of their distributional ranges here, and several bird species have been known to hybridize in the valley's short grass prairies (United States Park Service, 2015).

Nebraska has a varied topography, including miles of river valleys, rolling hills, dissected plains and over 19,000 square miles of grass covered sand dunes (Appendix E: Figure 12). The land elevation in the state ranges from 840 feet (255 meters) in the east to 5,424 feet (1,649 meters) in the west (United States Geological Survey, 2015).

Precipitation in Nebraska (Appendix E: Figure 13) ranges from an annual average of 34 inches (860 millimeters) in the southeastern area of the state to only 10 – 12 inches (254 millimeters – 304 millimeters) in the northwest. The statewide average precipitation is 23.5 inches (597 millimeters), but it is also quite variable from year to year (Appendix E: Figure 14) (Korus et al. 2011).

Evapotranspiration (Appendix E: Figure 15) and groundwater recharge (Appendix E: Figure 16) also vary greatly. The recharge to groundwater in central and eastern Nebraska is greater than 4 inches (100 mm), but in areas in the west evapotranspiration exceeds precipitation resulting in negative recharge rates as low as – 20 inches (-508 millimeters) or lower (Korus et al. 2011).

Nebraska has 23,686 miles (38,134 kilometers) of streams and canals (Baltensperger 1985), most of which flow from the west to the east (Appendix E: Figure 17). These rivers are fed by a combination of surface water runoff from precipitation and baseflow from groundwater. The recharge to groundwater in the Sandhills provides significant quantities of water to several of Nebraska's rivers, (Bleed & Flowerday, 1998), which in turn provide water to the state's two largest cities. The Platte

Figure 2: Map showing Major Nebraska Cities, Rivers and Reservoirs. (nationalatlas.gov)

River also receives significant inflows from snow melt in the Rocky Mountains to the west (Korus et al. 2011).

Surface water irrigation occurs along most of Nebraska's major streams and canals. Major surface water development started in the 1880s and continued until the early 1990s. A number of large irrigation and hydropower projects and canals were built during the first half of the 20th century. In some cases seepage from these projects recharged the groundwater and caused groundwater levels near the projects to rise as much as 80 feet (24 meters) or more (Appendix E: Figure 18) (Korus et al. 2011).

These rises have been well documented because Nebraska has a strong history of data collection on the state's surface and groundwater resources. The State DNR and the United States Geological Survey (USGS) cooperate in providing a statewide stream gaging and canal measurement system. Since 1931, the University of Nebraska Conservation and Survey Division has operated a large geological test hole drilling program (Appendix E: Figure 19) and the USGS, the University of Nebraska Conservation and Survey Division, and the NRDs work together to maintain a groundwater level monitoring program. The State DNR maintains a database where a large number of these data can be found (Korus, et al. 2011).

Nebraska is blessed with several large groundwater reservoir systems, (Appendix E: Figure 20), but the location and depth of these aquifers vary greatly across the state. The High Plains aquifer, also called the Ogallala Aquifer, covers 84% of Nebraska and stretches from South Dakota to Texas. This aquifer system averages 600 feet (180 meters) in saturated thickness, but has thicknesses as great as 1,000 feet (300 meters) in some areas (Korus et al. 2011).

Climate and Hydrology

Nebraska has made great use of the state's groundwater resources. Since the early 1930s, when only a small number of shallow irrigation wells were drilled, mostly along rivers, the number of groundwater irrigation wells has grown to more than 112,000 registered irrigation wells (Nebraska Department of Natural Resources, 2014a). Appendix E: Figure 21 shows the density of active irrigation wells in Nebraska.

Since the 1930s, the University of Nebraska Conservation and Survey Division, along with the USGS, the NRDs, the Central Nebraska Public Power and Irrigation District, the Nebraska Public Power District, and the U. S. Bureau of Reclamation, have been monitoring groundwater levels. Prior to 1981 groundwater levels in almost all areas of the state were declining. Where groundwater irrigation had proliferated water levels had declined as much as 30 to 40 feet (9-12 meters) (Appendix E: Figure 22). In other areas where surface water projects were built, groundwater levels rose as much as 50 feet (15 meters) due to seepage from canals and reservoirs and deep percolation from irrigated fields (Appendix E: Figure 18) (Korus et al. 2011).

After 1981, groundwater levels in the eastern part of Nebraska started to rise. These rises were likely caused by a combination of several long periods of above-average precipitation that reduced the need for groundwater pumping and increased groundwater recharge; increased irrigation efficiencies that reduced pumping rates; the stabilization of groundwater levels as the aquifer depleted by earlier pumping equilibrated to new hydrological conditions; and perhaps to the lagged impact of recharge from the previous years of the over-application of surface water (Korus et al. 2011, 2013). In contrast, groundwater levels continued to decline in parts of western Nebraska from 1981 to 2013, in some areas as much as 60 feet (18 meters) in just 50 years, an average of about one foot (0.3 meters) per year, despite changes in groundwater management practices and water use restrictions (Appendix E: Figure 23).

The net result is shown on the map of changes in groundwater levels from predevelopment to the spring of 2013 (Appendix E: Figure 24). As the map shows there are many areas in Nebraska where water levels have not declined, or have even risen, since predevelopment. However, there are also areas where groundwater levels have declined significantly, and although in some areas the rate of decline has slowed, it is has not been stopped.

In general Nebraska has high quality groundwater, but the use of fertilizers and pesticides has caused groundwater contamination in many areas of the state. The major contaminant is nitrate-nitrogen. Because the NRDs are responsible for managing nonpoint source pollution (the State Department of Environmental Quality regulates point source pollution), the NRDs sample thousands of wells across the state. Appendix E: Figure 25A shows recently sampled wells that have nitrate levels greater than 10 parts per million, which is the maximum contaminant limit for nitrate nitrogen. Appendix E: Figure 25B shows recently sampled wells that have less than 10 parts per million nitrogen.

III. Nebraska's Legal and Institutional Framework and the Evolution of the NRDs

A. The State Department of Natural Resources and the Appropriative Right System

As the western U.S. developed and farmers started diverting water from the streams, conflicts among water users increased. To bring peace and order, in 1895 Nebraska followed the lead of states to the west and passed water laws establishing who had the right to use the waters of the state. The waters of the state were considered to be a "natural want" and were dedicated to the people of the state, but the state adopted a prior appropriation system of law in which a person could obtain a right from the state to divert and use the waters of the state (Gless & Longo, 2008) for a beneficial use (Nebraska State Constitution 2014, Sections XV-4 through XV-6). The water right allows the appropriator to divert surface water up to a set rate and volume for a specified use. The right is given an appropriation date based on when the application for the right was filed. In times of shortage the appropriators with the earliest rights are given priority to divert up to their stated rate first. If water is still available, more junior appropriators are allowed to divert, i.e. "first in time, first in right" (Neb. Rev. Stat. §46-203 - 46–206 [3]).

In the arid west where stream flows can be highly variable, the prior appropriation system makes more sense than a system based on sharing the resource. In dry years sharing a limited resource equally among all users is likely to result in no one user being able to pump sufficient water to successfully grow a crop, but under the prior appropriation system, at least some users, the senior appropriators, are likely get a sufficient water supply.

[3]Neb. Rev. Stat. refers to the State of Nebraska Statutes as revised in 2014. § refers to the section numbers of the statutes.

A water right is a usufructuary right, that is, a right to use, not own, the water. However, under Nebraska's Constitution, a surface water right is a property right that is entitled to the same protection as any other property right (Loup River Public Power Dist. v. N. Loup River Public Power & Irr. Dist. 1942). This opinion was recently reaffirmed by the Nebraska Supreme Court (Bond and McClaren v. Nebraska Public Power Dist. and Dept. of Natural Resources, 2013). As with other property rights, water rights can be bought and sold, subject to the transfer laws of the state, which were established to keep track of the water rights and to protect the interest of other appropriators.

Since the late 1800s surface water rights have been administered by the state under the authority of the governor and have been funded primarily by appropriations from the Legislature. Currently surface water rights are administered by the State DNR.[4] When stream flows are not sufficient to satisfy an appropriator's water right, the appropriator can ask the State DNR to put a "call" on the river. The State DNR will then shut off or regulate as many junior appropriators as necessary to try to ensure the senior's water right is satisfied. If stream flows increase, the State DNR starts allowing the junior appropriators to divert again. To ensure proper water rights administration, the State DNR also operates stream gages, and often requires measuring devices on the diversions and pumps of appropriators to help administer these rights.

Nebraska also adopted a set of preference statutes. Under these statutes, the use of water for a domestic use has preference over a senior water right being

[4]The agency administering water has evolved over time. Early in the State's history the water administration agency was part of a larger agency; later it became a separate State agency, the Department of Natural Resources. In 2007 Department of Water Resources was merged with the State Natural Resources Commission, which was the States' natural resources planning division, to become the State Department of Water Resources. In this report the term State DNR will be used to refer to all previous State water administration agencies.

used for irrigation, and a junior irrigator has preference over a senior industrial right. However, to exert one's right to the preference status, an appropriator must negotiate a contract with the senior appropriator with a lower preference or file a lawsuit with the state to use their preference status (Nebraska State Constitution XV-6, Neb. Rev. Stat. § 46-606). This process is more time consuming and difficult than exercising a senior priority right.

B. Development of Groundwater Law and the Correlative Rights System

Disputes over groundwater use were very limited in Nebraska until the drought of the 1930s. The first significant groundwater law development in Nebraska was in 1933 when the Nebraska Supreme Court ruled that groundwater was not the private property of landowners, that landowners could use groundwater on their land without waste, and that groundwater would be shared by competing users during periods of shortage. The sharing principle was later embodied in the 1975 Groundwater Management Act (Aiken, 1987).
In the 1940s and '50s, geological research by the University of Nebraska Conservation and Survey Division demonstrated the presence of several large groundwater reservoirs under Nebraska. This research, combined with improved well-drilling methods and pumping equipment — as well as the development of the center pivot, which allowed the easy and efficient application of irrigation water even in hilly terrain — led to the widespread increase of groundwater irrigation (Aiken 1980, Korus et al. 2013) and to further disputes between groundwater users. To try to prevent these disputes and prevent groundwater mining, in the 1950s the legislature gave limited authority to the State DNR to require the registration of large wells and establish well spacing requirements and locally-controlled groundwater conservation districts. The legislature also created a preference system for groundwater, which was similar to the preference statute for surface water (Aiken, 1980).

During the dry period of the 1970s groundwater well development increased dramatically, and concerns over groundwater mining increased.
In 1975 the legislature passed the Groundwater Management Act, which gave the primary authority for regulating groundwater to the NRDs (Nebraska Legislature 1975 LB 577). The final remnants of the state's control area authority were rescinded in 1998 (Nebraska Legislature 1998 LB 896 § 11).

C. The Evolution of the NRDs and Their Authority to Administer Groundwater

The Nebraska NRDs can trace their beginning back to federal legislation in 1937 that created the national Soil Conservation Service and enabled local soil conservation districts to help farmers combat the soil erosion and dust storms of the 1930s drought. Dr. G. E. Condra, Dean and Director of the University of Nebraska Conservation and Survey Division, was "the Grand Old Master" who worked on the federal legislation and, along with other University of Nebraska

officials, helped push it through (Fairchild, 1994). Under this law, local soil and water districts were established. The districts had broad responsibilities and could enforce land use regulations upon approval of the majority of the land occupiers in the district (Herpel, 1995). However, such land use regulations were rarely implemented and natural resource problems continued to increase. As each problem arose, the Nebraska Legislature passed a law creating a special local district to deal with the problem. Over time the number of these special purpose local districts increased and it became obvious "that if something wasn't done there would be a thousand districts," (Fairchild, 1994) a concern that was referred as "districtitis" (Fairchild, 1994). By 1969 there were 21 separate sections of the Nebraska statutes and a chaotic system of special-purpose districts, which had overlapping authorities over the administration of land and water resources (Mazour, 1972). Yet, in spite of these multiple districts, there were also administrative gaps. Specifically, there were no districts with adequate authority to regulate groundwater effectively, manage the conjunctive use of water, or participate in basin-wide planning (Mazour, 1972).

To address these problems, in 1966 the Nebraska Association of Soil and Water Conservation Districts called for a study of reorganization possibilities and in 1969 developed and introduced a bill to consolidate 154 local districts into 24 NRDs (Jenkins, 1975).

However, a number of special-purpose districts, fearing they would lose their local control (Edson, 2005), especially the most successful conservation districts (Oltmans, 2013), opposed the bill. Some federal agencies also opposed the bill (Fairchild, 1994). Although it was generally accepted that, because of the need to control flooding, the boundaries of the NRDs should be based on surface watershed boundaries, there were still disputes over how to draw the boundaries. There was also a prevailing concern that the law would diminish local control, which was (and still is)

important to the citizens of Nebraska (Fairchild, 1994). Hundreds of meetings were held throughout Nebraska in 1970 and 1971 to try to hammer out an acceptable plan. Finally, in 1972, after much discussion and lobbying, the Legislature passed an amended NRD bill and transition to the new districts began. However, just 25 days before the NRDs were to be operative, there was a final legal challenge to the constitutionality of the NRD law from southeast Nebraska. With little time to waste, arguments were made before the Nebraska District and Supreme Courts. Both courts upheld the NRD law and the NRD system was finally implemented in 1972 (Jenkins 1975, Cook 2014, personal communication). Originally there were 24 NRDs, but in 1989 two districts merged (Papio-Missouri NRD, 2015), so there are now 23 (Figure 1).

According to several people who were involved, it took the presence of strong leaders who took action at crucial points in time to get this legislation passed (Fairchild, 1994; Oltmans, 2013; Williamson and Starr, 2013; Yeutter, 2014). The creation of the NRDs generated a lot of interest across the entire nation, but Nebraska was the only state that had the courage and fortitude to actually adopt this type of water management system (Orton, 2014, personal communication). According to Yeutter, "personal leadership was at the heart of Nebraska's effort. Also, in the 1950s not much was happening, but in the 1960s the time was ripe for a hard-charging, aggressive governor, Norbert Tiemann, to move forward on several issues, one of which was the formation of the NRDs." (Yeutter, 2014).

The new law gave NRDs broad authority to administer the state's natural resources (Edson, 2005). The law states:

"The purposes of natural resources districts shall be to develop and execute, through the exercise of powers and authorities granted by law, plans, facilities, works, and programs relating to (1) erosion prevention and control, (2) prevention of damages from flood water and sediment, (3) flood prevention and control, (4) soil conservation, (5) water supply for any beneficial uses, (6) development, management, utilization, and conservation of groundwater and surface water, (7) pollution control, (8) solid waste disposal and sanitary drainage, (9) drainage improvement and channel rectification, (10) development and management of fish and wildlife habitat, (11) development and management of recreational and park facilities, and (12) forestry and range management. As to development and management of fish and wildlife habitat and development and management of recreational and park facilities, such plans, facilities, works, and programs shall be in conformance with any outdoor recreation plan for Nebraska and any fish and wildlife plan for Nebraska as developed by the Game and Parks Commission" (Neb. Rev. Stat §2-3229).

In their early years the primary focus of the NRDs was flood control, drainage, and soil conservation. However, the framers of the legislation sensed that groundwater was going to be a major issue in the future (Yeutter, 2014), and because there was strong support for the locally controlled NRDs, not the state, to regulate groundwater, when the Groundwater Management and Protection Act was passed in 1975 the primary authority to regulate groundwater was given to the NRDs (Neb. Rev. Stat. §46-701-754). The split of jurisdiction between the State DNR, which regulated surface water, and the NRDs, which were to regulate groundwater, was not a major point of discussion, in part because at the time, decision makers in Nebraska did not appreciate the significance of the hydrologic connection between surface water and groundwater (Cook 2014, personal communication).

As early as 1978 the Upper Republican NRD enacted the first groundwater-use controls that provided significant restrictions on the use of water. This action was a brave decision for a locally elected board. Many objected to these new rules, and eventually a lawsuit challenging the

Nebraska's Legal and Institutional Framework and the Evolution of the NRDs

NRD's authority to restrict groundwater use was filed (Aiken, 1980). The NRD won the lawsuit, and in 1994 the legal authority for the NRDs to regulate groundwater was clearly established (Bamford v. Upper Republican Natural Resources District, 1994).

During the dry 1970s there was also a growing concern that the use of groundwater wells was drying up streams. In 1963 the state legislature passed a law allowing the State DNR to regulate wells within 50 feet (15 meters) of a stream (Aiken, 1980; Mossman, 1996), but this was the only recognition in the law that there was a need to administer the connection between surface water and groundwater. The 1980s were a time of plentiful precipitation and swollen streams, so the concerns receded. However, with the drought of the 1990s surface water users and environmental groups again started complaining that groundwater pumping was causing depletions to streams. In addition, the State of Kansas, which had been complaining about Nebraska's groundwater pumping since the middle 1980s, started threatening litigation alleging that groundwater pumping in Nebraska was a violation of the Republican River Compact, an interstate compact among the states of Nebraska, Kansas, and Colorado. In response, in 1993 Governor Ben Nelson formed the Governor's Nebraska Water Council and charged them with studying the hydrological connection between surface water and groundwater and making recommendations on how such water should be managed. After much debate the council finally developed a recommendation, which the Legislature passed in 1996. The bill provided a rather convoluted process for the regulation of hydrologically connected surface water and groundwater (Mossman, 1996; Nebraska Legislature, 1996, LB 108). No real actions to limit groundwater pumping resulted from this legislation.

Still under the threat of lawsuits, many continued to pressure the Legislature to do something to address the growing conflicts between surface water users

and groundwater users. The Legislature, however, was extremely reluctant to tackle this issue. Not only was the issue complicated, both legally and hydrologically, but also few legislators wanted to suffer the political repercussions of imposing restrictions on groundwater users, who then, as they do today, far outnumber the surface water appropriators and have considerable political power.

It was not until 2002 when Governor Mike Johanns and State Senator Ed Shrock, both of whom were familiar with water issues and water law, showed the leadership and political will to take action. Understanding the complications the Legislature would face in developing an integrated surface water and groundwater management law, these two men pushed the Legislature to enact a law that created a 49-member Water Policy Task Force. This group, composed of a wide range of users from all over the state, was charged with reviewing the laws to determine what, if any, changes were needed to reduce the conflict between surface water users and groundwater users (Report of the Nebraska Water Policy Task Force, 2003). After 18 months of education and discussion, the task force developed a consensus and wrote a law that was enacted by the Legislature and signed by the Governor in 2004 (Nebraska Legislature 2004, LB 962).

It should be noted, however, that a consensus is not the same as a unanimous agreement. A number of surface water users did not believe the law provided enough protection for their surface water rights, but given the political power of the groundwater users, they could not get the task force to recommend the additional safeguards they sought. Nevertheless, believing the new law would be better than the status quo, they chose not to block the consensus and allowed the recommended law to go to the Legislature (Report of the Nebraska Water Policy Task Force, 2003).

D. Nebraska's Integrated Surface and Groundwater Management Law

Nebraska's integrated surface and groundwater management law (integrated management law) (Neb. Rev. Stat §46-713 -§46-720) like the NRDs, is also unique. In most U.S. western states, groundwater is administered by the state under the prior appropriation system. Although the task force considered this option, applying the prior appropriation system to Nebraska's groundwater was rejected. Instead, the task force agreed to maintain the existing groundwater governance framework with the State DNR administrating surface water under the prior appropriation legal system and the NRDs administering groundwater under a modified reasonable-use/correlative rights system (Report of the Water Policy Task Force, 2003). This decision made sense because of the widespread interconnection between groundwater and surface water, and the long lag times between the initiation of groundwater pumping and the resulting depletions on stream flow in Nebraska would make implementing a prior appropriation system very complicated. The fact that the water rights of groundwater users would have been very junior in comparison with most surface water appropriators was also an important, though rarely openly discussed, consideration of the task force.

To integrate the actions of these two administrative systems, the law requires the State DNR do an annual evaluation of the water supplies and uses in every river basin of the state to establish where surface water and groundwater are hydrologically connected and to determine whether the hydrologically connected water is fully appropriated. A basin is considered to be fully appropriated if the current uses of hydrologically connected water cause, or will in the reasonably foreseeable future cause, surface water or groundwater supplies to be insufficient to sustain the beneficial purposes of the existing uses (Neb. Rev. Stat. §46-713(3) over the long term. If a basin is determined by the State DNR to be fully

appropriated, the law requires that an immediate temporary stay be placed on issuing new surface water permits and drilling new groundwater wells until the State DNR and the NRD have jointly adopted an integrated management plan. The integrated management plan must be completed within three to five years of the initial "fully appropriated" determination (Neb. Rev. Stat. §46-715).

The integrated management plan must meet several requirements, including developing a plan to gather, evaluate and use the best scientific information available on surface water and hydrologically connected groundwater, developing clear and transparent procedures to track gains and depletions to stream flows, formulating a set of procedures for the NRD and the state to consult with water users in the basin, and establishing a list of controls that may be used to regulate surface water and groundwater use. Also, and most importantly, the plan must have "clear goals and objectives with a purpose of sustaining a balance between water uses and water supplies so that the economic viability, social and environmental health, safety, and welfare of the river basin, sub-basin, or reach can be achieved and maintained for both the near term and the long term" (Neb. Rev. Stat. §46-715-717). The plan must also propose surface and groundwater controls that when considered with any applicable incentive programs are sufficient to both ensure the state will remain in compliance with applicable state and federal laws and with any applicable interstate water compact, decree or agreement, and protect groundwater users whose wells are dependent on recharge from the stream and surface water appropriators on such stream from stream flow depletions caused by surface and groundwater uses begun after the determination that the basin was fully appropriated (Neb. Rev. Stat. §46-715(4)). The general idea was that as long as a basin was not fully or overappropriated, additional consumptive water uses could occur without adversely impacting existing water users. But if the basin was fully appropriated, any

additional uses would deplete the water supplies for existing users and threaten their investments, which were based on the availability of that water supply.

The law also authorized a basin to be declared "overappropriated" if, "on July 16, 2004, the river basin …is subject to an interstate cooperative agreement among three or more states and if, prior to such date, the department has declared a moratorium on the issuance of new surface water appropriations … and has requested each natural resources district with jurisdiction in the affected area … either (i) to close…the river basin to the issuance of additional water well permits …, (ii) or to temporarily suspend … the drilling of new water wells" (Neb. Rev. Stat. §46-713(4)(a)). Only one sub-basin, a portion of the Platte River Basin, met, or in the future could ever meet, these criteria. These more legal than hydrological criteria eliminated a concern by some that other areas of the state, which were hydrologically overappropriated, would be legally designated as "overappropriated." In fact, the Water Policy Task Force, which developed Nebraska's integrated management law, identified two basins that were clearly being affected by overuse of the water supply — the Republican Basin and the Platte River Basin, upstream from Elm Creek, Nebraska. However, the task force recommended that the joint integrated management plans being developed by the State DNR and NRDs in the Republican Basin to ensure Nebraska's compliance with the Republican River Compact be the primary action taken to address the over-appropriated status in that basin. Although some objected to the elimination of the Republican Basin from being officially designated as overappropiated (Report of the Nebraska Water Policy Task Force to the 2003 Nebraska Legislature, 2003), accepting this provision was necessary to achieve a consensus within the task force.

If a basin is declared to be "overappropriated," the law requires that a basin-wide plan be developed. In developing the plan the State DNR and the NRD were required to both consult and collaborate with surface water users, municipalities and other affected stakeholders (Neb. Rev. Stat. §46-715(5)(a)). The use of the word "collaboration" was the subject of much debate when the task force was writing this law, and the insertion of the word "collaboration" was an important factor needed to gain a consensus from surface water users.

If a dispute arises between the State DNR and the local NRD or between two NRDs, the law also authorizes the NRD or the State DNR to appeal to the Governor to create an ad hoc Interrelated Water Review Board. The Board consists of five members appointed by the Governor from a list developed by the State Natural Resources Commission, which until recently had 16 members, 13 nominated by the NRDs. Of note, is the fact that an individual citizen cannot go directly to the Governor to convene the Interrelated Water Review Board, but must appeal to either the NRD or State DNR to get relief if he/she has a grievance (Neb. Rev. Stat. §46-718 - 719).

Shortly after the 2004 integrated management law was enacted, all or parts of seven NRDs were declared by the State DNR to be fully appropriated, and one area, including parts of five NRDs, was declared to be overappropriated (Figure 3). Several years later, at the request of the NRDs, several changes were made to the integrated management law, including the addition of more requirements for scientific information and monitoring and, importantly, an amendment authorizing an NRD to voluntarily work with the State DNR to develop an integrated management plan, even though the basin has not been legally determined to be fully appropriated.

One recommendation of the task force was not adopted by the Legislature. The task force was very concerned that the state needed to provide a secure and sufficient source of funding for the water research and water projects needed to fully implement the integrated management plans (Report of the Nebraska Water Policy Task Force to the 2003 Nebraska Legislature, 2003). However, the law was not funded until 2014 when the Legislature

finally passed a funding bill that will provide $32 million initially and thereafter $11 million annually to a Water Sustainability Fund to implement water research, programs and infrastructure with a primary purpose of providing sustainability for water use in Nebraska (Neb. Rev. Stat. §61-222, Nebraska Legislature 2014, LB 906, LB 1098).

E. Water Quality

For the management of water quality the Legislature also gave authority to the NRDs to implement rules and regulations to prevent groundwater contamination from non-point sources of pollution, but at the same time, to comply with the federal Environmental Protection Act, the Legislature gave authority to the State Department of Environmental Quality to determine whether an area needed to be designated for the protection of groundwater quality (Peterson et al. 1993). If protection is needed, the State Department of Environmental Quality is to work with the affected NRD to develop an acceptable groundwater quality management plan and rules to implement the plan. The law also authorizes the State Department of Environmental Quality to specify and implement rules on their own if the state and the NRD cannot agree on an acceptable plan (Neb. Rev. Stat. §46-722-734).

In sum, today in Nebraska, surface water is administered by the State DNR under the appropriative rights doctrine and groundwater is administered by 23 locally elected Natural Resources District Boards (NRDs) under a modified correlative rights/reasonable use legal framework. Where surface water and groundwater are hydrologically connected and either fully or overappropriated, the State DNR and the NRD collaborate on an integrated management plan for the district. The NRDs are also to work with the State Department of Environmental Quality to prevent groundwater contamination.

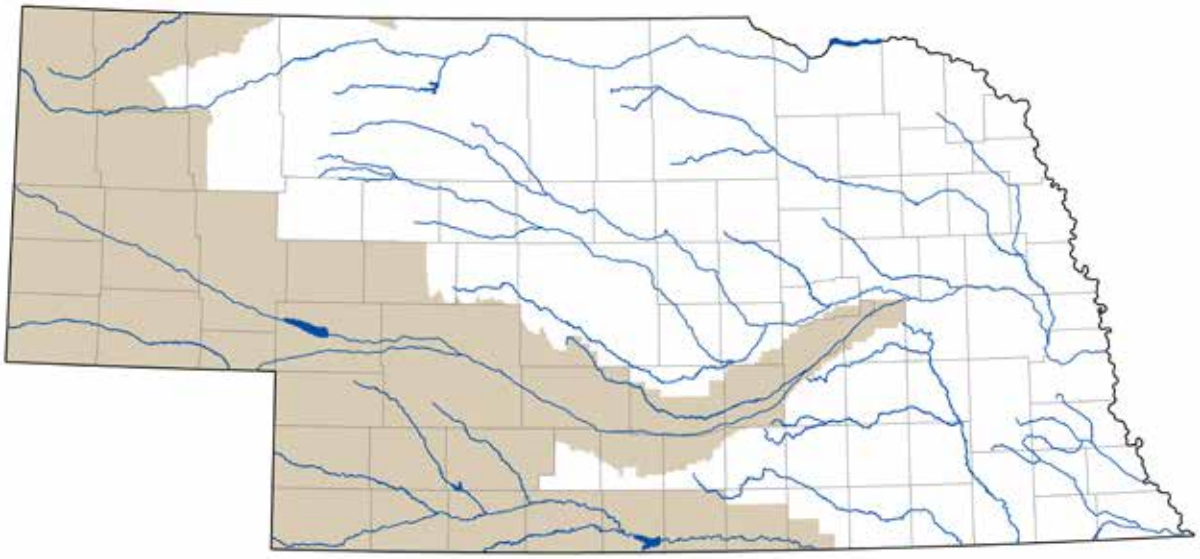
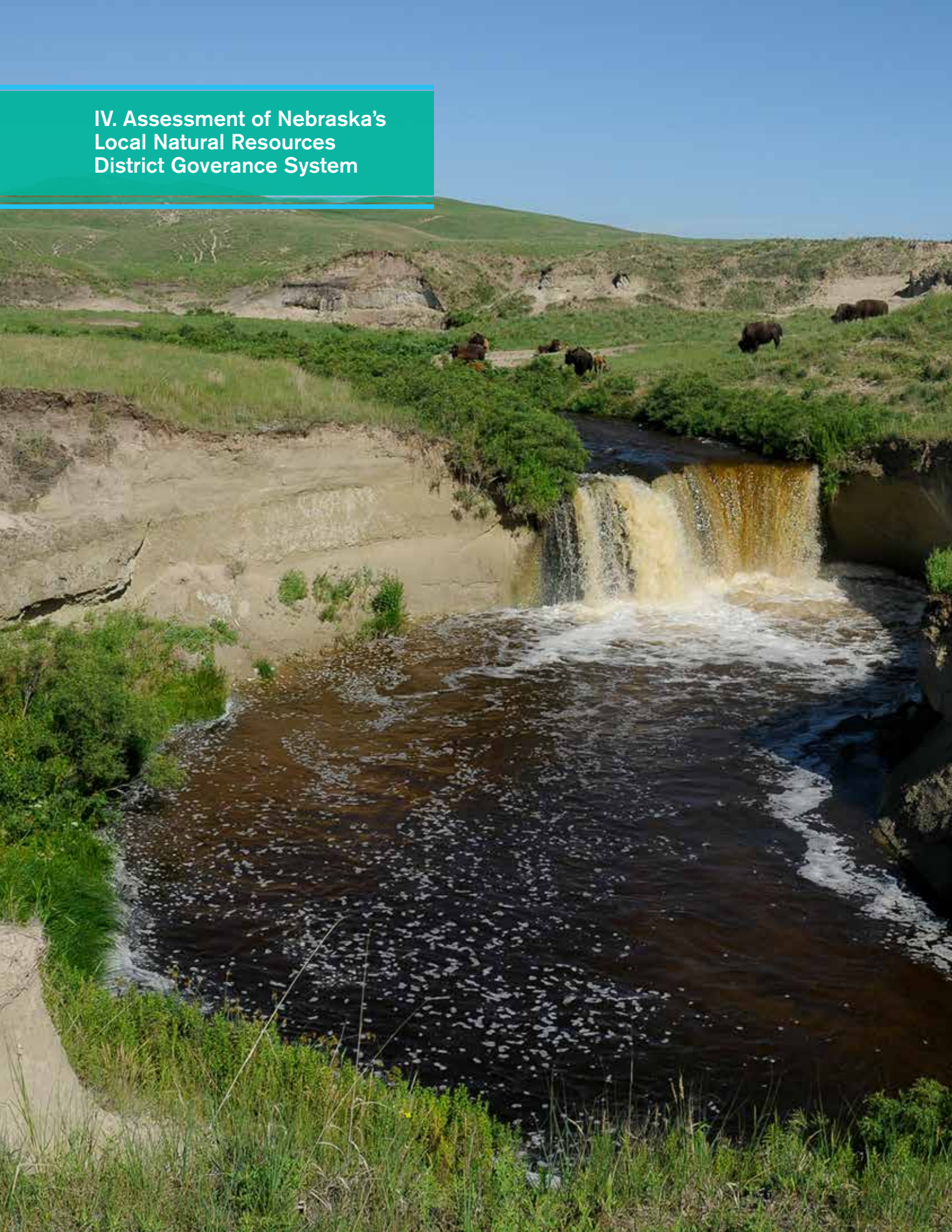


Figure 3: Fully and Overappropriated Groundwater and Surface Water in Nebraska[5]

[5]Adapted from Korus et al. 2013 with permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

IV. Assessment of Nebraska's Local Natural Resources District Goverance System



A. Research Methodology

Ultimately the robustness of a water governance system will depend on whether the governance system can manage the water resource so that water availability and its benefits can be maintained for both current and future generations. Thus, one way to assess the robustness of a water governance system would be to assess the quantity and quality of the water supply being managed. However, in Nebraska, as elsewhere, such an assessment alone would be overly simplistic. As previously described, in addition to the governance system, other factors, such as climatic changes, have contributed to rising groundwater levels in the eastern part of the state (Korus et al. 2011, 2013). Economics also may have a large impact on water resources. Decreases in pumping rates may be more the result of high fuel prices than any government intervention (Supalla and Nedved, 2005). Even if one could isolate the exogenous factors and focus only on the endogenous governance impacts, because of the lagged impacts of using and managing groundwater, it may be too soon to determine whether the relatively short period of groundwater governance will eventually be able to sustain the resource where water tables are declining. Thus, for Nebraska, as well as many other large-scale groundwater governance systems, it is probably too soon to judge the robustness of the governance system based solely on the current state of the groundwater resources.

To find alternatives to evaluate the success of water governance systems, we turned to the work of Elinor Ostrom, who developed a list of eight governance characteristics that more often than not were present in robust water governance systems for locally controlled "common-pool resources." "The term 'common-pool resource' refers to a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom, 1990, p. 30.)

Table 2: Criteria for Assessing Successful Water Governance

1	**Clearly Defined Boundaries –** Both the individuals who have rights to withdraw from the resource and the boundaries of the resource being governed must be clearly defined.
2	**Rules to Prevent Overharvesting –** There must be rules to restrict use to prevent depletion of the resource. The purpose of these rules is not necessarily to allocate water among uses or to water users.
3	**Recognition of Rights to Organize at the Local Level –** The rights of users to devise their own institutions are not challenged by external governmental authorities.
4	**Congruence Between Appropriation/Provision Rules and Local Conditions; Proportional Equivalence between Benefits and Costs –** A one-size approach to water governance does not fit all situations; the approach must reflect the conditions of a given locale and must provide benefits and costs acceptable to water users.
5	**Secure Tenure Rights –** To encourage sustainable practices and investment, water users have assurance that their right to the resource is secure for the long term.
6	**Graduated Sanctions –** Users who violate rules are likely to receive graduated sanctions dependent on the seriousness and context of the offense.
7	**Rapid Access to Low-Cost Effective Conflict Resolution Mechanisms –** Users and their officials have rapid access to low-cost local arenas to resolve conflicts among users or between users and officials.
8	**Monitoring –** Monitors, who actively audit biophysical conditions and user behavior, are at least partially accountable to the users, or are the users themselves.
9	**Adequate Funding –** A stable and sufficient funding source is necessary to develop and sustain water management and regulation programs.
10	**Collective-choice Arrangements –** Ability to Influence Rules and Collaboration - Most individuals affected by harvesting and protection rules are included in the group that can modify these rules.
11	**Effective and Efficient Communication Systems –** Effective and efficient communication must be in place; groups that do not communicate well are more likely to overuse the resource.
12	**Leadership –** Good leadership is critical. Good leadership involves making difficult choices that are in the best interest of society as a whole, providing overarching direction to constituents, and being willing to be a part of the long-term decision-making process.
13	**Trust –** Trust is an essential component in building reciprocity and cooperation.
14	**Equity and Procedural Fairness –** Mechanisms are available to achieve equity and procedural fairness. Despite differences in how people use and value water, it is essential that all water users feel they are treated fairly.
15	**Adaptive Management –** Water institutions must be able to adapt to changing conditions. To adapt they must have the freedom and flexibility to develop and implement innovative solutions, learn from new information, and revise their action plans.
16	**Nested Enterprises and Adaptive Co-management –** local institutions are part of a larger, integrated network with different hierarchies and scales that collaborate with each other to manage the resource.
17	**River Basin Approach –** A governance system must have the ability to holistically manage a basin's water system as well as other key aspects of the basin's ecosystems.

According to Ostrom (1990), the central question is what criteria can one use to determine whether a group of interdependent individuals can organize and govern themselves to obtain continuing joint benefits from a common pool resource when all face temptations to free-ride, shirk, or otherwise act only in their own short-term interest? Using game theory, laboratory experiments, and the examination of governance institutions all over the world that have sustained the benefits from "common-pool resources" for up to 1,000 years, Ostrom developed a list of eight principles or characteristics of sustainable governance (Ostrom, 1990 and 2009b).

To provide more clarity for our assessment, and in keeping with later research, we have chosen to separate several of Ostrom's principles, which resulted in an expansion from eight to a total of 14 criteria. To this list we added three criteria: Adequate Funding, River Basin Management and Adaptive Management, which are currently being discussed as also being necessary for good water governance. Although these criteria are based on the study of small-scale governance institutions, as suggested by Anderies et al. (2004), we believe they form a good basis for evaluating a large-scale system. These criteria are listed in Table 2.

The data used in this study were collected from a number of sources, including: state law, which provides the structure of the legal and institutional framework of the NRD water governance system; the rules, regulations, and actions of the State DNR and the NRDs; newspaper reports; and interviews recorded by the Nebraska Natural Resources Districts Oral History Project.

We also used the results of separate work by Hoffman[6] from semi-structured interviews and qualitative and quantitative studies of the perspectives and experiences of resource managers and stakeholders in the overappropriated portion of the Platte River Basin (Hoffman, 2013; Hoffman et al. 2015). As a result of this overappropriated designation in 2004, five NRDS (the North Platte NRD; South Platte NRD; Central Platte NRD; Twin Platte NRD; and Tri-Basin NRD) governing the overappropriated area and the State DNR are legally required to develop integrated management plans for each NRD and a basin-wide plan for the overappropriated area. The region exhibits a number of water management challenges, many common to other basins, including increasing demands on limited water resources and a diversity of stakeholders and interest groups with often conflicting agendas. In addition, the presence of federally listed endangered and threatened species in this basin has resulted in additional regulatory requirements to protect stream flows under the Federal Endangered Species Act and the development of an ongoing over $320 million collaborative tri-state/federal threatened and endangered species recovery program within the study region (Hoffman, 2013; Hoffman et al. 2015).

For some criteria, including those pertaining to the state's legal framework, the data are objective and apply to the entire governance system; for others, such as each NRD's rules, monitoring system, and funding, the data are also objective, but vary among NRDs. Finally, the data pertaining to communication, collaboration, leadership, trust, and equity, are both subjective and vary among NRDs.

For the assessment of the more subjective criteria, we relied heavily on the perceptions and beliefs of government officials and stakeholders that were expressed in the news media, and on questionnaires and during personal interviews in Hoffman's studies (Hoffman 2013; Hoffman, et al. 2015)

To provide the reader with some sense of the range of conditions faced by the NRDs, as well as a more in depth understanding of how the NRDs operate, we also include excerpts highlighting the activities of three NRDs: the Central Platte (CPNRD), the Upper Big Blue (UBBNRD), and the Lower Platte South NRD (LPSNRD) (see Appendices A-C). Briefly, the CPNRD has a lot of surface water; plentiful groundwater, often accessible at very shallow depths; vast areas of fertile irrigated cropland; and the Platte River, a large river that is hydrologically connected to the district's groundwater reservoir. The federal government has a major influence on water use in this NRD, because a number of federally listed endangered and threatened species rely on the flows of the Platte River. The UBBNRD also has extensive cropland, as well as a larger groundwater reservoir. However, unlike the CPNRD, the water table in much of the district is greater than 200 feet deep, and in contrast to the CPNRD, the major river in the district is not in close connection to the major groundwater reservoir system. The LPSNRD has a large urban center, with a growing population of almost 269,000 in 2013 (Lincoln-Lancaster County Planning Department, 2014), very little irrigated land, and a highly variable groundwater reservoir system, which is completely absent in many areas, and in other areas can only support small capacity domestic wells. Some groundwater in the district is also highly saline. Thus, within the LPSNRD, many do not have enough water for irrigation wells and many domestic wells struggle to have sufficient good quality water. Significantly, the source of the water supply for the City of Lincoln, where most of the district's population lives, is outside of the district.

B. Criteria Description and Assessment

In this section each of the criteria used for the assessment will be described. The description will be followed by an assessment of whether the NRD governance system meets the described criterion.

1. Clearly Defined Boundaries

Criterion: As a first step towards robust governance, the boundaries of the resource system being governed and the individuals or households with rights to harvest the resource must be clearly defined.

Without defining the boundaries, and closing the use of the resource to outsiders, local appropriators face the risk that any benefits they contribute to the effort will not return to them, and those who have made investments based on the availability of the resource will not receive as high a return as expected on their investment (Ostrom, 1990; Ostrom 2009a).

Assessment: The NRDs have clearly defined, legislatively determined boundaries drawn along surface watershed boundaries (Figure 4). There is no question of which NRD permits the right to drill a groundwater well and regulate groundwater use on a piece of land. Likewise, the rights to use surface water are governed by the State DNR, and there are no questions about the boundaries for the governance of surface water use. Thus the resource boundaries and the

[6]Hoffman's Platte River Basin research involved data collection, synthesis, and analysis of relevant documents (i.e. Integrated Management Plans; newspaper articles); 33 in person and two telephone semi-structured, confidential interviews with stakeholders (including state and local water managers, surface and groundwater users, NRD board members, environmental representatives) ranging from 30 to 90 minutes; and a self-administered, anonymous mail survey sent to water users (1,615 mail surveys were sent and 338 completed and returned resulting in a response rate of 21%). For an in-depth description of the methodology used in Hoffman's study, see Hoffman 2013.

users who have the rights to use the resource are clearly defined. Nevertheless, there are problems related to how the boundaries were drawn.

One issue relates to the scale of the governance units in relation to the resource. To provide for locally controlled governance for large river basins, the creators of the NRDs deemed it necessary to split the larger basins among several NRDS. The Platte River Basin, which crosses the entire state, was split into seven different NRDs (Figure 4). The legislature recognized that splitting a basin among several jurisdictional units could be a potential problem when it stated in intent language:

"The Legislature recognizes that groundwater use or surface water use in one natural resources district may have adverse effects on water supplies in another district or in an adjoining state. The Legislature intends and expects that each natural resources district within which water use is causing external impacts will accept responsibility for groundwater management in accordance with the Nebraska Groundwater Management and Protection Act in the same manner and to the same extent as if the impacts were contained within that district" (Neb. Rev. Stat. §46-703 (4)).

This intent language, however, does not have the enforceability of an actual legal requirement.

Second, although drawing the NRD boundaries along surface watershed boundaries made sense when the NRD legislation was being developed and the major concern was controlling flooding and drainage problems, as the law evolved and the NRDs were given increasing authority over the use of groundwater, the NRD boundaries became more problematic. Nebraska's groundwater reservoirs not only do not coincide with the surface watershed boundaries, but they also extend large distances beyond the surface watershed boundaries and thus interact not only with different NRDs, but also with different river systems[7] (Figure 5). The resulting problems are compounded where surface water

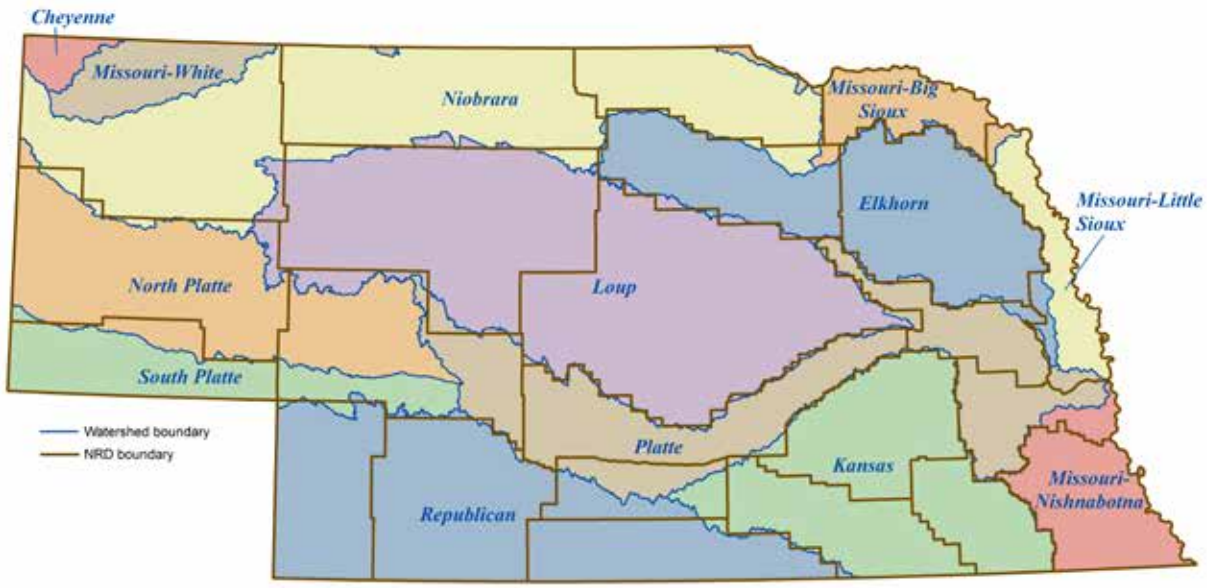


Figure 4. Nebraska Natural Resources District Boundaries and Surface Water Shed Boundaries

and groundwater are hydrologically connected and impacts to streams within one NRD can be carried great distances downstream affecting other NRDs. Such hydrological boundary problems are not unique to Nebraska.

To resolve the administrative problems related to boundary issues the integrated management law requires the State DNR to delineate the boundary within which surface water and groundwater are hydrologically connected when a basin is declared to be fully or overappropriated (Neb. Rev. Stat. §46-713(1)(a)). To make this determination, the State DNR first had to develop a rule to define what areas of the groundwater would be considered as hydrologically connected to the surface water streams for purposes of administering a fully appropriated or overappropriated basin. Using a negotiated rule-making process, the State DNR adopted a rule based on the extent to which withdrawals by a well a certain distance from the stream would have an impact on a stream within a certain period of time (Nebraska Administrative Code Title 457 – Department of Natural Resources rules for Surface Water Chapter 24 - 001.02).[8] The final rule, a compromise between achieving a certain level of

[7] The importance of the hydrologic connection between surface water and groundwater was recognized when drawing the boundaries of the Tri-Basin NRD. The boundaries of the Tri-Basin NRD, which includes parts of three different river basins, coincides with the area influenced by recharge from the Central Nebraska Public Power and Irrigation District, Nebraska's largest irrigation district. The intent in drawing the Tri-Basin NRD boundaries was to create a district that would collaborate with the Central Nebraska Public Power District on management of the hydrologically connected water supplies (Orton 2014, personal communication).

[8] Chapter 24 - 001.02 The geographic area within which the Department preliminarily considers surface water and groundwater to be hydrologically connected for the purpose prescribed in Section 46-713(3) is the area within which pumping of a well for 50 years will deplete the river or a base flow tributary thereof by at least 10% of the amount pumped in that time.

protection that wells would not deplete streams, and the practicality of implementing regulations of wells at some distance from the stream on a timely basis limited, but did not eliminate, the problem of groundwater wells adversely impacting surface water users, or vice-versa.

Shortly after this rule was adopted, the State DNR declared that a small area of the Upper Big Blue NRD was hydrologically connected to a stream in the Central Platte NRD. Consequently, the State DNR required the Upper Big Blue NRD to control groundwater pumping to protect water users in the Central Platte NRD. A lawsuit challenging this requirement was filed by the Upper Big Blue NRD, but the State Supreme Court upheld the State DNR's decision, maintaining the requirement that an NRD must regulate wells in their district to protect water users in another district if that district is hydrologically connected (Upper Big Blue NRD v. State, DNR 2008). As a result of these decisions, the administrative boundaries for hydrologically connected surface water and groundwater governance in fully and overappropriated basins were able to be clearly defined.

In sum, the boundaries delineating the resource and restricting who can use the resource are clearly defined statewide.

2. Rules to Prevent Overharvesting

Criterion: Rules limiting the use of the resource are needed to prevent the users from overharvesting the resource itself (Ostrom, 1990). Without limiting use to prevent overharvesting, local appropriators face the risk that any benefits they contribute to the governance effort will not return to them, and those who have made investments based on the availability of the resource will not receive as high a return as expected on their investment. Moreover, if there are a lot of appropriators and a high demand for the resource, the chances the resource will be overused are also high (Ostrom, 1990). For this criterion, we define

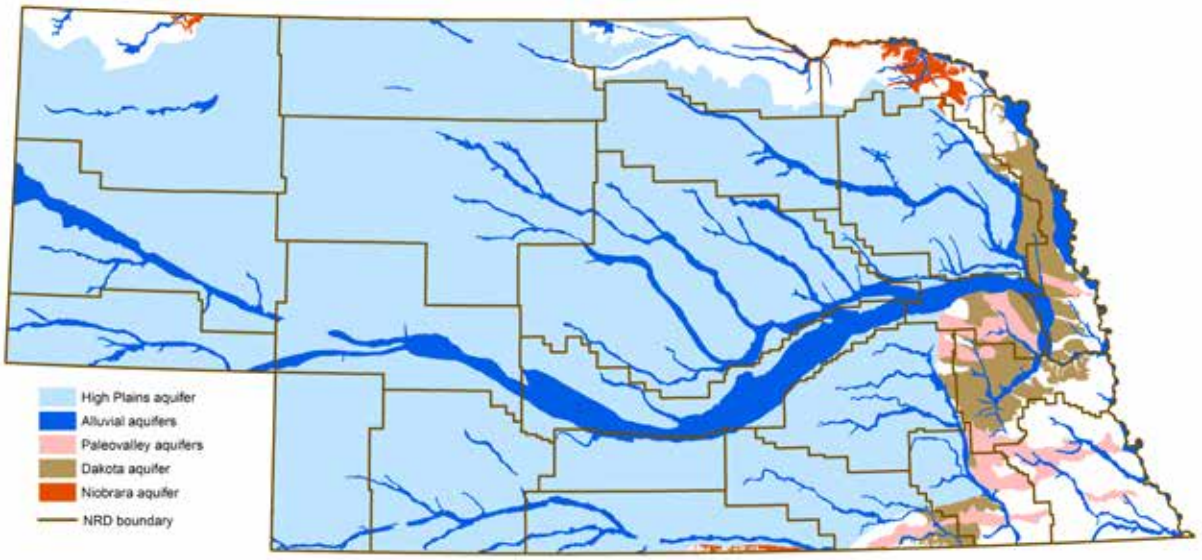


Figure 5. Nebraska Natural Resources District Boundaries and Principal Groundwater Aquifers Boundaries

the term overharvesting simply as the long-term overuse of the resource to the extent that the resource itself cannot be sustained. Issues related to how the resource should be allocated among types of uses or among individual users are not considered as part of this criterion. Where resources are frequently renewed by precipitation and other water inflows, long-term overharvesting may not be a major problem. On the other hand, in cases such as groundwater aquifers with little or no inflow from recharge, overharvesting can be a major problem. In such cases any use of this groundwater supply is likely to cause overharvesting. In these cases overharvesting may be acceptable as long as the stakeholders depending on the resource are aware of the overharvesting and are willing to accept the consequences.

Assessment: The NRDs were given authority to limit overharvesting. The Upper Republican NRD in 1978 was the first to implement rules to restrict groundwater use (Aiken, 1980). The recently enacted integrated management law (Neb. Rev. Stat. §46-701 – 739) provides additional legal requirements designed to prevent overharvesting in areas where surface water and groundwater are hydrologically connected. This law requires the State DNR to annually determine which river basins are fully appropriated. When such a determination is made, the State DNR and the NRD must jointly develop an integrated management plan with the purpose of "sustaining a balance between water uses and water supplies so that the economic viability, social and environmental health, safety, and welfare of the river basin, sub-basin, or reach can be achieved and maintained for both the near term and the long term" (Neb. Rev. Stat. §46-715(2)). If a basin is designated as overappropriated, the law also requires the integrated management plan to incrementally reduce the consumptive uses of water in the basin

to achieve the goal of sustaining a balance between water supplies and uses. There were two basins in the state that had already been overharvested before the integrated management law was passed in 2004. One of these sub-basins met the legal criteria for being designated as overappropriated[9] . In the other basin, the Republican River Basin, restrictions on groundwater use have been implemented to achieve compliance with the interstate Republican River Compact, but because this basin is officially designated as fully appropriated, not overappropriated, reductions in groundwater use to eliminate overharvesting are not specifically required by law, but water rights existing at the time the basin was designated as fully appropriated must still be protected from adverse impacts due to new water uses. Twelve NRDs have implemented rules to prevent overharvesting.

In some cases, NRDs have been able to prevent overharvesting by educating and providing assistance to irrigators to reduce their use of groundwater. For example, because of such efforts by the Upper Big Blue NRD, groundwater levels are above what they were in 1961, in spite of the addition of more than 420,000 groundwater irrigated acres (169,000 hectares) (Appendix A: Figure 6, Upper Big Blue NRD 2014). However, in other areas, overharvesting has occured, and the groundwater tables are continuing to decline (Appendix E: Figure 23).

In some cases, NRDs have been able to avoid overharvesting by educating and providing assistance to irrigators to reduce their use of groundwater. For example, because of such efforts by the Upper Big Blue NRD, groundwater levels are above what they were in 1961, in spite of the addition of more than 420,000 groundwater irrigated acres (169,000 hectares) (Appendix A: Figure 6, Upper Big Blue NRD 2014). However, in some areas the NRDs have failed to prevent overharvesting, and the groundwater tables are continuing to decline (Appendix E: Figure 23).

In sum, NRDs have the authority to reduce or eliminate overharvesting. In addition, where surface water and groundwater are hydrologically connected, which includes a large portion of the water resources of the state, the recently passed integrated management law requires water use restriction to prevent overharvesting in the future. Groundwater reservoir levels in some areas are still declining, but given the lagged impacts related to groundwater use, it is too early to tell whether actions of the NRDs to restrict groundwater use, together with the joint actions of the NRDs and the State DNR under the new integrated management law, will ultimately succeed in providing robust governance of the state's water supply.

3. Recognition of Rights to Organize at the Local Level

Criterion: Robust governance also requires that the rights of users to devise their own institutions are not challenged by external governmental authorities. The ability to establish local rules, in some cases, has allowed the evolution of fairly complex rules that are nevertheless accepted and enforced by the stakeholders without external government authority. For example, irrigation associations, which often have complicated regulations, have been acclaimed as major contributors to efficient irrigation and thus to substantial agricultural development. On the other hand, when external governmental officials do not understand the local system, but in an effort to help, presume that only they have the authority to set the rules, systems previously robust for long periods of time have largely been destroyed (Anderies et al. 2004; Ostrom 1990 and 2009a).

Assessment: As far back as 1959, when the legislature passed the Groundwater Conservation Act, Nebraskans have advocated and the Legislature has supported the local control of groundwater resources (Aiken, 1980). Today in the Platte River Basin stakeholders purported that locally tailored management districts can better address the diverse water resource challenges that exist from one end of the state to the other. Furthermore, they stated, the NRDs have fostered the development of "innovative solutions" that would not be possible if management was imposed from the state (Hoffman Babbitt et al. 2015).

The rights of the NRD boards to devise their own rules, particularly as the rules relate to the management of groundwater, are clearly recognized by the Nebraska statutes,[10] and a 49-member Water Policy Task Force, formed by the Governor and Legislature in 2004, strongly reaffirmed this policy. The Water Policy Task Force was charged with reviewing the state existing water laws to determine what, if any, changes were needed to address Nebraska's conjunctive use and integrated management of hydrologically connected surface and groundwater. Although eliminating the split between the State DNR administering surface water under the prior appropriation system and the NRDs administering groundwater under the correlative rights system was a potential option under the charge of the Legislature, the Water Policy Task Force decided to maintain the basic framework of the existing law, clearly recognizing and affirming the rights of the NRDs to organize at the local level.

[9] Neb. Rev. Stat. §46-713(4)(a) A river basin, sub-basin, or reach shall be deemed overappropriated if, on July 16, 2004, the river basin, sub-basin, or reach is subject to an interstate cooperative agreement among three or more states and if, prior to such date, the department has declared a moratorium on the issuance of new surface water appropriations in such river basin, sub-basin, or reach and has requested each natural resources district with jurisdiction in the affected area in such river basin, sub-basin, or reach either (i) to close or to continue in effect a previously adopted closure of all or part of such river basin, sub-basin, or reach to the issuance of additional water well permits in accordance with subdivision (1)(k) of section 46-656.25 as such section existed prior to July 16, 2004, or (ii) to temporarily suspend or to continue in effect a temporary suspension, previously adopted pursuant to section 46-656.28 as such section existed prior to July 16, 2004, on the drilling of new water wells in all or part of such river basin, sub-basin, or reach.

[10] The Nebraska statutes state "The legislature also finds that natural resources districts have the legal authority to regulate certain activities and, except as otherwise specifically provided by statute, as local entities are the preferred regulators of activates which may contribute to groundwater depletion." Neb. Rev Stat §46-702.

The law developed by the task force did, however, say that where surface water and groundwater were hydrologically connected and determined to be fully appropriated, the NRDs were required to work with the State DNR to jointly develop an integrated water management plan. (Nebraska Water Policy Task Force to the 2003 Nebraska Legislature, 2003). If the State DNR and the NRD cannot agree on a plan, the issue is decided by an ad-hoc, five-member Interrelated Water Review Board, appointed by the Governor (Neb. Rev. Stat. §46-719).

In sum, the rights of users to organize at the local level are fully endorsed and supported by the state.

4. Congruence Between Appropriation/Provision Rules and Local Conditions; Proportional Equivalence between Benefits and Costs

Criterion: Rules specifying the quantity of the resource a user is allocated must be related to local conditions and to rules requiring labor, materials, and/or money inputs. If the initial set of rules established by the users, or by a government, are not tailored to fit the local problem, or the benefits derived from the resource do not outweigh the costs to use the resource, long-term sustainability may not be achieved (Ostrom, 1990 and 2009a; Anderies et al. 2004.) Assessment of the benefits and costs also extends over time (Ostrom, 1990). Ostrom concluded that one rule does not fit all circumstances (1990). She also concluded that simple blueprint policies that do not consider the specifics of each situation do not work (Ostrom, 2009a and 2009b).

Assessment: One of the most-touted benefits of the NRDs is that they can, and do, implement different rules to fit differing conditions among and within the NRDs. According to water users in the Platte River Basin, local expertise and firsthand knowledge of the resource not only allows management strategies to be customized to the issues at hand, but also more quickly and effectively address problems if they arise (Hoffman, 2013; Hoffman & Zellmer, 2013). For example, NRDs in the drier

areas of the state with larger water-table declines implemented stricter water-use allocations relatively early, whereas in the more humid eastern areas of the state, groundwater controls are only now beginning to be implemented. Depending on the need to supplement rainfall and the water in storage in the groundwater reservoirs, the number of inches an irrigator is allowed to pump per acre varies among NRDs from highs of an average of 65 inches (165 cm) over five years (an average of 13 inches [33 centimeters] per year) to 21 (53 centimeters) inches over three years, (an average of 7 inches [18 centimeters] per year (Table 3). NRDs also establish different rules for different areas within their NRD. Usually the delineation of the sub-area and the rules themselves are based on the results of a water quantity- or quality-monitoring network. For example, if a certain percentage of monitoring wells show a certain level of a contaminant has been exceeded in an area, a sub-area will be created and rules will be established for that sub-area to address the specific issue of concern. Where contamination is low and no preset limit or "trigger" has been exceeded, the NRD may simply encourage education on best management practices. Where contamination is higher and a trigger has been exceeded, required education certification, soil and water monitoring, and/or annual water and fertilizer use reports, may be required (Table 4). Where contamination is highest, restrictions on the use of farm chemicals and or irrigation scheduling will likely be imposed. If contamination levels decrease, the rules may also be relaxed.

The NRDs also set their own tax levies. However, the NRD boards are locally elected so that tax payers are in a position to, and with their vote do, judge whether the benefits they receive from the NRDs are worth the costs. Thus, NRD boards prefer not to raise taxes, but when expenditures are justified, they can and do increase tax levies. One NRD, which had one of the lowest tax levies in the state, was able to more than quadruple its taxes over four years, because the NRD was able to justify the need for an increase (Miller, 2014). Within the Platte River Basin, Hoffman found a strong majority of water users (85%) believed that the benefits they receive from using water resources outweigh the associated costs of supporting the NRD. However, during in-person interviews, research revealed that several environmental water users believed that while there is a cost associated with water used for irrigation, there is currently no cost associated with the environmental impacts of taking water out of the river or for costs associated with related ecosystem services (Hoffman Babbitt et al. 2015).

In sum, the rules are highly congruent with local conditions and the local electorate ensures that the monetary costs do not outweigh benefits. However, some environmentalists would argue that there are currently no costs associated with the environmental impacts of taking water out of the river or for costs associated with related ecosystem services.

5. Secure Tenure Rights

Criterion: Secure tenure arrangements, including secure water rights, determine who, when, and how people can use a natural resource. Defined water rights empower people and provide the basis for investing in the future, which helps sustain the resource (The International Bank for Reconstruction and Development/The World Bank, 2006; Meinzen-Dick, 2007; Perry, 2013). Although Ostrom did not use the term tenure right, she discussed the importance of having long-term rights to the resource. Ostrom observed that if people believe their right to reap the benefits of a resource will continue for a long time, they are more likely to invest to preserve the resource (Ostrom, 1990). On the other hand, if water tenure arrangements are insecure, talk of effective water governance may well be an illusion (Hodgson, 2013). Secure tenure rights may also reduce transactional costs related to developing conjunctive management solutions to surface and groundwater resources (Blomquist et al. 2001).

Because of the ephemeral nature of water, a tenure right to water is not as secure as a tenure right to land (Trelease, 1957; Sax, 1990; Tarlock, 2012). In addition, a water right is often not an ownership right, but is a usufructuary right, that is, a right to use a portion of the public's water supply. Nevertheless, despite their usufructory nature, water rights have always been treated as transferable property rights (Tarlock 2002) and providing secure tenure rights is a basic underpinning of most of the water rights administration systems in the Western U.S. According to Hobbs (2007) the objective of water law is to guarantee a secure and reliable source of water. Security resides in the system's ability

to identify and obtain protection for the right of water use, and reliability springs from the system's assurance that the right of water use will continue to be recognized and enforced over time (Hobbs, 2007).

Assessment: In Nebraska, as elsewhere, the waters of the state were considered to be a "natural want," and were dedicated to the people of the state. However, for surface water the state adopted a prior appropriation system of law in which a person could obtain a right from the state to divert and use the waters of the state for a beneficial use (Nebraska State Constitution XV-4 through XV-6). Under the prior appropriation system, a senior appropriator has the first rights to water and therefore cannot be harmed by a junior appropriator. In addition, under Nebraska's Constitution, a surface water right is considered to be a property right that is entitled to the same protection as any other property right (Loup River Pub. Power Dist. v. N. Loup River Power & Irr. Dist., 1942; Bond and McClaren v. Nebraska Public Power Dist. and Department of Natural Resources, 2013).

Swearing in ceremony for new board members

As with other property rights, surface water rights can be bought and sold, but these sales are subject to the transfer laws of the state, which were established to both keep track of the water rights, and to protect other surface water appropriators from being harmed by the transfer (Neb. Rev. Stat § 46-290-294). Thus, to the extent climatic variations allow, the law provides a high degree of security that surface water rights will not be harmed by other surface water users.

The NRDs have authority to, and all do, require permits for drilling groundwater wells and all regulate groundwater transfers (Table 3). Like surface water, the groundwater users' tenure security is also impacted by climate, but, unlike surface water rights, which have clearly defined protections vis-à-vis other surface water users, protections for groundwater users are not as clearly defined. Rather, under Nebraska's modified correlative rights system, under which groundwater is shared in times of shortage, the security of a groundwater permit depends on the willingness of the NRD to regulate all groundwater users sharing a groundwater reservoir. In addition, although groundwater use is shared and may be equally allocated among users, not all users may be able to access their allocated share. For example, if, because of the specific conditions of a groundwater reservoir, the wells of only a few groundwater users are dewatered, the NRD board may choose not to restrict the groundwater use of all the groundwater users to protect only a few. Finally, Nebraska law does not authorize any entity to require a permit for or restrict the use of groundwater wells pumping 50 gallons per minute (190 liters/minute) or less that are for domestic human use or stock watering (Neb. Rev. Stat §46-735). Thus, although the NRDs have the authority to restrict the use of water by non-domestic wells, neither the NRDs nor the state can proactively protect water users from being impacted by domestic wells. In all such cases, the only recourse for an aggrieved water user is to file a lawsuit.

Where surface water and groundwater are hydrologically connected and water is in short supply, the integrated management law requires existing water rights to be protected by an integrated management plan (Nev. Rev. Stat. §46-715(4)),[11] but state law provides very little legal recourse for those who believe their water rights are not protected by the integrated management plan. This issue was even emphasized by the Nebraska Supreme Court in a case involving a surface water user who complained that groundwater pumpers had been allowed to deplete stream flows to the detriment of his surface water rights. In this case the court opined "Although the integrated management law is a step toward reducing future conflicts through general regulation, ideally, the Legislature would develop a more comprehensive administrative appropriation system, including procedures and remedies, to adjudicate direct conflicts between groundwater and surface water users in Nebraska" (Spear T Ranch, Inc. v. Knaub, 2005, p. 201). To date, the Legislature has not taken such action. Thus Nebraska state law provides little legal protection to assure the security of tenure rights for surface water users where surface water and groundwater are hydrologically connected (Aiken, 2013b).

In sum, the law provides a high degree of security that surface water rights will not be harmed by other surface water users. However, the law does not provide a similar level of security that the rights of groundwater users will be protected from the overuse. Rather the security of groundwater rights depends on the willingness of the NRD to regulate groundwater use. Likewise, where surface water and groundwater are hydrologically connected, the rights of all water users depends on the willingness of both the State DNR and the NRD to regulate water under an integrated management plan.

6. Graduated Sanctions

Criterion: Users who violate rules are likely to receive graduated sanctions in which the punishment depends on the seriousness and context of the offense. It has been shown that in robust institutions, sanctioning is not implemented by external authorities, but by the participants themselves, who are willing to take the time and effort to monitor and sanction each other's performances. Furthermore, initial sanctions are surprisingly low, because the appropriator-monitor is often in the same situation, and, therefore, has a good understanding of why a rule was violated (Ostrom, 1990 and 2009b). Nevertheless, to ensure the long-term management and sustainability of the resource, participants need to be willing to apply graduated sanctions that fit the offense committed in an equitable and enforceable manner.

[11] Nev. Rev. Stat. §46-715(4) states "The groundwater and surface water controls proposed for adoption in the integrated management plan pursuant to subsection (1) of this section shall, when considered together and with any applicable incentive programs, …(c) protect the groundwater users whose water wells are dependent on recharge from the river or stream involved and the surface water appropriators on such river or stream from streamflow depletion caused by surface water uses and groundwater uses begun, in the case of a river basin, sub-basin, or reach designated as overappropriated or preliminarily determined to be fully appropriated in accordance with section 46-713, after the date of such designation or preliminary determination.

Assessment: The Nebraska statutes provide graduated sanctions for those that violate either a state or an NRD regulation. The penalties can increase on a daily basis. For example there are four classes of misdemeanors with penalties ranging from no penalty up to one year in prison and/or fines from zero to up to $1,000 per day of infraction. (Neb Rev Stat. §46-254, 263, and 266). In addition, the NRDs can and do grant variances to their rules and provide a period of time for a violator to achieve compliance without incurring a penalty. In these cases the sanctions may be surprisingly low because the NRD board members have been in the same position themselves.

In sum, state law provides for, and the NRDs often grant variances to their rules. In addition, in many cases violators are allowed to achieve compliance without a penalty. Thus users who violate rules are likely to receive graduated sanctions dependent on the seriousness and context of the offense.

7. Rapid Access to Low-Cost, Effective Conflict Resolution Mechanisms

Criterion: At the most local level, water users and their officials must have rapid access to low-cost, local arenas to resolve conflicts among users or between users and officials. Anyone who possesses a legal water right should be able to initiate an action to enforce compliance without needing to rely on a higher-level entity to initiate punitive actions against non-conformers. Without such alternative mechanisms, the only recourse for aggrieved water users is a lawsuit, which can become expensive, time-consuming and burdensome. In such cases water users and their officials can be left feeling powerless and ineffective in their efforts to adequately and effectively manage the resource (Ostrom 1990 and 2009a).

Resolution of water disputes at the local level also helps to ensure that the decision makers resolving the dispute understand the legal and local hydrological conditions involved in the dispute. Hobbs, a former water attorney and now a Justice

on the Colorado Supreme Court, observed that, in general, courts don't understand water. In part for this reason, Colorado water is administered in seven sections, and each section has a water referee and its own water court. Furthermore, any decision of a water court bypasses the Court of Appeals and goes directly to the Colorado Supreme Court (Hobbs, 2014).

Assessment: In Nebraska disputes among surface water users are often resolved informally by the local division office of the State DNR, and disputes among groundwater users are often resolved informally or through a more formal complaint process by the NRDs. In addition, under Nebraska law, if conflicts over hydrologically connected surface water and groundwater arise, either between the State DNR and an NRD or between two NRDs, the dispute may be taken to an ad-hoc five-member Interrelated Water Management Board appointed by the Governor (Neb. Rev. Stat. §46-717-719). To date, the Interrelated Water Management Board has not been used.

On the other hand, there are no established institutionalized alternatives to formal lawsuits for disputes between surface water users and groundwater users or for individual users, or any other entity that is not the State DNR or an NRD, who have a dispute with water officials. For these entities, the only recourse is to file a lawsuit. Furthermore, the Nebraska courts developed a very high standard that must be met to be successful in such a lawsuit. As discussed in Hoffman and Zellmer (2013), the Nebraska Supreme Court has adopted the Restatement (Second) of Torts §858 for dealing with competing equities of groundwater and surface water appropriators. In their restatement the Nebraska Supreme court said "in order to prove a claim under the Restatement, the surface water user must show that groundwater pumping has a 'direct and substantial effect' on the river or stream which 'unreasonably causes harm' to the surface water user." (Hoffman & Zellmer 2013, pp. 826-827). What is "reasonable" is determined on a case-by-case basis using an array of factors ranging from considerations of the actual water use, value, and harm caused. As Hoffman and Zellmer (2013) conclude, although this judicial tactic may lead to equity among parties in some cases, the process is likely to be fact and time intensive, as well as costly.

In looking at the perceptions of water users within the Platte River Basin, quantitative survey results indicate water users are split on whether Nebraska's water management system has adequate conflict mechanisms in place; 46.2% of those surveyed indicated that they believe the system is working well in this regard, whereas 53.8% do not (Hoffman Babbitt et al. 2015).

In sum, although there are some alternatives to filing a lawsuit at the local level, there are no institutionalized local venues to resolve conflicts between surface water users and groundwater users or between water users and officials.

8. Monitoring

Criterion: Monitors, who actively audit biophysical conditions and user behavior, must be at least partially accountable to the collective group of users or are the users themselves. In the cases studied by Ostrom (1990), there were no outside authorities who played a role in enforcing the rules, but the local social norms were not sufficient by themselves to make sure the rules were followed over the long run. Rather the long-term effectiveness of rules depended on the users' willingness to monitor one another's harvesting practices and the ability of the users to understand and verify the results (Dietz et al. 2003; Ostrom, 2009a). As Ostrom describes, with communication and neutral monitoring, no appropriator pumper can expect to over extract without everyone else learning about any noncompliance (1990).

Assessment: Monitoring systems vary greatly among the NRDs, depending in part on the intensity of the perceived groundwater problems, and also (and importantly) on funding. All NRDs at least to some extent monitor the quantity and quality of the water in their districts, and some NRDs implement sophisticated and comprehensive groundwater monitoring networks and protocols. Nebraska has the largest database for monitoring nitrates and agricultural pesticides in groundwater in the United States because of the NRDs' collection efforts (Link, 2014, personal communication). The willingness of the NRDs to invest in monitoring is directly related to their understanding of the importance of protecting the groundwater on which they personally depend.

As described above, often these measurements are related to "triggers" that prompt either more restrictive regulations, or relax the regulations, depending on whether or not the aquifer conditions improved in various sub-areas within the NRD (Tables 3 and 4).

Interviews confirmed that in the Platte River Basin, water-use monitoring practices vary considerably throughout the basin and can even involve annual or semi-annual low-level infrared photography to ensure that farmers are complying with the established limits on irrigating land. However, interviews with NRD managers revealed that while some NRDs require meters, many do not. One NRD manager who supports water metering, made the case that actual facts (i.e. data from water meters) are much more informative in substantiating management actions than rhetoric. Survey results within the Platte River Basin, indicated that although the majority of respondents agreed that monitoring efforts are working "relatively well" to "very well" within the basin, respondents were mixed on the effectiveness of current monitoring efforts (Hoffman Babbitt et al. 2015).

In sum, both the state and the NRDs have widespread monitoring systems, but the quality of monitoring varies among NRDs and is particularly dependent on the availability of adequate funding.

9. Adequate Funding

Criterion: A stable and sufficient funding source is essential in developing and sustaining water management programs (Folke et al. 2005, Doremus et al. 2011, Hoffman and Zellmer 2013). When conditions are complex and uncertainty is high, as is the case with most decisions involving water, funding is critical for research that can not only accurately identify the problems and assist in designing effective solutions, but also provide information about the uncertainty and inherent unpredictability in the system, as well as the nature and extent of scientific ignorance and disagreement (Dietz et al. 2003). According to Coman (1911) the importance of knowledge of the resource was a key factor in whether early irrigation systems in the west succeeded. This knowledge must be accessible to and understood by the governing decision makers. Funding is also necessary to build infrastructure to alleviate problems and provide incentives to encourage compliance (Dietz et al. 2003).

Assessment:

Platte River Basin water users and managers recognize that funding is an important component of successful water management. According to one water manager, "the biggest solution that we need is, where the funding is going to come from." Throughout the Basin, water users recognize the challenges of finding financial resources to fund water projects and research, as well as for monitoring and water management (Hoffman, et al. 2015) Funding is also needed to ensure that the NRD staff and board members have the understanding and knowledge to make good decisions, and to educate the public so that support for these decisions, and the required funding, is developed and maintained.

NRDs have the authority to raise funds by levying taxes. However, there is a fairly wide disparity in the tax base across the state. For example, in 2013 -2014 the tax valuations of an NRD district dominated by urban uses were 37 times greater than a more rural NRD, which had the lowest valuation (Edson, 2014, personal communication).

There are also upper limits to this taxing authority,[12] and the elected board must ensure there is sufficient public support to levy the taxes. Thus, the number of cents per $100 assessed taxes approved by the NRD boards also varies. In 2013-2014 it ranged from 1.9 cents to 6.9 cents per $100 dollars of assessed valuation (Edson, 2014, personal communication). NRDs also have access to state and federally-funded programs, but the grant application must be approved by the funding agency, and these funds often require a local match. In 2007, the NRDs with an integrated management plan were also given the authority to levy an occupation tax of up to $10 per acre on irrigated agricultural lands (Neb. Rev. Stat. §2-3226.05). In addition some NRDs have used special bonding authority (Neb. Rev. Stat. §2-3226.01 and §2-3226.10) to fund their activities. Thus, in 2013-2014 the NRD budgets for their programs ranged from a low of $900,000 to $17 million[13] (Edson, 2014, personal communication). NRDs also have access to state and federally funded programs, but the grant application must be approved by the funding agency, and these funds often require a local match. In 2007, the NRDs with an integrated management plan were also given the authority to levy an occupation tax of up to $10 per acre on irrigated agricultural lands (Neb. Rev. Stat. §2-3226.05). In addition some NRDs have used bonds to fund their activities. In 2013-2014 the NRD

[12] See Hoffman and Zellmer (2013) for a discussion on the parameters of NRD taxing authority and the role of funding in adaptive water management efforts.

[13]This high figure was the result of a special bond issued to deal with a major, but one-time, expenditure.

[14]This high figure was the result of a special bond issued to deal with a major, but one-time, expenditure.

program budgets ranged from a low of $900,000 to $17 million[14] (Edson, 2014. personal communications). Funding for agencies that support the NRDs, especially those agencies that provide technical assistance to the NRDs, is also critical. The total budget of the State DNR in 2013-2014 was $26 million (Official Nebraska Government Website 2014). Although the State DNR is responsible for other natural resource activities, its primary focus is on water planning and regulation, as well as providing technical assistance to the NRDs and maintaining a large natural resources database for the state.

As previously discussed, the governance of water, especially groundwater, is technically complex. Effective water governance requires sufficient funding for data collection and research. Furthermore, with a high degree of hydrological variability from one locale to another, much of this research must be conducted at the local level. For many years the University of Nebraska, particularly the University's Conservation and Survey Division, was the major focal point for much of this research. In recent years the funding support from the University has waned for the kind of localized, descriptive hydrological studies necessary for water governance. To fill the gap, some, but not all, NRDs, were able to generate their own funding for such research. Often these NRDs turned to private consultants to provide the studies they needed. In other instances, particularly in basins that were the subject of an interstate lawsuit, the state provided funding for research; again in many instances private consultants were hired. Recently the state has provided additional funding for the State DNR to provide technical support for the NRDs.

While the state and federal government have provided funds for NRD infrastructure projects, often additional funds were needed so the NRDs themselves, using property and occupation taxing authorities, have generated their own funds for critical water projects. Examples of such projects

include the conjunctive use projects developed by the Central Platte NRD (See Appendix A), and the N-CORPE project, developed jointly by several NRDS in the Republican and Platte River Basins to assist the state in maintaining compliance with the Republican River Compact and the Platte River Recovery and Implementation Program for protecting endangered species (Aiken, 2013a,; Upper Republican NRD 2015).

Even with these funding sources, water users and managers believed additional funds were still needed. One of the recommendations of the 2003 Water Policy Task Force was to create a dedicated fund, not subject to the political whims of the Legislature every budget year, to enable water research and maintain and develop water infrastructure (Nebraska Water Policy Task Force to the 2003 Nebraska Legislature, 2003). This recommendation was not implemented when the integrated management law went into effect. To remedy this problem, in 2013 the Legislature formed the Water Funding Task Force to develop a plan to list and prioritize the water funding needs of the state, and to develop a governmental framework to administer these funds (2013 LB 517, Neb. Rev. Stat. §50-505). After 20 public meetings, tours, and educational sessions, and much to the surprise of some, the task force achieved a consensus on creating a Water Sustainability Fund that they hoped would receive $50 million in funding every year. However, the question of who should be on the committee that would allocate the funds was contentious and threatened to block a final task force consensus. Previously, state funds for water projects had been allocated by a 16-member Natural Resources Commission. Thirteen members of the commission were representatives from the NRDs. Many surface water users, municipalities, and environmental groups believed that the makeup of the commission meant that only NRD projects were likely to be funded. A number of members of the Water Funding Task Force indicated they might block a consensus if the commission that would administer the new funds were not changed to provide for greater representation. The impasse was broken when one task force member asked, "How many would agree that surface and groundwater are really one resource?" All agreed. At that point everyone realized they all shared the same water supply, and they could not afford a divide between surface water users and groundwater users. Also important were the task force members' observations that "We worked well together, we had an open discussion, it was a very good process," and "this group represents the water interests of the state and we have trust in each other." Based on that discussion, the task force then agreed to a board make-up for the Natural Resources Commission that would be similar in representation to the task force itself. Another comment sums up this sentiment: "the makeup of the commission is about trust, not representation." (Griffin 2014, personal communication).

Based on this consensus, bills creating a Water Sustainability Fund and changing the makeup of the Natural Resources Commission were introduced into the legislature in 2014. The Water Sustainability Fund was provided a one-time start-up fund of $21 million, and the dedication of $11 million per year, with no sunset clause indicating when the funding should end. The law creating the Water Sustainability Fund and an expanded commission to allocate the funds was passed by an almost unanimous vote of the Legislature (Neb. Rev. Stat. §61-222, Nebraska Laws 2014 LB 906 and LB 1098). This successful vote was achieved in part because six senators attended the task force meetings throughout and developed a better understanding of why funding was needed for water programs. With this understanding they were able to articulate the water funding needs to the entire legislature. The task force also developed a plan to continue the dialogue with senators until the bill was passed (Karen Griffin, 2014, personal communication). Also critical to the success of this funding bill was the leadership of the

Chair of the Natural Resources Committee of the Legislature and certain members of the task force. The importance of the Water Sustainability Fund cannot be overestated. The goals of the Water Sustainability Fund are to provide financial assistance to programs that increase aquifer recharge, reduce aquifer depletion, increase streamflow, improve drinking water, promote the goals and objectives of integrated management plans, reduce flooding, provide wildlife and recreational benefits, assist municipalities with sewer infrastructure, increase water productivity, enhance water quality, and comply with interstate compacts and agreements. Investment in research, infrastructure, and education are critical to successful water governance. Moreover, because the use of water in one area impacts the availability of water in others, these investments must be made throughout the state, not just in those areas that have the capacity to raise funds on their own.

In sum, funding to date has been inadequate and varies among NRDs, but recent legislative actions will help address this problem.

10. Efficient and Effective Communication Systems

Criterion: When people have different interests, good communication is critical for people to identify areas of alignment and effectively establish the rules. Deliberation allows the differences in interests, perceptions, and explanations to be explored without forcing an outcome. Importantly, groups that do not communicate are more likely to overuse the resource. In contrast in laboratory tests, where people had to resolve a common-pool resource conflict, groups that were allowed to communicate reached 90% of the optimal solution (Ostrom, 2009b). In the development of the west, communication was one of the key criteria for determining whether irrigation systems would survive (Ostrom, 2011). Effective governance is easier to achieve when communities maintain frequent face-to-face communication and dense social networks. Such communication increases the potential for trust, allows people to express and see emotional reactions

to distrust, and thus lowers the cost of monitoring behavior and inducing rule compliance (Dietz et al. 2003). Simply allowing "cheap" talk enables people to reduce overharvesting and increase joint payoffs (Ostrom, 2010).

Assessment: Because members of the NRD live, work, and play in the district, and importantly have to run for election every four years, there are many opportunities within the NRD for communication. In addition, NRDs across the state are actively engaged in many education initiatives and cost-sharing programs that provide benefits to and require NRD staff to interact with landowners. These efforts go a long way to increase camaraderie and communication. By law all board meetings are open to the public (Neb. Rev. Stat. § 84-1408 – §84-1410), although some complain that the deliberations of sub-committee meetings, which are not subject to the open-meetings law, should be more transparent.

In contrast, there are instances when NRDs have not communicated well, particularly with surface water users (Kearney Hub, September 25, 2012, and March 25, 2013). However, the Hoffman study observed that many stakeholders in the Platte Basin believed communication has increased, because the NRDs were required to develop integrated management plans (Hoffman, 2013).

In sum, communication is generally high, but communication varies among the NRDs.

11. Collective-Choice Arrangements: Ability to Influence Rules and Collaboration

Criterion: When multiple appropriators are all dependent on the same resource as a source of economic activity, they are jointly affected and tied together in a lattice of interdependence by almost everything they do. At the most general level, the problem facing these appropriators is one of both organizing governance systems to avoid the situation in which appropriators act independently, and creating situations in which they adopt coordinated strategies to obtain higher joint benefits, or reduce their joint harm (Ostrom, 1990). For these reasons in successful governance systems, most individuals affected by harvesting and protection rules are included in the group that can modify the rules (Ostrom, 1990; Deetz et al. 2003; Anderies et al. 2004).

If the rules are, in fact, to be established by the resource users, collaboration between the decision makers and water users is a necessity. In contrast to simply receiving input from stakeholders, such as at a public hearing, collaboration involves having the stakeholders actively take part in joint problem solving activities, such as gathering and analyzing information, formulating alternatives, and ranking preferred solutions. However, collaboration does not mean that the legally authorized decision makers must cede their authority to the collaborating group (Bruns, 2003).

According to Ostrom (1990), governance institutions that collaborate are better able to tailor their rules to local circumstances, because the individuals who directly interact with one another and the physical world are in the best position to modify the rules to better fit the specific characteristics of their setting. Collaboration also increases knowledge, results in more creative and new solutions, and increases trust and good relationships among those involved. Furthermore, once appropriators have made contingent self-commitments to the rules, they are motivated to monitor and help ensure the compliance of other appropriators. Finally, rules established by the resource users are better known and understood, and are more likely to be perceived as being legitimate (Anderies et al. 2004), which helps prevent legal challenges during later stages of the decision process (Ostrom, 1990, Dietz et al. 2003; Lebel et al. 2006; Berkes, 2009; Huitema et al. 2009).

In an analysis of public participation in water reuse projects in three states in the United States, Birkhoff

(2003) found that substantively better decisions emerged when diverse interests, knowledge, and expertise were involved in the decision-making process. On the other hand, when stakeholders were not fully involved in framing, analyzing, generating, and implementing solutions to complex public problems, they sought other ways of meeting their interests, often by hampering the decision process.

Collective choice and collaboration are particularly important when dealing with uncertainty. Uncertainties involving water resources include variations in the quantity and timing of water supplies, and other outside stresses such as economic factors. When groundwater is involved, uncertainty is particularly high (Ostrom, 1990).

Assessment: The NRDs are governmental institutions, but because they operate at such a local level and with locally elected directors, in many ways they function more as a local association than as a formal governmental entity. When the NRD board members, who make the rules, must also follow the rules, and in addition, go to the same church, grocery store, and coffee shop as the people they represent, the rule-makers hear and have many reasons to pay heed to local sentiment. Furthermore, the NRD board is elected by all registered voters and any citizen can run for the NRD board, not just landowners who are directly involved in a specific natural resource. Thus, all registered voters have a voice in the goals, objectives and programs of the district (Edson, 2005). In this way, the individuals affected by water use and protection rules are included in the group who can modify the rules.

Furthermore, state law requires the NRDs and the State DNR to collaborate with "official participants" to develop a basin-wide plan in the overappropriated area of the Platte River Basin (Neb. Rev. Stat. §46-715(5) and any basin with three or more natural resources districts that have been required to develop an integrated management plan for all or substantially all (85 %) of the district

(Neb. Rev. Stat. §46-755). The law defines official participants as "representatives from irrigation districts, reclamation districts, public power and irrigation districts, mutual irrigation companies, canal companies, groundwater users, range livestock owners, the Game and Parks Commission, and municipalities that rely on water from within the affected area and that, after being notified of the commencement of the plan development process, indicate in writing their desire to become an official participant in such process." (Neb. Rev. Stat. §46-755(5)(c)). Other stakeholders may also be added to the official participant list. Furthermore, this law states that collaboration shall "involve official participants in formulating, evaluating, and recommending plans and management actions," (Neb. Rev. Stat. §46-755(5)(c)) and if agreement is reached by all parties involved, the department and the affected natural resources districts shall adopt the agreed-upon basin-wide plan. If agreement cannot be reached by all parties involved, the basin-wide plan shall be developed and adopted by the department and the affected natural resources districts or by the Interrelated Water Review Board (Neb. Rev. Stat. §46-755(5)(c)).

Two NRDs in Hoffman's study area – the North Platte NRD and the Central Platte NRD – demonstrate a case where groundwater and at least some surface water users have come to understand that the surface and groundwater supplies, as well as the benefits derived from both, are truly interconnected. As a result, these two NRDs have collaborated closely with specific surface water irrigation districts to conjunctively manage surface water and groundwater in the region (Central Platte NRD, 2014, also see Appendix B). In situations where such understandings are strong and collaboration has occurred, the conflict between water users is much less.

In sum, the local nature of the NRDs encourages collective-choice arrangements. In certain situations the law requires collaboration, but collaboration and collective choice arrangements vary among NRDs.

12. Leadership

Criterion: According to Folke et al. (2005) good leadership involves making difficult choices that are in the best interest of society as a whole, providing overarching direction to constituents, and being willing to be a part of the long-term decision-making process. In their study on adaptive governance, Folke et al. (2005) found that after funding, effective leadership and management were identified as the second most frequent factors for developing successful partnerships. Leadership is essential in shaping change. Leaders are important for building trust, managing conflict, linking actors, initiating partnerships among actor groups, compiling and generating knowledge, and mobilizing broad support for change. When leaders are absent, inertia often results. Good governance depends on key personalities. Such persons are altruistic individuals with a diversity of contacts who can broker information. They also are innovative and willing to take risks (Folke et al. 2005; Ostrom, 2009a).

Assessment: One cannot discuss leadership without first mentioning the incredible leadership that was shown by the Governor of Nebraska, his staff, certain legislators, and members of the original soil and watershed conservation boards when the legislation creating the NRDs was developed and implemented in 1974 (Oltmans, 2013; Williamson and Starr 2013; Barr 2014; Yeutter, 2014). This leadership clearly involved making difficult choices for the best interest of society as a whole and providing overarching direction to constituents. It also required altruistic, innovative individuals with a diversity of contacts who could broker information, and who were willing to take risks to create a long-term solution. Without such leadership, there would not have been an NRD system. Furthermore, the NRD system itself has been responsible for developing some very good leaders, (Oltmans, 2013). These leaders, along with state officials and other citizens, were also critical to

the successful creation and operation of the Water Policy Task Force, which developed and fought for the passage of Nebraska's integrated management law, and the Water Funding Task Force, which ensured the passage of the bills that created and funded the Water Sustainability Fund.

Because leadership depends so highly on personal characteristics, leadership varies among the NRDs. There are many examples of leaders, both NRD staff and board members, who have stepped forward to take on projects, develop new ideas, and when necessary take unpopular stands to increase restrictions on groundwater users for the long-term betterment of the community. A few examples are included in descriptions of the individual NRD actions in the Appendices. In our view, many of the projects and studies of the NRDs would not have been implemented if the state was solely in charge of water management. It was leadership at the local level that got the job done.

In the Platte Basin, Hoffman's survey found 54.7% of water users agreed that Nebraska's current water management institutions possess good leadership, however 45.3% did not.

When Hoffman asked during interviews whether Nebraska's water management institution possesses good leadership, many thought that the state still struggles with leadership issues. One interviewee said that until recently "we really haven't been in a position where we had to manage water too aggressively; we are still finding our way and are still struggling with the concept that people have to be shut off from time to time."

Stakeholders also stated that leaders must have the "political fortitude" to make tough decisions, and numerous interviewees spoke of the enormous political pressures that exist on water managers at both the state and local level. They pointed out that the governor can exert tremendous political pressure on the State DNR, and NRD board members must make decisions that are adverse

to both themselves and their neighbors. As one manager stated, "it is pretty tough to shut off somebody's well and then see them in the grocery store a day later" (Hoffman, 2013).

In sum, local control encourages the development of leadership. Many leaders have stepped forward, but at both the state and local level, the struggles with leadership continue.

13. Trust

Criterion: Trust is the basis of all social institutions; trust creates a sense of community, and makes it easier for people to work together (Folke et al. 2005). Learning to trust others is central to good governance; only when there is trust can governance institutions work well over time (Ostrom, 2009b; Ostrom, 2011). With trust comes reciprocity and cooperation, which lowers the transaction costs in reaching agreements, and induces rule compliance, which in turn lowers the costs of monitoring and enforcement (Ostrom, 1990; Dietz et al. 2003; Anderies et al. 2004, 2006; Hamm et al. 2013). When the parties do not have trust among themselves, fragmentation and conflicts are more likely (Huitema, 2009). Trust is also important for leadership. It is easier to be influenced by someone who is trustworthy (Folke et al. 2005). In sum, trust is a prerequisite of effective governance and ecosystem management. Critically, it seems that it is trust in the specific institution requesting cooperation that matters most, not trust in other closely related institutions or trust in others generally (Hamm, 2014). In undertaking any analysis of a governance system, we should be asking whether the rules of governance support or undermine the development of trust and reciprocity (Ostrom, 2011).

Assessment: In Nebraska, there is a history of mistrust between the State DNR and local NRDs, and between surface water and ground water users. However, when communication and collaboration have occurred, as in the Water Policy Task Force and the Water Funding Task Force, and in instances when surface water and groundwater users have collaborated on conjunctive use projects, trust has developed.

In the Platte River Basin, quantitative survey results of water users revealed that 52.8% of users trust the current system, whereas 47.8% do not. Importantly, almost 6% of those surveyed stated that they have no trust whatsoever in the system. Survey and interview results indicate that mistrust is amplified by an array of factors, ranging from perceived inequities in representation to variations in abilities to influence water-use rules (Hoffman Babbitt et al. 2015). These results, and the presence of lawsuits filed by surface water users against some of the NRDs and the State DNR, are indicative that in some cases, particularly among surface water users, distrust of the NRDs and the State DNR is high.

In sum, trust of both the NRDs and the State DNR varies among NRDs and among different groups.

14. Equity and Procedural Fairness

Criterion: Despite differences in how people use and value water, it is essential that all water users feel they are treated fairly (Ostrom, 1990 and 2009a; Syme et al. 1999). Generally, two forms of equity have been emphasized in the literature: distribution justice, which emphasizes a fair distribution of impacts, benefits, and costs (in terms of conditions and outcomes), and participatory justice, which stresses procedures that provide for fair involvement of all parties in decision making (Wiek & Larson, 2012).

In other words, the equity principle requires the participation of all relevant groups with a stake in the outcome in developing policies and rules and in coordinating the water-related supply, delivery, use, and outflow activities. This must be done in a way that ensures a sufficient and equitable level of social and economic welfare without compromising the viability and integrity of the supporting hydro-ecosystems in the long term (Langsdale et al. 2009; Reed & Kasprzyk 2009; Wiek & Larson, 2012). Equity between and among the various interest groups, stakeholders, and consumer-voters needs to be carefully monitored throughout the process of policy development and implementation (Rogers and Hall, 2003). Protecting inter-generational equity is also important because it provides future generations with the same opportunities afforded to the current population, including equitable access to sufficient quantities of good quality of water, as well as a range of other ecosystem services.

Procedural fairness, the participant's belief that he or she will be treated fairly by the governing institution, has also been consistently identified as important for shaping the perceptions of confidence in both the management actions and the managers themselves. Ensuring that procedural decisions are being made on a level playing field where both the institution and stakeholders' concerns are taken

into account, reduces the chances that the resource users will try to challenge, avoid, or disrupt the policies of the governing institution (Anderies, 2004; Hamm, 2014). Attention to fair procedures is important, especially when decisions must be made in the face of uncertainty (Hamm et al. 2013). Above all, water governance has to be strongly based upon ethical principles and the rule of law, which manifests itself as justice and respect for property rights for use, access, and ownership of water (Rogers and Hall, 2003).

Assessment: One of the major reasons the Nebraska Legislature convened the Water Policy Task Force in 2003 was to address the issue of equity and the resulting conflict between surface water appropriators and groundwater users. A major charge from the Legislature to the Water Policy Task Force, was to determine "if any inequities between surface water users and groundwater users need to be addressed, and [to determine what] potential action the state could take to address any such inequities" (Report of the Water Policy Task Force to the 2003 Nebraska Legislature 2003, p. 4). In their final report to the Legislature, the Water Policy Task Force stated that, "The primary concern [of the Water Policy Task Force] was that existing law was not sufficiently proactive to effectively manage hydrologically connected surface water and groundwater to prevent the development of problems and conflicts before they occurred, … and [that existing law] did not require such management, even when it was clear that such management was needed to avoid conflicts." (Nebraska Water Policy Task Force to the 2003 Nebraska Legislature 2003, p.9). This concern for equity is also recognized in the legislative findings expressed in the statutes:

"Hydrologically connected groundwater and surface water may need to be managed differently from unconnected groundwater and surface water in order to permit equity among water users and to optimize the beneficial use of interrelated groundwater and surface water supplies." (Neb. Rev. Stat. §46-703 (2)).

Although under the integrated management law, Nebraska is now more proactive in its management of hydrologically connected surface water and groundwater supplies, particularly in basins where water supplies are not sufficient to meet existing demands, many water users believe equity between surface water users and groundwater users has yet to be achieved. In a survey of Platte River Basin water users, just over half of respondents did not agree that Nebraska's water management system was equitable and 6% said there was no equity at all (Hoffman Babbitt et al. 2015).

In interviews with Platte River Basin stakeholders (Hoffman Babbitt et al. 2015), questions of equity arose when discussing issues related to who holds the power in making water-use decisions, what interests are represented in the decision-making process, and where the responsibility lies in solving water-quantity problems. In developing solutions to reduce water use within the basin, and in efforts to address threatened and endangered species concerns, surface-water interests often feel they have to "feed the losses that somebody else created."

The starkest case of inequity is in the Republican Basin, which was recognized by the Water Policy Task force as being overappropriated (Nebraska Water Policy Task Force to the 2003 Nebraska Legislature 2003), but did not meet the legal requirements to be designated as overappropriated. For years, in part due to groundwater pumping, some surface water users in the Republican River Basin have received substantially less water than groundwater irrigators, and in 2013, to comply with an interstate Republican River Compact, surface water users for a period of time were told they could not exercise their rights to store or divert water (Nebraska Department of Natural Resources, 2013a). As a result, in 2013, in one irrigation

district, irrigators were only able to use from 0 to 2 in/acre (0-13 centimeters/ha) (Edgerton, 2014, personal communication), while groundwater users in the basin were able to use from 10.5 inches to 13 inches per acre (66 to 82 centimeters/ha), or in some cases more (Upper Republican NRD, 2013; Lincoln Journal Star, January 3 and April 3, 2013).

This situation prompted one state senator who irrigates with both surface water and groundwater in the Republican Basin to state that when looking at his own experience, where his surface irrigated acreage was allocated two to three inches this year, yet his groundwater irrigated acreage was allocated nine to ten inches of irrigation, "You can't have discrepancies like that in water short years and expect the groups to work together," (Christenson, 2013). In addition, the federal U.S. Bureau of Reclamation has also complained in letters to the DNR that surface water users were "disproportionately impacted" so that Nebraska could maintain compliance with an interstate compact (Ryan, 2014). In 2014, the State DNR again issued orders restricting the surface water users' abilities to divert and store water, but these orders were later modified because of increased stream flows due to higher precipitation and the implementation of the N-CORPE[15] project, a project built to enhance stream flow for compact compliance (Edgerton, 2014, personal communication; Nebraska Department of Natural Resources, 2014b).

One way to provide equity in such cases would be to compensate water users who were disproportionately impacted. In fact, the state statutes pertaining to surface water irrigation districts require such payment stating, "Nothing in said sections [pertaining to irrigation districts] shall be deemed to authorize any person or persons to divert the waters of any river, creek, stream, canal or ditch from its channel to the detriment of any person or persons having any interest in such river, creek, stream, canal or ditch, or the waters therein, unless previous compensation be ascertained and paid therefore

under the laws of this state authorizing the taking of private property for public use" (Neb. Rev. Stat. §46-159). However, this law does not pertain to surface water depletions from groundwater pumping. On the other hand, state law allows for such payment, and the integrated management plans for the Republican River Basin provide the possibility of making such payments. For example the URNRD's integrated management plan states, "To the extent possible, it is the intent of the URNRD to provide compensation to water users that are required to forgo water use to allow the URNRD and the state to comply with the compact." (Upper Republican NRD, 2010. p. 11) No such compensation for taking water to comply with the Republican River Compact during water short years has ever been paid.

As a result, in 2014 a class action lawsuit was filed by some surface water users in the Republican Basin seeking compensation for damages that resulted from the state taking water that otherwise would have been available to the irrigators. The suit does not contend the state lacked authority to divert the water; rather it claims the state must pay for the crop losses caused by the taking (Domina 2014, Holt County Independent, 2014).

In sum, although there is a stated intention in the law to provide equity, many still perceive that equity is lacking, particularly between surface water users and groundwater users.

[15] Three NRDs in the Republican Basin and one NRD in the Platte River Basin worked collaboratively to purchase irrigated land, cease irrigation on the land, and build a project to pump the water that would have been used for irrigation in the Republican and Platte River to augment stream flow.

15. Adaptive Management

Criterion: Adaptive management is an approach developed to cope with the surprises and uncertainties of ecosystem changes. Adaptive management is particularly useful when there is uncertainty due to environmental variation, difficulty in observing the status of the resource, incomplete controllability, and a lack of understanding of the underlying system processes (Allen et al. 2011). Water is a highly variable resource, only partially controllable, often difficult to observe (especially when working with groundwater), and difficult to understand and manage. The behavior of water users may also be difficult to predict or manage. For example, irrigators often do not comply with regulations as expected. Meeting these challenges requires proactive planning institutions that have knowledge of the ecological and social systems, are open to learning, are willing to accept the inevitability of change, have the freedom and flexibility to experiment and implement innovative solutions, and learn from the new information provided by experiments (Lebel et al. 2006; Allen et al. 2011). Experimentation implies the probing of the system to be managed, monitoring its response, and adjusting interventions on the basis of the findings. Unexpected outcomes are not seen as failures but as opportunities for learning (Huitema et al. 2009).

Adaptive management, often characterized as "learning by doing," was developed to be a formal, iterative, ongoing process that requires defining the problem, identifying clear objectives, formulating evaluation criteria, estimating outcomes, evaluating tradeoffs, deciding on a plan of action, implementing the plan, monitoring the results, evaluating the success of the actions, and adjusting the plan as necessary to achieve the desired results (Allen et al. 2011). In adaptive management, policies are treated as hypotheses and all management can be seen as a kind of hypothesis testing (Huitema et al. 2009). The involvement of representative stakeholders in all steps of the process is a key component of adaptive management (Folke et al. 2005).

Many forms of adaptive management have been applied with varying levels of success, but the use of adaptive management continues to grow (Allen et al. 2011). Ruhl and Fishman (2010) examined the success of using adaptive management to comply with various environmental laws. The adaptive management process has been successfully challenged in the courts, but when the process of adaptive management is rigorously applied, and it can be shown that the adopted plan meets the substantive management criteria required by law, the use of adaptive management has often been upheld (Ruhl and Fishman, 2010). These authors also suggest that establishing better legal requirements so that the experimental elements of adaptive management are precisely defined, and assuring funding to carry out the process, would provide judicially enforceable benchmarks for oversight of natural resources planning and management and would likely achieve more of the benefits we wish to extract from ecosystems with less rancor (Ruhl and Fischman, 2010).

Assessment: Although state law does not specifically have a requirement to implement "adaptive management," the law requiring the State DNR and the NRDs to develop integrated management plans for hydrologically connected surface water and groundwater in fully and overappropriated basins requires the implementation of most of the steps that are part of the adaptive management process. By law, an integrated management plan must include objectives, and specific actions to meet the goal "of sustaining a balance between water uses and water supplies so that the economic viability, social and environmental health, safety and welfare of the river basin, sub-basin, or reach can be achieved and maintained for both the near term and the long term" (Neb. Rev. Stat. §46-715(b)(2)). The law also requires a plan to 1) gather and evaluate data, information, and methodologies to increase understanding of the water system; 2) test the validity of the conclusions and information upon which the integrated management plan is based; and 3) consult with stakeholders to provide opportunities for their input (Neb. Rev. Stat. §46-715). As described earlier, in certain cases where a basin-wide plan is required, by law the NRDs and the State DNR must also collaborate with stakeholders, (Neb. Rev. Stat. §46-755). The statutes also require the use of the best available information, accepted methodologies, and clear and transparent procedures to track gains and losses to stream flows from water use activities (Neb. Rev. Stat. §46-715(3).

Also, as described earlier, many NRDs have strong monitoring programs from which they can observe the state of the resources in their district and assess the effectiveness of their interventions. Their management plans also require changes in management actions based on the results of data from monitoring networks. For example, many NRD water quality management plans state that if a certain level of nitrates in the groundwater are observed according to a detailed set of water-quality monitoring protocols, producers will be required to take specific actions, including attending required training programs and restricting the application of nitrogen fertilizers (Table 4). Finally, the plans also allow for changes in rules and management actions. The flexibility allows NRDs to experiment, learn from mistakes, and when necessary develop new actions and policies.

In addition, the State DNR is advocating for the more formal adoption of adaptive management protocols and is providing help in developing the tools for implementing this approach (Nebraska Department of Natural Resources 2013b). Thus, although NRDs may not have formally set out to use the protocols of a formal adaptive management program per se, most NRDs are already using or planning to use these protocols.[16]
Finally, with the creation of the Water Sustainability Fund, which can only be used by those NRDs

[16]See Hoffman and Zellmer (2013) for an in-depth review of how Nebraska's water management system is supporting adaptive, integrated water resources management.

involved in the integrated management planning process, the state is providing some of the financial support so necessary for adaptive management and providing a strong incentive for all NRDs to develop an integrated management plan. To date, ten NRDs have developed required integrated management plans and eight NRDs have voluntarily developed, or are in the process of developing, such plans (Heineman, 2014).

Being proactive is an important component of adaptive management when dealing with the lagged impacts of groundwater use and management. Unfortunately, although groundwater development has a long history, integrated planning and adaptive management have not, so in some cases Nebraska has already missed the chance to be proactive. Nevertheless, for most basins the law contemplated a proactive approach by requiring the State DNR to determine whether a basin was fully appropriated before the basin's water uses were in excess of the water supply. Furthermore, the analysis used by the State DNR for determining whether a basin is fully appropriated is designed to consider the lagged impacts of existing groundwater use and thereby to eliminate the possibility that, even without future development, the basin could become fully appropriated (Nebraska Department of Natural Resources, 2015). The use of adaptive management is relatively new in Nebraska and only time will tell if these plans will succeed in sustaining a balance between water supplies and uses, but for a majority of NRDs, the necessary components of adaptive management are already in place.

However, the integrated management plans and use of adaptive management are only focused on the management and regulation of hydrologically connected surface water and groundwater. To fully implement adaptive management, other issues including water quality, soil conservation and the maintenance of essential ecosystem services should also be a part of the adaptive management process. For many years the NRDs have used their wide range of authorities to conserve and improve soil

resources, encouraged the use of buffer strips to improve water quality, and implement a number of other conservation activities. The NRDs have been mindful of the interacting impacts these activities, but adaptive management could be improved by a more focused effort to include these activities into a more holistic adaptive management planning process. The Middle Niobrara NRD is leading the way in this effort as it embarks on a water quality watershed plan on Long Pine Creek (Middle Niobrara NRD, 2015).

In sum, a relatively new law requires developing an integrated management plan. Such plans require the use of most of the components of adaptive management, and technological and financial support for the program are high. Although the enactment of this law was too late to prevent some areas of the state from becoming overappropriated, the law is designed to be proactive and to prevent additional areas from becoming overappropriated. To date the adaptive management process has only focused on water quantity issues where surface water and groundwater are hydrologically connected, but these plans could be expanded to include a focus on water quality and the maintenance of other ecosystem services. A more holistic approach would increase the effectiveness of the adaptive management planning efforts.

16. Nested Enterprises and Adaptive Co-Management

Criterion: In the past, governance focused on having a limited number of hierarchical entities. However, simple strategies for governing the world's resources that rely exclusively on one-level centralized command and control have often failed, sometimes catastrophically (Hajer, 2003). In today's more complex society, governance activities are best organized in nested enterprises in which appropriation, monitoring, enforcement, conflict resolution and other governance activities are organized in multiple layers. The ability to engage effectively at multiple scales is crucial for regional systems, because they are invariably subject to powerful external influences, including changes in regulations and investments, as well as changes in the environment (Lebel et al. 2006, Ostrom, 2009b). Furthermore, a nested enterprise can ensure that the allocation and management of water resources across upstream and downstream regions does not create harmful impacts to others without mitigation or compensation (Wiek and Larson, 2012). Because local entities are under intense pressure from local entitlement holders, it is difficult for them to restrict water rights without the support from higher level institutions (Peterson et al. 1993). Ostrom found that establishing rules at one level without rules at the other levels will produce an incomplete system that may not endure over the long term (Ostrom, 1990). She also emphasized that complexity does not mean chaos (1990, 2009a, 2009b).

In many instances, successful water management systems are polycentric; that is, they are organized with multiple centers with overlapping

power (Huitema et al. 2009; Ostrom, 2010). In her study of irrigation governance systems Meinzen-Dick (2007) found that effective irrigation management requires going beyond a strong emphasis on a single governance institution and single-policy solutions to a more nuanced approach that provides polycentric structures that allow local associations to work together with larger governmental providers of infrastructure and resources. Polycentric institutions create opportunities for understanding and for servicing needs in spatially heterogeneous contexts, and can be important for handling scale-dependent interactions (Deetz et al. 2003; Blomquist et al. 2001; Ostrom, 2005; Lebel et al. 2006; Huitema et al. 2009).

Additional benefits include the emergence of economies of scale in dividing tasks across government bodies, greater citizen involvement, increased learning and levels of trust between organizations, and greater success in lobbying higher-level authorities. Polycentric systems also have a high degree of overlap and redundancy, which makes them less vulnerable; if one unit fails, others may take over their functions. Such redundancy also makes it possible to risk experimenting with new approaches and provides the opportunity for separate governmental units to learn from each other (Ostrom, 2005; Huitema et al. 2009). These characteristics and the general diversity found in polycentric systems also are an advantage when complex and uncertain problems need to be addressed (Huitema et al. 2009).

Polycentric systems also create the opportunity for adaptive co-management. Adaptive co-management combines the emphasis on learning and experimentation of adaptive management with the emphasis on co-management, or the sharing of rights, responsibilities, and power between the different levels and sectors of government and civil society found in polycentric governance systems (Berkes, 2009; Huitema et al. 2009; Allen et al. 2011). Adaptive co-management relies on the

collaboration of a diverse set of stake- holders, operating at different levels, often through bridging networks from local users to municipalities, to regional and national organizations, and also to international bodies (Folke et al. 2005). The use of such a bridging organization can enhance participation of stakeholders, improve communication, facilitate collaboration and cooperation among various governance institutions, lower transaction costs, create a venue for resolving conflicts, enable legislative polices, and increase creativity, all of which can play critical roles in facilitating adaptive management in a polycentric governance setting (Folke et al. 2005; Allen et al. 2011). Well-structured dialogue involving scientists, resource users, and interested publics, who are informed by analysis of key information about physical environmental and human systems, also appears to be critical (Dietz et al. 2003).

Although science must play a key role in successful natural resource governance, there is still a need to view all policies as ongoing learning experiments that need to be monitored, evaluated, and adapted over time (Ostrom, 2005). An adaptive co-management system can focus on learning by doing and can afford to treat policies as hypotheses and management actions as experiments. The redundancy inherent in polycentric governance limits the risk of experimentation.

Adaptive co-management also implies a focus on the bioregion, which when managing water often translates into management at the basin level (Huitema et al. 2009). Huitema et al. (2009) concluded that four prescriptions are considered key for successful water governance: polycentric governance, public participation, experimentation, and a bioregional approach.

Nested or polycentric governance systems also have some disadvantages. Accountability and economies of scale may be lost, collective decision making is often difficult and costly, duplication of effort may be wasteful and counterproductive, and there may be a loss of accountability (Huitema, 2009). Also tension is likely to be inherent in a nested hierarchy, because there is often a conflict between what is in the best interests for a local area and what is in the best interest for the larger area as a whole. This type of tension is readily seen in the United States and elsewhere between the national government and the individual states. However, such tension is not necessarily bad, and in fact, may be a benefit because tension and conflict can lead to creative problem solving, as long are there are ways to manage the tension so that it does not result in hostile conflict (Deetz et al. 2003).

In spite of the potential drawbacks, collaborations at the basin level that result from a shared set of regulations provide evidence of environmental improvements (Dinar et al. 2005). Where collaborative adaptive co-management exists, polycentric governance systems are likely to be more robust and better able to cope with change and uncertainty.

Assessment: In Nebraska the local NRDs are part of a nested hierarchy, but they have significant power to act at the local level. Furthermore, with 23 NRDs, there is a high degree of overlap and redundancy, which makes the system as a whole less vulnerable to failure. This redundancy also allows an NRD to risk experimenting with new policies and rules, see what approach works best, and then share the lessons learned with other NRDs. In 2014 the Upper Big Blue NRD and the adjoining LPSNRD faced a new problem involving an aquifer they shared. Both NRDs adopted rules to address the shared problem, but the NRDs took two very different approaches to address the problem (See Appendix A and Appendix C). Time will tell which approach provides the best solution.

On the other hand, the state has very limited authority in the hierarchy, which limits the ability of the governance system to effectively engage at

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multiple scales and across NRD boundaries. For water quality the Legislature gave authority to the NRDs to implement rules and regulations to prevent groundwater contamination, but at the same time, gave authority to the State Department of Environmental Quality to implement rules if the NRDs did not (Neb. Rev. Stat. §46-722-734; Peterson et al. 1993). To their credit many NRDs did not wait for the state to act, but instead requested the Department of Environmental Quality to do a study and to help them develop a plan. To date the NRDs and the Department of Environmental Quality have always been able to agree on a plan and the state has never deemed it necessary to take over and implement its own rules (Link 2014, Personal communication), but that authority can be used if necessary. However, no such authority was given to the State DNR for regulating groundwater depletions, and without a relevant state regulatory program to encourage and support the NRDs in adopting and implementing local programs, groundwater depletion policies have been relatively ineffective (Peterson et al. 1993). The Water Policy Task Force, which was charged with finding ways to reduce the conflicts between surface water and groundwater users, did consider giving the state more authority to regulate groundwater pumping, but early in the deliberations the decision was made to maintain the emphasis on the local control of groundwater under the NRDs. There are still concerns about Nebraska's strong focus on local control and some question whether the split jurisdictions can work (Hoffman and Zelmer, 2013).

When Platte River Basin water users were surveyed about whether they believe Nebraska's water management system was well integrated; 47 agreed it was, while 53% did not. Notably, 5% replied that the system was not at all integrated, giving the system the lowest possible score for integration. As one stakeholder reasoned, upholding significantly different approaches to priorities in water-use, as well as different management authorities, "makes it very difficult to manage the water resources"

(Hoffman, 2013). However, one resource manager stated that although the IMP [integrated management planning] process is in its "infancy," the "entities are learning to communicate," and when surveyed, approximately 75% of Platte River Basin water users indicated that they believe in general Nebraska's water management system is working well (Hoffman, 2013).

In interviews conducted by Hoffman (2013) many stakeholders also said the state needs to look at the big picture and should do a better job of setting overarching goals and standards that would then be implemented at the local level. However, numerous stakeholders also emphasized that they do not want the state dictating what should be done (Hoffman, 2013). During in-person interviews by Hoffman, stakeholders also stressed the importance of leadership that looks at the big picture when managing water resources, as water is a flowing resource that transcends boundaries. Interviewees mentioned that water resource management as a whole can be fragmented, that managers can struggle to set overarching goals, and that the process is heavily influenced by political pressures. As one NRD board member described, "we really haven't been in a position where we've had to manage water too aggressively until just recently." Consequently, "I think we are still finding our way." (Hoffman Babbitt et al. 2015). Jim Barr, who has been involved with the NRD process since before the NRDs were created, also indicated there was a need to have overall guidance from the state where impacts extend beyond NRD boundaries and where there were issues related to the sustainability of the water supply (Barr, 2014).

Finally, in their decision in Kansas v. Nebraska and Colorado regarding the dispute among the states over the Republican River Compact, the United States Supreme Court was critical of Nebraska stating that "Nebraska failed to put in place adequate mechanisms for staying within its allotment in the face of known substantial risk that it would otherwise violate Kansas' rights" (U.S. Supreme Court, 2015, p. 11). Rather, Nebraska "chose to leave operational control of water use in the hands of district boards consisting primarily of irrigators, who are the immediate beneficiaries of pumping. No sanctions or other mechanisms held those local bodies to account if they failed to meet the plans' benchmark. They bore no legal responsibility for complying with the Compact, and assumed no share of the penalties the State would pay for violations" (U.S. Supreme Court, 2016, pp 12-13). With these findings the Court increased the level of fines that Nebraska had to pay Kansas for violating the compact (U.S. Supreme Court, 2015).

By maintaining a split between the State DNR and the local NRDs, Nebraska clearly established a nested hierarchy with a strong emphasis on local control. While emphasizing the need for local control, many suggested a need for better overarching statewide standards. Simply knowing the state has such authority also encourages NRD board members to voluntarily take actions they otherwise might not take.

In addition the NRDs are part of a polycentric system, which, in addition to the state, includes irrigation districts, counties, and municipalities. Individual NRDs may have jurisdiction in several different counties, one NRD has jurisdiction in 13 different counties, and many counties have to work with several different NRDs. These overlaps can be a source of irritation for county officials. Nevertheless, to deal with issues of mutual concern, some NRDs have been able to work with these other jurisdictions to establish bridging organizations through inter-local agreements that were authorized by the Inter-local Cooperation Act, (Neb. Rev. Stat. §13-804). These bridging organizations allow for the relevant stakeholders to collaborate to solve a problem at the appropriate scale. The Antelope Valley Project, which involved a city and a university, and the COHYST project, which involves the state, several NRDs, irrigation

districts and municipalities are just two examples (See Appendices B and C). Notably lacking from the comments about the NRD systems were complaints about waste or duplication of effort between the state and the NRDs, among the NRDs themselves, or between the NRDs and other local entities.

In at least one case, a bridging organization is taking an additional step toward adaptive co-management. In the lower Platte River Basin the Lower Platte River Corridor Alliance, composed of three NRDs and six state agencies, is implementing a combination of adaptive management based on scientific research and public involvement and a bioregional, polycentric governance system. The Lower Platte River Corridor Alliance is working with towns, cities and counties to develop and implement locally drawn strategies, actions, and practices to protect, enhance, and restore not just the water resources (both quantity and quality), but also many other natural resources in one of the most heavily populated and fastest growing areas of Nebraska (Lower Platte Corridor Alliance, 2014; Sittler, 2014, personal communication).

In sum, a number of NRDs are part of a polycentric nested enterprise system that includes bridging organizations and at least three NRDs are using such organizations to implement adaptive co-management.

17. River Basin Approach

Criterion: John Wesley Powell famously advocated that the arid regions of the U.S. be organized into natural hydrographic districts (Powell, 1890). He recognized that upstream water use impacted downstream users and that if a basin was split into more than one governing unit, there would be conflicts over the allocation and use of water. Today we also recognize that other factors, such as land use, impact a basin's water supply, but land use policies, as well as other policies affecting water resources, are often established by city, county, and state governments, which are not administered along river basin boundaries. A basin approach

is particularly important in water-scarce basins, where demands and the impacts of change are high (Rosegrant et al. 2002). Hence, in addition to Powell, many others have also suggested that to successfully govern water resources, there needs to be a formal basin-wide governance structure with a high level of authority (Ruhl et al. 2003).

However, unlike the existing city and county authorities, such river basin authorities are not usually viewed by stakeholders as having the legitimate authority needed to regulate. Hence, watershed management must confront the question of how watershed-based political institutions can work within the existing political framework so that the resulting plan will be viewed as legitimate (Lant, 2003). Ruhl et al. (2003) identify five characteristics that are necessary for success in adopting a river-basin approach: 1) a nested governance structure in which the overall basin governance entity must have the authority of a centralized government, but also must establish democratically based legitimacy at the local level; 2) the ability to manage the water quality and quantity, as well as other key aspects of the ecosystem, such as flood control, soil conservation, land use and wildlife habitat holistically and on a system level; 3) the availability of a full range of compliance instruments (information, reporting regulations, incentives, and reporting and planning requirements); 4) institutional capacity, that is, a sufficient budget; a staff with expertise to carry out complex scientific, economic, and social analyses; a willingness and the authority to make policy and regulatory decisions through public transparent procedures; the ability to use on-going adaptive management; and 5) institutional structural and communication protocols that are applicable across watershed types and political units.

Assessment: The basic concept of the NRD governance structure was to adopt a river basin approach to natural resource management. However, to ensure local control, the authority to manage larger basins was often split among several NRDs. By their local nature, NRDs tend to focus on internal issues rather than basin-wide concerns. At times downstream NRDs have complained about the use of water by upstream NRDs. Nevertheless, often in response to a basin-wide problem, such as needing to comply with the Endangered Species Act and the Republican River Compact in the Platte River and the Republican River basins, respectively, the NRDs have worked together to achieve a basin-wide solution (Cooperative Hydrology Study, 2014; Upper Republican NRD, 2014). In the Lower Platte River Basin seven NRDs, along with the State DNR, formed the Lower Platte River Basin Water Management Plan Coalition. The coalition's goal is to develop a basin wide water management plan for the entire Lower Platte River Watershed to maintain a balance between current and future water supplies and uses (See Appendix C). In addition, state law requires basin-wide planning in the overappropriated area in the Platte River Basin (Neb. Rev. Stat. §46-715(5)(a)). Also, in 2014 the Legislature passed a bill requiring basin-wide planning in areas in which at least 85% of three or more NRDs are fully determined to be fully appropriated (Neb. Rev. Stat. §46-755, Nebraska Laws 2014, LB1098, § 15).

In addition, the authority for the NRDs provides for the five characteristics that Ruhl et al. (2003) identified as necessary for success in adopting a river basin approach. The NRDs are part of a

[17]Neb. Rev. Stat. §2-3229. Districts; purposes. The purposes of natural resources districts shall be to develop and execute, through the exercise of powers and authorities granted by law, plans, facilities, works, and programs relating to (1) erosion prevention and control, (2) prevention of damages from flood water and sediment, (3) flood prevention and control, (4) soil conservation, (5) water supply for any beneficial uses, (6) development, management, utilization, and conservation of groundwater and surface water, (7) pollution control, (8) solid waste disposal and sanitary drainage, (9) drainage improvement and channel rectification, (10) development and management of fish and wildlife habitat, (11) development and management of recreational and park facilities, and (12) forestry and range management.

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nested governance system, they have the authority (Neb. Rev. Stat. §2-3222)[17] and a wide range of compliance instruments to manage both water quality and quantity, as well as flood control, soil conservation, land use and wildlife habitat. However, they do not have authority to regulate land use, which is often an important component of basin-wide planning. The NRDs do have the responsibility to make policy and regulatory decisions through publicly transparent procedures, and with the creation of the Water Sustainability Fund, they will have increased institutional capacity to carry out complex scientific, economic, and social analyses and implement adaptive management. Finally, with the Nebraska Association of Resources Districts, an organization that assists and coordinates the education and actions of the NRDs, Nebraska Association of Resources Districts, 2014, and the ability to form inter-local agreements, the NRDs have the ability to build institutional structural and communication protocols that are generalizable across watershed types and political units. Of course, the implementation of these authorities depends on the willingness of the NRDs to exercise their authorities.

In Nebraska there are no centralized basin-wide authorities with jurisdiction over all the governmental entities in the basin. However, the efforts of the Nebraska Association of Resources Districts, which focuses on coordinating the work of the NRDs across political boundaries, and the polycentric governance structure that is being adopted by many NRDs, have achieved many of the same outcomes as may have been envisioned by a centralized river-basin authority. Moreover, the polycentric structure has avoided many problems of legitimacy and has implemented management actions in a more democratic fashion than would have been likely with a central-top-down basin authority. As the NRDs' understanding of how various components of our ecosystems and of our socio-ecological systems interact, they will be in a good position to enact holistic natural resources management.

In sum, NRDs are organized along river basin boundaries with authority to manage a wide range of natural resources. Although some basins are governed by more than one NRD, the NRDs are increasingly developing basin-wide plans. To date these plans are primarily focused on water quantity issues, but the NRDs have the authority to adopt a broader, more holistic, approach that would include water quality and other aspects of basin-wide management. No centralized basin-wide authorities exist in Nebraska, but some basins have adopted a polycentric governance approach, which could prove to be more effective for managing the natural resources of the basin than the top-down approach of a centralized basin-governance authority.

A brief summary of all the criteria and assessments is displayed in Table 3.

[17]Neb. Rev. Stat. §2-3229. Districts; purposes. The purposes of natural resources districts shall be to develop and execute, through the exercise of powers and authorities granted by law, plans, facilities, works, and programs relating to (1) erosion prevention and control, (2) prevention of damages from flood water and sediment, (3) flood prevention and control, (4) soil conservation, (5) water supply for any beneficial uses, (6) development, management, utilization, and conservation of groundwater and surface water, (7) pollution control, (8) solid waste disposal and sanitary drainage, (9) drainage improvement and channel rectification, (10) development and management of fish and wildlife habitat, (11) development and management of recreational and park facilities, and (12) forestry and range management.

Table 3: Assessment Summary

1	**Clearly Defined Boundaries –** Statewide boundaries delineate who governs the resource and who can use the resource.
2	**Rules to Prevent Overharvesting** – Note: The criterion of overharvesting does not include issues related to how water is allocated among different types of uses or among individual users. NRDs have authority to limit, if not eliminate, overharvesting. Where surface water and groundwater are hydrologically connected, the integrated management law requires that water use be restricted. Groundwater reservoir levels in some areas are still declining, but given the lagged impacts related to groundwater use, it is too early to tell whether the law will ultimately succeed in eliminating overharvesting.
3	**Recognition of Rights to Organize at the Local Level** – Rights of users to organize at the local level are fully endorsed and supported by the state.
4	**Congruence Between Appropriation/Provision Rules and Local Conditions; Proportional Equivalence between Benefits and Costs** – Rules are highly congruent with local conditions and the local electorate ensures that the monetary costs do not outweigh benefits. Some environmentalists would argue there are currently no costs associated with the impacts of taking water out of the river or for costs associated with associated ecosystem services.
5	**Secure Tenure Rights –** The law provides a high degree of security that surface water rights will not be harmed by other surface water users. However, the law does not provide a similar level of security that the rights of ground-water users will be protected from the overuse. Rather the security of groundwater rights depends primarily on the willingness of the NRD to regulate groundwater use. Likewise, where surface water and groundwater are hydrologically connected, the rights of all water users depends on the willingness of both the State DNR and the NRD to regulate water under an integrated management plan.
6	**Graduated Sanctions** – State law provides for, and the NRDs often grant, variances to their rules. In addition, in many cases, violators are allowed to achieve compliance without a penalty. Thus users who violate rules are likely to receive graduated sanctions dependent on the seriousness and context of the offense.
7	**Rapid Access to Low-Cost Effective Conflict Resolution Mechanisms** – Although there are some alternatives to filing a lawsuit at the local level, there are no institutionalized local venues to resolve conflicts between surface water users and groundwater users or between water users and officials.
8	**Monitoring** – Both the state and the NRDs have widespread monitoring systems, but the quality of monitoring varies among NRDs.
9	**Adequate Funding** – Funding to date has been inadequate and varies among NRDs, but recent legislative actions will hopefully address this problem.

10	**Collective-choice Arrangements** – The local nature of the NRDs encourages collective-choice arrangements. In certain situations the law requires collaboration, but collaboration and collective choice arrangements vary among NRDs.
11	**Effective and Efficient Communication Systems** – Communication is generally high, but varies among the NRDs, and is sometimes notably lacking between surface water users and groundwater users.
12	**Leadership** – Local control encourages the development of leadership. Many leaders have stepped forward, but at both the state and local level, the struggles with leadership continue.
13	Trust – Trust of both the NRDs and the State DNR varies among NRDs and varies among different interest groups.
14	**Equity and Procedural Fairness** – Although there is a stated intention in the law to provide equity, many still perceive that equity is lacking, particularly between surface water users and groundwater users.
15	**Adaptive Management** – A relatively new law requires developing an integrated management plan. Such plans require the use of most of the components of adaptive management, and technological and financial support for the program are high. Although the enactment of this law was too late to prevent some areas of the state from becoming over-appropriated, the law is designed to be proactive and prevent additional areas from becoming over-appropriated. To date the adaptive management process has only focused on water quantity issues where surface water and groundwater are hydrologically connected, but these plans could be expanded to include a focus on water quality and the maintenance of other ecosystem services. A more holistic approach would increase the effectiveness of the adaptive management planning efforts.
16	**Nested Enterprises and Adaptive Co-management** – By maintaining a split between the State DNR and the local NRDs, Nebraska clearly established a nested hierarchy. However, while emphasizing the need for local control, many, suggested a need for better, overarching statewide standards. In addition, a number of NRDs are also part of a polycentric nested enterprise system that includes bridging organizations, and at least three NRDs are using such organizations to implement adaptive co-management.
17	**River Basin Approach** – NRDs are organized along river basin boundaries with authority to manage a wide range of natural resources. Although some basins are governed by more than one NRD, the NRDs are increasingly developing basin-wide plans. To date these plans are primarily focused on water quantity issues, but the NRDs have the authority to adopt a broader more holistic approach that would include water quality and other aspects of basin-wide management. No centralized basin-wide authorities exist in Nebraska, but some basins have adopted a polycentric governance approach, which could prove to be more effective for managing the natural resources of the basin than the top-down approach of a centralized basin-governance authority.

C. Meeting the Challenges and Increased Uncertainty of the 21st Century

The other question that still needs to be addressed is whether this governance system will be robust when stressed by the unknowns and uncertainties related to the future and particularly to climate change. To explore this question we turn to the work of a number of resilience theory researchers who, in the book Social-Ecological Resilience and Law (Garmestani and Allen eds. 2014), looked at whether current environmental laws have the adaptive capacity to deal with such changes.

Observers from nearly every discipline and ideological perspective have recognized the need to improve the adaptive capacity of U.S. natural resources law (Garmestani et al. 2014). In the past the legal and governance frameworks for natural resource and water governance have been based on the presumption of stability (Doremus and Hanemann 2008, Ruhl 2010, Garmestani et al. 2014) and assumptions that social-ecological systems are predictable and that changes are incremental and linear (Ruhl, 2010, Eason et al. 2014). Also, in the past, the basic features of the legal system included a monocentric structure, with narrow goals focused on stabilizing particular benefits that used relatively inflexible rules to limit actions from the top down (Ruhl 2010, Arnold and Gunderson 2014). Resilience theory, based on Holling's work, which demonstrated that ecosystems are not stable, but in fact are dynamic systems that shift into alternative, sometimes undesirable, states when stressed, has called such a management strategy into question. We now know that both environmental and social-ecological systems are not linear and stable, but rather are complex, multi-scalar, and dynamic, and when stressed will produce sudden, unexpected, and sometimes unwanted results if we continue down the traditional legal and administrative paths (Walker and Salt 2006, Ruhl 2010, Cosens and Stow 2014). Such shifts have been seen in the past, but today we are facing unprecedented additional stresses, particularly stresses resulting from climate change. Existing governmental institutions lack the adaptive

capacity to manage such substantial changes (Camacho and Beard, 2014).

There is substantial agreement among the researchers noted above that to develop more adaptive capacity and robustness in both the social and physical components of our social-ecological systems we will need to:

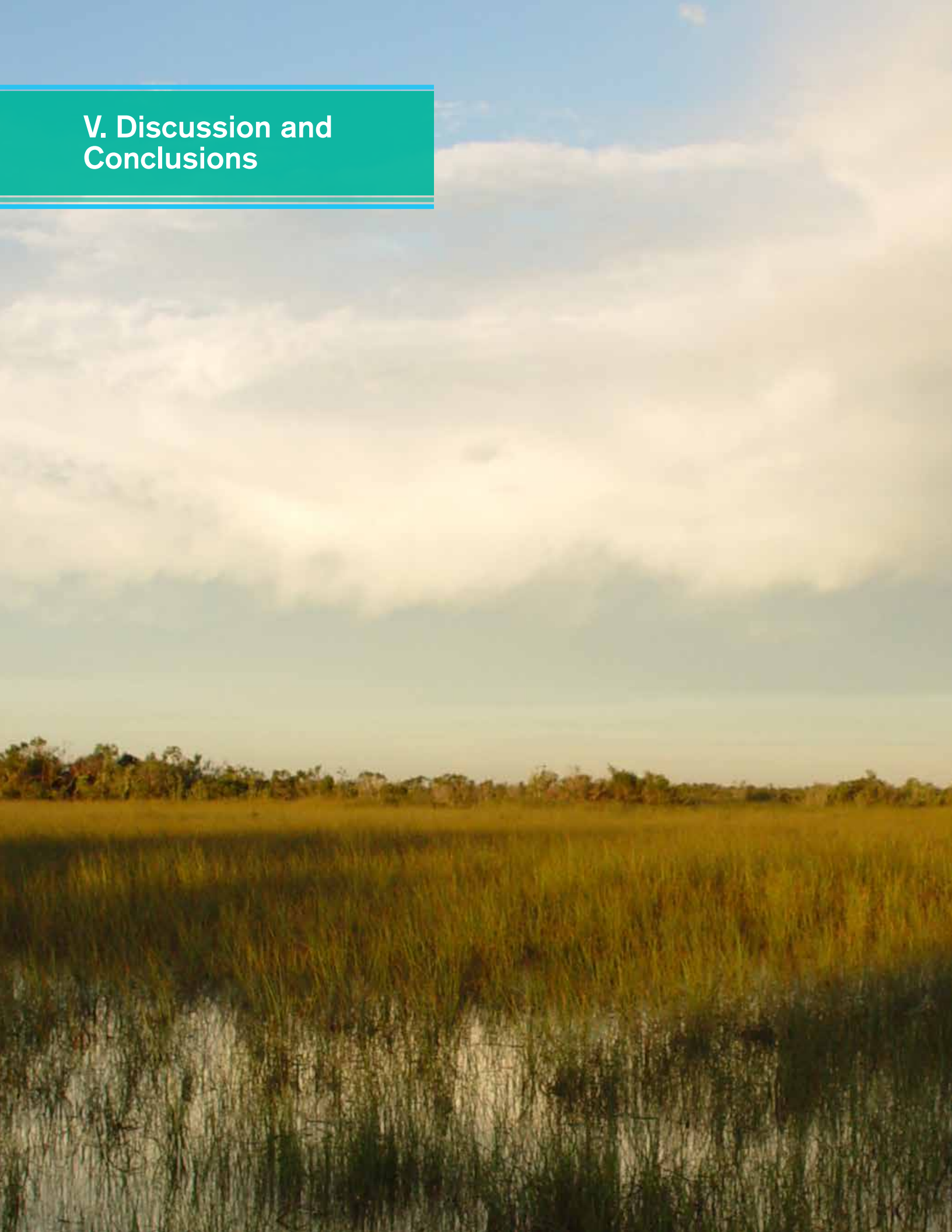
- transcend artificial and political boundaries and address interrelated water issues at watershed scales;
- match the governance system to issues and scales appropriate to what is needed to address the problem;
- allow for both technical and policy experimentation and innovation, in an integrated fashion in a way that diversifies risk so if the experiment fails, the entire system does not fail;
- use more adaptive approaches that require systematic monitoring, assessment and adjusting of regulatory strategies over time;
- facilitate multiple actors who can access social memory and provide the diversity of knowledge, experience, and viewpoints needed to create solutions to complex problems and collaboratively share this information;
- provide for adequate public participation to add legitimacy to the decision making process and generate trust in the administrative agencies;
- use a planning process and rules and policies that can be monitored, tested, and rearranged in a dynamic on-going, self-organized process of learning by doing; and
- allow for flexibility to adapt to changing conditions (Olsson, 2004, Fabricius et al. 2007, Doremus and Hanemann 2008, Ostrom 2009b, Ruhl, 2010, Doremus 2011, Arnold and Gunderson 2014, Camacho and Beard 2014).

Ostrom (2009c) advocates the use of polycentric governance systems to address a number of these problems, and to provide the world's governance systems the adaptive capacity that will be need to address climate change.

Nebraska's NRD water governance legal framework authorizes and enables many of the characteristics required for adaptive capacity and robustness listed above. The initial delineation of the NRD boundaries along surface watershed boundaries was a major first step toward working at the watershed scale. The more recent development of basin-wide plans and integrated management plans to integrate surface water and ground water has increased this ability. The NRDs' emphasis on local control facilitates the involvement of multiple actors with different viewpoints. With 23 different NRDs each solving their problems in their own way, experimentation with technical and policy innovation occurs regularly, and when an experiment fails, it does not threaten the entire system. Through organizations like the Nebraska Association of Resources Districts, as well as other state and National water associations, the NRDs also share their knowledge, learn from each other, and collaborate on developing solutions to mutual problems.

Given a legal framework that provides for adaptive capacity, to varying degrees each of the NRDs has taken actions that meet the above criteria. They have demonstrated that their diversity of knowledge, experience, and viewpoints can create a variety of innovative solutions to complex problems. The have enacted monitoring systems, which are used to determine when and where to implement rules, and thus, within their NRD, they match the governance system to issues and scales appropriate to what is needed to address the problem. They also use the monitoring system to assess whether the rules are having the desired results, and if they learn that the rules aren't working, they can and regularly do change them. Changing rules at the NRD level is a lot easier process than changing state law. The NRD system also promotes communication and collaboration, and leadership at the local level, which adds to the legitimacy to the decision making at the local level. Finally, through the integrated management planning process NRDs are beginning to implement adaptive management, and perhaps most significantly, the NRDs are experimenting with polycentric adaptive co-management, which could prove to provide the high degree of adaptive capacity and flexibility that will be needed in the future.

V. Discussion and Conclusions



Nebraska's NRD governance system was established in the mid-1990s to consolidate the multitude of local single-purpose natural resource districts into a more comprehensive and efficient, but still locally controlled, natural resources management system. Although when first formed, many argued that the NRD governance system would never work because it took too much power away from the local citizens, probably it has done just the opposite (Edson, 2005). The NRD governance system was not created with the above criteria for robust water governance explicitly in mind. Nevertheless, the legal and administrative framework that was established clearly exhibits many of the criteria for robust governance.

Two criteria, Clearly Defined Boundaries and Recognition of Rights to Organize Locally, are legally defined by state law for the entire state. State law also provides for Graduated Sanctions. The NRD governance system ranks highly on all these criteria, although some would argue environmental costs are not appropriately considered. Except for protecting surface water users from adverse impacts from other surface water users, state law does not provide for Secure Tenure Rights. There are only a few statewide laws to ensure protection for groundwater users from abuses caused by other groundwater users and in the areas where surface water and groundwater are hydrologically connected, which includes a large portion of the state, there are no state-wide laws protecting surface water users from being adversely impacted by groundwater users, or vice-versa. The resulting conflicts have led to costly litigation, in part because state law does not provide Rapid Access to Low-Cost, Effective Conflict Resolution Mechanisms as an alternative to litigation. Assuring rapid access to a more local conflict-resolution process could possibly be addressed by requiring disputants to go through a non-binding arbitration process, conducted by officials who understand water and water law, before a formal lawsuit could be filed. Such processes have often successfully resolved conflicts and avoided a lawsuit. If the process is unsuccessful, the disputants would always have the option of filing a formal lawsuit, but in this

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case, the court, who may or may not understand water issues, would have the benefit of reviewing the arbiter's opinion, which could help the court develop a better informed final decision.

For other criteria, state laws enables action, but relies on the State DNR and the NRDs to take the actions required for robust water governance. Because each NRD is different, the performance on these criteria also varies among the NRDs. Throughout Nebraska, the NRDs have done extremely well in Adapting their Rules to Local Conditions, and Ensuring a Proportional Equivalence Between Benefits and Costs. Moreover, the NRDs have initiated educational and other activities to promote water use efficiency and decrease water pollution, and have developed groundwater recharge and flood control projects to an extent that greatly exceeds what would likely have been accomplished without the NRDs. Several NRDs have on their own initiative enacted Rules to Prevent Overharvesting of the state's groundwater reservoirs, and with the passage of the integrated management law in 2004, the majority of the NRDs, together with the State DNR, have implemented or are in the process of implementing integrated management plans that have added additional rules restricting water use. No doubt these actions have slowed the rate of overharvesting, and in some areas of the state water levels rose significantly, even as groundwater irrigation developed rapidly.

Effective and Efficient Communication Systems and Collective - Choice Arrangements, are strongly supported and encouraged by the state laws, but there is a great deal of variation on how well the State DNR and the NRDs rank on these criteria. The NRD system with its emphasis on local control has enhanced communication, as well as the development of leaders, but Leadership, is also highly dependent on personal character traits and therefore, it should be no surprise that the ranking on this criterion also varies across the state. Trust and Equity and Procedural Fairness are both interactive and are highly dependent on the previous three criteria, and therefore, the ranking for these criterion also varies. The lack of state laws providing security for tenure rights

and rapid access to conflict resolution mechanisms further exacerbates the problem where equity and procedural fairness are lacking at the local level.

Adequate Funding is highly dependent on the local tax base and the Legislature. To date, because the tax base varies greatly among the NRDs, funding among the NRDs has varied, and in general water resource managers and stakeholders have been frustrated by the overall lack of funding. However, recent laws have significantly increased funding for water management. Consequently, although the NRD governance system would currently only achieve a medium rank on this criterion, there is the potential for a much higher ranking in the future. Related to adequate funding, as well as to perceived need, Monitoring systems also vary among NRDs and therefore rankings vary by NRD.

The laws of the state require Adaptive Management for managing hydrologically connected surface water and groundwater, which covers most areas of the state. The state has provided technical assistance and funding to provide the capacity to implement adaptive management. Therefore Nebraska's water governance system ranks fairly highly on this criterion. Adaptive management could be ranked even higher if the adaptive management process not only focused on water quantity issues, but also included management of other natural resources problems, such as maintaining wetlands that prevent flooding and remove contaminants from our water supply.

Nebraska's water governance system also ranks fairly highly on the criterion for a Nested Enterprise. However, the strong emphasis on local control without enforceable rules at the state level makes the system incomplete. According to Ostrom (1990) incomplete systems are not as likely to sustain the resource over the long term. When local-control governance is practiced at a larger statewide scale, it becomes even more critical to provide the state with authority to ensure equity across jurisdictional boundaries.

Nebraska's water systems are highly interconnected and widespread. Decisions made by one NRD for the benefit of their water users can, and often do, have adverse impacts on water users in other NRDs. Some have also argued that Nebraska's split legal system, with the State DNR administering surface water under the prior appropriation system, and the local NRDs regulating groundwater under a system of correlative rights, cannot provide a robust water governance system for Nebraska. Requirements for collaborative basin-wide planning were implemented to help prevent such problems. However, if such efforts fail, there are no enforceable statewide regulations that could be used to ensure equity in water allocation within and across NRD boundaries.

Implementing a few state-wide guidelines could address some of these problems. Simply knowing that the state has authority to ensure compliance with such guidelines would also be an incentive for those at the local level to voluntarily develop equitable basin-wide plans (Peterson et al. 1993). Developing appropriate statewide guidelines may not be easy, but efforts such as the Water Policy Task Force and the Water Funding Task Force, as well as the effort to develop the NRD framework itself, have already proved that difficult issues can be successfully tackled through good leadership and collaborative processes involving the affected stakeholders. With a greater emphasis on overarching guidelines and rules to protect the greater interests of the state and ensure equity among all water users, there is no reason to believe that Nebraska's split legal and administrative systems could not work.

Although the NRDs are organized along river basin boundaries and the governance system exhibits many of the characteristics to rank highly on the River Basin Approach criterion, because basin-wide planning does not occur throughout the state, and because much of the basin-wide planning that does exist is focused only on water quantity issues, the ranking for this criterion is only moderately high. However, the authors believe that the beginning of the development of Polycentric Governance and Adaptive Co-management could not only provide a successful basin-wide natural resource management

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governance system, but also could provice a much better alternative than the creation of a single river basin authority. Such a polycentric system avoids the problems of legitimacy and other problems related to the top-down hierarchical approach, which has failed in so many circumstances, but still promotes the transcendence of boundaries and the matching of governance systems to the appropriate issues and scale. It also diversifies risk, so if a new policy or experiment fails, the entire system does not fail. Moreover, Nebraska's water governance system provides flexibility, facilitates multiple actors and public involvement, and allows experimentation and innovation in an integrated fashion. Polycentric governance and adaptive co-management have only just begun, but the potential is there for using this approach statewide.

Finally, and importantly, all these characteristics, with their emphasis on flexibility, monitoring, learning from mistakes, collaboration, and redundancy so that if one policy fails, the whole system does not necessarily collapse, meet the criteria many suggest will be necessary to enable Nebraska to adapt to the challenges of the 21st century.

There can be no doubt that Nebraska still has water problems that need to be solved. In some areas water tables are still declining, and water quality problems, especially due to nonpoint source contamination, are still widespread. Moreover, because of the lagged impacts of pumping and contamination on groundwater, the adverse impacts of current actions may be even greater in the future, even if there is no further development. However, the impacts of management actions are also lagged, and thus it is probably too soon to tell whether the impacts of the NRD's current governance actions will successfully sustain the resource over the long term. As one stakeholder opined, "it took us a long time to create these problems, and it will probably take a long time to fix the problems." (Hoffman, 2013).

Nevertheless, Nebraska has become one of the most intensely irrigated and most productive agricultural areas in the world without creating major areas where water supplies have been depleted or degraded. In many areas of the state, water tables have risen, even with significant increases in

irrigated agriculture, and where declines are still occurring, the rate of decline has been reduced. In some areas, water quality has improved significantly after the initiation of governance actions by the NRDs to reduce fertilizer applications.

In sum, the NRD governance system Nebraska scores highly on most of the criteria that years of research have shown are indicative of robust water governance. There are many reasons to believe that with a few additional improvements, the legal structure of the NRD governance system, with its greater reliance on local problem solving and management, better meets the criteria for robust governance than a system based on top-down management. Furthermore, the NRD governance system has the characteristics that many believe will be necessary for to meet the challenges of the 21st century.

However, as is true for all governance structures, good legal frameworks can enable, but cannot assure, good governance. No matter how strong a legal framework may be, good governance depends on the will of the people themselves to communicate and collaborate with all stakeholders, to work to develop trust, and to provide the leadership necessary to ensure that the intent of the laws is in fact realized.

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VII. Appendices

A. Upper Big Blue Natural Resources District

The Upper Big Blue NRD[18] (UBBNRD) is in the upper portion of the Big Blue River water basin (Figure 1 and Appendix E: Figure 17). The average annual rainfall ranges from 24 inches (600 millimeters) to 32 inches (800 millimeters). There are a few cities in the district, but the largest, half of which is in another district, only has a population of around 25,000 people, and the next largest a population of 7,800 people (U.S. Census, 2010).

[18]The information in Appendix A is based on an interview with John Turnbull, General Manager, and Rod DeBuhr, Manager of the Water Department of the Upper Big Blue NRD or was from the Upper Big Blue NRD website: March 2015 URL http://www.upperbigblue.org. Figures were provided by the Upper Big Blue NRD.

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Two major branches of the Big Blue River arise in and cross the district. The Big Blue River provides surface water for some irrigation, but also causes floods, which prompted the NRD to build flood control dams. The river is connected to shallow aquifers along the river, but has little connection with the main groundwater reservoir system in the district. This groundwater system has on average approximately 100 feet (35 meters) of saturated thickness, but the thickness varies from only a few feet to over 300 feet (91 meters). In a few areas the aquifer is thin or absent and in other areas it is confined, creating artesian wells that pump up to 700 gallons per minute (2,650 liters per minute). The depth to water ranges from less than 50 feet (15 meters) to over 200 feet (61 meters).

The primary economic activity in the district is irrigated agriculture. The district has 15% of Nebraska's irrigated acres, 2% of the nation's irrigated acres, and more irrigated acres than can be found in 36 other states. In the drought year of 2012, you could actually see the irrigated area outlining the district on a satellite image from space.

In the 1960s there were already about 300,000 groundwater irrigated acres and by the early 1970s there were concerns about groundwater level declines due to groundwater pumping. From 1961 to 1979, the groundwater table had declined by an average of 7 feet (2 meters) and ground-water models of the area predicted further declines. At that time the average use of groundwater for irrigation was estimated to be 22 inches (560 millimeters) per year.

The Upper Big Blue NRD Board of Directors, consisting of 17 members, started talking about groundwater issues in 1974. The state of Nebraska had already authorized groundwater conservation districts. Five such districts in the UBBNRD, organized along county boundaries, formed the Blue River Association of Groundwater Districts, but these control districts were slow to take any substantial action to reduce water use.

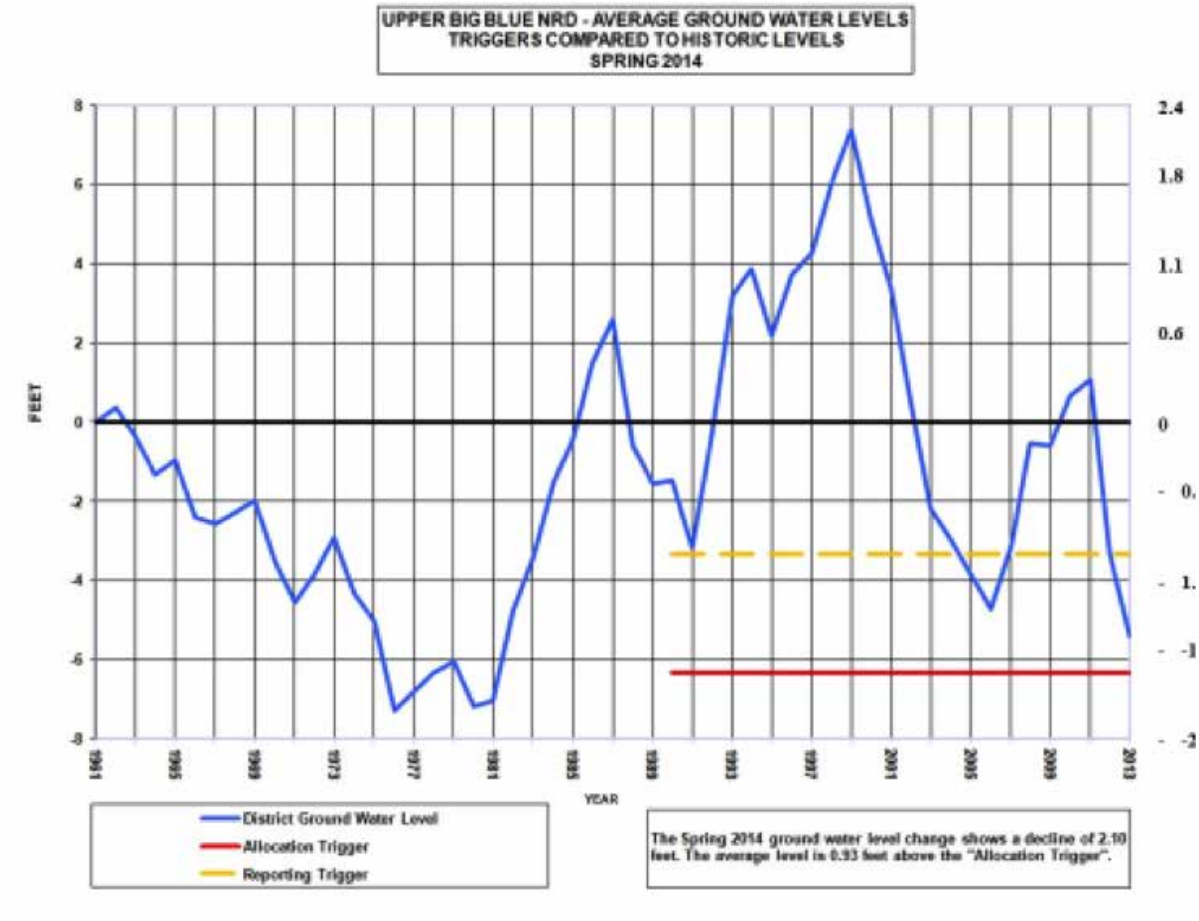

Figure 6: Upper Big Blue NRD Average Groundwater Levels Triggers Compared to Historic Levels - Spring 2014

In 1977, as soon as possible after the Groundwater Management and Protection Act gave NRDs the authority to regulate groundwater use, the Upper Big Blue NRD adopted regulations to manage groundwater quantity. The Upper Big Blue NRD was the second NRD to adopt such regulations. To develop the plan and rules for the area the NRD met with irrigators and the board of the Blue River Association Groundwater District. It took 13 drafts to develop an acceptable plan. The directors of the original groundwater district not only did not resent the NRD, but were glad to cede control to the NRD in order to avoid the negative political feedback that any regulation of groundwater was likely to cause.

The NRD took over the well monitoring network from the groundwater districts when they were dissolved by law in 1985. One of the first actions of the NRD was to establish a groundwater level monitoring network and one of the first rules of the groundwater management plan was to start restricting water use for irrigation if the water table dropped at a rate of greater than 0.5 feet (.15 meters) per year for three consecutive years. In 1981 the NRD also started asking producers to certify how many acres were being irrigated. The district started requiring permits to construct a well pumping more than 50 gallons (189 liters) per minute for nondomestic use in 1978.

From 1981 – 1999 the precipitation in the district was on average about 3 inches (76 millimeters) above normal and, even though by 1986 there were 6000 wells and 720,000 groundwater irrigated acres (291,000 hectares), 420,000 more

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groundwater irrigated acres (169,000 hectares) than in 1961, the water table rose to about 7 feet (2 meters) above the 1961 water level, and was 14 feet (4.3 meters) higher than the low water levels in the late 1970s. (Figure 6)

With water levels so high the established trigger for increasing restrictions on groundwater use made little sense, so in 2000 the UBBNRD changed the trigger for implementing water quantity management actions. The district's current goal is to hold the average groundwater level above the 1978 level. Two triggers for action were set: a trigger to require reports from water users if the average groundwater level in the district drops to less than three feet above the 1978 water level, and an allocation trigger, a trigger to enact regulations to restrict the quantity of water that can be used if the average water level drops below the 1978 water level. The NRD also considered placing a moratorium on new irrigated acres, but decided against this action, in part because the board's philosophy was in keeping with the correlative rights policy of sharing groundwater in times of shortage, and in part because over 90% of the cropland was already being irrigated by groundwater so the adoption of a moratorium on additional acres would not have a significant impact on district water levels.

In 2006 the water table fell below the reporting trigger level (Figure 6). Thus today all nondomestic water well owners must report their water use to the NRD. Currently the total number of irrigation wells in the district is 12,115 of which 48.2% are metered. All owners of irrigation wells must certify the number and location of the acres they irrigate, and report what was irrigated every year. There are also well spacing requirements and in areas where water is short, there can be no increase in irrigated acres, and regulations limit the transfer of groundwater use from one area to another. Throughout the district any proposal to pump more than 500 acre feet (617,000 cubic meters) per year from a tract of land, or existing users that pump

500 acre feet (617,000 cubic meters) annually that want to expand by 250 acre feet (308,000 cubic meters) or more, must do a hydrologic evaluation showing the impacts of the groundwater withdrawal as part of the permitting process. In addition, all new or replacement wells pumping 50 gallons per minute (190 liters per minute) or more are required to have a flow meter, and by 2016 all wells pumping 50 gallons per minute (190 liters per minute) or more must be metered. If in the interim, the water levels drop below the 1978 water level trigger, the district will immediately require meters on all of wells, and will also impose allocations restricting the amount of water that can be pumped. The first allocation has been set at 30 inches (76.2 centimeters) for a 3 year groundwater use period. If necessary, a second allocation period will be 45 inches (114 centimeters) for a 5 year period (a 10% reduction). Up to 4 inches (10.2 centimeters) of any unused allocation may be carried forward to the next allocation period. Allocations would end if the district groundwater level rises more than 3 feet above the allocation trigger level in the last year of an allocation period. Noncompliance with these regulations can result in a prohibition on water use.

In 2014 the UBBNRD created special "High Risk" groundwater areas to deal with seasonal declines that were causing problems for municipal wells. Although many NRDs have developed rules to deal with long-term decreasing groundwater levels, the UBBNRD, as well as the adjoining LPSNRD (See Appendix C), faced a somewhat new problem. Rather than long term declines due to dewatering the aquifer, in this confined aquifer the declines, caused by pressure changes in the confined aquifer, occur only during the irrigation season. Nevertheless, the declines were having serious impacts on domestic and municipal wells. To address this problem the UBBNRD voted to require new wells that pump at least 50 gallons per minute (189 liters per minute) to be at least 1,250 feet (381 meters), an increased distance of 25 feet (7.6 meters), away from the nearest irrigation well or domestic well, regardless of ownership, and at least two miles (3.1 kilometers) from any municipal well. Furthermore, no more than two wells can be sited on a given 160 acres (65 ha), and no more than one well can be sited on a given 80 acres (32 ha).

The NRD has also adopted regulations to address water quality problems resulting from the over-application of nitrogen fertilizer. In the 1980s the district began testing water samples from domestic wells and found nitrate levels were above the safe drinking water standards of 10 parts per million of nitrogen in several communities. Since 1995, the district implemented triggers for action and regulations to reduce the application of nitrogen fertilizer. Nevertheless, nitrates in the groundwater have continued to increase and these increases have in turn raised concerns over the cost of treating drinking water. In response the NRD adopted additional regulations on the use of nitrogen. Today throughout the NRD, anhydrous ammonia cannot be used before November 1 and nitrogen fertilizer cannot be used before March 1. In addition in Phase II areas, where the nitrates have exceeded the trigger of 7 parts per million, producers must obtain nitrogen management training, take soil samples for nitrates, install soil moisture sensors and practice irrigation scheduling in at least one field, and provide an annual report on their nitrogen management to the NRD. In the one area that exceeded the Phase III trigger of 10 parts per million, producers must also use a nitrification inhibitor and take additional soil samples for nitrates. To further protect drinking water the NRD, in cooperation with the city of Hastings and the adjacent NRD, has also established the Hastings Wellhead Protection Groundwater Management Area. Within this area there are increased nitrogen use regulations, as well as additional training opportunities on how to reduce nitrogen uses for not only agricultural producers, but also homeowners and lawn care companies.

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All the above rules and regulations can be changed when deemed appropriate by the Board of Directors and, in fact, the regulations have changed on average at least once every three years.

Throughout the district, the Upper Big Blue NRD has also been very active in assisting producers to achieve the NRD's goals for water quantity and quality so that the need for additional regulations can be avoided. Such programs include providing education opportunities on how to conserve water and apply other best management practices, providing water quality testing and irrigation flow measurements on wells and providing funds to help producers install water meters. Also, in cooperation with other NRDs in the basin and the University of Nebraska, the NRD supports the Nebraska Agricultural Water Management Demonstration Network, which includes more than 450 active partners/cooperators who are learning best management practices and demonstrating to others how to use irrigation scheduling and other conservation measures. The district is also promoting the use of atmometers, which provide information on evapotranspiration and soil moisture to assist irrigators in making better irrigation scheduling decisions.

As a result of these education efforts, not only have many producers adopted these water conservation measures without being required to do so, but also the attitudes toward water regulations in the district have changed. Although, according to long-time members of the UBBNRD staff, it took a generation to change attitudes, today most producers in the district accept that water use restrictions are necessary if they are going to maintain their ability to irrigate in the future. The staff also pointed out that there was much better reception to increased regulations by the NRD, as opposed to the State DNR, because the NRD has many roles, not just the regulation of water use, and because people feel comfortable talking to the NRD board, which consists of people from their community.

These efforts have obviously paid off. The average use of irrigation water in the early 1970s was around 22 inches (56 centimeters); today it is 6.5 inches (16 centimeters), and in 2012, one of the driest years on record, on average only 12.2 inches (31.0 centimeters) of groundwater were used. In addition, even though today, there are over 800,000 more irrigated acres (323,000 hectares) in the district than there were in 1961, the average groundwater levels in 2013 were still 3.3 inches (8.4 centimeters) above the 1978 water level and about 10 inches (25.0 centimeters) above the 1961 average groundwater level. On the other hand, nitrate levels are still rising in the district. Although education is the preferred management tool, when necessary, the Upper Big Blue NRD is not afraid to take regulatory actions.

B. Central Platte Natural Resources District

The Central Platte NRD[19] (CPNRD) runs east to west along 205 miles (330 kilometers) of the Platte River, in the center of Nebraska (Figure 1 and Appendix E: Figure 17). Average rainfall in the district ranges from 22 inches (559 millimeters) in the southwest to 26 inches (660 millimeters) in the northeastern portions of the district. Except in the most eastern parts of the district, the evapotranspiration rates exceed precipitation rates by about four to eight inches. Groundwater reservoirs are plentiful and range in thickness from over 600 feet (180 meters) to less than 50 feet (15 meters). Along the Platte River, the groundwater is recharged by precipitation falling on fields and percolating through the soil profile or from runoff losses in the tributaries and Platte River. Groundwater also flows into the district from the Sandhills, a 19,300 square mile (5,000,000 hectares) area of grass-covered sand dunes (Korus et al. 2013; Bleed and Flowerday, 1998), under which there is a large groundwater reservoir. Given that fertile cropland is abundant in the district, evapotranspiration exceeds precipitation, and groundwater is relatively plentiful and often available at shallow depths, it is no surprise that most of the cropland (over a million certified acres, 404,000 hectares) is irrigated, with eight[19] surface water canals and over 21,000 groundwater irrigation wells.

In the early years of the NRD, flood control was the major concern. One of the district's first actions was to build a flood control project; today there are more than 30 flood control projects built by the NRD. During a flood in 2005, the largest project built by the NRD was estimated by the U. S. Army Corps of Engineers to have prevented $24 million of damage.

In 1987, two years after the Legislature gave authority to the NRDs to create groundwater management plans to manage water quality as well as water quantity, the CPNRD voluntarily established a Groundwater Management Area to

manage both groundwater quality and quantity. To implement the plan the NRD established a groundwater monitoring system to monitor both water levels and water quality. Today this system consists of 575 monitoring wells, which are monitored every spring and fall to determine groundwater level changes, and every third year to monitor nitrate levels. To establish the rules, the CPNRD met with farmers, crop consultants, fertilizer industry representatives, and others to determine how best to implement the controls. To assure controls are implemented only when needed, the CPNRD uses the results of the monitoring network and only initiates actions when a groundwater level and/or a water quality trigger is exceeded. The plan can be and has been updated over time. Penalties for noncompliance also vary depending on the extent of noncompliance and number of violations.

The controls for nitrates, which are adapted to local conditions, include limited or no fall application of nitrate fertilizer, nitrate level testing requirements for both the soil and groundwater, educational requirements on fertilizer application for producers, and reporting requirements on testing results, including the amounts of fertilizer used and quantity of groundwater pumped. These results are shared with other producers, resulting in an effective general education program. These controls are implemented in phases depending on the extent of the nitrate problem. In Phase 1 areas, where five-year average nitrate levels are less than 0.75 parts per million and do not impact municipal water supplies, there are only restrictions on fall applications of nitrate fertilizer on sandy soils. Where nitrates are higher (Phases II and III), the controls are increasingly more restrictive. In Phase IV areas, where existing controls are failing to reduce nitrate levels at an acceptable rate, additional actions can also be taken.

In addition, farmers throughout the CPNRD are recruited to work with the NRD in using the best management practices to demonstrate that nitrates can be managed efficiently and effectively while maintaining crop yields. The producer receives weekly irrigation assistance on one field and a complete evaluation of his or her irrigation system. In return, the producer is expected to share the experience with other producers and to consider improved irrigation techniques. The CPNRD also provides cost-share funds for tools needed to implement best management practices. Because research indicated that most farmers did not know how much water they were using during irrigation, to simply make producers aware of their water usage, the Board also requires producers in some areas to monitor the amount of groundwater they pump.

At first, there was some resistance to these controls (partly because the irrigators had to pay for groundwater testing for nitrates). However, with time, the conscientious operators realized that following the rules resulted in economic gains that outweighed the additional costs, including the costs of the testing. Seeing the benefits, other producers soon willingly adopted the controls. The local fertilizer companies, while selling less fertilizer per field, provided testing services for nitrates, so they also gained business and were supportive of the program.

In the early days of the program it was not uncommon to see greater than 200 lbs per acre (224 kilograms per ha), in some cases up to 300

[19]Except where citations are provided, the information in Appendix B is based on an interview with Ron Bishop, the General Manager of the NRD from its inception until his retirement in June 2013; Duane Woodward, Engineering Hydrologist; and Lyndon Vogt, the current General Manager of the NRD, or was drawn from the CPNRD website: March 2015 URL: http://www.cpnrd.org/. Figures were provided by the Central Platte NRD. Sandy Noecker assisted in updating the Average Nitrate Levels Graph.

pounds per acre (336 kilograms per ha), of nitrates applied. Now the typical application is less than 150 pounds per acre (168 kilograms per ha). As a result of these declines in fertilizer use, the nitrate levels in the district are starting to decline. Until the CPNRD Groundwater Quality Management Program was adopted, the nitrate level in the high nitrate areas of the district was increasing at a rate of about 0.5 parts per million per year, up to an average of 19.24 parts per million. Now there is an average drop of 0.25 parts per million nitrate per year and over the 14 years of implementation, nitrate levels in the groundwater have been lowered from average levels of 19.24 to 14.24 parts per million (Figure 7) (Ferguson, 2014).

Although the CPNRD approved a groundwater quantity management plan, to date none of the triggers for additional controls have been surpassed and no controls for groundwater quantity have been implemented (Figure 8). However, in an area in the lower part of the district where water table declines are approaching the trigger for enacting controls, the CPNRD board has placed a one year moratorium on developing new groundwater irrigated acres (http://www.cpnrd.org/2013%20Oct%20In%20Perspective.pdf). To assist land owners and operators, the CPNRD provides a number of programs and services, including water well registration verification and the decommissioning of abandoned wells. The actions taken to control nitrates are also useful in managing groundwater quantity throughout the district.

In the 1990s, concerns over declining stream flows in the Platte River began to increase. In part these concerns were triggered by the need to provide river flows to comply with the federal Endangered Species Act, but there were also concerns about declines in summer flows for surface water irrigators and for municipal wells that relied on Platte River water for recharge. In response, the CPNRD applied for and obtained some of the state's first surface water instream flow rights to provide instream flows for fish and wildlife. These

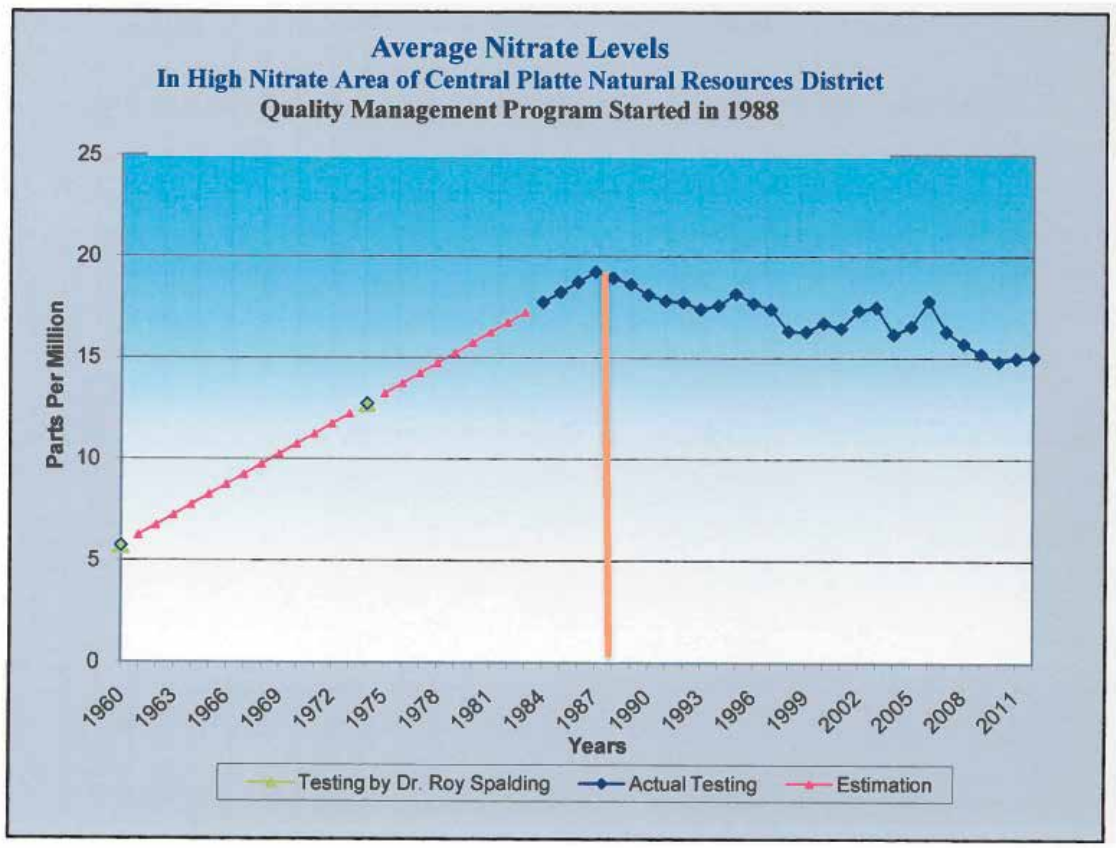

Figure 7: Average Nitrate Levels in High Nitrate Area of Central Platte Natural Resources District (Dr. Roy Spalding, University of Nebraska)

rights helped protect the surface water flows on the Platte River from additional surface water diversion, but they did nothing to reduce the threat of stream flow depletions from pumping groundwater wells.

As concerns over the impacts of groundwater use rose, the manager of the CPNRD, in a proactive and insightful move, proposed to the State DNR that a cooperative study should be conducted on how groundwater well pumping impacted the Platte River. The resulting Cooperative Hydrology Study (COHYST), initiated in 1998 (COHYST, 2014), included other Platte River NRDs, the State DNR, surface water irrigation and power districts, and other stakeholders. The collaborative research and modeling developed by COHYST is now the key instrument for determining how wells and other water uses in the area impact stream flows along the Platte River. The United States Fish and Wildlife Service, the State DNR and the NRDS rely on COHYST for determining Nebraska's compliance with the federal Endangered Species Act.

However, the CPNRD did not take steps to restrict the use of groundwater until, in accordance with the integrated management law, a large portion of the CPNRD was determined to be fully appropriated and certain western portions of the CPNRD were designated as overappropriated. As required by the new law, the CPNRD in conjunction with the State DNR developed an integrated management plan, which 1) placed a moratorium on new or expanded consumptive uses of water from wells and on new irrigated acres in areas determined to be fully or overappropriated, 2) required certification of existing irrigated acres, 3) placed restrictions

on municipal and industrial uses, and 4) in the overappropriated area, took actions to reduce stream flow depletions from groundwater use to ensure that the consumptive uses of groundwater are no greater than they were in 1997. The ultimate goal for the overappropriated area is to achieve and maintain a balance between water supplies and the consumptive use of both surface water and groundwater.

To assist producer compliance with the new rules, the CPNRD developed rules to allow the transfer of well use and irrigated acres only if the transfer did not adversely affect other groundwater or surface water users or increase stream flow depletions. To avoid increased stream flow depletions, new users were allowed to retire existing uses as offsets as long as the offset replaced flows needed for other water users or flows to comply with the Endangered Species Act. COHYST is used to calculate these impacts. The CPNRD also initiated a water banking program, funded by the district, to purchase water rights from willing sellers to provide water to meet their legal requirements. The prices paid by the CPNRD vary for each purchase based on the incremental assessed value of irrigated land as compared to non-irrigated land in the NRD, and the location of the water source, which impacts the ability of the purchased water to meet the regulatory water requirements of the district. In recent years the NRD has paid on average $8,000/acre foot of groundwater that reaches the Platte River, and $2,500/acre foot of surface water. As the value of water increases, these prices are also expected to increase (Vogt, 2014, personal communication).

Finally, to further help the NRD meet its requirements under the integrated management law, the CPNRD initiated a cooperative program with several surface water irrigation canals. In these programs the CPNRD, assisted by state funding, either purchased the canal outright, worked out a lease/joint management agreement with the canal company to retire surface water rights, switched surface water irrigators to groundwater wells, and/or help maintain the remaining

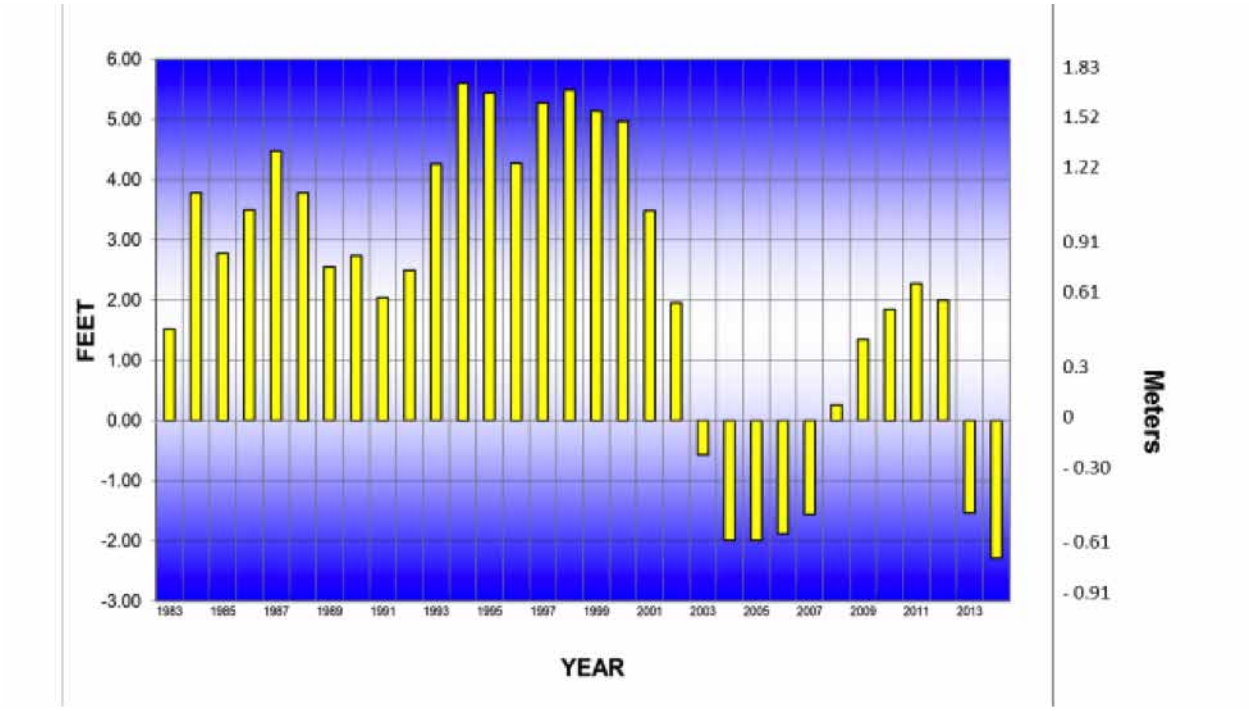

Figure 8. Central Platte NRD 1982 - 2014 Accumulated Change in Groundwater Levels by Groundwater Management Area

canals. The program was beneficial in several ways: 1) it allowed the canal districts to rehabilitate their canals, which had fallen in disrepair; 2) it benefitted the irrigators by switching them to groundwater wells, which can be operated more efficiently and offer a more stable water supply; 3) it benefitted the flows in the river by reducing surface water diversions at times when water is needed in the river for other uses; and 4) it allowed for the diversion of water in times when water is not needed in the river to recharge the groundwater and increase the base flows to the river. These programs should allow the CPNRD to meet all of their existing legal requirements under the integrated management law (reoperation of the canals with water accounting just started in 2014 so time will tell what benefits are provided), and, importantly, have been well received by the canal users.

A number of factors have contributed to the success of the CPNRD. The district is relatively well funded, which has allowed the NRD to hire a competent technical staff in sufficient numbers to implement its programs, develop technical studies, and implement monitoring programs. Further, the NRD's emphasis on communication, its willingness to work closely with producers in developing the rules, its stated goal of developing adequate regulations to protect the rights of all legal existing users, and the resulting trust between the NRD and producers have all contributed to the district's success. Moreover, the long-term leadership provided by its manager and at least one board member, have provided stability and long-term vision, not only within the NRD, but also within the basin as a whole, and throughout the state. This strong and consistent leadership, as well as the technical

capacity of the staff in the district, has allowed the CPNRD to remain on the forefront of developing innovative programs to help Nebraska meets its water challenges. Without the locally initiated activities of the CPNRD, these programs would not have been developed.

C. Lower Platte South Natural Resources District

The Lower Platte South NRD[20] (LPSNRD) is in the eastern part of the state at the mouth of the Platte River (Figure 1 and Appendix E: Figure 17) and receives an average annual precipitation of 30.1 inches (76.5 centimeters). About 48% of the District's land is used for dry-land agriculture; 32% is either pasture or grassland, and with fairly abundant precipitation, only 3% of the land in the Lower Platte South NRD is used for irrigated agriculture (Brown and Caldwell, 2012). The majority of the district's population lives in urban and suburban areas. In fact, roughly twice as much water is consumed by urban interests as is for irrigated agriculture. The City of Lincoln, with a population of nearly 269,000 in 2013 (Lincoln-Lancaster Planning Department, 2014), is the largest city in the district; most other communities in the district have populations of 4,000 or fewer. With so many urban residents, an early issue for the LPSNRD was the concern by rural residents that urban representatives and interests would dominate the NRD's activities.

There are many small streams that flow through the LPSNRD, but two large rivers, the Platte River and the Missouri River, flow along the northern and eastern boundaries of the District. There are a few groundwater reservoirs in the LPSNRD, but in most of the District the availability of groundwater is extremely unpredictable and in small quantities.

Before the LPSNRD was formed, the local Soil and Water Conservation District Boards were active in implementing the federal United States Department of Agriculture Soil Conservation Service mandates to conserve soil and water. After the LPSNRD was

formed, and still today, these cooperative activities, continue to be important to the rural citizens.

The major concern of both urban and rural citizens was flooding. The LPSNRD responded by obtaining federal, state, and local dollars to help build flood control projects. The first project was initiated in 1974. Today, there are 180 flood control structures in the district, many protecting rural landowners.

The NRD also works closely with the City of Lincoln to prevent floods. The LPSNRD has many projects in the city, ranging from the maintenance of a flood control levee along a major creek, the stabilization of stream banks to prevent stream erosion, and helping the City to pass and implement legislation to control storm water runoff and decrease water contamination. The latest and most ambitious project in Lincoln is the Antelope Creek Flood Reduction Project.

In the early 1970s, federal flood plain maps showed that Antelope Creek, which flows through a large populated area of Lincoln and through the University Nebraska-Lincoln's campus, had a high potential for causing major flood damage. Through the most congested part of the creek's path, the creek flowed through an underground conduit that would accommodate only a five-year flood event. Moving such a large portion of the city's and University's buildings and numerous homes and businesses from the flood plain was not a feasible option. However, alternative options for alleviating the problem were cost prohibitive, so nothing was done at that time. In the late 1980s, the Federal Emergency Management Agency remapped and expanded the floodplain. The NRD, along with the city, asked the U.S. Army Corps of Engineers to do a study and suggest a feasible flood control project. The reconnaissance study was completed in 1989. Meanwhile the City tried to address some major traffic problems in the Antelope Creek area and the University wanted to expand its campus, but was blocked because the expansion would be in the flood plain of Antelope Creek. In 1993, at the urging of the LPSNRD and after much discussion, the three entities decided to work together to plan a joint project to address all three issues. The Corps initiated the Feasibility Study in 1995 to parallel a Major Transportation Investment Study. The joint study effort was completed in 2000 and a plan was approved by the City, the NRD and the University of Nebraska-Lincoln. Administering the project threatened to be a problem because all three entities have elected boards, which would have to approve the major project decisions, a process that would have taken too much time to effectively develop the project. To resolve this issue the three entities formed the Joint Antelope Valley Authority (JAVA) through an inter-local agreement and gave JAVA the responsibility of managing the project.

Funding for the Antelope Valley Flood Reduction Project, as with other large NRD projects, was a huge challenge. Although the LPSNRD sought and was able to get funding from both the state and the federal government, the LPSNRD, which at the time had no bonding authority itself, had to get a large loan from a private bank to finance the project and the LPSNRD had to assume the responsibility of paying back the loan. The project was completed in 2013. Today the Antelope Creek project has reduced the flood plain to the width of the new waterway, allowed the University to expand, greatly alleviated traffic congestion, and created an open stream with a bike trail and other recreation opportunities in the project area. (See photograph on pp. 100-101 in which Glenn Johnson, the Manager of the LPSNRD is explaining the Antelope Valley Project.)

There can be little doubt that the strong leadership of the NRD was a key factor in making this project happen. The University did not have the authority to make such a project happen, and the City of Lincoln, although it had the authority, had other more pressing issues and did not see the project as a priority. Nor would the State of Nebraska

have focused on such a local project. It took the LPSNRD, which focuses on natural resources issues, to make the project a priority and make it happen.

With fairly abundant precipitation, little irrigation, and the City of Lincoln getting almost all its water from outside the district, groundwater management was not initially a major concern for the LPSNRD. However, after the state passed the Groundwater Management and Protection Act in 1975, which gave the NRDs authority over groundwater, the NRD started a groundwater monitoring program and initiated other efforts to learn about the groundwater resources in the district. Their research, in cooperation with the University of Nebraska Conservation and Survey Division, showed that the groundwater resources in the LPSNRD are very different from many of the other NRDs. Absent are large, deep groundwater reservoirs; instead there are many smaller aquifers that vary greatly in size and are scattered in pockets in glacial till. The unpredictability of these groundwater reservoirs makes managing groundwater in the district extremely difficult. The monitoring program also showed that nitrate contamination was high in some areas of the district. To address these problems, the NRD developed and adopted a groundwater management plan and adopted rules and regulations to manage both groundwater quantity and quality. The rules include triggers for the several phases of management and regulation.

High nitrates were a problem; many small communities and a large number of domestic wells in the District rely on groundwater. The LPSNRD started working with the local communities to identify the source of the nitrates, to develop a plan to monitor the nitrates, to create community water protection areas, and if necessary to help the community identify a new water supply. The LPSNRD also started to encourage voluntary efforts to minimize the use of nitrogen fertilizer and, based on its monitoring program, to establish triggers for initiating the regulation of fertilizer when nitrates or other contaminants exceed

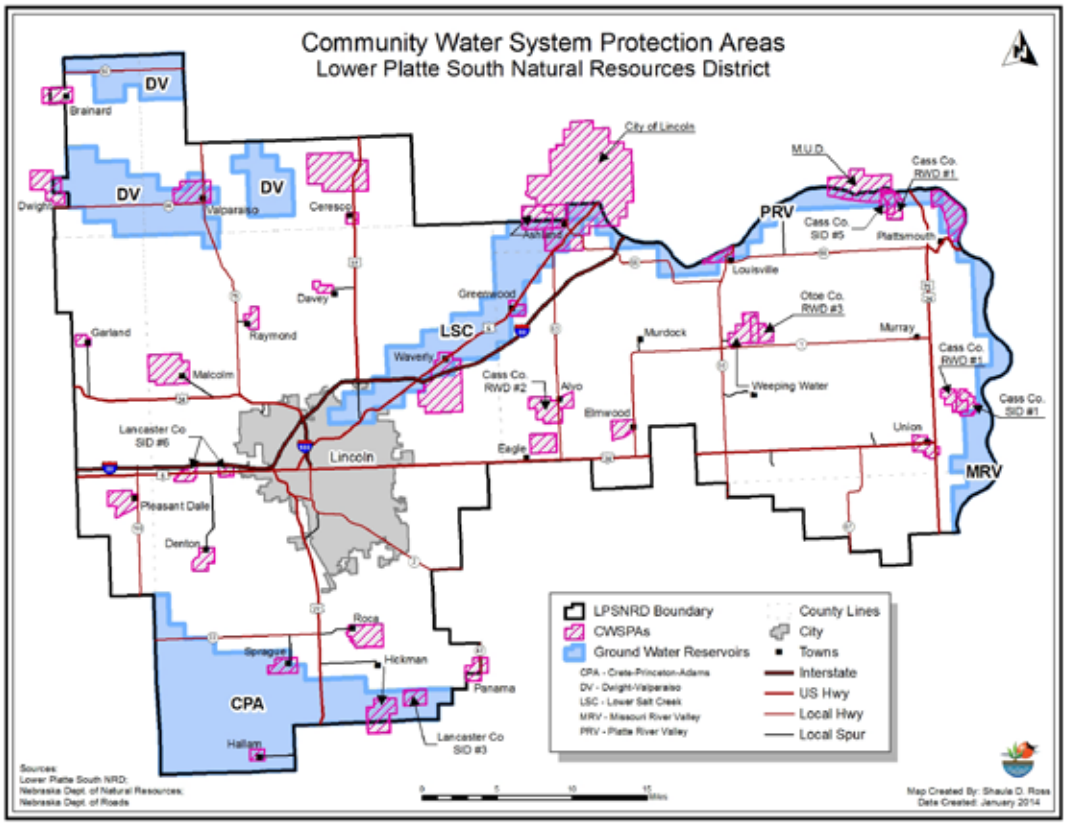

Figure 9: Groundwater Reservoirs and Community Water Protection Areas in the Lower Platte South NRD

a predefined defined trigger. Today, there are a number of areas in the District where these regulations are in place (Figure 25). Through this process the NRD established a good working relationship with the communities in its district.

The LPSNRD also established water quantity triggers, which vary among the groundwater reservoirs throughout the district (Figure 9). As with the water quality triggers, if groundwater monitoring results indicate a water quantity trigger has been exceeded, restrictions will be placed on the use of groundwater. The rules for these restrictions will be developed with assistance from an advisory group of stakeholders from within the area.

During the recent very dry years in certain areas of the district, domestic wells started to go dry during the irrigation season. Domestic well-owners' complaints led to calls for the LPSNRD to regulate groundwater pumping by nearby irrigation wells. The problems were the worst in a confined aquifer shared with the UBBNRD, which was also experiencing short-term water table declines during the irrigation season. To deal with these short-term declines the LPSNRD created a Special Management Area, within which new groundwater irrigated acres are prohibited, groundwater use for irrigation is restricted to 21 inches (53.3 centimeters) over three years, with a maximum use of 9 inches (23.0 centimeters) in any one year in the Dwight-Valparaiso Management Area (DV on Figure 9). Within this area irrigators are also required to obtain water-use management training.

Partially in response to a possibility that the State DNR might determine that the Lower Platte River was fully appropriated, a determination that would require the implementation of an integrated management plan, the LPSNRD decided to develop a voluntary integrated management plan. The LPSNRD worked closely with the State DNR and a 20-member stakeholder group. After numerous meetings over a several-year period, the LPSNRD became the second NRD to adopt a voluntary integrated management plan. The plan follows the legal requirements that are similar to implementing an adaptive management process.

The staff also observed that the public and other elected officials now expect more input on project planning in managing the NRD's resources. When the LPSNRD was first formed, resource projects were designed by the federal government and implemented from the top down without much input from local stakeholders. Now, however, the NRD is getting comfortable with including the public in the decision-making process even though it is more costly and time consuming and sometimes it is a challenge to get stakeholders to attend meetings. The LPSNRD staff has concluded that there is value in such an open and inclusive process. They also stated that the NRD has never seen a project fail as a result of employing it.

Another tool used by the district is the development of an inter-local agreement to bring various local interests and expertise together to work on problems of common interest. As noted above, the LPSNRD used such an agreement to develop the Antelope Creek Project and to work with local communities on water supply wells. The LPSNRD, together with two other NRDs, also used an inter-local agreement to create the Lower Platte River Corridor Alliance, which, along with six state agencies, is working to develop and implement locally developed strategies, actions, and practices to protect, enhance, and restore the natural resources in one of the most heavily populated and fastest growing areas of Nebraska (Lower Platte River Corridor Alliance,

2014). The LPSNRD is also one of seven NRDs, which along with the State DNR, formed the Lower Platte River Basin Water Management Plan Coalition. This inter-local agreement was created to develop a basin-wide water management plan for the entire Lower Platte River Watershed. The plan's goal is to maintain a balance between current and future water supplies and demands. This effort is particularly important to the LPSNRD because it is at the downstream end of the watershed and because most of its population depends on water that is managed by other NRDs in the watershed.

Appendices

Table 4: Overview of Water Quantity Rules by Natural Resources District

This table is a simplified summary of the rules for the NRDs. Also, the rules for NRDs are constantly being reviewed and updated. To understand the actual rules for a specific NRD, please visit the NRD's website. You can find the website by going to http://nrdnet.org/find-your-nrd.php.

Note: All NRDs require permits for wells over 50 gallons per minute, restrict transfers, monitor water levels, and promote water conservation through education and/or incentive programs.

Natural Resources District	Precipitation		Population	Area		Rules (In some cases these actions are not specified by rule, but actions are in described in a ground water management plan.)						
						Certifies Ground Water Irrigated Acres	Requires Meters on High Capacity Wells	Requires Water Use Reporting	Moratorium on Drilling New Wells or Adding New Irrigated Acres If No Offset	Allocations		Intergrated Management for Surface and Ground Water in Part or All of District (either completed or in process)
	Inches	Millimeters		Acres (1,000s)	Ha (1,000s)					Inches/ Years	Centimeres/ Years	
North Platte	14-18	350-460	46,135	3,227	1,307	Yes	In Subareas and enitre district by 2016	Yes	Entire District	70/5; 36/3 by sub area	178/5; 92/3	Required
South Platte	14-18	350-460	15,760	1,652	669	Yes	All wells	Yes	Entire District	42-54/3	106-137/3	Required
Upper Niobrara White	15-19	380-480	26,690	4,476	1,813	Yes	All wells	Yes	Yes	65/5	137/4	Required
Upper Republican	17-20	430-510	8,937	1,727	699	Yes	All wells	Yes	Entire District	65/5	165/5	Required
Middle Niobrara	16-20	410-510	9,100	2,900	1,175	Yes	New Wells	Sub-Area	No	No		No
Middle Republican	16-20	410-510	18,273	2,449	992	Yes	All wells	Yes	Entire District	60/5		Required
Upper Loup	18-22	460-560	4,301	4,275	1,731	Yes	New wells and all wells by 2020	Yes	Entire District	No		Voluntary
Twin Platte	18-22	460-560	44,331	2,746	1,112	Yes	No	No	Entire District	No		Required
Central Platte	18-26	460-660	137,966	2,136	865	Yes	No	Yes	Entire District	No		Required
Lower Niobrara	22-24	560-610	6,985	1,699	688	Yes	New wells	Sub-Area	Entire District	No		Voluntary

Natural Resources District	Precipitation		Population	Area		Rules (In some cases these actions are not specified by rule, but actions are in described in a ground water management plan.)						
Tri-Basin	22-24	560-610	17,721	975	395	Yes	Sub-Area	Yes	Entire District	27/3 in sub-area	69/3	Required
Lower Republican	22-24	560-610	15,787	1,578	639	Yes	All wells	Yes	Entire District	45/5	114/5	Required
Lower Loup	22-27	560-690	69,179	5,071	2,054	Yes	Sub-Area	Sub-Area	Entire District	No		Voluntary
Lewis and Clark	24-26	610--660	15,018	956	386	Yes	New wells	New wells	When triggered	When triggered		Voluntary
Upper Elkhorn	24-28	610-710	18,764	1,955	792	Yes	New wells	Yes	Entire District Reviewed annually	No		No
Upper Big Blue	26-28	610-710	54,349	1,828	740		New wells and all by 2016 unless triggered earlier	Sub-Area	Sub-Area	30/3 and 45/5 when triggered	76/3 and 114/5 when triggered	Required
Lower Elkhorn	26-30	610-760	89,256	2,527	1,023	Yes	New wells and Sub-Area	Yes if need meter	No	13-14/1 Sub-Area	33-36/1	Voluntary
Lower Platte North	26-30	610-760	63,518	1,028	416	Yes	Sub-Area and new wells entire district	Sub-Area and new wells entire district	Sub-Area	27/3 Sub-Area	69/3 Sub-Area	Voluntary
Little Blue	26-31		47,584	1,537	622	Yes	Yes	Yes	Sub-Area	Set When Triggered		No
Natural Resources District	Precipitation		Population	Area		Rules						
Lower Platte South	28-30	710-760	314,722	978	396	All	All wells	Yes	Sub-Area	21/3 max 9 in any year in Sub-Area	53/3 max 23 in any one year	Voluntary
Lower Big Blue	28-30	710-760	36,964	1,054	427	Yes	New Wells	On new wells	Ranking System*	Set When Triggered		No
Papio Missouri	30-32	760-810	725,250	1,117	452	Yes	No	No	Sub-Area	No		Voluntary
Nemaha	34-36	860-910	44,560	1,537	622	No	New Wells	Yes	No	No		No

*A ranking system was established for new wells to determine well performance and water availability at the new location.

Appendices

Table 5: Overview of Water Quality Rules by Natural Resource District

There is a great deal of variation in the rules for managing water quality among the NRDs. This table is a simplified summary of these rules. Also the rules are constantly being reviewed and updated. To understand the actual rules for a specific NRD, please visit the NRD's website. You can find the website by going to http://nrdnet.org/find-your-nrd.php.

All NRDs have monitoring programs for the detection of water quality contamination. In many cases, if there is an indication of a rise in contamination, the level of monitoring will be increased. All NRDs have also established a contaminant level, which if exceeded, will trigger the development of a special management area.The actual trigger is usually defined as a certain percentage of the wells tested that are at or above a certain percentage of the maximum contaminant limit (MCL) that has been established by the federal government. In Nebraska the major contaminant of concern is nitrate nitrogen, which has an MCL of 10 parts per million. For some NRDs the trigger for action is expressed in units of parts per million of nitrogen, but in this table, these triggers are all expressed as a percentage of the MCL. When a special management area is developed, the NRD implements rules to address the problem. This table is a summary description of the trigger values for each phase of management and a summary of the rules for each phase.

In all NRDs, any part of the NRD that is at a higher Phase must follow also all the rules for the lower phases.

Natural Resources District	Water Quality Triggers for Phase I	Rules for Phase I (Note: Usually the entire NRD is considered to be in Phase I until a second or third phase is designated for a specific area of the district.	Water Quality Triggers for Phase II	Rules for Phase II	Water Quality Triggers for Phase III	Rules for Phase III, and IV
North Platte		Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 75%	No fall and winter fertilizer application, required flow meters, soil and water sampling, annual reporting.		
South Platte	> 65% for 3 consecutive years	Require operator training. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 80% for 3 consecutive years	Require soil and water testing, and annual reporting	> 95% for 3 consecutive years	Require flow meters, irrigation scheduling, restictions on fertilizer application, ground water allocations
Upper Niobrara White	> 50%	Encourage soil sampling. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 70%	Require operating training and soil and water testing; encourage irrigation scheduling	> 95%	Require irrigation scheduling, may require restrictions on fall and winter fertilizer application, and on spring application on sandy soils or when depth to groundwater is shallow.
Upper Republican - Proposed	< 40%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	40% - 60%	To be determined when triggered	> 60%	To be determined when triggered
Middle Niobrara	< 50 % wells pumping are > 50 %	Require operator training. Encourage education and offer cost-share incentive programs and technical assitance for BMPs. (Note: These rules pertain to Phase I and II.)	> 50 % wells pumping are >50 % (Phase III)	No fall application of fertilizer. Require soil testing, use of 2 BMPs, annual reports	> 50 % wells pumping are > 100 % (Phase IV)	Requirewater testing, fertilizer budgeting, 3 BMPs

Natural Resources District	Water Quality Trig-gers for Phase I	Rules for Phase I (Note: Usually the entire NRD is considered to be in Phase I until a second or third phase is designated for a specific area of the district.	Water Quality Trig-gers for Phase II	Rules for Phase II	Water Quality Trig-gers for Phase III	Rules for Phase III, and IV
Middle Republican	Land area 36 square siles (9.3 square kilometers) showing significant contamination		Encourage education and offer cost-share incentive programs and technical assitance for BMPs. Rules to be determined when triggered			
Upper Loup	< 45%	Required water sampling, encourage no fertilizer on sandy soils, encourage attendance for fertilizer and irrgation water management. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 45% - 90%	No fall or winter application of fertilizer on sandy soils. Require operator training, soil and water testing, annual reporting, meters on wells.	> 90%	Require monitoring for more efficient fertilizer application and irrigation scheduling
Twin Platte	3 year increase reaches 50%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 70%	Require operator training, encourage BMPs, additional rules to be determined,	> 85%	Require soil and water testing, annual report. Additional rules to be determined
Central Platte	0 - 75%, no municipal in sub-area	No fall application of fertilizer, no winter application of fertilizer on sandy soils. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	76% - 150%, municipal in sub-area	No fall or winter application of fertilizer. Required operator training, soil and water testing, water use measurement, and nitrate budgeting.	> 150%, municipal supply in sub-area	Require use of split application and inhibitors. Areas where contaminants are not declining at an acceptable level, District staff will work with producers on BMPs
Lower Niobrara	< 75%	Required operator training, discourage fall application of fertilizer, encourage soil and water testing. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 75% - < 95%	No fall application of fertilizer. Require soil and water testing, well meters, use of fertilizer budgeting, annual reports	> 95%	No fall or winter application of fertilizer. Require irrigation scheduling, use of 2 BMPs. Where conamination leves are > 130%, require split appllication and budgeting of fertilizer, encourage use of inhibitors
Tri-Basin	< 90%	No fall fertilizer application for spring-planted crops on loam or clay soils and no fall or winter fertilizer application for spring planted irrgated crops on sandy soils. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 90% or increasing 10% per year	Require water and soil testing, annual reports, and operator training.	> 90% and not declining at least 10% during last 4 years	No fall and winter fertilizer application for spring crops on all soils. Require split applications of fertilizer

Table 5: Overview of Water Quality Rules by Natural Resource District (continued)

Natural Resources District	Water Quality Trig-gers for Phase I	Rules for Phase I (Note: Usually the entire NRD is considered to be in Phase I until a second or third phase is designated for a specific area of the district.	Water Quality Trig-gers for Phase II	Rules for Phase II	Water Quality Trig-gers for Phase III	Rules for Phase III, and IV
Lower Republican	< 55%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	55% < 75%	Increased educa-tion and demon-stration plots.	55% < 95%	No fall application of fertilizer.Require operator training. Require soil analysis, fertilzer budgeting, and annual report-ing on one demon-stration field. In areas > 95%, require irrigation scheduling, soil analysis, fertil-izer budgeting, and annual reporting on all fields.
Lower Loup	< 65%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	66% - 85%	No fall or winter application of fertilizer on sandy soils, no fall application on all sois and use of inhibitor inwinter. Require operator training, soil and wtrer analysis, meters on wells.	> 85%	Require use of inhib-itor and split appli-cation of fertilizer.
Lewis and Clark	< 50%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	50% - 90%	Increased education	> 90%	No fall application of fertilizer. Require operator training, soil and water testing, irrigation scheduling, tissue sampling, split ap-plication of fertilizer, fertilizer budgeting,
Upper Elkhorn	< 75%	Discourage fall application fertilizer. Require operator training. Encourage education and offer cost-share incen-tive programs and technical assitance for BMPs.	75% - 95%	No fall applica-tion of fertilizer. Require deep soil testing, annual reports	> 95%	No fertilizer or winter applications of fertilizer. Required water monitoring and flow tests, submission of crop management plan.
Upper Big Blue	<70%	No fall and limited winter application of fertilizer. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 70%	Require irrigation scheduling, soil testing		
Lower Elkhorn	< 50%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	50% - 90%	Require operator training, soil and water testing, annual reports	> 90%	Require irrigation scheduling

Lower Platte North	< 80%	Require operator training. Encourage water and soil testing and no fall or winter fertilizer application on sandy and fine textured soils. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 80% < 100%	Required soil and water testing, annual reporting, use of inhibitors on sandy and fine soils for fall or winter fertilizer application. Encourage fertilizer budgeting.	> 100%	No fall or winter fertilizer application. Require use of split applications or inibitors.
Little Blue	<70%	No fall application of fertilizer, restrictions on winter applications. Require operator training, permit for applying fertilizer, annual reporting. Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	70% - 85%	Required education. Require irrigation scheduling, soil sampling, annual reports on one demonstration field per operator.	> 85%	Require soil and water testing, use of fertilizer budgeting, irrigation scheduling, annual reports on all fields. There are special rules for area shared with LRNRD.
Lower Platte South	< 50%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	50% - 80%	Cost share programs for BMPS, required education	> 80%	No fall or winter fertilizer application, require soil sampling and nitrogen budgeting,
Lower Big Blue	< 605	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	60% - 90%	No fall application of fertilizer. Require operator training, soil and water testing.	> 90%	No fall or winter application of fertilizer. Require use of split application and inhibitors
Papio-Missouri	< 50%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	> 50%	Specific actions planned when Special Management Area designated		
Nemaha	.1% - 79.9%	Encourage education and offer cost-share incentive programs and technical assitance for BMPs.	80% < 90%	No fall application of fertilizer. Require annual reports, require 1 BMP, develop incentive programs, may require education and other management actions	> 90%	Require operator training, soil testing, fertilizer budgeting, irrigation scheduling, use of inhibitor for fall application of fertilizer, annual reporting.

Definitions

Required operator training refers to required attendance at a course on applying fertilizer and/or using irrigation scheduling, and certification that the training has been obtained.

BMPs are best management practices.

Fertilizer budgeting refers to either limiting fertilizer, particularly nitrogen, use to no more than is recommended for a certain crop on certain soils, or limiting nitrogen fertilizer to no more than the recommended amount minus the amount of nitrogen remaining in the soils as determined by a soil test.

In many cases annual reports covering many aspects of the farming operation are required.

References

This table is based on the Rules and Regulations and Ground Water Manatement Plans of each NRD. The table was greatly improved by the comments of the Managers and Staff of the NRDs. The considerable help and cooperation of Jennifer Swanson from the Nebraska Association of Resources District is also gratefully acknowledged.

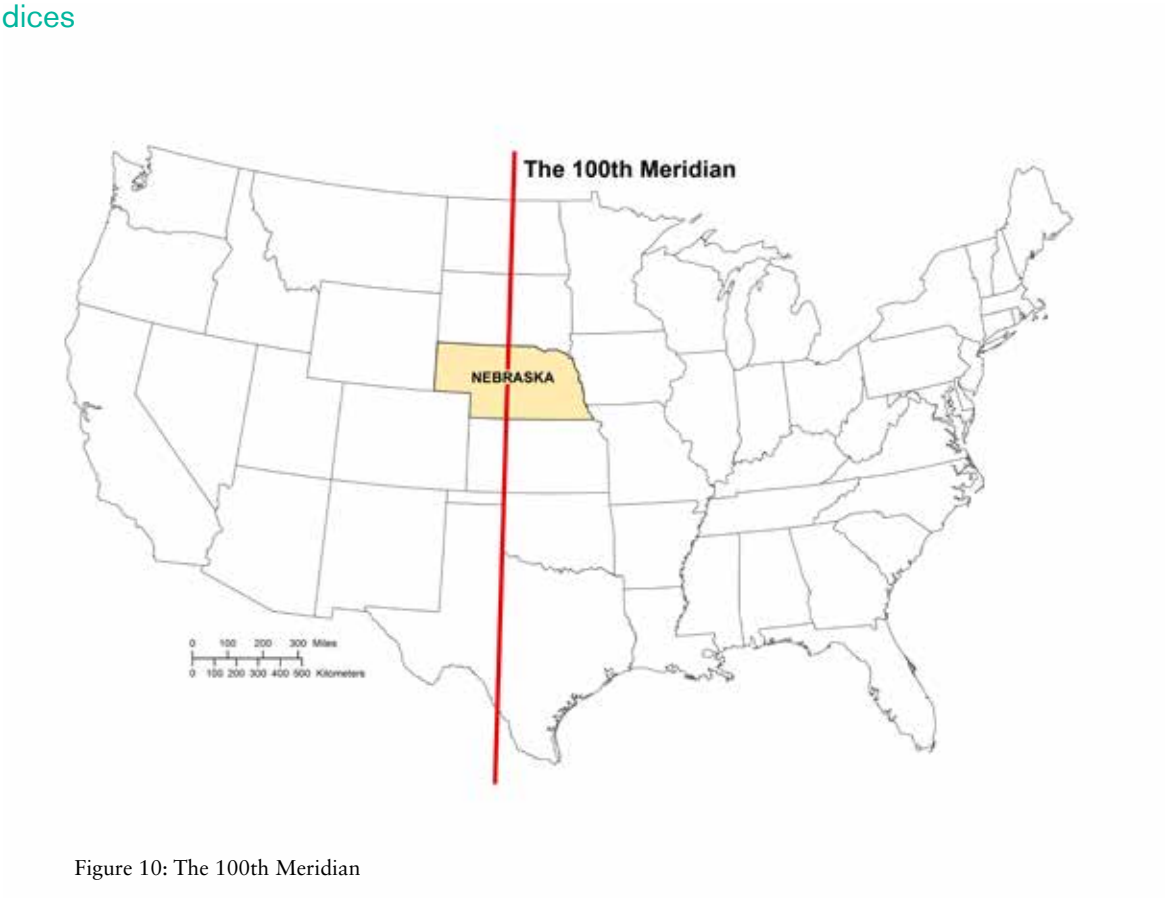

Figure 10: The 100th Meridian

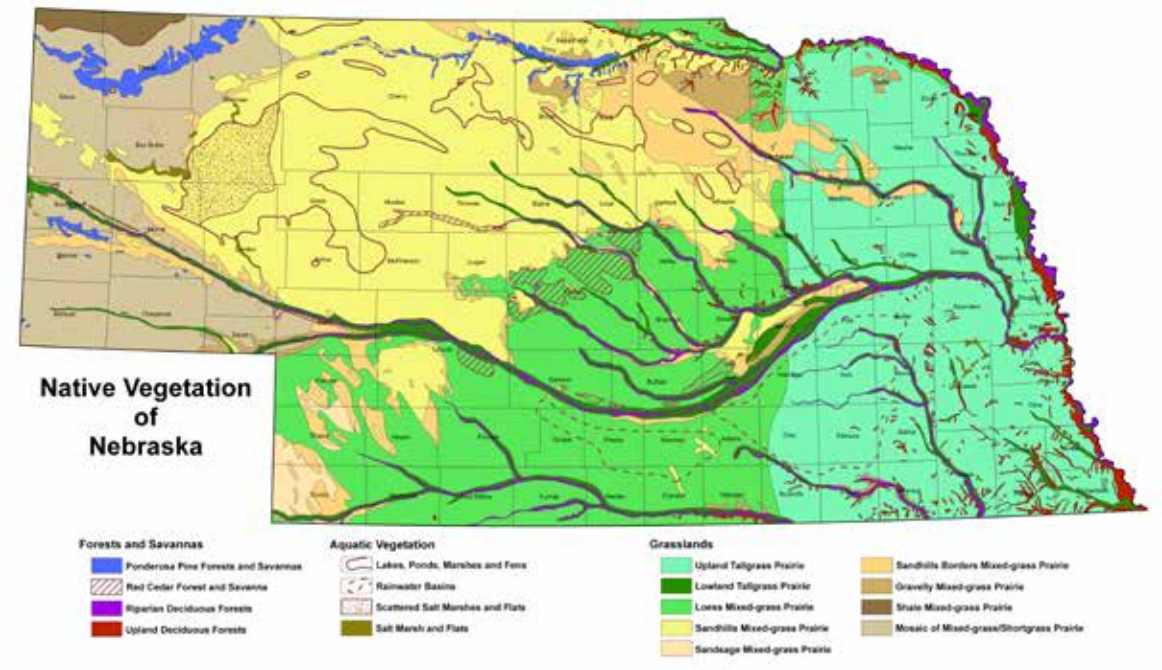

Figure 11: Native Vegetation of Nebraska[20]

E. Climate and Hydrology Figures

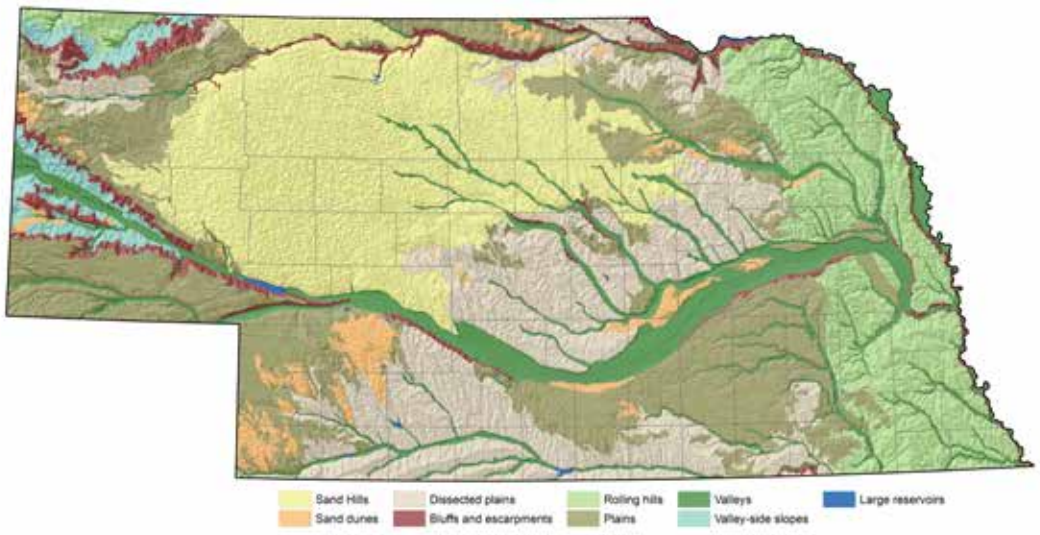

Figure 12: Topographic Regions of Nebraska[21]

[20]Adapted from Kaul and Rolfsmeier with permission from the Conservation and Survey Division, University of Nebraska-Lincoln

[21]Adapted from Korus et al. 2013 with permission from the Conservation and Survey Division of the University of Nebraska-Lincoln.

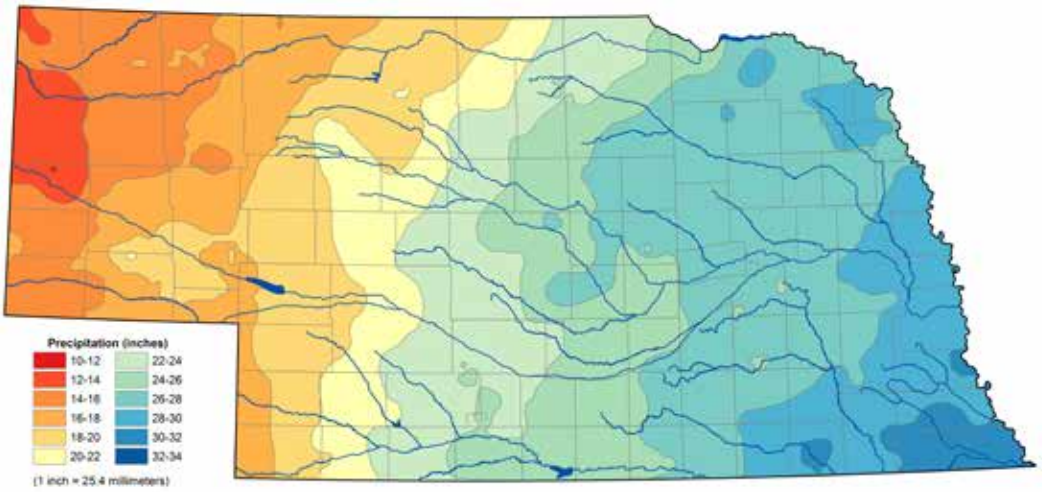

Figure 13: Average Annual Precipitation for Nebraska[22]

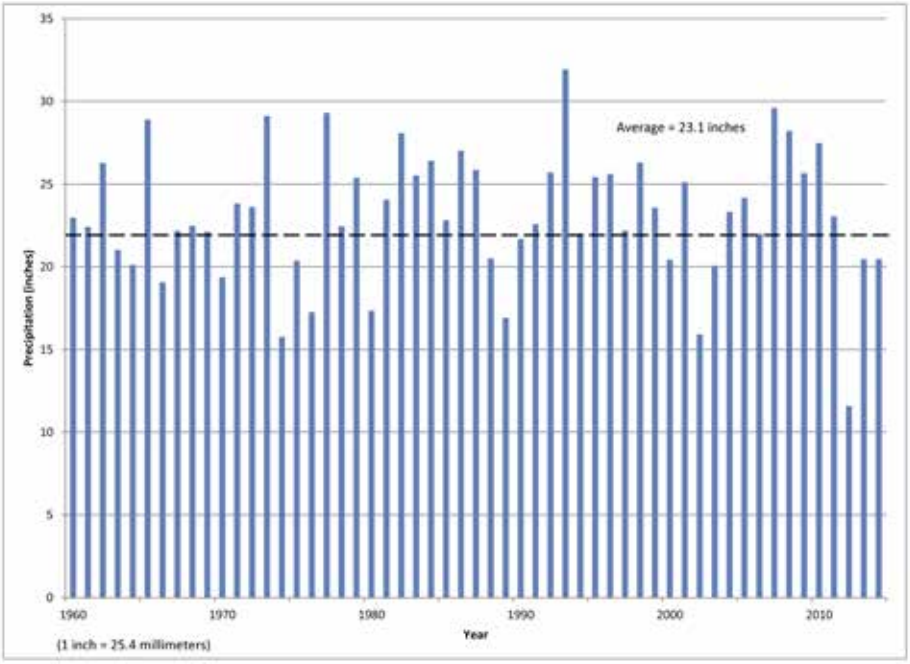

Figure 14: Graph of Average Annual Statewide Precipitation for Nebraska[23]

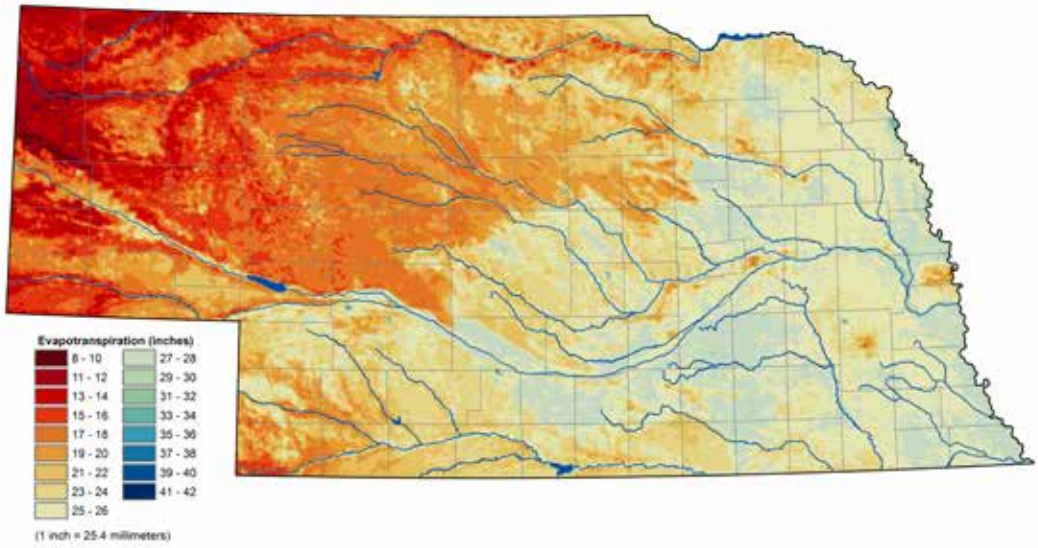

Figure 15: Average Annual Evapotranspiration[24]

[22]Adapted from Korus et al. 2013 with Permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

[23]Adapted from Korus et al. 2013 with Permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

[24]Adapted from Korus et al. 2013 with Permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

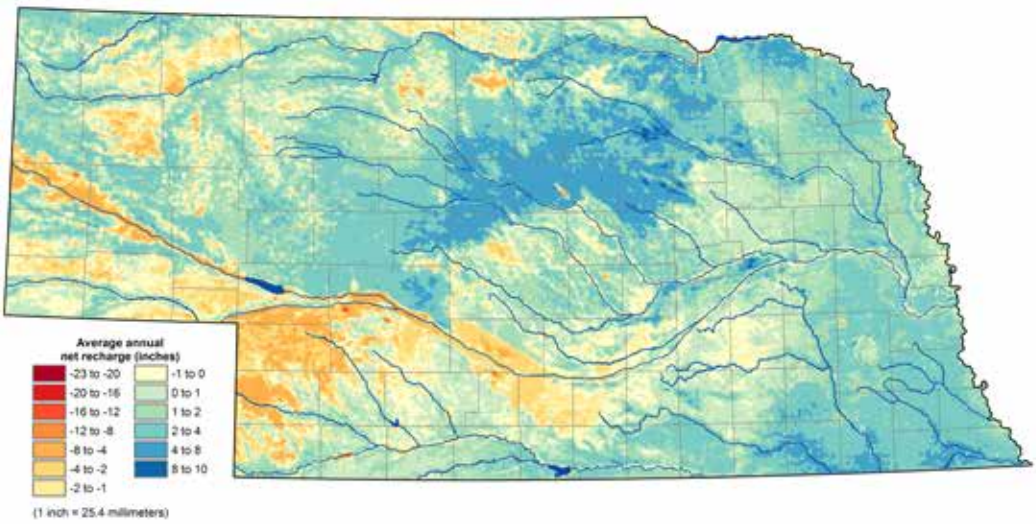

Figure 16: Average Annual Net Recharge to Groundwater[25]

Figure 17: Major Rivers in Nebraska[26]

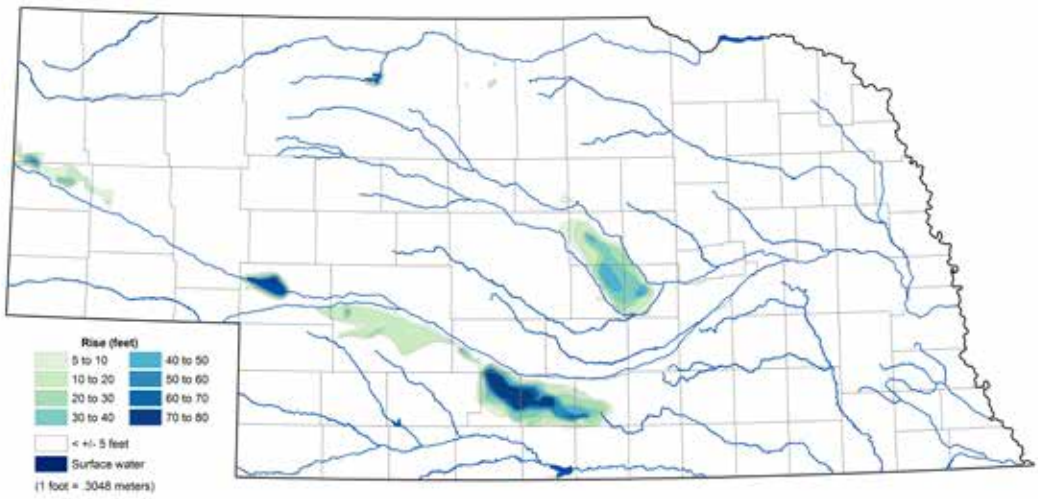

Figure 18: Rises in Groundwater Levels as a Result of Seepage from Surface Water Canals and Reservoirs from Predevelopment to Spring 2012[27]

[25]Adapted from Korus et al. 2013 with Permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

[26]Adapted from Korus et al. 2013 with permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

[27]Adapted from Korus et al. 2013 with permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

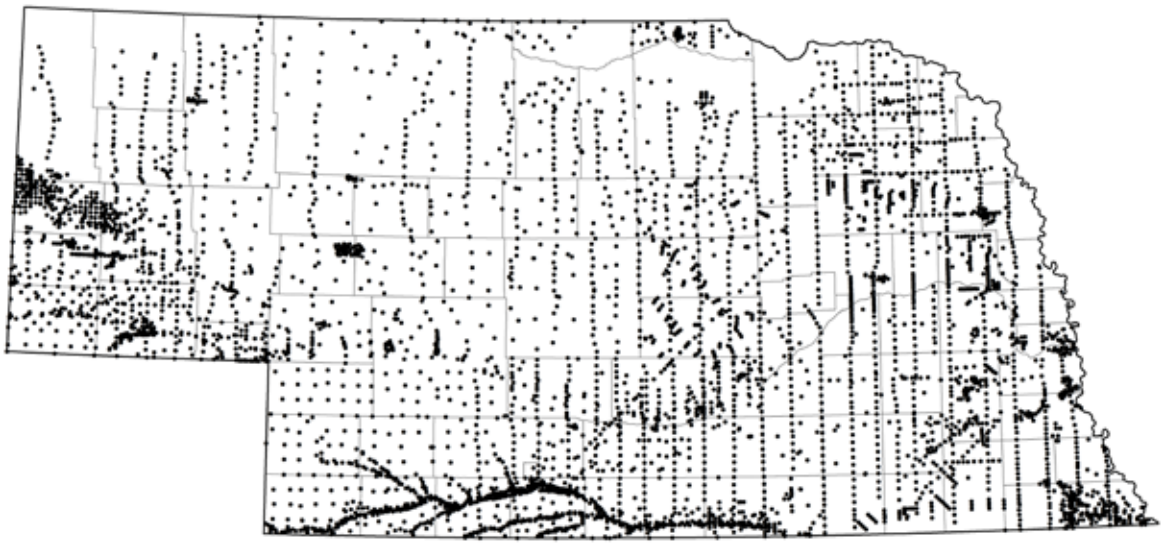

Figure 19: Locations of Exploratory Test Holes Drilled by the University of Nebraska Conservation and Survey Division from 1931 to 2012[28]

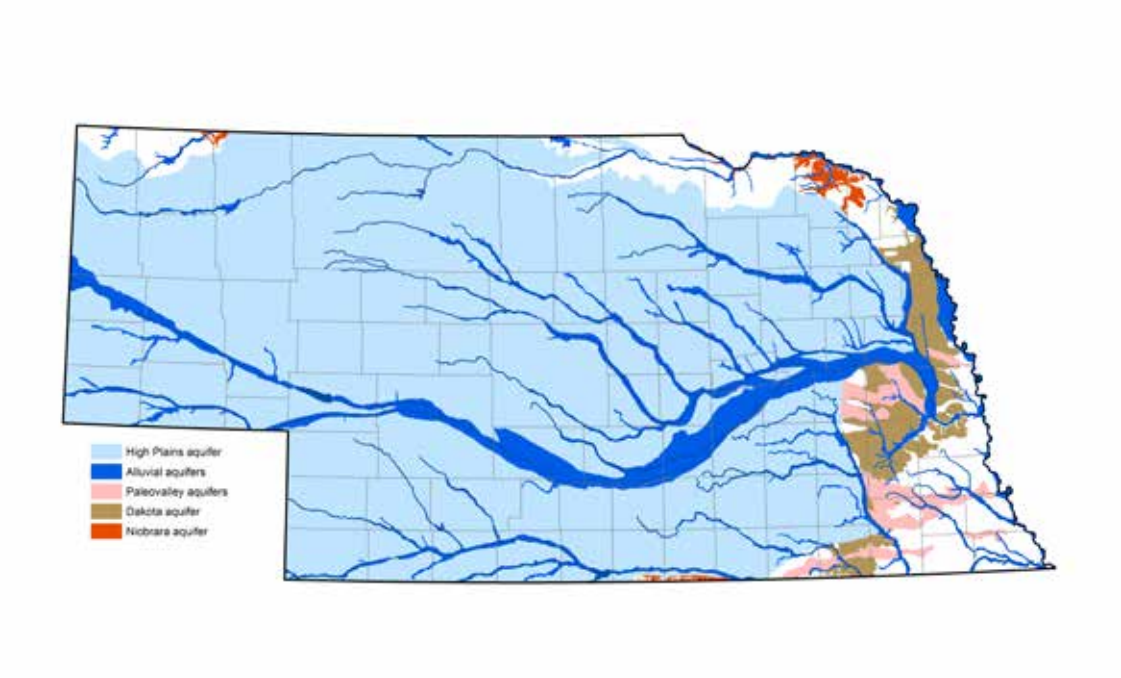

Figure 20: Principal Groundwater Reservoirs in Nebraska[29]

[28]Adapted from Korus et al. 2013 with Permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

[29]Adapted from Korus et al. 2013 with permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

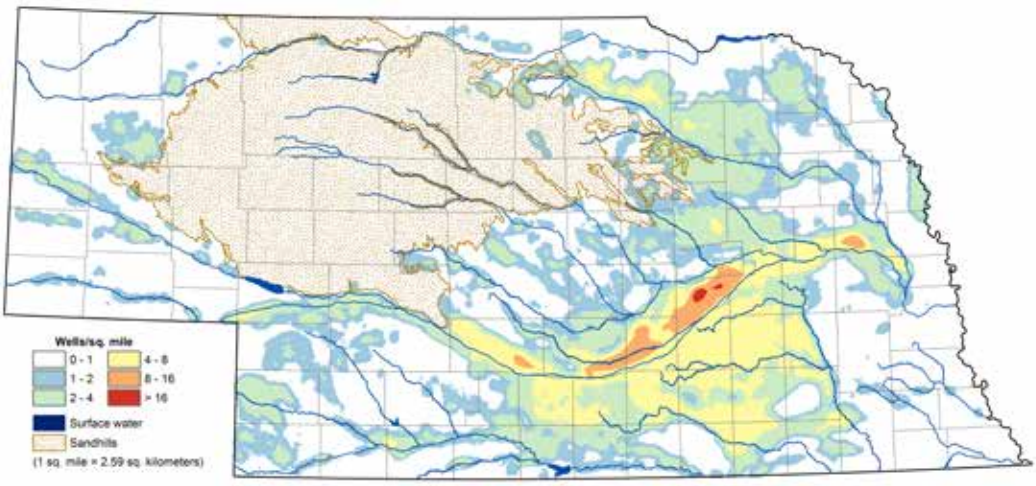

Figure 21: Density of Active Irrigation Wells in Nebraska – December 2013[30]

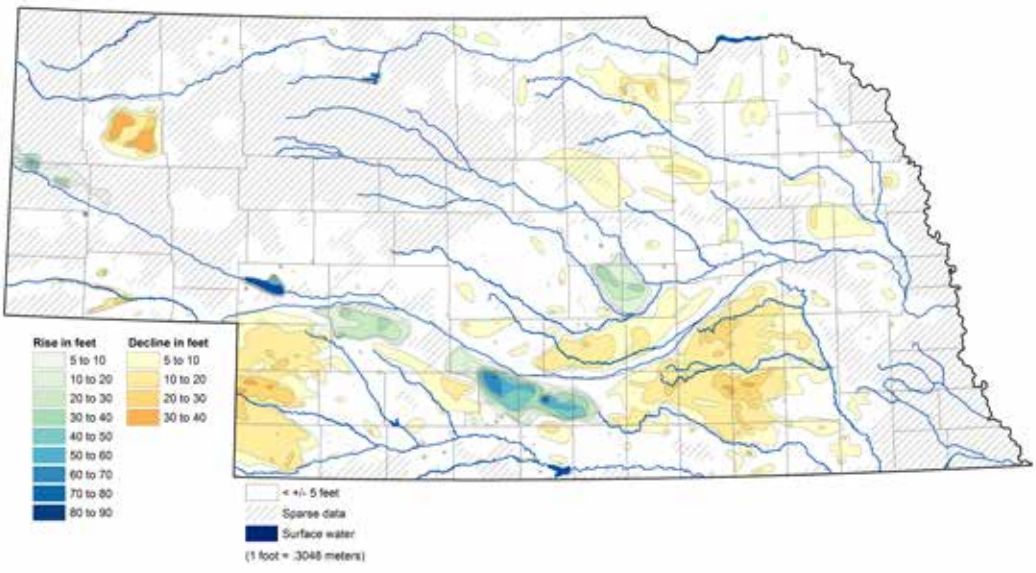

Figure 22. Changes in Groundwater Levels from Predevelopment to Spring 1981[31]

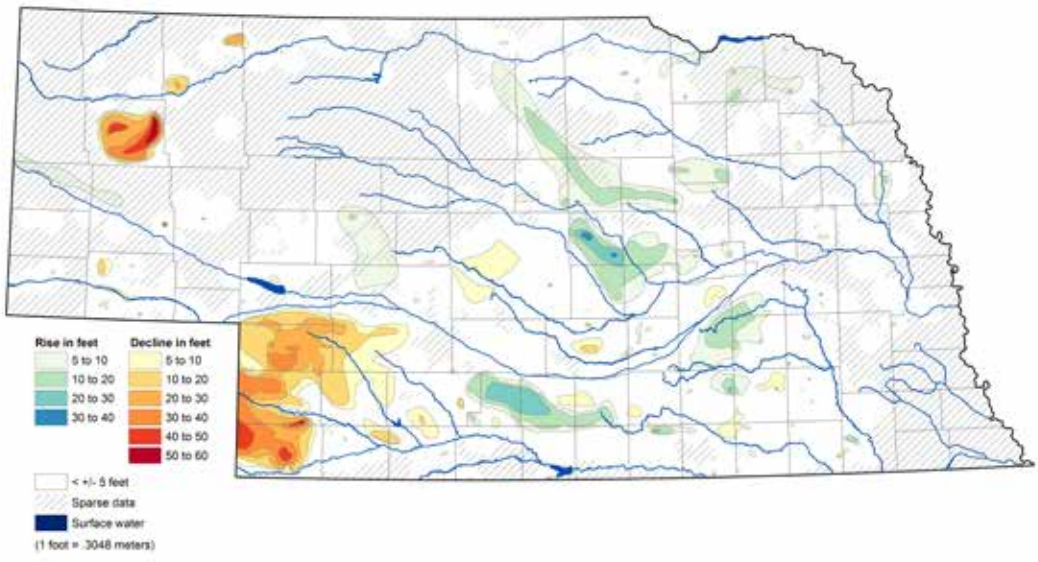

Figure 23: Changes in Groundwater Levels from Fall 1981 to Spring 2013[32]

[30]Adapted from Korus et al. 2013 with Permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

[31]Adapted from Korus et al. 2013 with permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

[32]Adapted from Korus et al. 2013 with permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

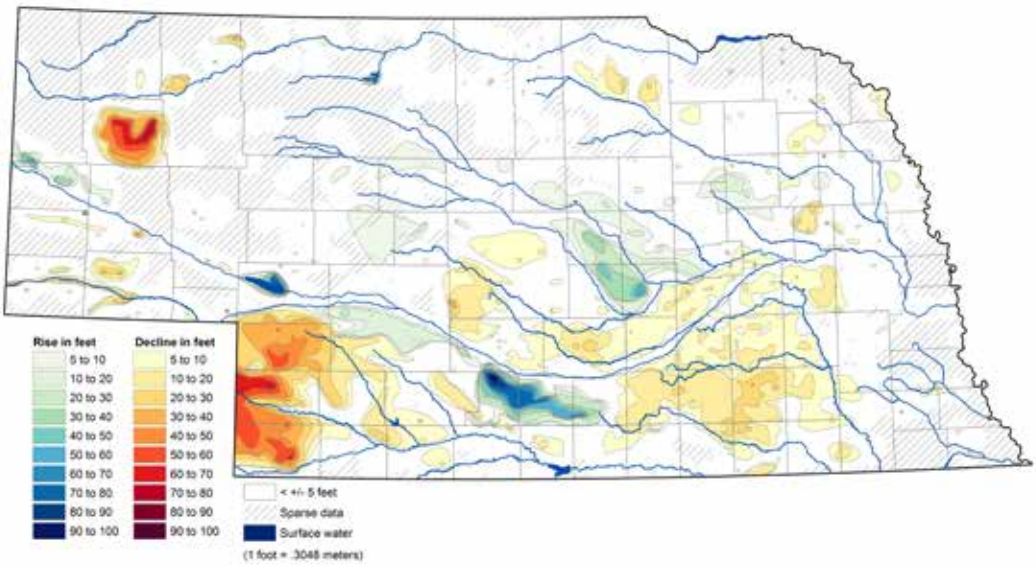

Figure 24. Changes in Groundwater Levels from Predevelopment to Spring 2013[33]

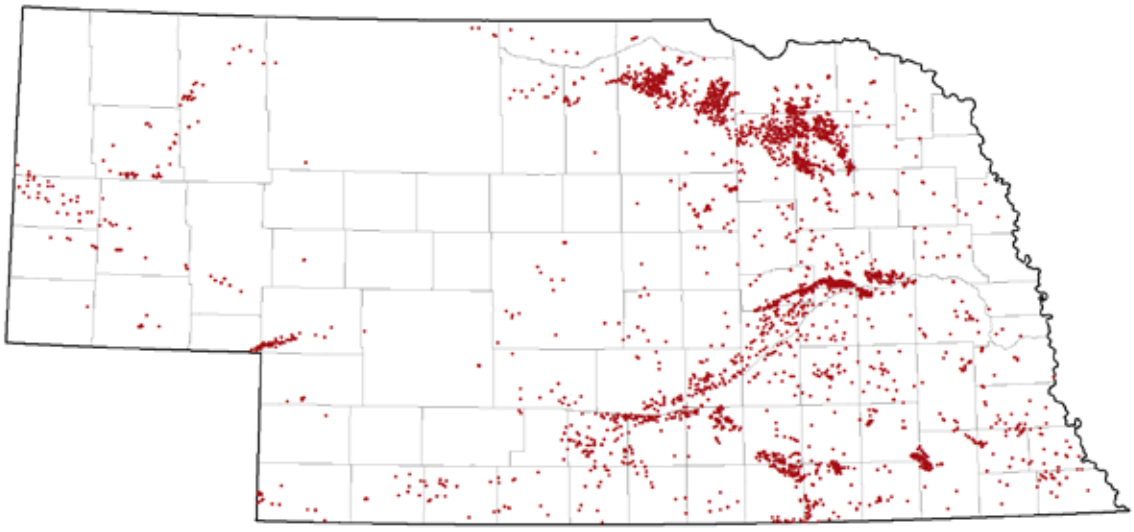

Figure 25A: Wells with most recent nitrate concentration greater than 10 parts per million.

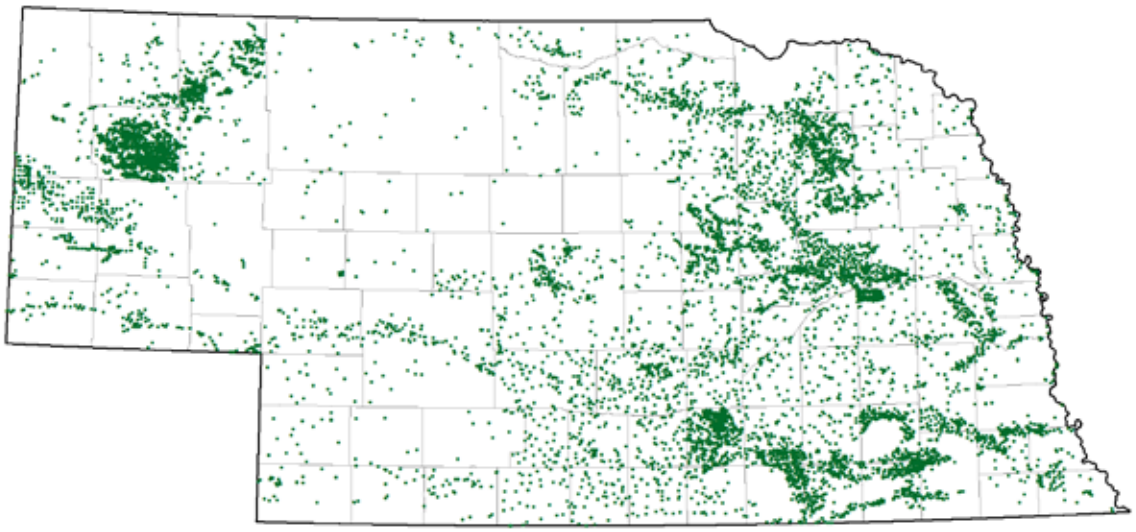

Figure 25B: Wells with most recent nitrate concentration less than 20 parts per million.

Figure 25. Most Recent Nitrate Concentrations Greater in Wells Sampled between January 2001 and December 2011[34]

[33]Adapted from Korus et al. 2013 with Permission from the Conservation and Survey Division of the University of Nebraska-Lincoln

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