Lower Platte River Drought Contingency Plan – DRAFT

Executive Summary

Beginning in 2016, the Lower Platte South Natural Resources District (NRD), Papio-Missouri River NRD, Lower Platte North NRD, Metropolitan Utilities District (MUD), Lincoln Water System (LWS), and Nebraska Department of Natural Resources (NeDNR), collectively referred to as the Lower Platte River Consortium (Consortium), embarked on a collaborative effort to develop a drought contingency plan for the Lower Platte River Basin in Nebraska.

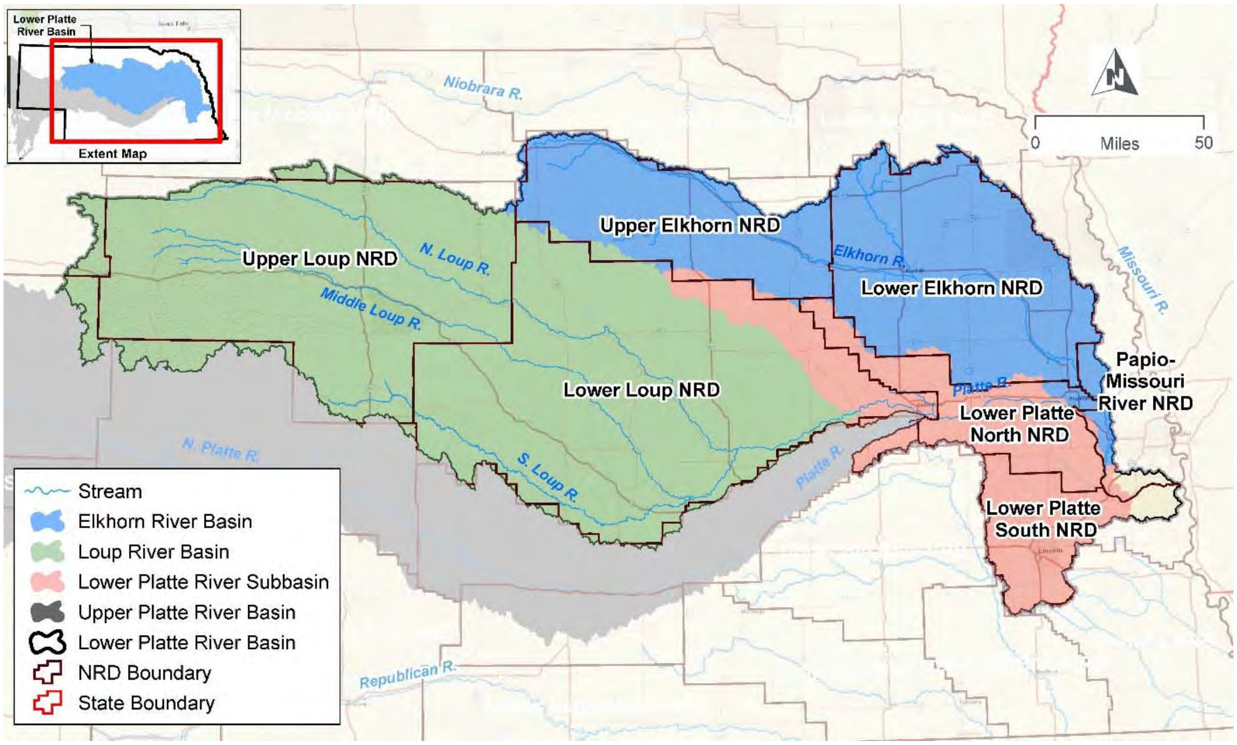
The Lower Platte River, its tributaries, and aquifers serve approximately 80 percent of Nebraska's population, thousands of businesses and industries, includes more than 2 million irrigated acres, and provides streamflows for threatened and endangered species. It was recognized that a potential drought in the region would pose serious risk to public health, economy, and fish/wildlife. The drought-driven risks are diverse and alternatives for resolving them were investigated through this planning effort.

The focus of this first increment of the Drought Plan is on augmenting surface water supplies in the Lower Platte River near Ashland. It is believed that in addressing the water supply shortages in the Lower Platte River, ancillary benefits to the remaining sectors would exist including: irrigation, power, environmental, and recreational.

There are a wide-range of stakeholder interests in the Lower Platte River Basin. The Consortium solicited stakeholder input throughout the planning effort. Two stakeholder workshops and two public open houses were held, and written comments were accepted via comment forms and a project email posted on the project website open to the public.

Member participation in the Consortium is voluntary and member agencies shall not be bound by any initiatives, recommendations or decisions made by the Consortium without a subsequent written agreement or resolution approved by the respective bodies. While represented agencies may elect to seek approval of the Plan by their respective elected officials, formal adoption of the Plan is not required for future participation in the Consortium.

Figure E-1: Map of Lower Platte River Basin



Drought Contingency Plan Background

In 2017, the Lower Platte River Basin Coalition, which includes the seven NRDs[1] in the Loup, Elkhorn, and Lower Platte River Basins, and NeDNR, adopted the *Lower Platte River Coalition Basin Water Management Plan (Basin Plan)*. The Basin Plan evaluated supplies and demands in the Lower Platte River Basin (Basin) and set criteria for managing new water development, and goals and objectives that work to protect the existing domestic, agricultural, and industrial water uses in the Basin. The Basin Plan found that annual water supplies in the Basin generally tend to be supportive of most water uses; however, peak demands in the summer months can create water shortages. These shortages are further exacerbated by drought periods when summer flows become most critical in supporting water demands. This planning effort for the *Lower Platte River Drought Contingency Plan* (Drought Plan) followed the development of the Basin Plan to further address water supply shortages during drought periods, when peak demands overlap periods of low streamflows.

Lower Platte River Basin

Basin Water Demands

The water demands and water uses in the Lower Platte River are diverse; they include municipal, domestic, and agricultural uses, instream flows, and hydropower. The water utilities for the municipalities of Omaha and Lincoln, Nebraska, serve the two primary metropolitan areas in Nebraska, constituting approximately 60 percent of Nebraska's population. Both municipalities hold induced recharge permits (permits that require streamflows adjacent to their well-fields) and municipal groundwater transfer permits (permits where groundwater is transferred from the water well site for use in another location).

[1] This includes the three NRD members of the Consortium (Lower Platte North NRD, Lower Platte South NRD, and Papio-Missouri River NRD).

The Nebraska Game and Parks Commission holds instream flow appropriations for much of the Platte River and specifically in the areas of municipal well-field operations. The Loup Public Power District holds a hydropower appropriation for off-channel hydroelectric power generation. In addition, thousands of individual water rights or groundwater permits are held to support irrigation from both surface water and hydrologically connected groundwater sources.

Basin Water Supplies

Water supplies of the Lower Platte River are driven by snowmelt, rainfall runoff, and aquifer baseflow contributions. Supplies can be highly variable, with annual flows ranging from 2 million acre-feet per year to more than 10 million acre-feet per year.

During low-flow years, the Upper Platte River becomes disconnected from the Lower Platte River with flows at Duncan, Nebraska, representing a negligible portion of flows observed in the Lower Platte River. During these times, most of the flow in the Lower Platte River originates from the groundwater-fed Loup River, Elkhorn River, and Platte River tributaries downstream from Duncan. The water supplies of the Loup River and Elkhorn River subbasins tend to be more reliable because of significant baseflow contributions. During drought periods, these water supplies reliant on baseflow contributions are stressed in support of irrigated agricultural production (primarily corn and soybeans).

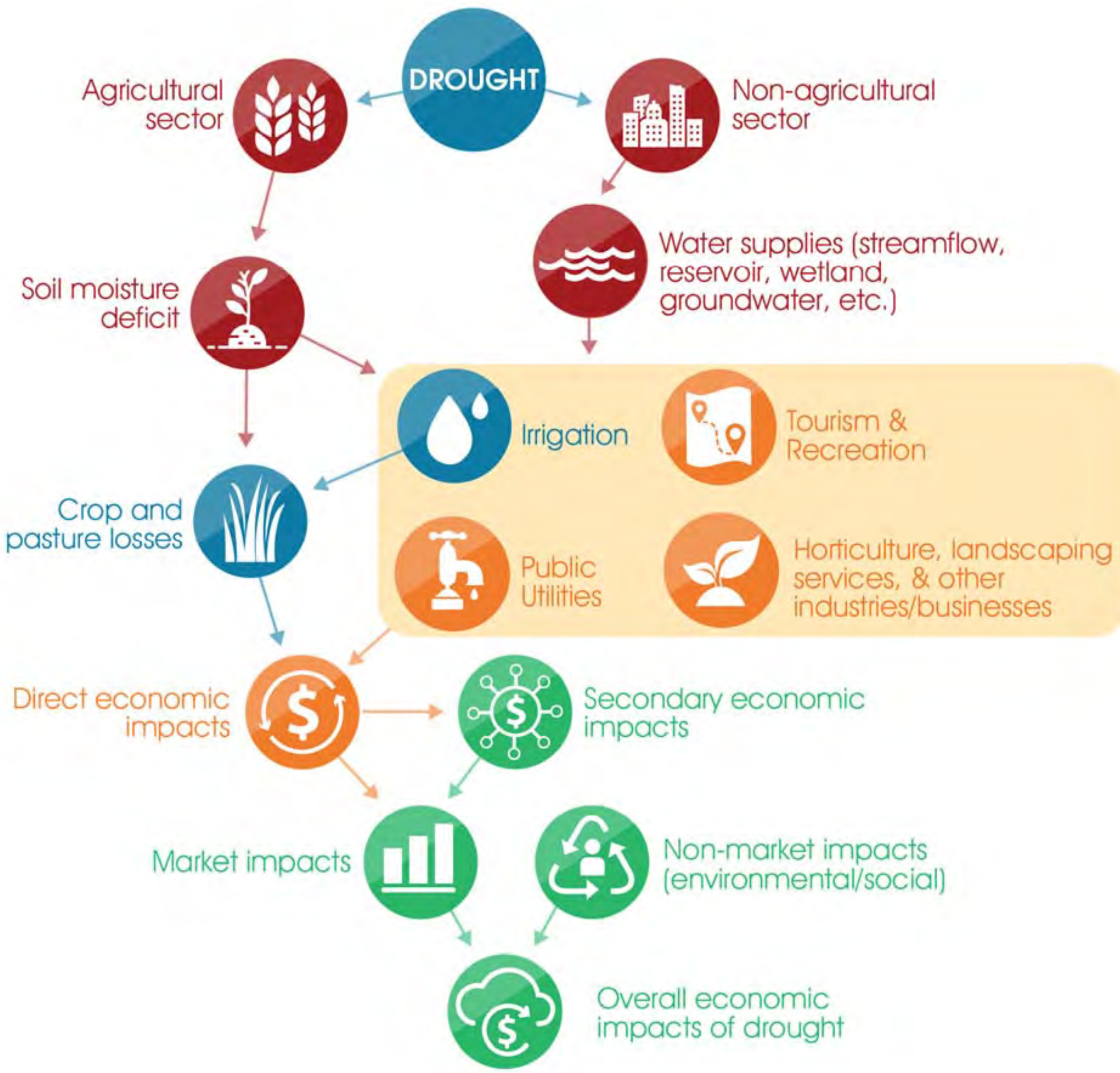
While annual water supplies in the Lower Platte River generally tend to be supportive of most water uses, peak demands in the summer months can create water shortages, typically in July and August. These shortages are further exacerbated by drought periods when summer flows become most critical in supporting water demands.

Vulnerability Assessment

"[V]ulnerability to drought is the product of numerous interrelated factors such as population growth and shifts, urbanization, demographic characteristics, water use trends, social behavior, and environmental susceptibilities…. The degree to which a population is vulnerable hinges on the ability to anticipate, to deal with, resist, and recover from the drought" (Commission on Water Resource Management 2003).

The effects from drought can be classified as direct and indirect. Direct effects include physical destruction of property, crops, natural resources, as well as public health and safety. Indirect effects are consequences of that destruction, such as temporary unemployment and business interruption (National Academy of Sciences 1999). "The most vulnerable portions of the state in terms of economic impact are cropland, pasture land for animals, recreational areas, and businesses that depend on agricultural industries for the bulk of their business. However, all areas of the state can be impacted by drought events" (Nebraska Emergency Management Agency [NEMA] 2014). Figure E-2 summarizes sectors that are affected by drought (both agriculture and non-agriculture).

Figure E-2: An Overview of Drought Economic Effects



Source: Adapted from Ding, Hayes, and Widhalm 2010

Public water systems along the Lower Platte River are largely dependent on aquifers hydrologically connected to the river and its tributaries, and dependent on streamflow for recharge. Omaha and Lincoln, Nebraska's two largest municipalities, rely heavily on water supplies in the Lower Platte River to support well-field operations adjacent to the river. MUD's water system receives roughly half of its capacity from the Lower Platte River and the other half is received from the Missouri River. The capacity of Lincoln Water Systems' Ashland Well-field is directly dependent on flows in the Lower Platte River adjacent to the well-field. The vulnerability of public water supply during drought is amplified in the Lower Platte River Basin due to the lack of redundant water sources. With the exception of MUD, public water systems along the Lower Platte River rely solely on the aquifers hydrologically connected to the Platte River and are reliant on its flows for recharge.

Executive Summary
The Lower Platte River provides habitat for numerous species, including federally listed threatened and endangered species, which are dependent on sustained flows. In addition, this reach of the river provides recreational amenities for the eastern portion of the state, including the primary population centers.

Drought Monitoring

Hydroclimatic indices assess drought severity and are essential for tracking and anticipating droughts as well as providing historical reference. Indices provide useful triggers to help direct decision-makers toward proactive risk management. For this increment of the Drought Plan, the Palmer Drought Severity Index (PDSI) will be utilized in combination with streamflow observations for drought determination in the Lower Platte River Basin. The PDSI reflects recent precipitation and the soil moisture balance. Zero or near zero PDSI values indicate normal conditions, a negative PDSI value indicates below normal (drought conditions); and a positive value represents above normal (wetter periods).

Four categories of drought have been identified for the Drought Plan. These levels of drought remain consistent with the National Drought Monitor definitions of drought. These categories and corresponding PDSI and streamflow thresholds are presented in Table E-1.

The following lists the levels of drought and their corresponding definition:

- A Level 0, "Abnormally Dry"[2] indicates an area may be experiencing "short-term dryness slowing planting, growth of crops or pastures" indicating the onset of drought or may be coming out of drought and experiencing lingering effects of drought.
- A Level 1, "Moderate Drought" involves "some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; and voluntary water-use restrictions requested."
- A Level 2, "Severe Drought" means that "crop or pasture losses likely; water shortages common; and water restrictions imposed."
- A Level 3, "Extreme Drought" involves "major crop/pasture losses" and "widespread water shortages or restrictions."

Table E-1: Drought Triggers

Category	Level	Palmer Drought Severity Index (PDSI)	Platte River Stream flow at Ashland
Mild Drought	Level 0	-1.0 to -1.99	--
Moderate Drought	Level 1	-2.0 to -2.99	3,000-1,500 cfs
Severe Drought	Level 2	-3.0 to -3.99	1,500-500 cfs
Extreme Drought	Level 3	-4.0 and below	Less than 500 cfs

Notes: PDSI = Palmer Drought Severity Index

[2] An "Abnormally Dry" classification by the National Drought Monitor corresponds to a PDSI "mild drought" classification.

Analysis of historic PDSI values from the last 116 years reveal that mild, moderate, severe, and extreme droughts have historically occurred in the Lower Platte River Basin once every three, six, nine, and fourteen years, respectively.

It should be noted that no groundwater trigger is included in Table E-1. Each NRD has some form of drought monitoring and triggers for response actions in defined areas of their District. The intent of the Drought Plan is not to replace each members' groundwater monitoring and management plans rather, to provide consistent, basin-scale data and information that can be used by NRDs, while maintaining locally-based management frameworks.. The individualNRD plans are discussed in detail in Appendix A.

Understanding the behavior of the Platte River at Ashland as flows recede is important to the ability of the Consortium to forecast and properly time the implementation of response actions. Using the Platte River at Ashland Recession Tool allows the user to enter the current observed flow in the Platte River at Ashland and predict the flow decay behavior for the next 30 days, assuming no further inputs to the system (precipitation runoff or upstream storage releases). The resulting recession curve can be used to estimate the days until a critical threshold is reached. The development of the Platte River at Ashland Recession Tool is discussed in detail in Appendix E. Figure E-3 is a schematic of the functional utility of the Platte River at Ashland Recession Tool in drought forecasting and response.

Figure E-3: Platte River at Ashland Recession Tool

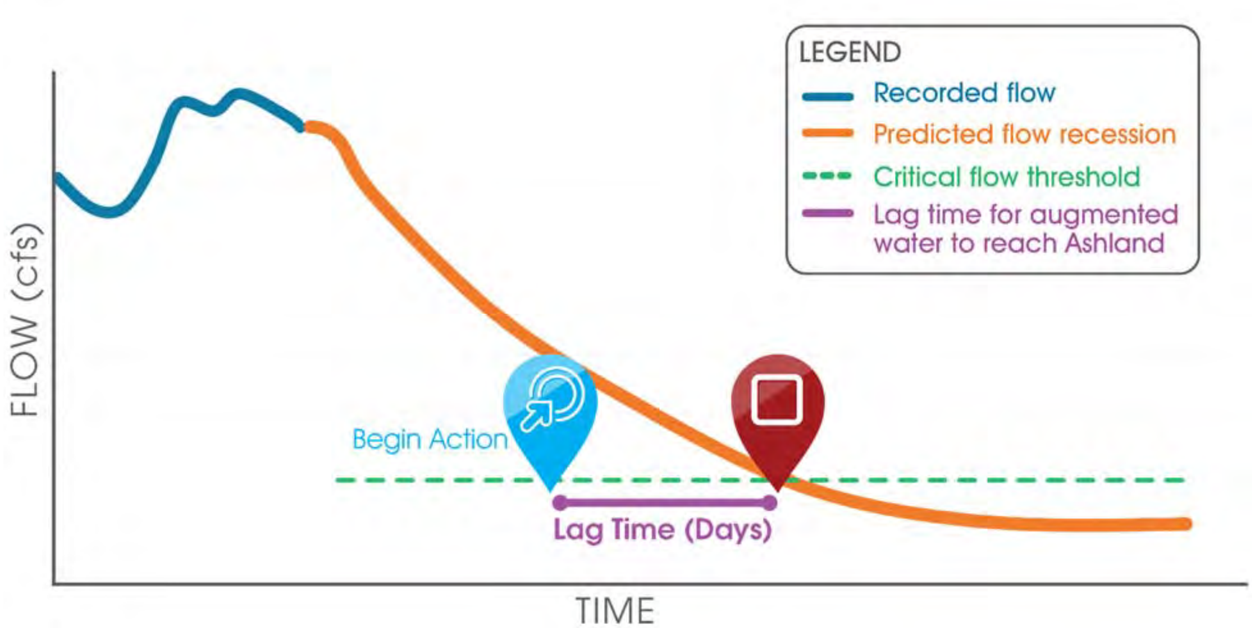
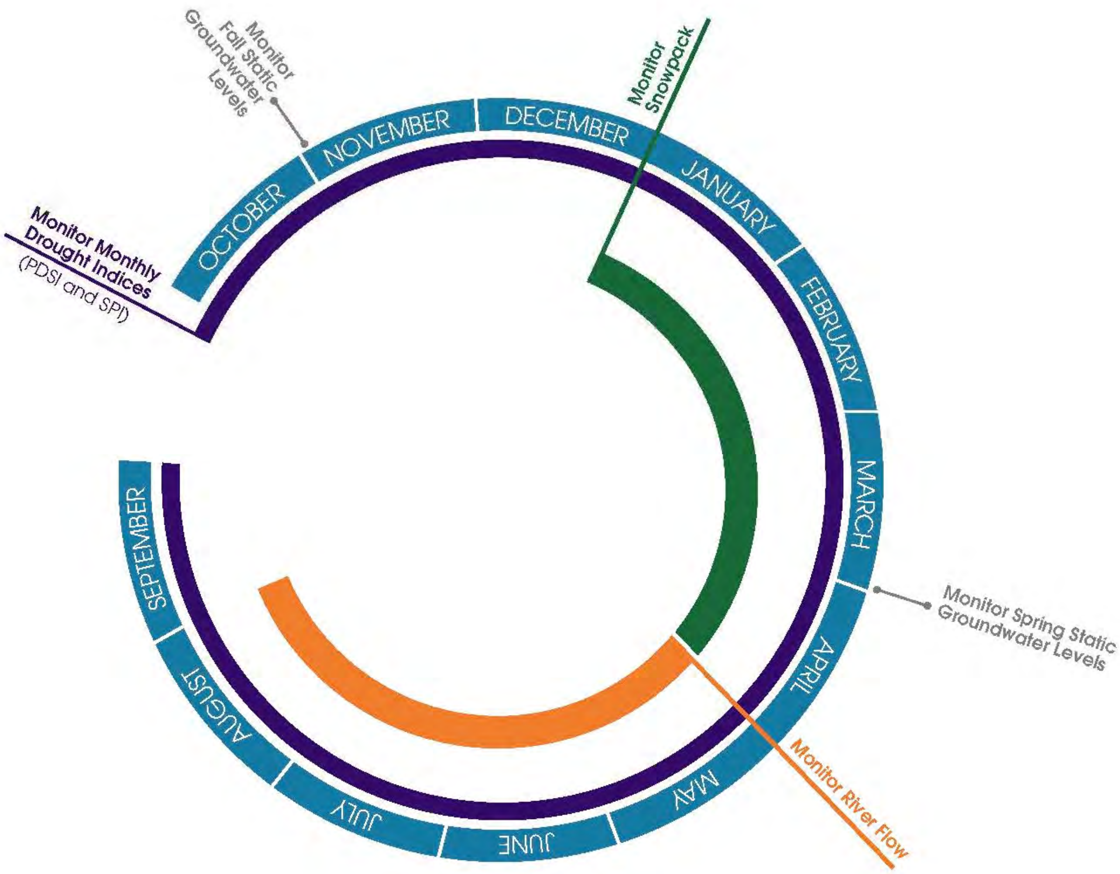


Figure E-4: Drought Monitoring Continuum



The recommended timeline for drought monitoring is displayed in Figure E-4. Hydroclimate indices SPI and PDSI should be monitored year round. Groundwater levels are monitored by NRDs in the spring and fall of each year in accordance with their individual groundwater management plans. Snowpack volumes should be monitored from the beginning of the calendar year through the runoff season. Streamflows should be monitored starting in late spring through the summer when water use for irrigation, cooling, and lawn watering is at its peak.

Drought Management

Drought Mitigation Measures

Drought mitigation measures are actions, programs, and strategies implemented during non-drought periods to address potential risks and effects and to reduce the need for response actions; implementation of drought mitigation measures improves long-term resilience and reliability of the regional water supply.

Eight mitigation measures, and variations or combinations thereof, were evaluated as part of the Drought Planning effort to estimate potential increases in regional water supply.. These measures include the following and are summarized in Tables E-2A and E-2B:

- Installing an alluvial well-field adjacent to the Missouri River and pumping water to a tributary of the Elkhorn River for availability on demand (two alternatives considered in Tables E-2A and E-2B: one that discharges directly into Bell Creek and a second that discharges into the proposed Bell Creek Reservoir);

- Purchasing storage in the existing Sherman Reservoir and releasing water on demand (two release volumes considered in Table E-2A);
- A new surface water storage reservoir on Skull Creek near Linwood for releasing water on demand;
- A new surface water storage reservoir on Bell Creek east of Winslow for releasing water on demand;
- Capture of Middle Loup River water in the non-irrigation season and diversion into the Middle Loup Canal system for intentional recharge and increase baseflow(two demand scenarios evaluated in Tables E-2A and E-2B: one that considers the historic Loup hydropower operations downstream and a second that considers the full Loup hydropower appropriation downstream);
- Installing a well-field to tap into groundwater aquifers with limited connection to streamflow that can be pumped to the river to augment flows;
- Pumping from alluvial sandpits directly to the river to augment flows; and
- A rapid response area/dry-year-lease agreement with farmers irrigating lands adjacent to the main channel of the Platte River from the alluvial aquifer.

Conceptual design of infrastructure requirements and anticipated operational characteristics were defined for each mitigation measure. In addition, the estimated project yield to the Lower Platte River at the Ashland gage was determined. For projects upstream in the basin, a routing tool was used to estimate the losses that occur during conveyance to the Ashland gage. This routing tool utilizes historic reach loss data during low-flow periods to estimate conveyance losses (see Appendix D). As part of this planning effort, continuous recording monitoring wells paired with stage recorders were installed to foster a better understanding of losses in the Lower Platte River under varying hydrologic conditions.

For comparison of alternative costs and benefits, a 20-year period was evaluated to reflect the relative reliability of water from the mitigation action, i.e. for some mitigation actions water will not be available every year. A 15-day operation period, targeting the typical late-July/early-August critical low-flow period in the Lower Platte River was assumed for project operations. For developing cost/acre-foot estimates included in Table E-2A, costs were estimated over a 20-year period without using a discount rate or otherwise accounting for the time value of money. Benefits were based on acre-feet of water estimated to be delivered at the Ashland gage during the 15-day target period over the 20-yr period. Assumptions for each mitigation action are described in Section 5.0 and Appendix C.

Table E-2A: Evaluation of Potential Mitigation Measures (cost estimate versus volume of water added)

	Volume Added at Source			Volume Increase at Ashland				
Alternative	Cumulative AF/15 days	Ave Daily cfs	Where Added	Cumulative AF/15 days	Ave Daily cfs	Cost Estimate	Cost per acre-foot added at Ashland
Import Missouri River Water (via alluvial well-field) to Bell Creek (no reservoir)	59,400	100	Waterloo	46,300	80	$76,572,840	$1,654
Sherman Release (400 cfs at St Paul)	47,520	400	St. Paul	15,720	132	$9,628,000	$612
Sherman Release (250 cfs at St. Paul)	29,700	250	St. Paul	9,800	83	$6,955,000	$710
Skull Creek Res. Rel. (100 cfs at Linwood)	59,400	100	Linwood	46,300	80	$32,630,000	$705
Bell Creek Reservoir (Release 100 cfs at Waterloo)	59,400	100	Waterloo	46,300	80	$81,520,000	$1,761
Pump Missouri River water (vial alluvial well-field) into Bell Creek Reservoir	59,400	100	Waterloo	46,300	80	$129,564,000	$2,798
Middle Loup Canal Recharge (Historic Loup Canal Operations)	7,525	13	Arcadia	2,525	4	$16,360,000	$6,478
Middle Loup Canal Recharge (Full Hydropower Right downstream)	2,034	3	Arcadia	634	1	$5,225,000	$8,238
Alluvial sandpit pumping	14,850	100	Leshara	14,850	100	$5,980,000	$403
Augmentation Well-field	59,400	100	TBD	59,400	100	$81,008,040	$1,364
Rapid Response Area/ Dry-year Lease	4,000	33	Columbus to Louisville	4,000	33	$248,500,800	$62,125

Notes: AF = acre-feet; cfs = cubic feet per second; 20-year period evaluated to reflect relative reliability of each measure; Fifteen-day operating period, targeting late July/early August critical low-flow period; Routing tool used to estimate reach gains/losses; Cost per acre-foot based on water that makes it to Ashland (common point). Reach losses for evaluation assume 66% loss from the Loup River to Ashland, 20% loss from the Elkhorn River to Ashland, and 20% loss from North Bend to Ashland.

Table E-2B: Evaluation of Potential Mitigation Measures (advantages, disadvantages, and uncertainties)00

Alternative	Advantages	Disadvantages	Uncertainties
Import Missouri River Water (to Bell Creek/no reservoir)	• Secondary source of water outside of Platte River basin increases reliability of supply. • Operational every year & year-round	• Larger construction cost than many alternatives • Implementation - 5-10 years	• Future regulation on Missouri River • Well field siting
Sherman Release (400 cfs at St Paul)	• Utilizes existing facilities (no construction cost; ability to pilot study) • Produces large volume of water on-demand • Loup River historically a reliable water supply source. • Implementation: 1-2 years	• Likely limitation on frequency of call on storage water • Significant conveyance losses from release point to Lower Platte River	• Requires cooperation and agreements with existing facility owners. • Negotiations will dictate price. • Cost estimates based on similar agreements in state.
Sherman Release (250 cfs at St. Paul)			
Skull Creek Res. Rel. (100 cfs at Linwood)	• Produces large volume of water on demand • Potential for multi-purpose facility	• Larger construction cost than many alternatives • Land requirements, involving multiple landowners • Implementation: 5-10 years	• Runoff volume varies year to year • Land use impacts on runoff • Implementation (permitting, land purchase, etc.)
Bell Creek Reservoir (Release 100 cfs at Waterloo)			
Pump Missouri River water (via alluvial well-field) into Bell Creek Reservoir	• Secondary source of water outside of Platte River basin increases reliability. • Operational every year & year-round. • Importing into Bell Creek Reservoir requires a lower capacity system for importing water - saving money	• Larger costs associated with combining alternatives that require both land and infrastructure. • Implementation: 5-10 years	• Future regulation on Missouri River • Well field siting • Implementation (permitting, land purchase, etc.)
Middle Loup Canal Recharge (Historic Loup Canal Operations)	• The canal recharge and dry-year lease projects are passive mitigation measures whose benefits (passive baseflow returns) accrue throughout the year, adding to the overall supply reliability. • Existing infrastructure – no initial construction costs • Implementation: 1-2 years	• Unavailable to release a pulse of water volume "on-demand". • Takes time for the full benefit to be realized in river (lag effect) and some attenuation	• Requires cooperation and agreements with existing facility and/or landowners. • Negotiations will dictate price. • Cost estimates based on similar agreements in state. • Amount of improvement of overall system supply reliability from year around accretions
Middle Loup Canal Recharge (Full Hydropower Right downstream)			
Alluvial sandpit pumping	• Minimal infrastructure costs (pumps from existing sandpits) • Utilizes existing sandpits (no construction costs) • Implementation: 3-5 years	• Limited operation window as pumping this close to the river may cause depletions to the stream (lag effect) that amplify impacts during extended drought • Logistics of securing agreements with multiple landowners • Likely limitation on the number of calls allowed in a 20-year period	
Augmentation Well-field	• Available every year & year-round • Can be located closer to critical reach to reduce losses compared to alternatives producing similar volumes upstream in the Basin.	• Land & infrastructure costs make this one of the more expensive alternatives. • Adds to overall depletions • Implementation: 5-10 years	• Siting to avoid interference with existing wells. • Long-term reliability of aquifer
Rapid Response Area/ Dry-year Lease	• No infrastructure or construction necessary.	• Logistics of securing agreements with thousands of producers • Likely limitation on the number of calls allowed in a 20-year period • Most expensive of all the alternatives by an order of magnitude based on assumptions.	• Negotiations will dictate price. • Cost estimates based on similar agreements in state, and factors such as cost differential between irrigated and dry land rental rates. • Uncertain how many producers would participate (benefits assume 100% participation which is unlikely)

Drought Response Actions

Drought response actions are near-term actions triggered during specific stages of drought to manage the limited supply and to decrease the severity of immediate effects of drought periods on the regional water supply. In this first increment of the Drought Plan, potential mitigation measures (Table E-2) have been evaluated, but preferred measures have not been determined or constructed; therefore, the primary drought response action available to the Consortium at this time is communication and outreach.

Consistent and coordinated messaging to basin water users (municipal, industrial, domestic, irrigation, etc.), as well as the general public, raises awareness of the current water supply conditions, allows water users to proactively alter their demand and usage based on limited water supplies, and defines expectations of forecasted conditions and potential actions in response to the drought.

Operational and Administrative Framework

Future Lower Platte River Drought Contingency Plan Updates

The Drought Plan and associated planning is meant to be part of an adaptive process that is routinely updated to reflect the needs of the basin. The Consortium will hold meetings each year and will evaluate the need for updating the Drought Plan every five years. The following list provides information related to the anticipated frequency of Consortium actions and steps taken in regard to updating the Drought Plan:

- On an annual basis, the Consortium will gather information and make any necessary updates to the Vulnerability Assessment.
- On an annual basis, the Consortium will review any changes in the Vulnerability Assessment, determine the need for new and revised actions, update the status of existing actions, and add new actions (as needed).
- Every five years, the Consortium will assess the need for and prepare an updated Drought Plan (as needed).

It should be noted that the Consortium may identify planning and technical efforts outside those anticipated that need to be undertaken based on changed conditions or a potential need.

Continued Communication and Outreach

The Consortium will consider the only drought response action available to it at this time, which is communication and outreach. The following list provides information related to communication and outreach:

- The Consortium will keep the project website updated and will send emails to keep interested stakeholders informed of meetings, new materials, and other information related to the Drought Plan and its implementation.
- Each individual agency in the Consortium will be responsible for informing its constituents, customers, and the public of any actions initiated and related progress and results.
- Coordination and information sharing with other ongoing efforts will be mutually beneficial (Missouri Basin Plan, Nebraska Emergency Management Agency, etc.). It is anticipated that this coordination and information sharing with other ongoing efforts and agencies will occur on an as-needed basis.

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1.0 Background

1.1 Plan Purpose

Beginning in 2016, the Lower Platte South Natural Resources District (NRD), Papio-Missouri River NRD, Lower Platte North NRD, Metropolitan Utilities District (MUD), Lincoln Water System (LWS), and Nebraska Department of Natural Resources (NeDNR), collectively referred to as the Lower Platte River Consortium (Consortium), embarked on a collaborative effort to develop a drought contingency plan for the Lower Platte River Basin in Nebraska (*Lower Platte River Drought Contingency Plan* [Drought Plan]).

In 2017, the Lower Platte River Basin Coalition, which includes the seven NRDs[3] in the Loup, Elkhorn, and Lower Platte River Basins, and NeDNR, adopted the *Lower Platte River Coalition Basin Water Management Plan (Basin Plan).* The Basin Plan evaluated supplies and demands in the Lower Platte River Basin (Basin) and sets criteria for managing new water development , and goals and objectives that work to protect the existing domestic, agricultural, and industrial water uses in the Basin. The Basin Plan found that annual water supplies in the Basin generally tend to be supportive of most water uses; however, peak demands in the summer months can create water shortages. These shortages are further exacerbated by drought periods when summer flows become most critical in supporting water demands. This planning effort for the Drought Plan followed the development of the Basin Plan to further address water supply shortages during drought periods, when peak demands overlap periods of low streamflows.

The primary objective for this first increment was to study regional solutions to improve water supply reliability and drought resiliency for the Lower Platte River. The Drought Plan will refine the Consortium's collective understanding of drought vulnerabilities while developing more robust monitoring and forecasting tools coupled with timely triggers, new mitigation strategies, and responsive actions to create a sound, operational framework and to improve critical water supply needs of the area through drought periods.

The Lower Platte River, its tributaries, and aquifers serve approximately 80 percent of Nebraska's population, thousands of businesses and industries, including more than 2 million irrigated acres, and provides streamflows for threatened and endangered species. It was recognized that a potential drought in the regional would pose serious risk to public health, economy, and fish/wildlife. The drought-driven risks are diverse and the alternatives for resolving them were investigated through this planning effort.

MUD provides drinking water to more than 600,000 customers while LWS provides drinking water to more than 265,000 customers. Both MUD and LWS have water supply well-fields near Ashland, Nebraska, on the Lower Platte River. While MUD has alternate sources of water supply, LWS's sole source of water for its public water supply is the Platte River. While the Drought Plan assesses the water supplies, demands, and vulnerabilities in the Lower Platte River Basin as a whole, the mitigation measures and response actions presented herein are focused on augmenting surface water supplies in the Lower Platte River while referencing additional drought management resources available through the University of Nebraska, National Drought Mitigation Center, and other sources. It is believed that in addressing the water supply shortages in the Lower Platte River, ancillary benefits to the remaining sectors would exist including irrigation, power, environmental, and recreational.

Member participation in the Consortium is voluntary and member agencies shall not be bound by any initiatives, recommendations or decisions made by the Consortium without a subsequent written

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[3] This includes the three NRD members of the Consortium (Lower Platte North NRD, Lower Platte South NRD, and Papio-Missouri River NRD).

agreement or resolution approved by the respective bodies. While represented agencies may elect to seek approval of the Plan by their respective elected officials, formal adoption of the Plan is not required for future participation in the Consortium.

1.2 Pre-Lower Platte River Drought Contingency Plan Activities

Prior to starting the Drought Plan development, the Consortium members (Lower Platte South NRD, Papio-Missouri River NRD, Lower Platte North NRD, MUD, LWS, and NeDNR) completed the following three required activities:

1. Development of detailed Work Plan.

   The Work Plan guided the Drought Plan development process. It described the specific planning tasks and the manner in which each would be completed, the associated schedule, and the roles and responsibilities. The Work Plan included four sections:

   a. Section A: Introduction – Description of the scope and purpose of the Drought Plan, the planning area, and background information.
   b. Section B: Planning Approach – Description of the project schedule for Drought Plan development, scope of work to complete the six required Drought Plan elements, planning oversight structure, decision-making process, roles and responsibilities, and coordination.
   c. Section C: Documentation and Reporting – Description of deliverables and documentation requirements, reporting requirements and responsibilities, and review process.
   d. Section D: Communication and Outreach Plan – Description of anticipated stakeholder and public involvement and schedule.

   The Drought Plan Work Plan was accepted by the Bureau of Reclamation in May 2017.

2. Establishment of a Drought Planning Task Force (DPTF).

   The Consortium members serve as the active participants for the DPTF. The Consortium members are key water management agencies that represent the Municipal and Industrial (M&I) and agricultural water suppliers in the Lower Platte River Basin. The NRDs are political sub-divisions within Nebraska with broad jurisdictional authorities in flood control, soil erosion, irrigation runoff, groundwater quantity and quality regulation, and integrated management planning. Each NRD is composed of local officials from business, industry, agriculture, planning/zoning, academia, and environmental backgrounds elected to the board. NRDs serve as key focal points for local input on a variety of water-related issues.

3. Development of a Communication and Outreach Plan to maximize stakeholder involvement during development of the Drought Plan.

   a. Section A: Introduction
   b. Section B: Goals for Stakeholder and Public Involvement
   c. Section C: Communications and Outreach Approach, Activities, and Tools

1.3 Lower Platte River Drought Contingency Plan Development Efforts

The Consortium's stakeholder and public outreach efforts continued throughout the development of the Drought Plan. All Consortium meetings were given public notice and were held at the offices of Lower Platte South NRD in Lincoln, Nebraska.

1.3.1 Consortium Meetings

The following is a list of Consortium meetings and dates those meetings were held (public notice was given for all meetings).

- Kickoff Meeting – November 9, 2016
- Project Meeting – December 15, 2016
- Project Meeting – February 23, 2017
- Project Meeting – March 27, 2017
- Project Meeting – May 2, 2017
- Project Meeting – August 22, 2017
- Project Meeting – November 28, 2017
- Project Meeting – February 22, 2018
- Project Meeting – March 30, 2018
- Project Meeting – May 9, 2018
- Project Meeting – July 17, 2018

1.3.2 Stakeholder and Public Outreach Efforts

Several activities were undertaken to encourage stakeholder and public participation, including the following:

- Consortium Project Meetings – All Consortium meetings were open to the public.
- Website updates – A website with Drought Plan-related content is managed by Lower Platte South NRD so that interested stakeholders could track Drought Plan progress: https://www.lpsnrd.org/lower-platte-river-consortium

1.3.3 Consortium Workshops

Two technical workshops were held in May 2017 and June 2018, respectively. These technical workshops targeted industry experts and NRD, LWS, and MUD personnel.

- Consortium Workshop 1 – May 16, 2017; (26 stakeholders in attendance)
- Consortium Workshop 2 – June 19, 2018 (31 stakeholders in attendance)

1.3.4 Public Open Houses

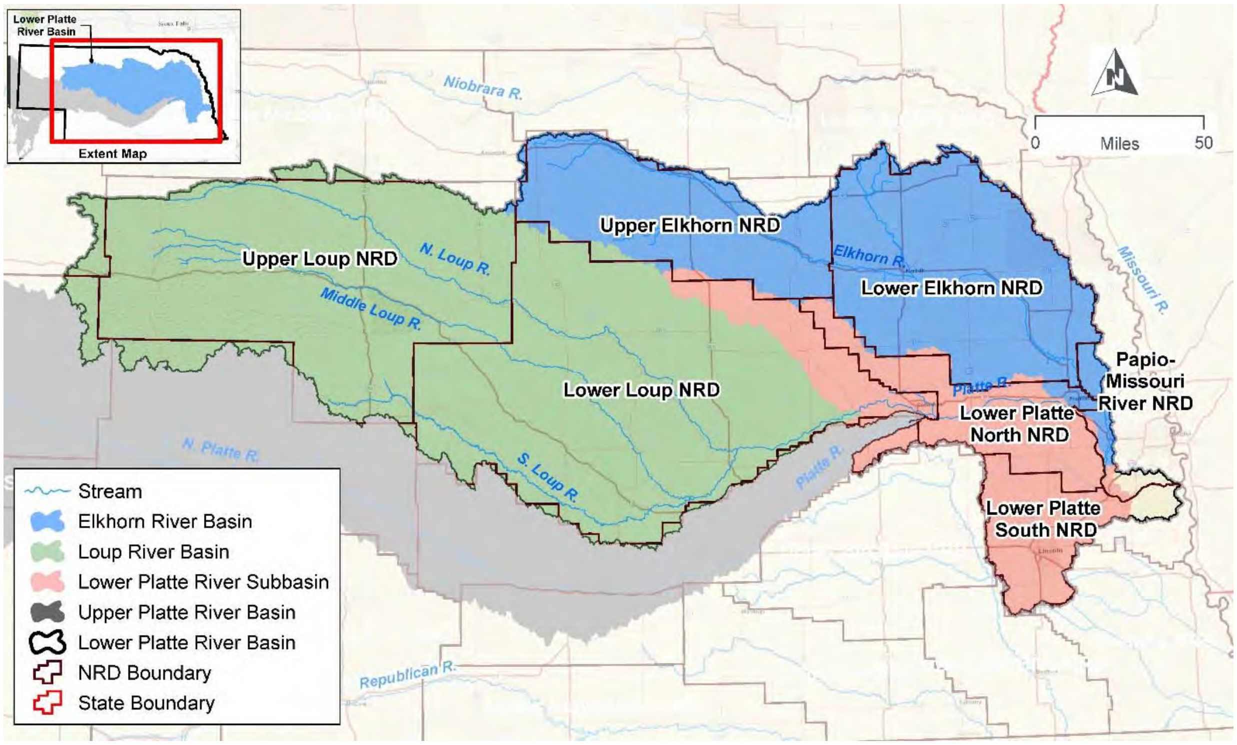
The first public open house was held June 19, 2018, in which 35 stakeholders attended. The following lists the public outreach efforts related to Public Open House 1:

- "Know Your NRD" Summer 2018 newsletter distributed electronically the week of June 4 and inserted into five district newspapers, including the *Lincoln Journal Star*, *Ashland Gazette*, *Hickman Voice*, *Plattsmouth Journal*, and *Waverly News* the week of June 11. Total distribution of the newsletter was 148,497.
- Legal notices of technical workshop and open house published two times in June, prior to June 19 in *Lincoln Journal Star*.
- Notice posted on Lower Platte South NRD Facebook page on June 14 and June 18.
- Notice posted on Lower Platte South NRD website home page from June 4 through June 19.
- Workshop and open house notices and agenda posted on Consortium and Lower Platte South NRD webpage.
- News release sent to local media in early June by HDR.

2.0 Lower Platte River Basin

The Lower Platte River Basin is defined as all surface areas that drain into the Lower Platte River, including those areas that drain into the Loup River and the Elkhorn River and all aquifers that affect surface water flows of the basin (Figure 1). The total area of the Lower Platte River Basin is approximately 25,400 square miles, which encompasses both the Loup River subbasin and the Elkhorn River subbasin. NRDs with significant area in the basin include Lower Platte South NRD, Lower Platte North NRD, Upper Elkhorn NRD, Lower Elkhorn NRD, Upper Loup NRD, Lower Loup NRD, and Papio-Missouri River NRD (NeDNR 2017).

Figure 1: Map of Lower Platte River Basin

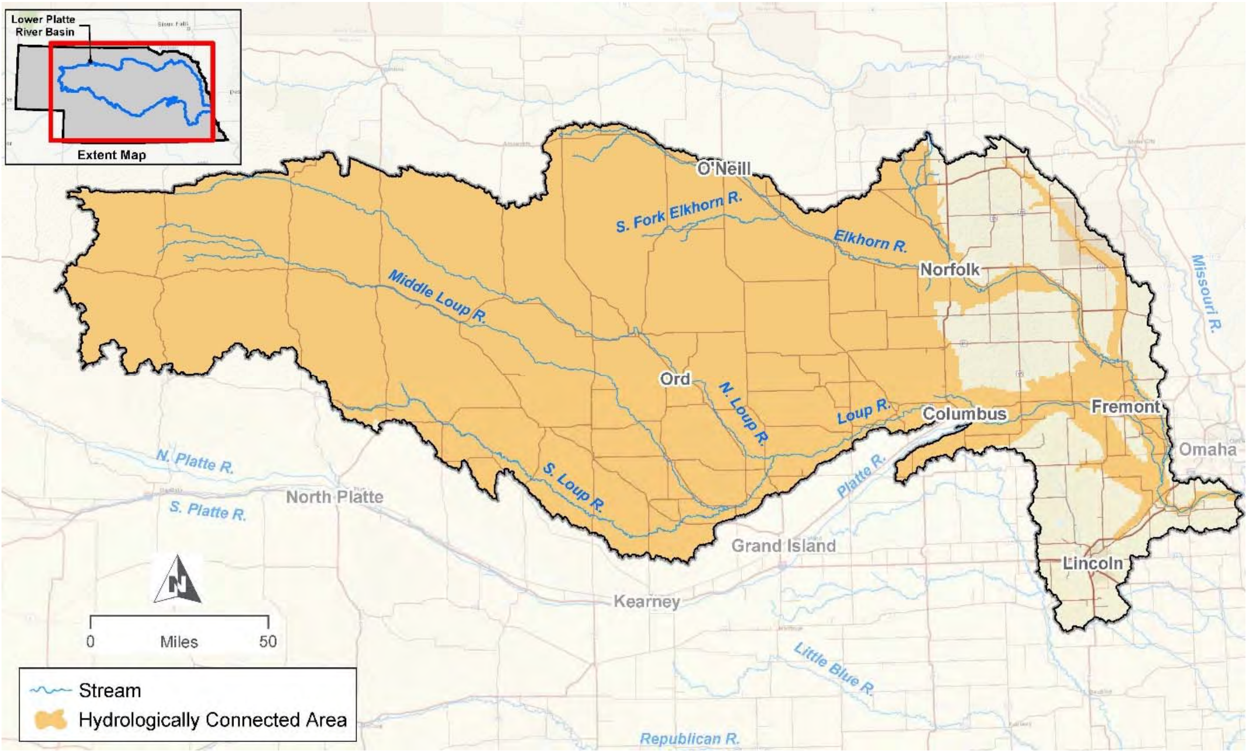


The Nebraska Legislature passed Nebraska Legislative Bill 962 (LB 962) on July 16, 2004, to address conflicts between surface water and groundwater users and to provide a framework for joint management of water resources. As required under LB 962, NeDNR must evaluate the expected long-term availability of hydrologically connected water supplies each year (Figure 2) to meet both existing and new surface water and groundwater uses for each river basin in the state.

Under Nebraska Revised Statutes § 46-713(3), a basin is considered fully appropriated when certain conditions for hydrologically connected surface water and groundwater are met, namely the following:

> When "then-current uses of hydrologically connected surface water and groundwater […] will in the reasonably foreseeable future cause:
>
> (a) the surface water supply to be insufficient to sustain over the long term, the beneficial or useful purposes for which existing natural-flow or storage appropriations were granted and the beneficial or useful purposes for which, at the time of approval, any existing instream appropriation was granted.
>
> (b) the streamflow to be insufficient to sustain over the long term the beneficial uses from wells constructed in aquifers dependent on recharge from the river or stream involved.
>
> (c) reduction in the flow of a river or stream sufficient to cause noncompliance by Nebraska with an interstate compact or decree, other formal state contract or agreement, or applicable state or federal laws" (Nebraska Revised Statutes § 46-713[3]).

Figure 2: Lower Platte River Basin – Hydrologically Connected Area



Source: Map layer provided by Nebraska Department of Natural Resources (Obtained 2016)

On December 16, 2008, NeDNR made a preliminary determination that the Lower Platte River Basin was fully appropriated. Following the preliminary determination, NeDNR held four public hearings on February 17, February 24, March 11, and March 12, 2009, where new information was brought forward. On April 8, 2009, NeDNR reversed its preliminary determination, making the determination that the Lower Platte River Basin was not yet fully appropriated.

Subsequent to the reversal of the preliminary determination, Nebraska Governor Dave Heinemann signed LB 483, which established procedures to limit new irrigation development in areas such as the Lower Platte River Basin. In accordance with LB 483, whenever NeDNR reverses the preliminary determination that a basin is fully appropriated, the NRDs subject to LB 483 adopt a 4-year plan to limit the number of new wells, so that the basin remains "not yet fully appropriated".

Together with NeDNR, the seven NRDs in the Lower Platte River Basin[4] entered into an Interlocal Cooperative Agreement in April 2013 to form the Lower Platte River Basin Water Management Plan Coalition (Coalition). The Coalition recognizes the interrelation of water resources inherent within the basin and has embarked on a critical mission to manage new uses while protecting and sustaining the long-term balance between the water uses and water supplies throughout the basin within the seven represented NRDs.

For the first 5-year increment of the *Lower Platte River Basin Water Management Plan* (through 2022), each Coalition member agreed to limit the total depletive effect of allowable new surface water and groundwater uses during the peak season (that is, June, July, and August). The allowable new depletions shown in Table 1 correspond to the effect new development (both agricultural and non-agricultural uses)

[4] Upper Loup NRD, Lower Loup NRD, Upper Elkhorn NRD, Lower Elkhorn NRD, Lower Platte South NRD, Lower Platte North NRD, and Papio-Missouri River NRD, along with NeDNR

would have on a stream in 50 years. Depletion estimates for new uses will be made using the best available data and models.

Table 1: First 5-Year Increment Allowable Development (Depletions) by Subbasin for New Surface and Groundwater Uses

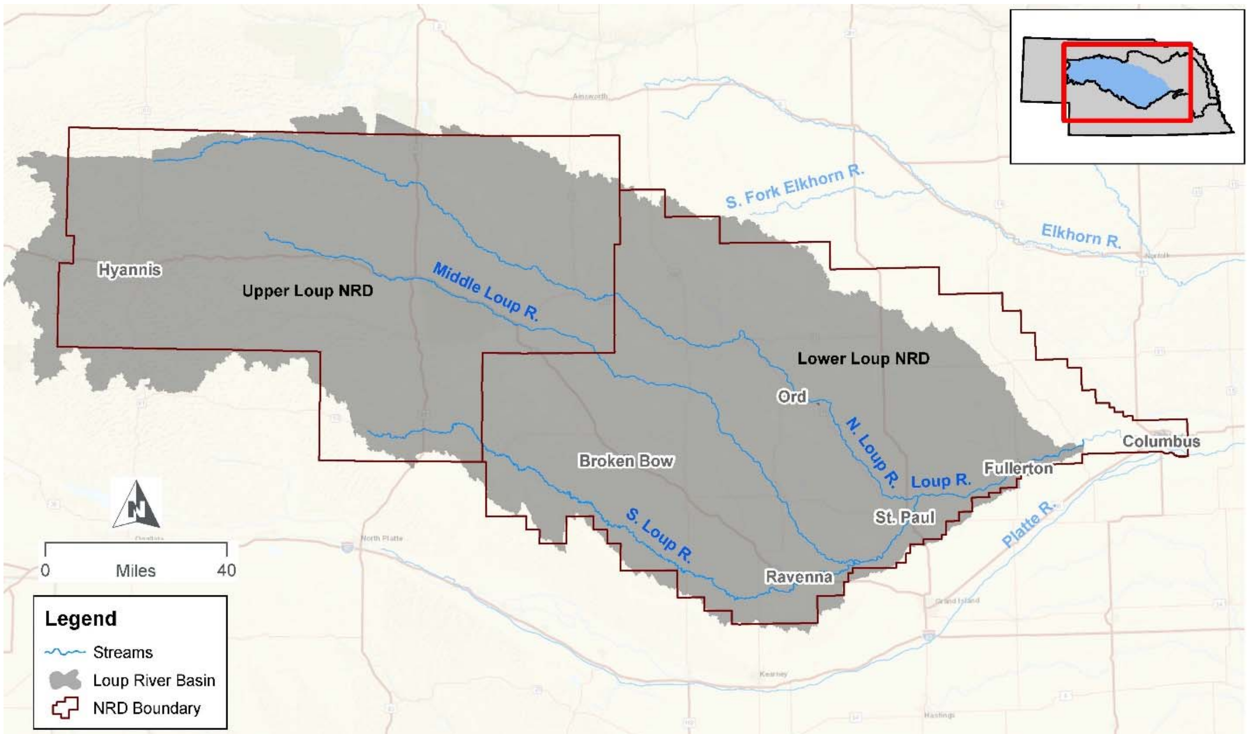
NRD	Subbasin	First 5-year Increment Allowable Development (Depletions) – Peak Season	
		Acre-feet/90-day season	Cubic feet per second
Upper Loup NRD	Loup River subbasin	2,768	15.5
Lower Loup NRD		5,883	33.0
Upper Elkhorn NRD	Elkhorn River subbasin	1,504	8.4
Lower Elkhorn NRD		4,514	25.3
Papio-Missouri River NRD	Lower Platte River subbasin	869	4.9
Lower Platte South NRD		993	5.6
Lower Platte North NRD		2,276	12.8
Total	Full Basin	18,807	105.5

Source: Basin Plan; Note: NRD = Natural Resources District

2.1 Loup River Subbasin

The Loup River subbasin is located in central Nebraska, and primarily includes the Upper Loup NRD and the Lower Loup NRD. The Loup River subbasin has an area of approximately 14,900 square miles (Figure 3).

Figure 3: Loup River Subbasin



At its farthest western extent, the Loup River subbasin boundary is about halfway between Alliance, Nebraska, and Hyannis, Nebraska, in Sheridan and Garden Counties. The Loup River headwaters are about seven miles northwest of Hyannis. The Loup River subbasin is defined as draining to the confluence of the Loup River and Platte River at Columbus, Nebraska. The Loup Hydropower facility, a major water user in the Loup River subbasin, is located near the bottom of the Loup River subbasin, approximately 32 miles upstream of the Loup River and Platte River confluence.

According to the 2010 U.S. Census, the largest city in the Loup River subbasin is Columbus, with a population of about 22,000. In descending order, the next largest cities in the Loup River subbasin in Nebraska include Broken Bow (3,600), St. Paul (2,300), Ord (2,100), Ravenna (1,400), and Fullerton (1,300).

Encompassing portions of the Sandhills, most of the upper portion of the Loup River subbasin is used as pasture and rangeland; water table lakes and wetlands are common, especially in the north and west portions of the subbasin. In the remainder of the subbasin, mostly in river valleys, the primary crop grown is corn, followed by soybeans.

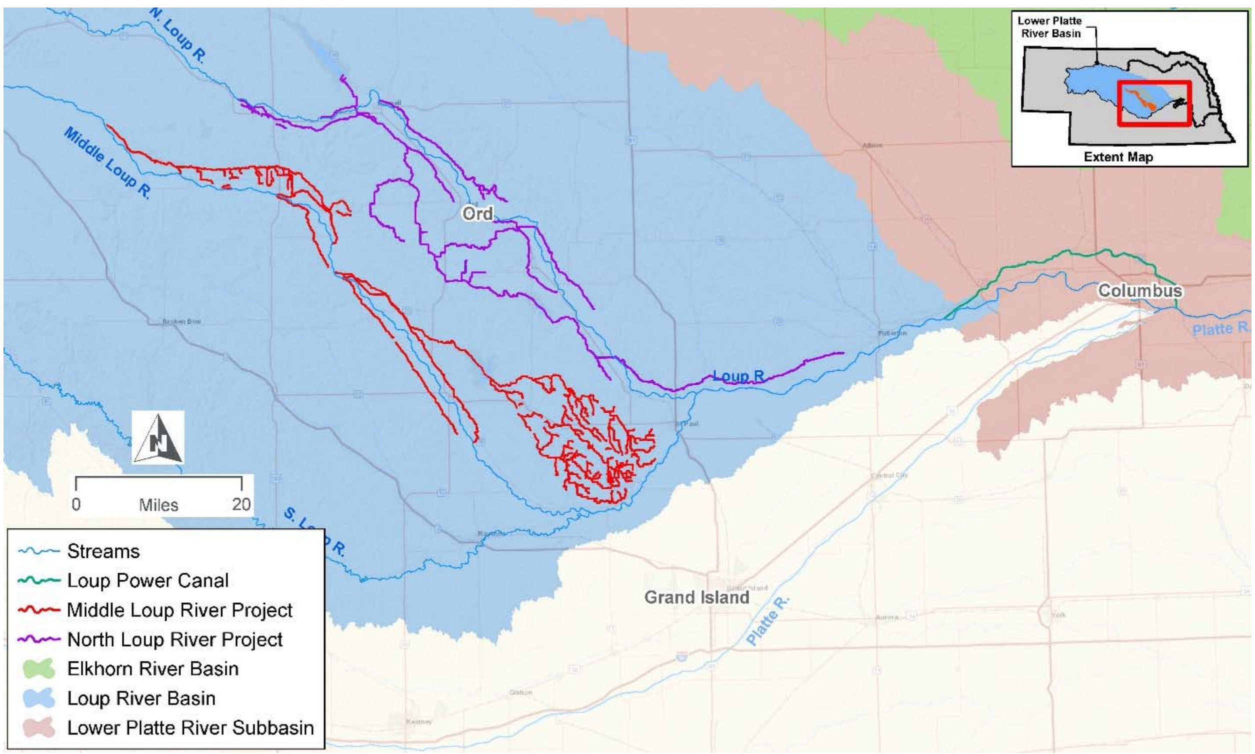
The primary aquifer in the Loup River subbasin is the Ogallala Group, which is part of a vast system of related sediments that make up the High Plains Aquifer. Early spring snowmelts contribute to high aquifer recharge. The highly permeable soils of the sand dunes limit runoff, enhance infiltration, and recharge the groundwater system. Large saturated thicknesses, high porosity and yield, and high hydraulic conductivity are common in the subbasin. The eastern margin of the subbasin is underlain by undivided

Quaternary-aged units of the Great Plains Aquifer. In contrast to the western subbasin, rivers in the eastern subbasin are wide and shallow and groundwater contributes less to total streamflow with these streams showing more seasonal fluctuation.

There are three reservoirs with normal pool surface area greater than one square mile in the Loup River subbasin. The Calamus Reservoir has a normal storage volume of almost 130,000 acre-feet, Sherman Reservoir has a normal storage volume of almost 70,000 acre-feet, and the Davis Creek Reservoir has a normal storage volume of more than 47,000 acre-feet.

There are five surface water irrigation districts (Sargent, Farwell, Middle Loup, North Loup, and Twin Loups) that serve approximately 129,000 acres of the approximately 1,081,481 total irrigated acres within the subbasin. Loup Public Power District is a hydropower district located within the Loup River subbasin with a natural flow appropriation of 3,500 cubic feet per second (cfs). The Loup Power Canal diverts Loup River flows upstream of Genoa, Nebraska, and the canal returns flow to the Platte River downstream of Columbus. Irrigators along the Loup Power Canal divert surface water from the Loup Canal to irrigate approximately 7,500 acres. These individual appropriations are independent and junior to Loup Public Power District's appropriation and the appropriators have entered into interference agreements with Loup Public Power District to fulfill their appropriation (Figure 4).

Figure 4: Loup River Subbasin Canals

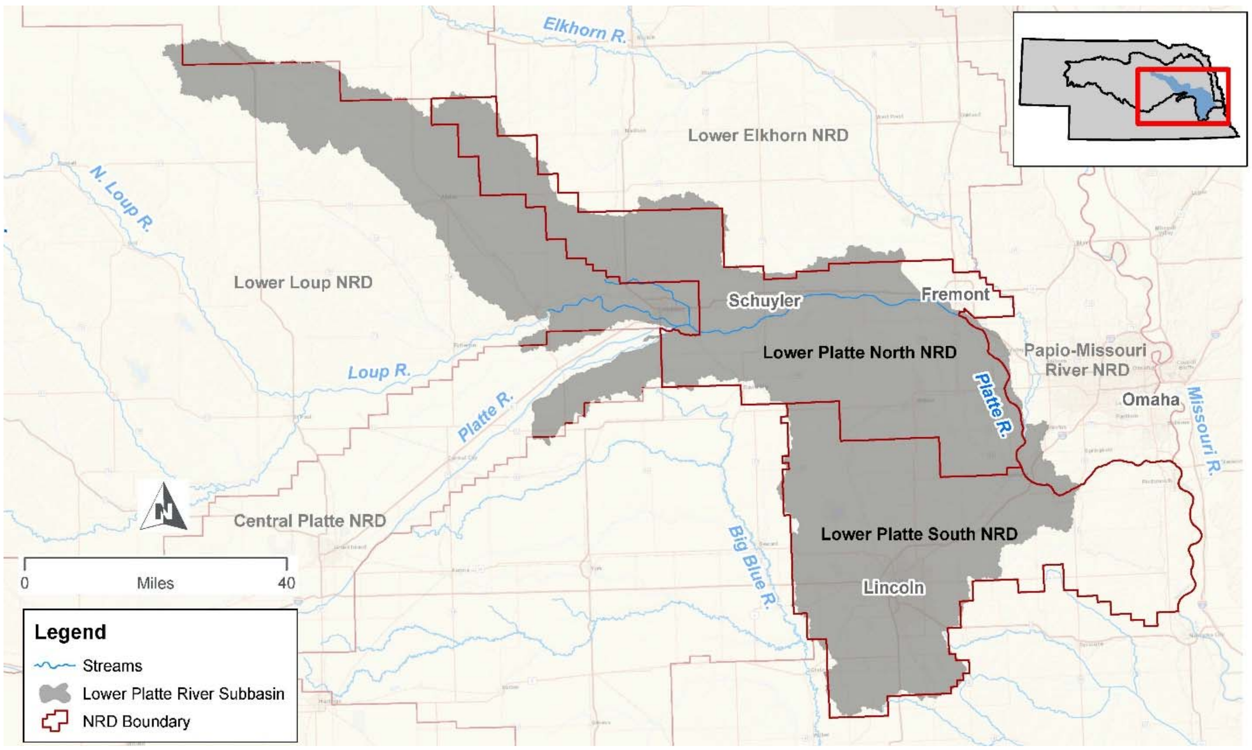


Average annual precipitation varies from 16 to 18 inches per year in the westernmost end of the subbasin and up to 28 inches per year in the easternmost end of the subbasin. The Loup River subbasin has an average subbasin water supply of 2.2 million acre-feet per year, an average near-term demand of 1.4 million acre-feet per year, and an average long-term demand of 1.8 million acre-feet per year (excluding hydropower demand).

2.2 Lower Platte River Subbasin

The Lower Platte River subbasin includes the lower Platte River and its tributaries (except the Elkhorn River) beginning at the confluence of the Loup River and Platte River at Columbus. It primarily includes a majority of the Lower Platte South NRD and Lower Platte North NRD, as well as a smaller portion of the Papio-Missouri River NRD. Approximately 3,400 square miles comprise the Lower Platte River subbasin. The subbasin extends from northeastern Boone County downstream to the Louisville, Nebraska, gage location (Figure 5).

Figure 5: Lower Platte River Subbasin



Lincoln, the capital of Nebraska, is the largest city wholly contained within the Lower Platte River subbasin, with a 2010 U.S. Census population of almost 260,000. The next largest city intersecting the Lower Platte River subbasin is Fremont, Nebraska, with about 26,000 citizens (Fremont is also in the Elkhorn River subbasin). The next largest city in the Lower Platte River subbasin in Nebraska is Schuyler (6,200). While Omaha is not contained within the Lower Platte River subbasin, several municipal well-fields that serve the metropolitan area are located within the subbasin.

In the northwestern corner and along the southwestern margins of the Lower Platte River subbasin, the land is primarily used as pasture and rangeland. The remainder of the subbasin is primarily agricultural production, with corn and soybeans as the primary crops.

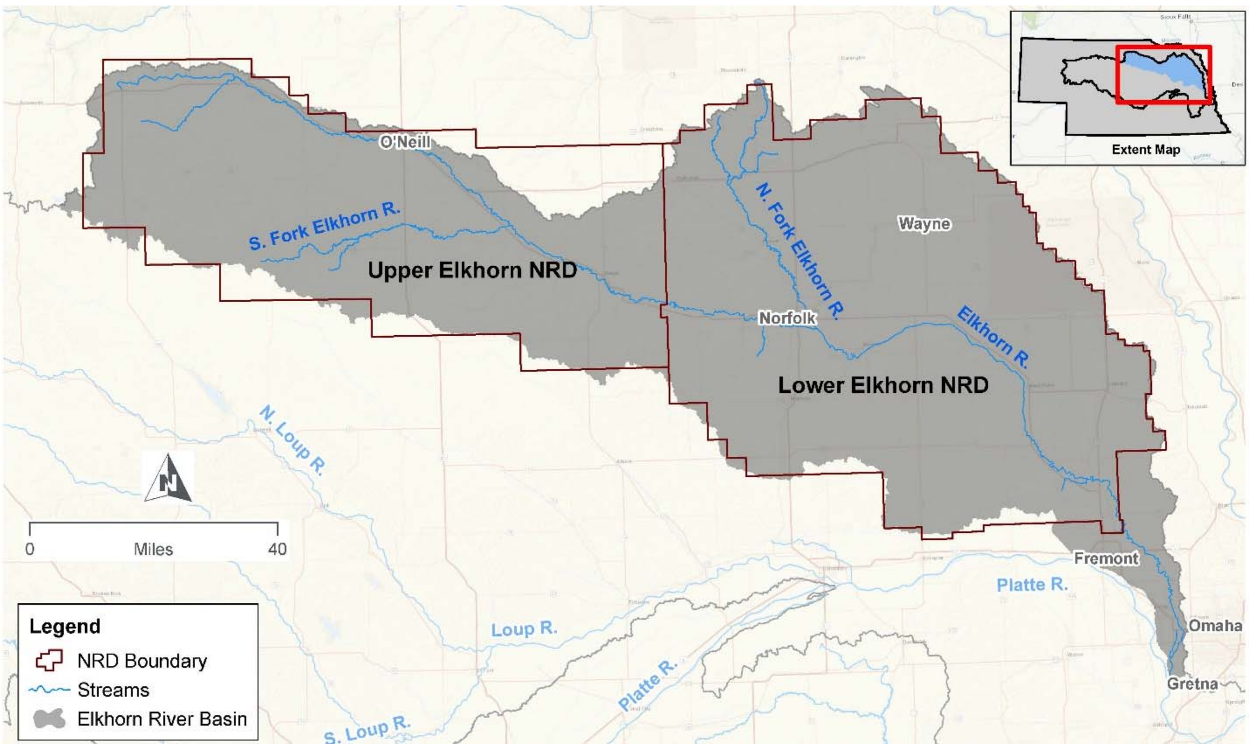
There are approximately 460,500 irrigated acres within the Lower Platte River subbasin. Average annual precipitation varies from 26 inches per year in the westernmost end of the subbasin up to 32 inches per year in the easternmost end of the subbasin. Based on the 25-year average (water year 1988 to 2012), the Lower Platte River subbasin has an average basin water supply of 2.66 million acre-feet per year, an average near-term demand of 2.55 million acre-feet per year, and an average long-term demand of 2.64 million acre-feet per year.

Three reservoirs exist in the subbasin with normal pool surface area greater than one square mile, Branched Oak Lake, Pawnee Lake, and Lake Wanahoo.

2.3 Elkhorn River Subbasin

The Elkhorn River subbasin is located in northeastern Nebraska, and primarily includes the Upper Elkhorn NRD and Lower Elkhorn NRD. Approximately 7,000 square miles comprise the Elkhorn River subbasin (Figure 6).

Figure 6: Elkhorn River Subbasin



At its farthest western extent, the Elkhorn River's headwaters feed into three major tributaries all in Rock County, Nebraska. The Elkhorn River extends to its junction with the Platte River just west of Gretna, Nebraska.

The largest city intersecting the Elkhorn River subbasin is Omaha, with some of its western suburbs located within the subbasin. A portion of Fremont is also within the subbasin. Based on the 2010 U.S. Census, Norfolk, Nebraska (24,000), is the largest city entirely within the subbasin, followed by Wayne, Nebraska (5,700), and O'Neill, Nebraska (3,700).

A majority of the subbasin is underlain by the High Plains aquifer (which includes the Ogallala Group). Pleistocene sand and gravel units overlie the Ogallala Group and comprise the primary aquifer unit in the western half of the Elkhorn River subbasin. The eastern portion of the subbasin is mostly underlain by the Great Plains aquifer system (which includes the Dakota Formation). The High Plains aquifer and alluvial sand and gravel aquifers are generally characterized by large saturated thicknesses, high porosity and yield, and high hydraulic conductivity, capable of supporting high capacity well development. Much of the Dakota aquifers groundwater availability remains unknown; however, there is generally adequate quantity in areas with sandstone dominant formations that are readily recharged by surface water. Glacial loess and till cover much of the eastern third of the subbasin, and where saturated, have much lower porosity and hydraulic conductivity and are not usually suitable as aquifers (Korus et al. 2013).

In the western third of the Elkhorn River subbasin, the land is primarily used as pasture and rangeland; water table lakes and wetlands are common. In the remainder of the subbasin, the primary crop grown is corn, followed by soybeans, with small amounts of alfalfa and open pasture and range lands.

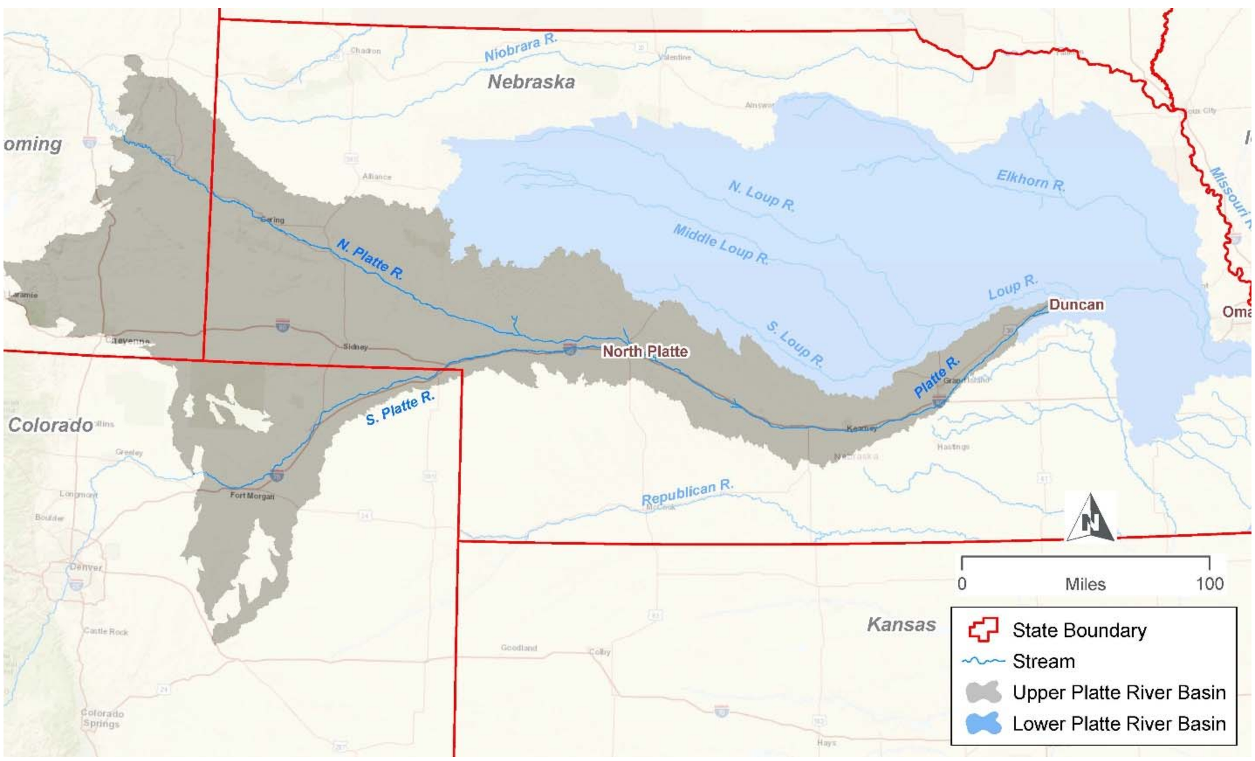
One reservoir exists in the Elkhorn River subbasin with normal pool surface area greater than one square mile; Willow Creek Reservoir on Willow Creek in Pierce County with more than 6,800 acre-feet of normal storage.

Approximately 900,000 irrigated acres exist within the Elkhorn River subbasin. Average annual precipitation varies from 20 inches per year in the westernmost end of the subbasin up to 30 inches per year in the easternmost end of the subbasin. The Elkhorn River subbasin has an average subbasin water supply of 1.39 million acre-feet per year, an average near-term demand of 0.8 million acre-feet per year, and an average long-term demand of 1.0 million acre-feet per year.

2.4 Upper Platte River Basin

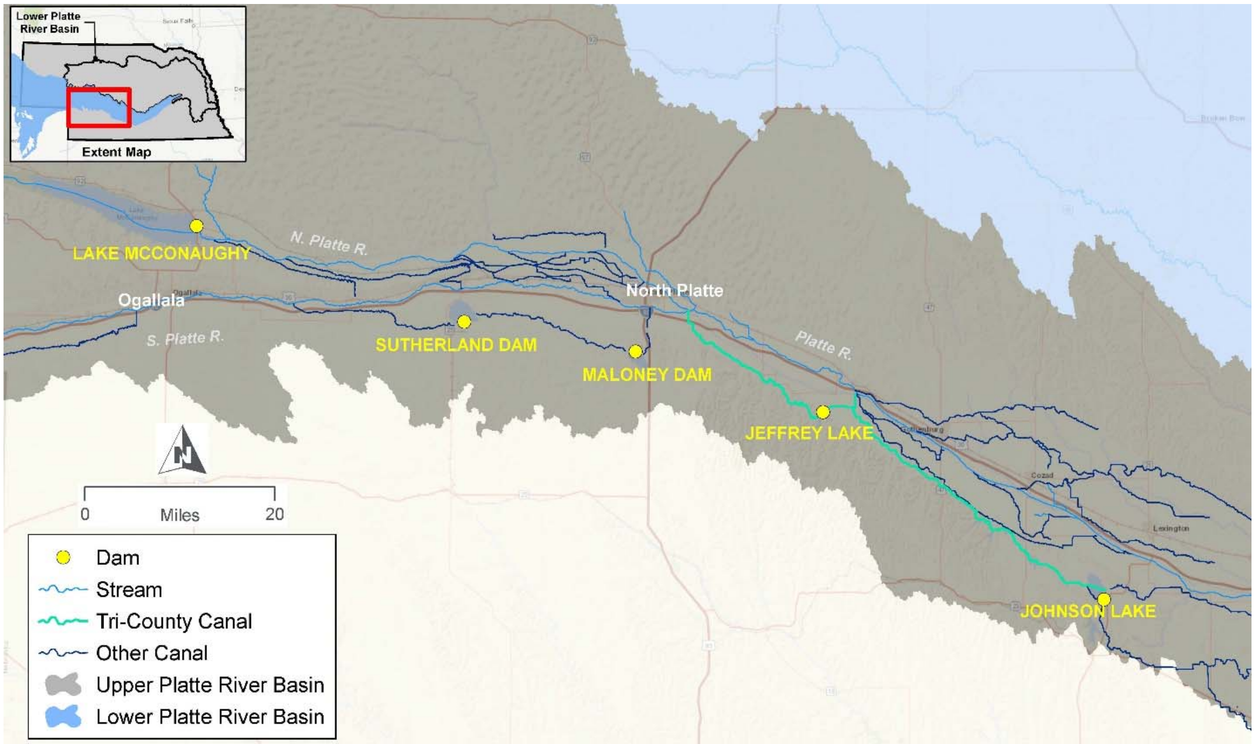
The Upper Platte River Basin is located immediately upstream of the Lower Platte River Basin. The Upper Platte River Basin includes the North Platte River, South Platte River, and the Platte River from the confluence to Duncan as shown in Figure 7.

Figure 7: Upper Platte River Basin and Lower Platte River Basin



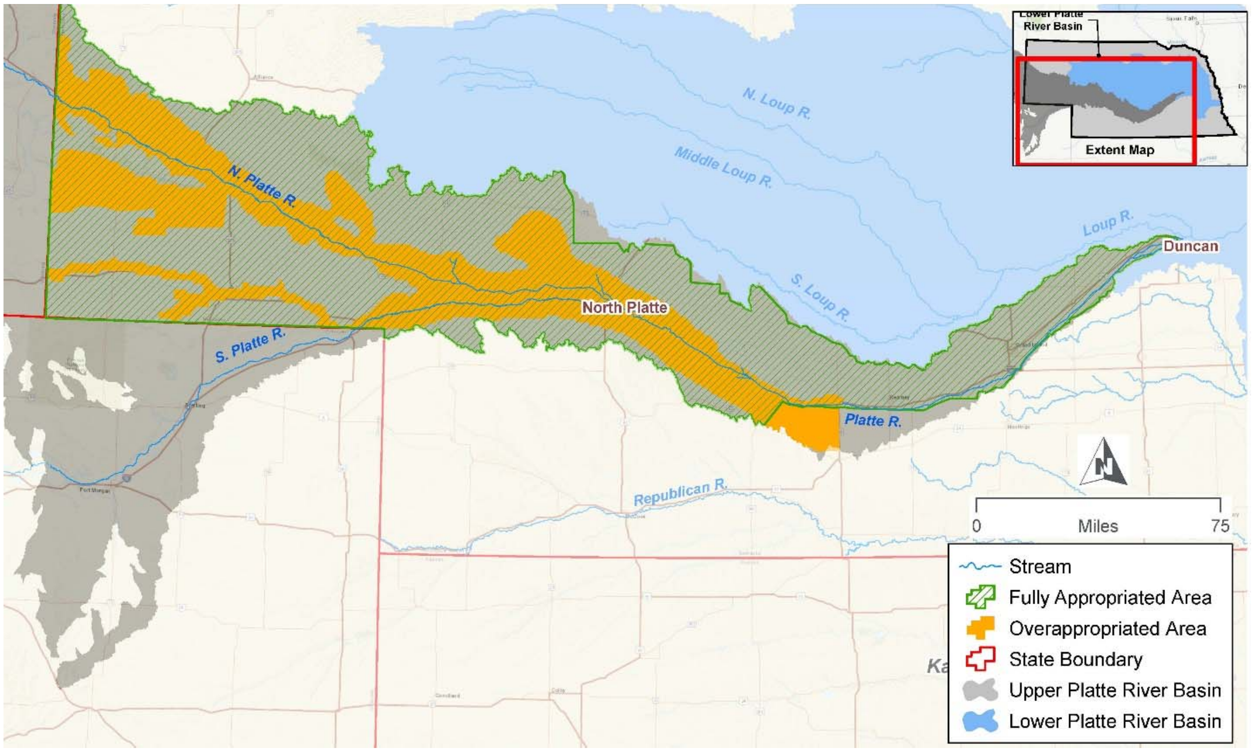
Multiple hydropower demands exist within the Upper Platte River Basin. The Central Nebraska Public Power and Irrigation District (CNPPID) owns and operates multiple hydropower facilities in the Upper Platte River Basin. CNNPID diverts water released from Nebraska's largest reservoir, Lake McConaughy (35,700 acres), into the Tri-County Canal, directs the water through Jeffrey Lake and Johnson Lake (regulating reservoirs), through three hydroelectric plants (Jeffrey, J-1, J-2), and then delivers it to the irrigation system (during the irrigation season) or back to the Platte River (non-irrigation season) (CNPPID n.d.) (Figure 8).

Figure 8: Upper Platte Hydropower and Canal Operation



As defined in LB 962 (defined in Section 2.0), the Upper Platte River Basin above Elm Creek, Nebraska, was declared overappropriated and the area from Columbus to Elm Creek was designated as fully appropriated; meaning, any additional uses would cause water supply to be out of balance with demand (Figure 9). With those designations, the NRDs and NeDNR developed Integrated Management Plans (IMPs) calling for no new uses in the river basin above Columbus that would adversely affect an existing surface water right or groundwater use. New uses are allowed, but any depletion to existing rights and uses must be offset with water.

Figure 9: Upper Platte River Basin Hydrologically Connected and Overappropriated Areas



Source: Map layer provided by Nebraska Department of Natural Resources (Obtained 2016)

Flow in the Upper Platte River originates from snowmelt in the Rocky Mountains of Colorado and Wyoming, as well as from precipitation runoff and baseflow contributions from the underlying aquifer.

Results from a 2007 U.S. Geological Survey (USGS) study pointed to difference in streamflow regimes between the central Platte River system and the lower Platte River system (Ginting, Zelt, and Linard 2008). Reservoirs upstream and diversions for power generation and irrigation control the majority of flow in the Upper Platte River. Many of the tributary streams upstream of Grand Island, Nebraska, where annual precipitation is less than 25 inches, are intermittent and most flow in those tributaries is from snowmelt and precipitation runoff. Therefore, Platte River flows near Grand Island and Duncan are extremely variable (Huntzinger and Ellis 1993).

A review of the minimum streamflow gage data for the Platte River at Duncan reveals that the Platte River has gone dry at Duncan during historical drought periods (Figure 10), effectively disconnecting the Upper Platte River Basin from the Lower Platte River Basin. During these times of drought, the water supply for the lower Platte River Basin is dependent on the more reliable groundwater-fed Loup River subbasin (Section 2.1) and Elkhorn River subbasin (Section 2.3).

Figure 10: Minimum Daily Discharge in Platte River at Duncan

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	2,430	2,400	2,530	1,870	1,050	736	460	209	248	498	502	640
2001	960	1,200	1,820	1,790	734	226	125	156	373	709	399	608
2002	700	840	660	449	514	21	-	-	-	76	120	349
2003	270	520	608	508	554	342	-	-	-	-	-	-
2004	194	627	384	185	37	3	2	-	-	-	-	561
2005	669	925	500	474	346	430	13	-	-	-	211	303
2006	510	375	414	446	26	-	-	-	-	39	240	180
2007	150	500	1,070	1,060	1,070	948	463	656	229	253	559	432
2008	440	583	841	896	906	1,350	662	225	227	257	1,160	266
2009	678	869	821	823	516	521	378	222	172	678	2,140	1,290
2010	1,150	955	1,570	1,280	1,320	2,540	2,130	957	948	1,170	1,330	1,670
2011	832	1,500	3,030	3,940	3,440	7,400	5,630	3,300	4,000	3,350	2,740	2,110
2012	1,720	2,410	1,490	1,270	399	64	-	-	-	14	55	197
2013	229	438	553	582	622	259	1	5	-	1,510	700	716
2014	454	298	749	731	283	293	134	74	575	508	323	1,010

Note: Measurements are in cubic feet per second.

2.4.1 Platte River Recovery Implementation Program

In 1997, the governors of Nebraska, Colorado, and Wyoming and the Secretary of the Interior entered into a Cooperative Agreement to address the needs of four threatened or endangered species[5] using the Platte River system—forming the *Platte River Recovery Implementation Program* (PRRIP). The long-term goal of the PRRIP is to improve and maintain the associated habitats, which includes the following:

1. Improving and maintaining migration habitat for whooping cranes and reproductive habitat for least terns and piping plovers;
2. Reducing the likelihood of other species found in the area being listed under the Endangered Species Act; and
3. Testing the assumption that managing water flow in the central Platte River also improves the pallid sturgeon's lower Platte River habitat.

The PRRIP is led by an 11-member governance committee consisting of representatives of Colorado, Wyoming, Nebraska, the Bureau of Reclamation, the U.S. Fish and Wildlife Service, South Platte River water users, North Platte River water users, downstream water users, and environmental groups. The first increment of the PRRIP is for 13 years, from 2007 to 2019.

The PRRIP's objective is to use incentive-based water projects to provide sufficient water to and through the central Platte River habitat area to assist in improving and maintaining habitat for the target species. During the first increment, the PRRIP focus will be on re-timing and improving flows to reduce target flow shortages by an average of 130,000 to 150,000 acre-feet per year. In addition to the improved flow conditions, small pulse flows in the spring are intended to create vegetation-free sand bars suitable for plover and tern nesting (PRRIP 2018).

Flow re-timing will be accomplished in part by releases from the Environmental Account in Lake McConaughy. The Environmental Account is a portion of the water stored in Lake McConaughy that is set aside and managed by the U.S. Fish and Wildlife Service for the benefit of the target species. Other

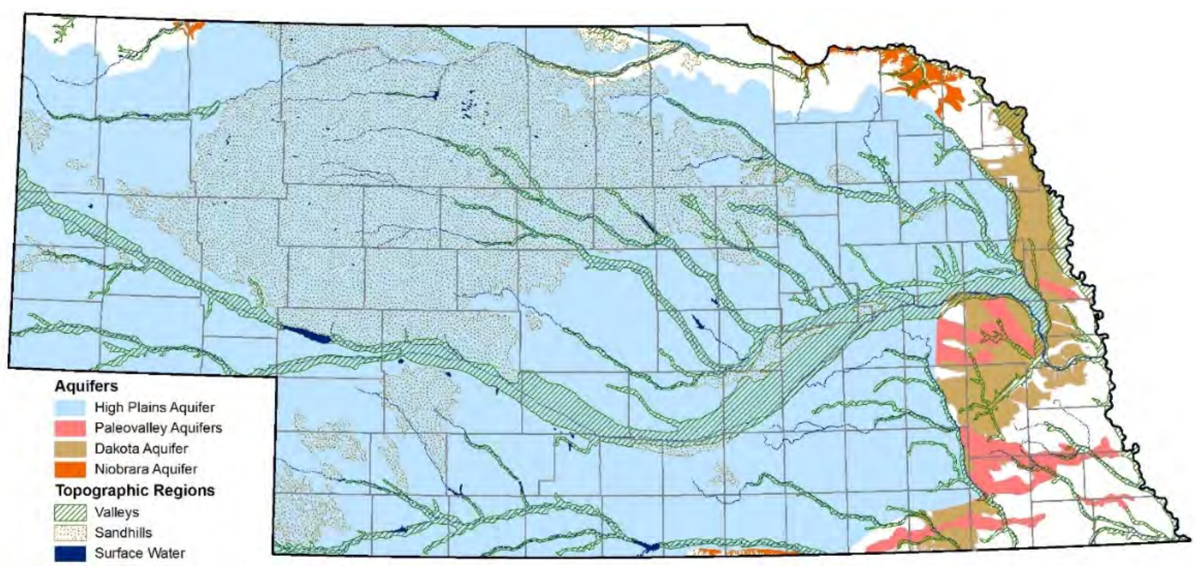
[5] The four threatened or endangered species are the least tern, piping plover, whooping cranes, and pallid sturgeon.

actions will include slightly revised operations of other water systems; general re-timing of Platte River system water projects and other project management actions; and implementation of new water supply and conservation projects in the Upper Platte Basin. Success of the PRRIP relies on implementation of agreed-upon New Depletions Plans in Colorado, Wyoming, and Nebraska and by the federal government in accordance with the PRRIP goal of offsetting new depletions to the Platte River that occurred after July 1997 (PRRIP 2018).[6]

2.5 Surface Water and Groundwater Interaction

Many of the municipal, industrial, and domestic wells in the lower Platte River draw on this alluvial aquifer. In the Platte River valley and its tributaries, the alluvial aquifers are highly connected to the streams, relying almost exclusively on streamflow for recharge. Drought effects on streamflow have a direct effect on groundwater users relying on the alluvial aquifers, as well as surface water users (Figure 11 and Figure 12).

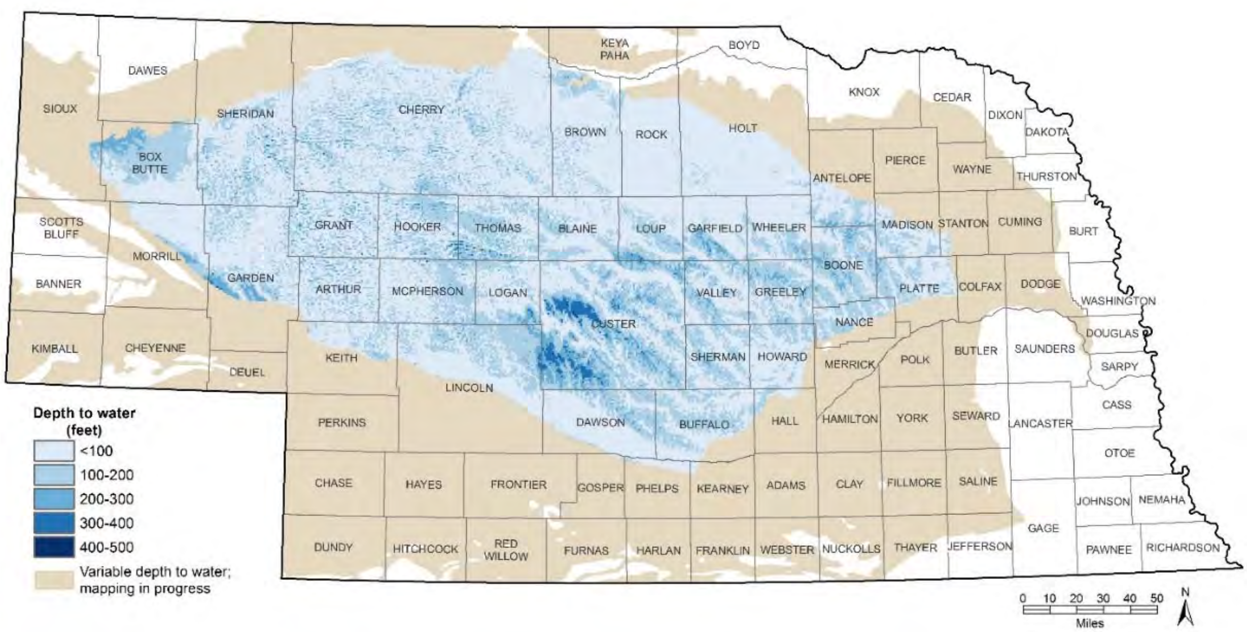
Figure 11: Nebraska Topographic Regions and Principal Aquifers



Source: University of Nebraska–Lincoln, Conservation and Survey Division

[6] https://www.platteriverprogram.org

Figure 12: Depth to Groundwater

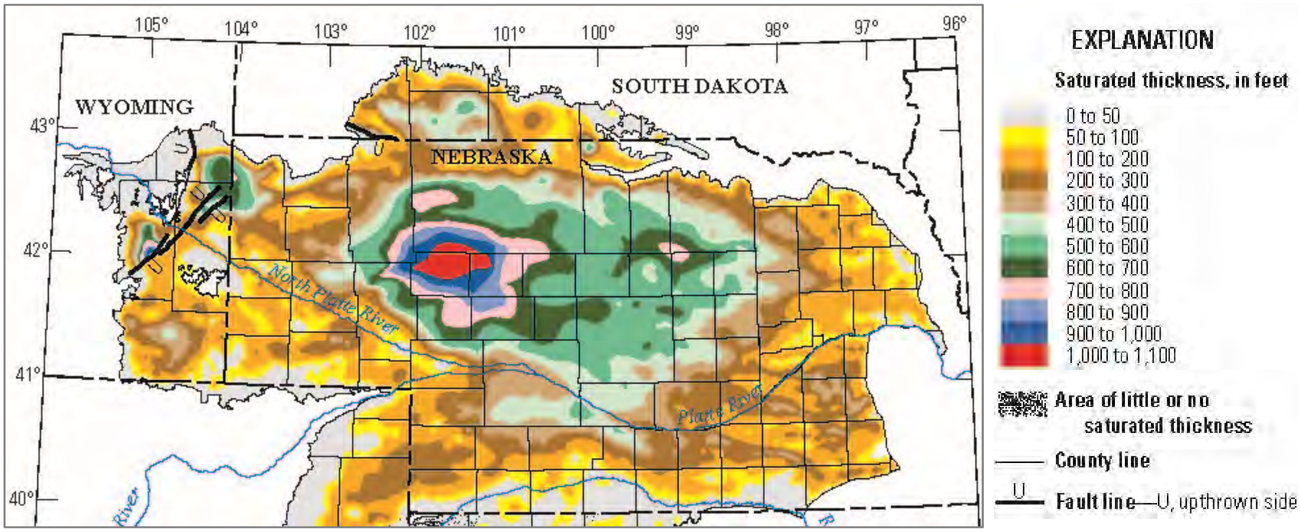


Source: University of Nebraska–Lincoln, Conservation and Survey Division (obtained August 2018)

The Nebraska Sandhills cover portions of the western Elkhorn River subbasin. Streamflow in the western region of the Elkhorn River subbasin stems from a combination of interflow and groundwater. Flows in the downstream reaches of the Elkhorn River, its tributaries, Salt Creek, and some downstream tributaries to the Platte River are affected by large runoff in spring and fall that result from many intense storms on steeper slopes and less permeable soil than occur farther west. Sixty-six percent of the annual flow in the Elkhorn River is derived by the groundwater discharge (USGS 2008).

Tributaries to the Loup River are sustained by shallow groundwater in the Sandhills and have an extremely consistent baseflow. The surficial material of the Sandhills region is very permeable resulting in nearly no overland runoff. The baseflows of the Loup tributaries and runoff in the eastern part of the Loup River watershed combine to produce larger and more consistent flows in the Platte River at North Bend (Figure 13).

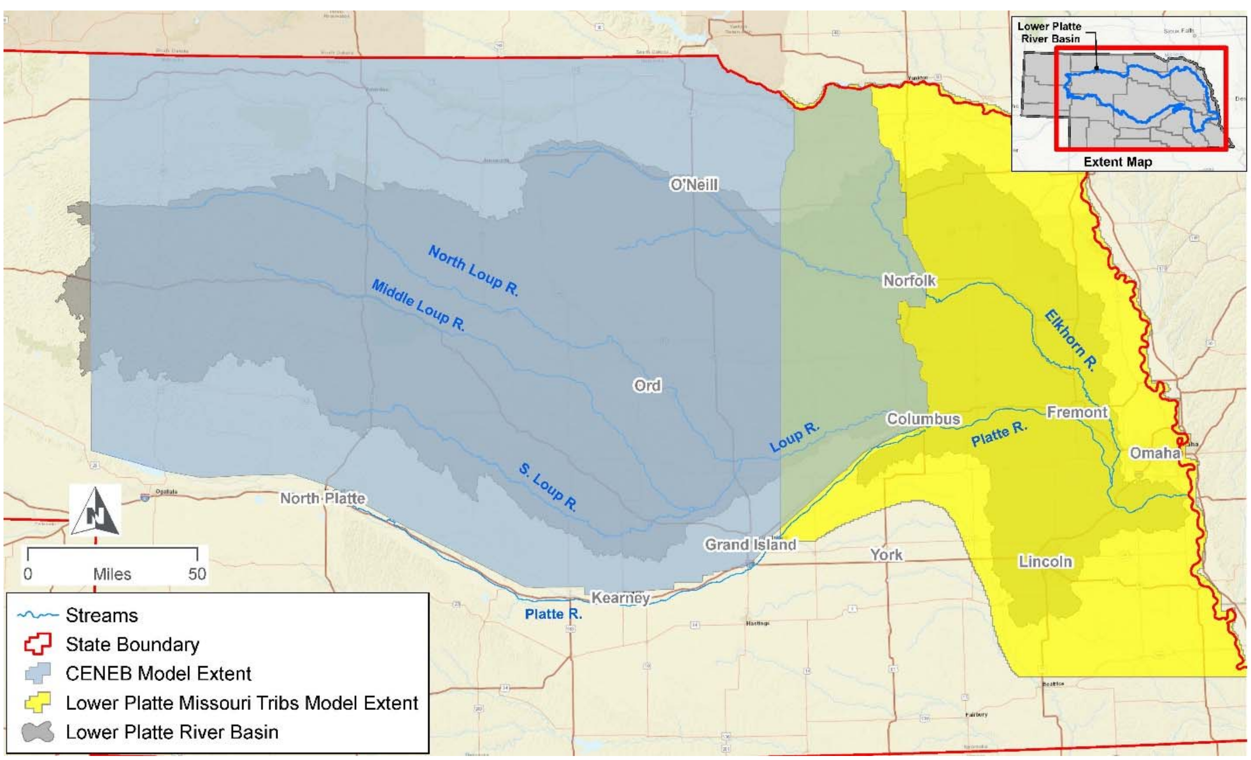
Figure 13: Saturated Thickness of the High Plains Aquifer, 2009



Source: USGS Scientific Investigations Report 2012-5177

Three main groundwater water models are encompassed by the Lower Platte River Basin. These include the Central Nebraska Model (CENEB) and Elkhorn-Loup Model (ELM) models in the western and central portions of the basin and the Lower Platte Missouri Tributaries Model (LPMT), currently under development, covering the eastern portion of the basin. These models analyze the surface and groundwater interaction in the basin (Figure 14). Background on these models is discussed in more detail in Appendix D.

Figure 14: Groundwater Modeling Studies

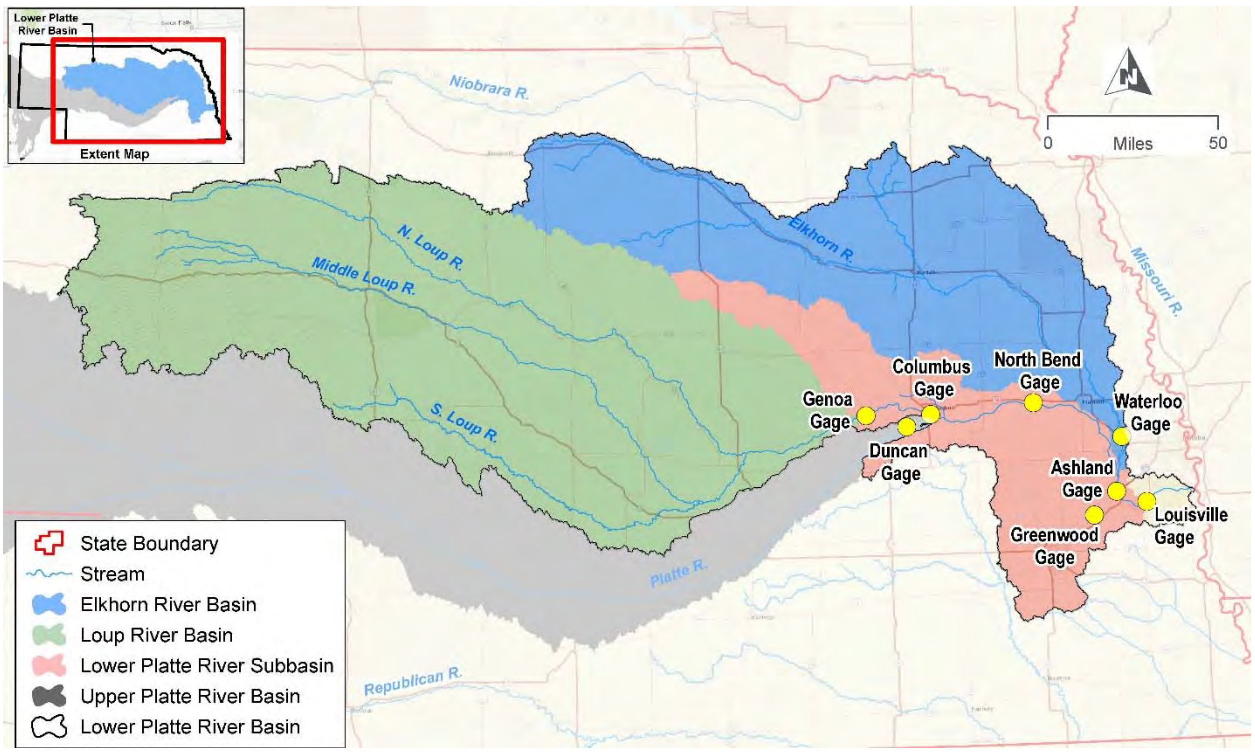


2.6 Water Supply

The Lower Platte River is a key source of water supply for more than 80 percent of Nebraska's population, thousands of businesses and industries, and more than 2 million irrigated acres. Streamflows of the Lower Platte River also support habitat for threatened and endangered species. Water supplies of the Lower Platte River can be highly variable, with annual flows ranging from 2 million acre-feet per year to more than 10 million acre-feet per year.

For the period 1954 through 2004, the Elkhorn River at Waterloo gage comprised, on average, about 21 percent of the annual mean flows recorded at the Platte River at Louisville gage while the Salt Creek at the Greenwood gage comprised, on average, 5 percent of the annual flow recorded at the Platte River at Louisville gage (Dietsch, Godberson, and Steele 2009). For the same period, about 37 percent of annual mean flows recorded at the Platte River at Louisville gage were measured in the Loup River near Genoa and an average of 26 percent were recorded in the Platte River at the Duncan gage (Figure 15).

Figure 15: USGS Stream Gage Locations

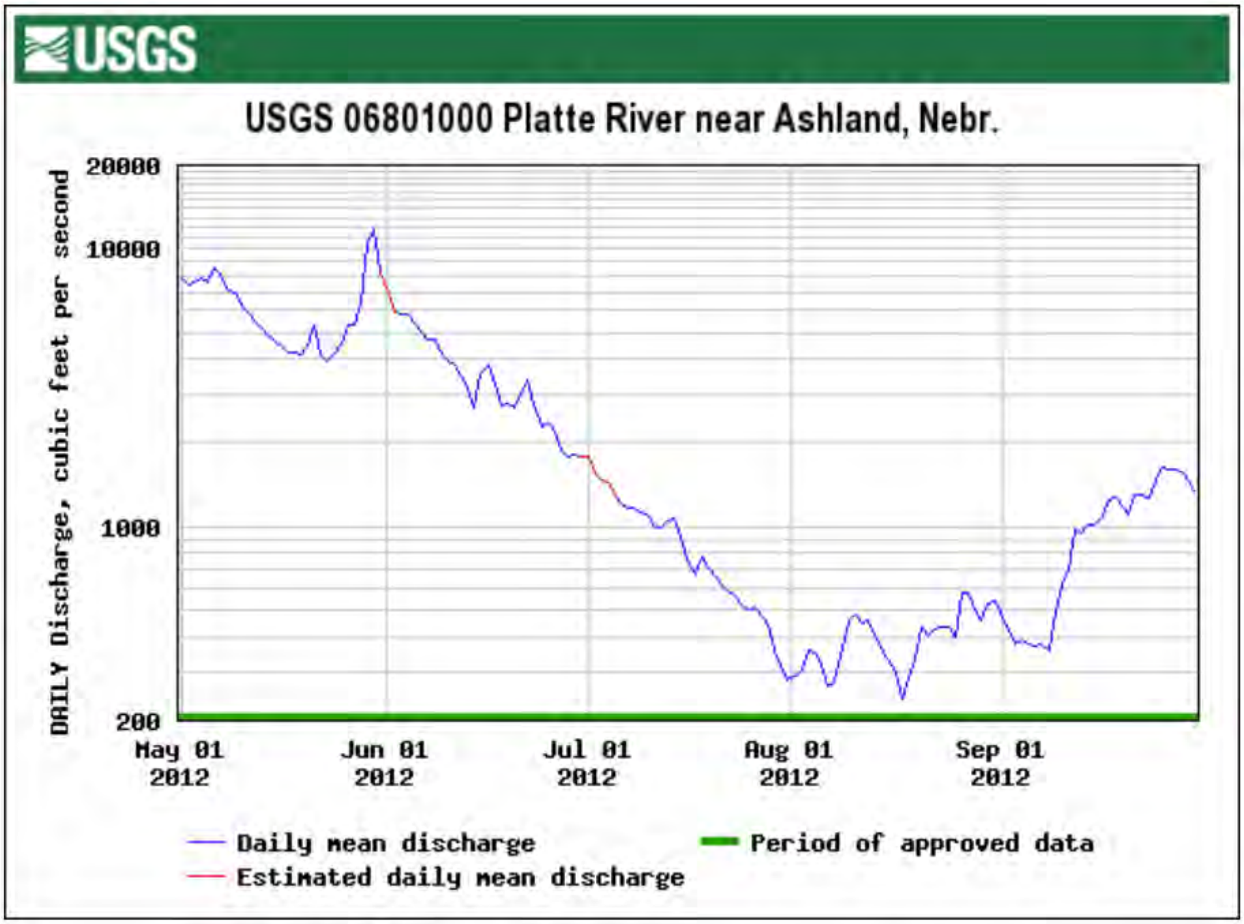


The water supplies of the Loup River subbasin and Elkhorn River subbasin tend to be more reliable because of more significant baseflow contributions. During drought periods, these upstream water supplies are stressed in support of irrigated agricultural production (primarily corn and soybeans). During low-flow years, the Upper Platte River becomes disconnected from the Lower Platte River with observed flows at Duncan, representing a negligible portion of flows observed on the Platte River at Duncan (see Section 2.4 for discussion). During these times, most of the flow in the Lower Platte River originates from the groundwater-fed Loup River, Elkhorn River, and other tributaries downstream from Duncan.

While annual water supplies in the Lower Platte River generally tend to be supportive of most water uses, peak demands in the summer months can create water shortages. These shortages are further exacerbated by drought periods when summer flows become the most critical in supporting water demands.

Figure 16 shows the daily discharge for the Platte River at Ashland during the drought of 2012. These low-flows directly affected the City of Lincoln (discussed further in Section 3.4).

Figure 16: Streamflow data for the Lower Platte River near Ashland



2.7 Water Demand

The water demands and uses in the Lower Platte River are diverse. They include municipal and domestic uses, agriculture, instream flows, and hydropower. The water utilities for the municipalities of Omaha and Lincoln serve the two primary metropolitan areas in Nebraska. Both municipalities hold induced recharge permits (permits that require streamflows adjacent to their well-fields) and municipal groundwater transfer permits (permits where groundwater is transferred from the water well site for use in another location). The Nebraska Game and Parks Commission holds instream flow appropriations for much of the Platte River and specifically in the areas of municipal well-field operations. The Loup Public Power District holds a hydropower appropriation for off-channel hydroelectric power generation. In addition, thousands of individual water rights are held to support irrigation from both surface water and hydrologically connected groundwater sources. Table 2 lists key water rights and water demands in the Lower Platte River Basin.

Table 2: List of key water rights and water demands in the Lower Platte River Basin

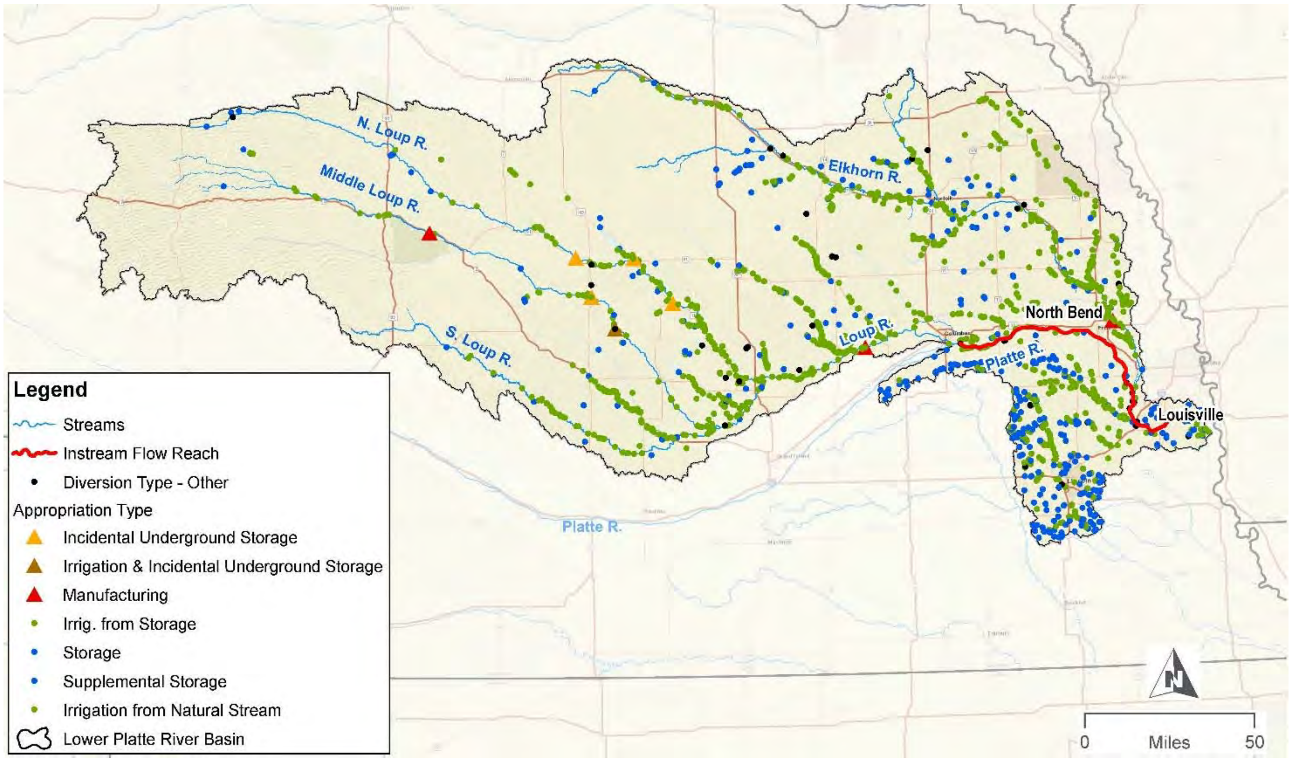
Water Right Holder	Appropriation Type	Grant Amount
Metropolitan Utilities District, Omaha – Platte West	Induced Recharge (1993)	1,000 cfs Population: 600,000
Metropolitan Utilities District, Omaha – Platte South	Induced Recharge (1970)	500 cfs Population: 600,000
Lincoln Water System, Lincoln	Induced Recharge (1964)	704 cfs Population: 265,000
Metropolitan Utilities District, Omaha – Platte South	Municipal Transfer	60 MGD
Metropolitan Utilities District, Omaha – Platte West	Municipal Transfer	104 MGD
Lincoln Water System, Lincoln	Municipal Transfer	110 MGD
Nebraska Game and Parks Commission	Instream flow Protection at the Platte River/Missouri River confluence	3,100 – 3,700 cfs
North Loup Division (USBR)	Irrigation	53,000 acres
Sargent/Farwell Irrigation Districts	Irrigation	67,000 acres
Loup Public Power District	Hydropower	3,500 cfs
Total irrigation in the Lower Platte River Basin	Both surface water and groundwater sources	Greater than 2,000,000 acres

Notes: cfs = cubic feet per second; MGD = million gallons per day; USBR = U.S. Bureau of Reclamation.

2.7.1 Surface Water Demands

As of December 31, 2015, there were 2,250 surface water appropriations held in the Lower Platte River Basin. Table 3 summarizes these appropriations by type: irrigation, storage, manufacturing, or other. Most of the surface water appropriations are for irrigation use and tend to be located on the major streams (Figure 17). In addition, two instream flow appropriations are held in the basin. The instream flow appropriations are located on the Platte River and are measured at North Bend and Louisville and are discussed in more detail in Section 2.8 (NeDNR 2017).

Figure 17: Surface Water Point of Diversions



Source: NeDNR Map layer (obtained 2014)

Table 3: Surface Water Appropriations by Number of Diversion Points, Lower Platte River Basin

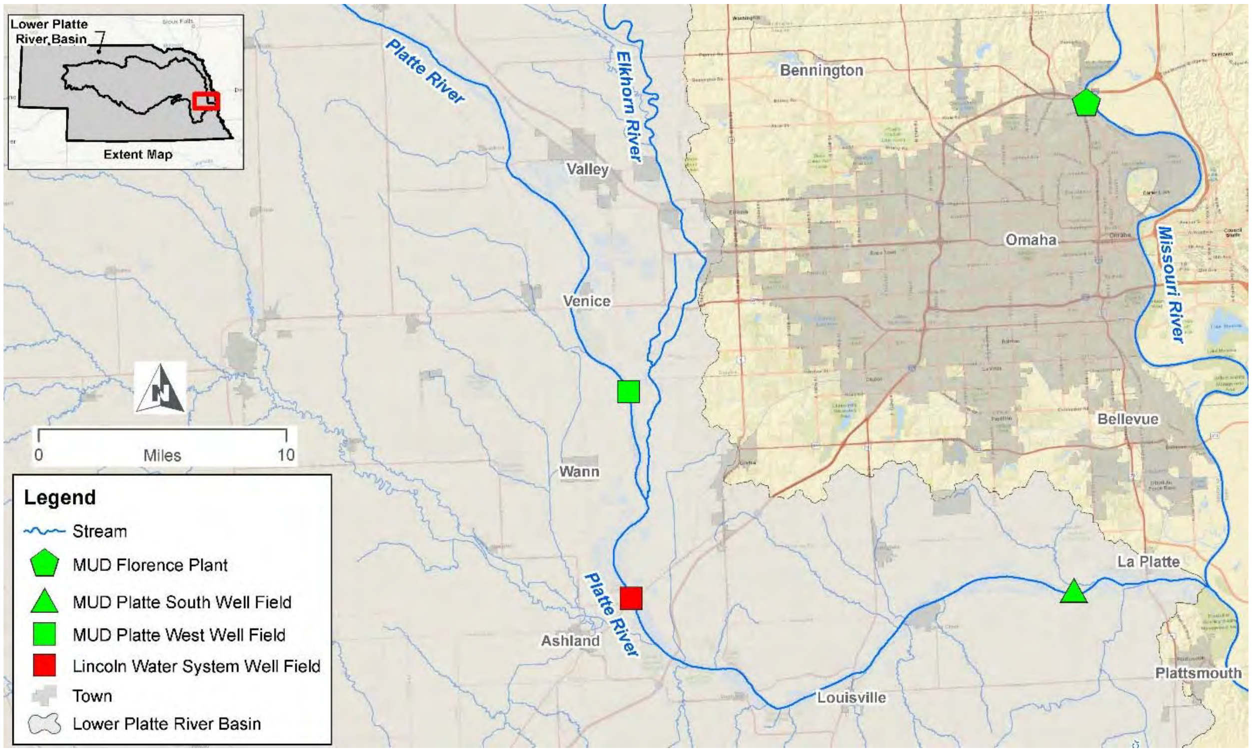
Type	Number of Appropriations
Irrigation from Natural Stream	1,667
Storage	490
Manufacturing	4
Other	89

Source: NeDNR Fully Appropriated Basin Analysis (NeDNR 2017)
Note: 2,250 appropriations as of December 31, 2015.

2.7.2 Induced Groundwater Recharge Permits (Lincoln and Omaha Public Water Utilities)

MUD has three supply locations: 1) Florence Plant in north Omaha that obtains its water from the Missouri River with a capacity of 160 million gallons per day (MGD); 2) Platte West well-field located south of Venice, Nebraska, that obtains its water from the Platte River with a capacity of 100 MGD; and 3) Platte South well-field located near La Platte, Nebraska, that obtains water from the Platte River with a capacity of 60 MGD. Total system output for MUD from all three facilities is 320 MGD. MUD has the ability to use all three of their facilities interchangeably to meet their demand (Figure 18).

Figure 18: Metropolitan Utilities District and Lincoln Water System Municipal Well-field Locations



LWS serves the City of Lincoln. Currently, LWS's only source of water is the Platte River. LWS's well-field consists of 40 vertical wells, four (4) existing horizontal collector wells. LWS's well-field has a maximum instantaneous pumping capacity of between 135 MGD and 145 MGD, depending on streamflow conditions. The summer seasonal capacity of the well-field for 50- and 90-day production capacity ranges from 85 to 90 MGD when streamflow in the Platte River at Ashland is less than 1,000 cfs. (City of Lincoln 2018).

LWS maintains two types of water rights permits through NeDNR: an induced recharge permit and groundwater transfer permits. The induced recharge permit allows LWS to induce groundwater recharge from the Platte River for municipal use. LWS maintains two groundwater transfer permits maintained by the City of Lincoln (totaling 110 MGD) (City of Lincoln 2014b)[7].

The *LWS Facilities Master Plan* projected the future water demand using demand projections (City of Lincoln 2014b). The anticipated future seasonal peak water demand is approximately 84 MGD by 2040 and approximately 116 MGD by 2060.

Figure 19 shows that the model-predicted maximum availability of groundwater that can be pumped from the well-field varies based on streamflow and decreases with increased pumping duration. These model predictions were developed using LWS's well-field configuration as of 2003 and do not include the third horizontal collector well (City of Lincoln 2014b).

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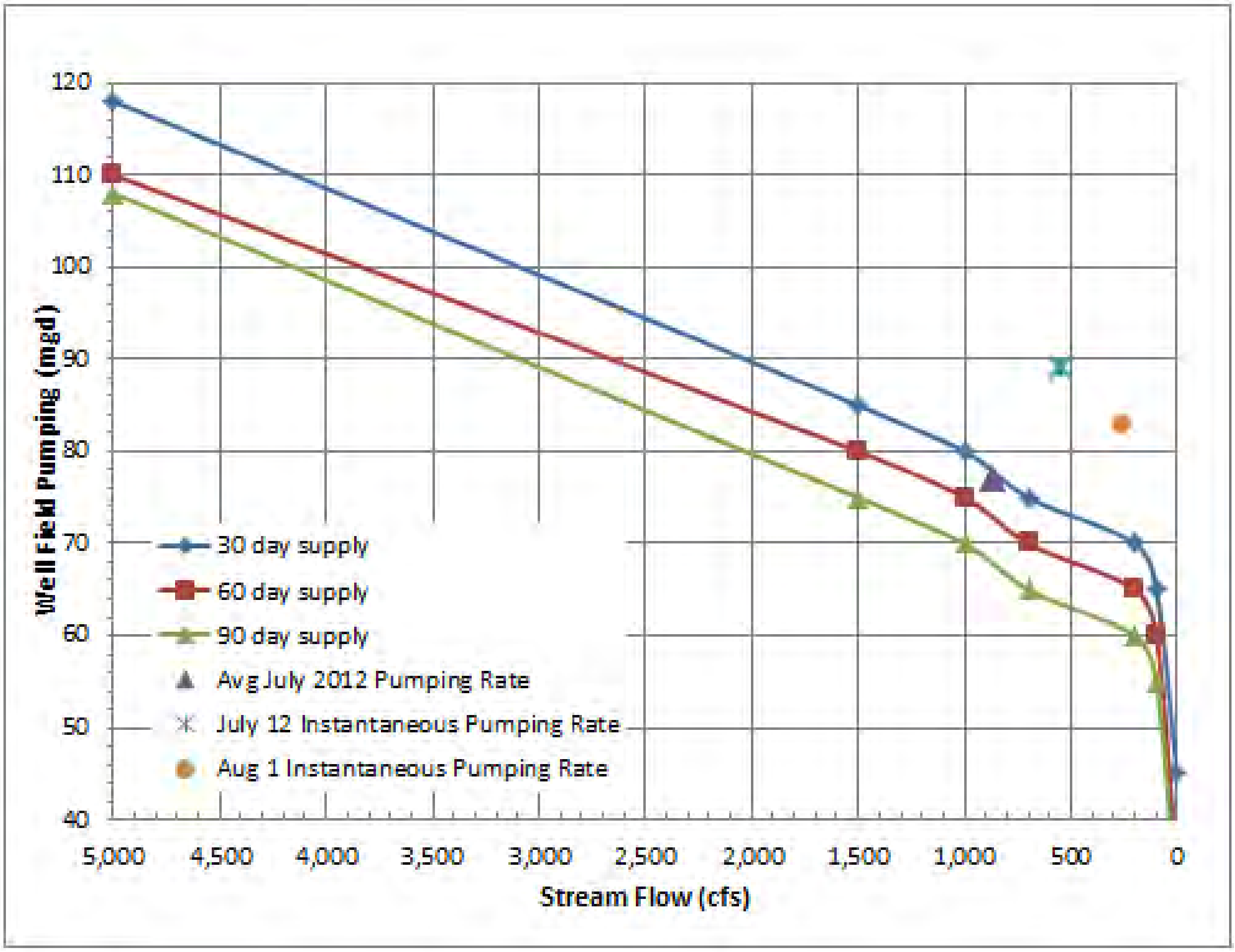
[7] The groundwater transfer permits are optional permits. There is no limitation to only pump within the terms of these permits. The maximum daily withdrawal under permit A-10367 is 60 MGD and under permit A-16917 is 50 MGD. If LWS pumps more groundwater than the permitted amount, the portion that exceeds their permitted amounts is simply being withdrawn without a specific permit tied to that portion of pumping.

Figure 19: Model-Predicted Well-field Capacity and 2012 Pumping Conditions



Source: LWS Facilities Master Plan (City of Lincoln 2014b)

There is a nearly linear relationship between the well-field yield and change in streamflow over a large range of streamflow values. When streamflow is below 200 cfs, the relationship between streamflow and well-field yield changes dramatically, which indicates that, based on the model results, 200 cfs is a critical streamflow value for Lincoln's well-field. At this streamflow condition, it appears that the source of water to the well-field changes from predominantly induced recharge of the Platte River to predominantly groundwater in aquifer storage. A daily streamflow of 200 cfs has never been observed at the Ashland gage. The lowest daily streamflow observed at the Ashland gage is 237 cfs, and the lowest monthly average streamflow observed at this gage is 368 cfs. Both of these record low streamflow values were observed in August 2012 (City of Lincoln 2014b).

It should be noted that the wellfield capacity is dependent on duration of pumping as well as the location of the river channel during low flow conditions.

2.7.3 Groundwater Demands

Groundwater in the Lower Platte River Basin is used for a variety of purposes: domestic, industrial, livestock, irrigation, and other uses (Table 4). As of December 31, 2015, 49,092 groundwater wells had been registered within the basin (NeDNR 2016). Nebraska leads the nation in irrigated acres accounting for one acre of every six acres of irrigated land in the U.S. in 2007 (UNL 2009).

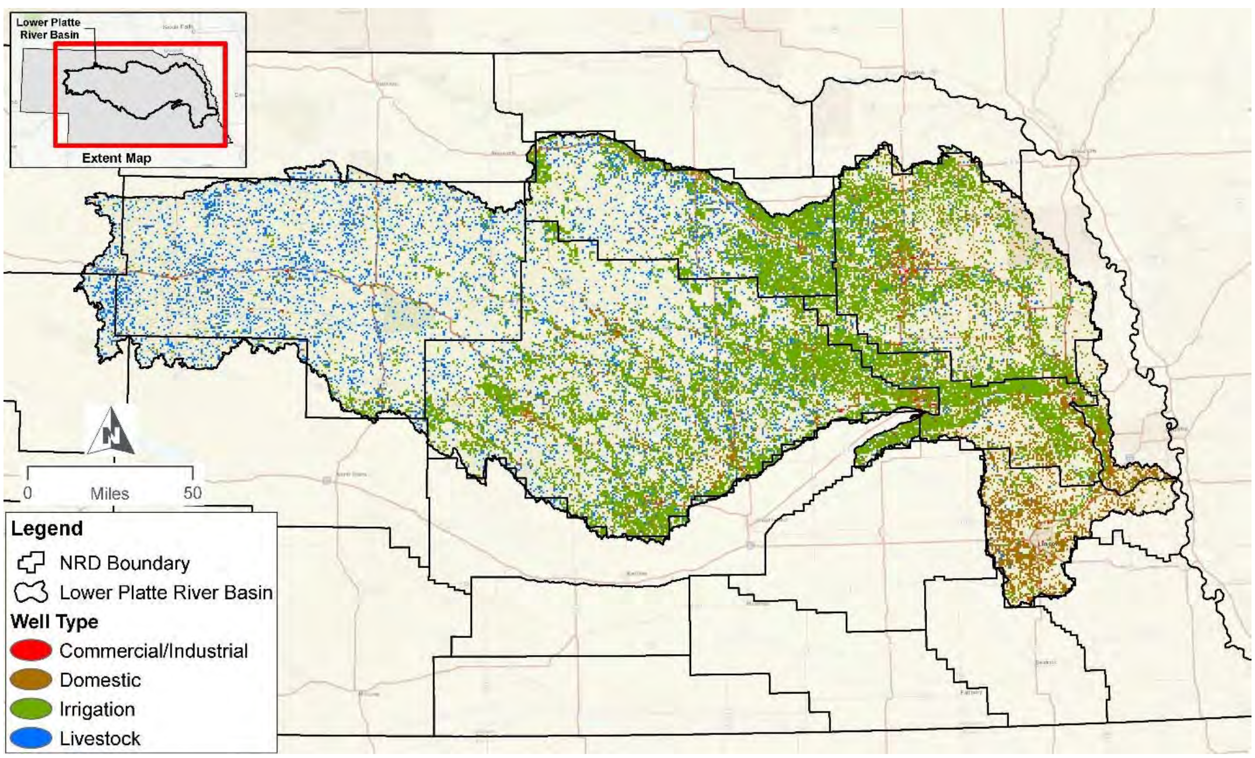
Table 4: Current Groundwater Well Development by Number of Registered Groundwater Wells, Lower Platte River Basin

Type	Percentage of Wells
Irrigation	51.2
Domestic	26.9
Livestock	17.4
Commercial/Industrial	10.9
Public Water Supplies	2.1
Other	1.5

Source: NeDNR Fully Appropriated Basin Report (NeDNR 2017)
Note: 49,092 wells as of December 31, 2015.

Figure 20 shows the distribution of groundwater wells in the Lower Platte River basin by type. The Sandhills of the Upper Loup subbasin are dominated by livestock wells.

Figure 20: Distribution of Groundwater Wells in Lower Platte River Basin



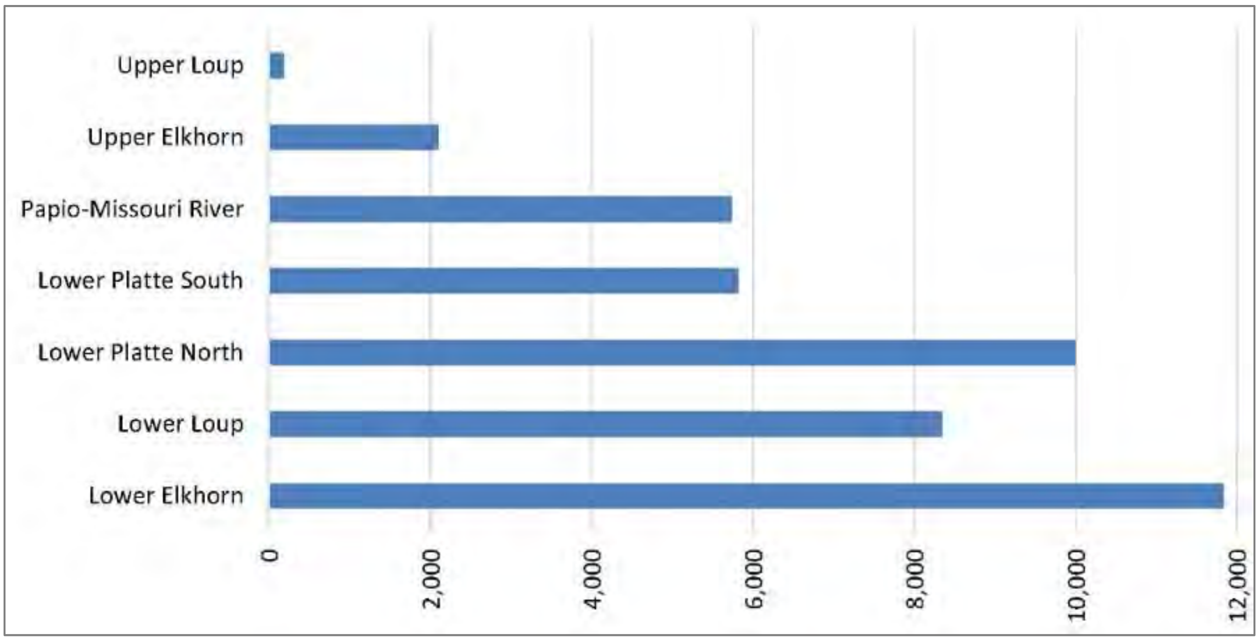
Source: NeDNR Map layer (obtained February 2018)

The majority of the commercial and industrial wells are located in the larger population centers, as expected. There are noticeably less irrigation wells located in the eastern portion of the Lower Platte River Basin where the irrigation is primarily located in the hydrologically connected areas.

2.7.3.1 Municipal Groundwater Demands

The Flatwater Group (TFG), under contract with the NeDNR, estimated 2012 municipal water use for Nebraska. The estimated pumping for municipal (with the exception of MUD and LWS), governmental, and educational wells was developed using monthly per capita pumping estimates and 2012 population estimates. A summary of LWS and MUD demand was previously discussed in Section 2.7.2. Outside of MUD and LWS, the top five public water suppliers are the cities of Fremont, Papillion, Columbus, Norfolk, and Schuyler. Those areas not served by public water providers are assumed served by domestic groundwater wells. Figure 21 shows the estimated municipal groundwater demand by NRD (excluding MUD and Lincoln well-fields). Outside of Omaha and Lincoln, the largest municipal groundwater demand is located in the Lower Elkhorn NRD followed by the Lower Platte North NRD, Lower Loup NRD, Lower Platte South NRD, Papio-Missouri River NRD, and Upper Loup NRD, respectively.

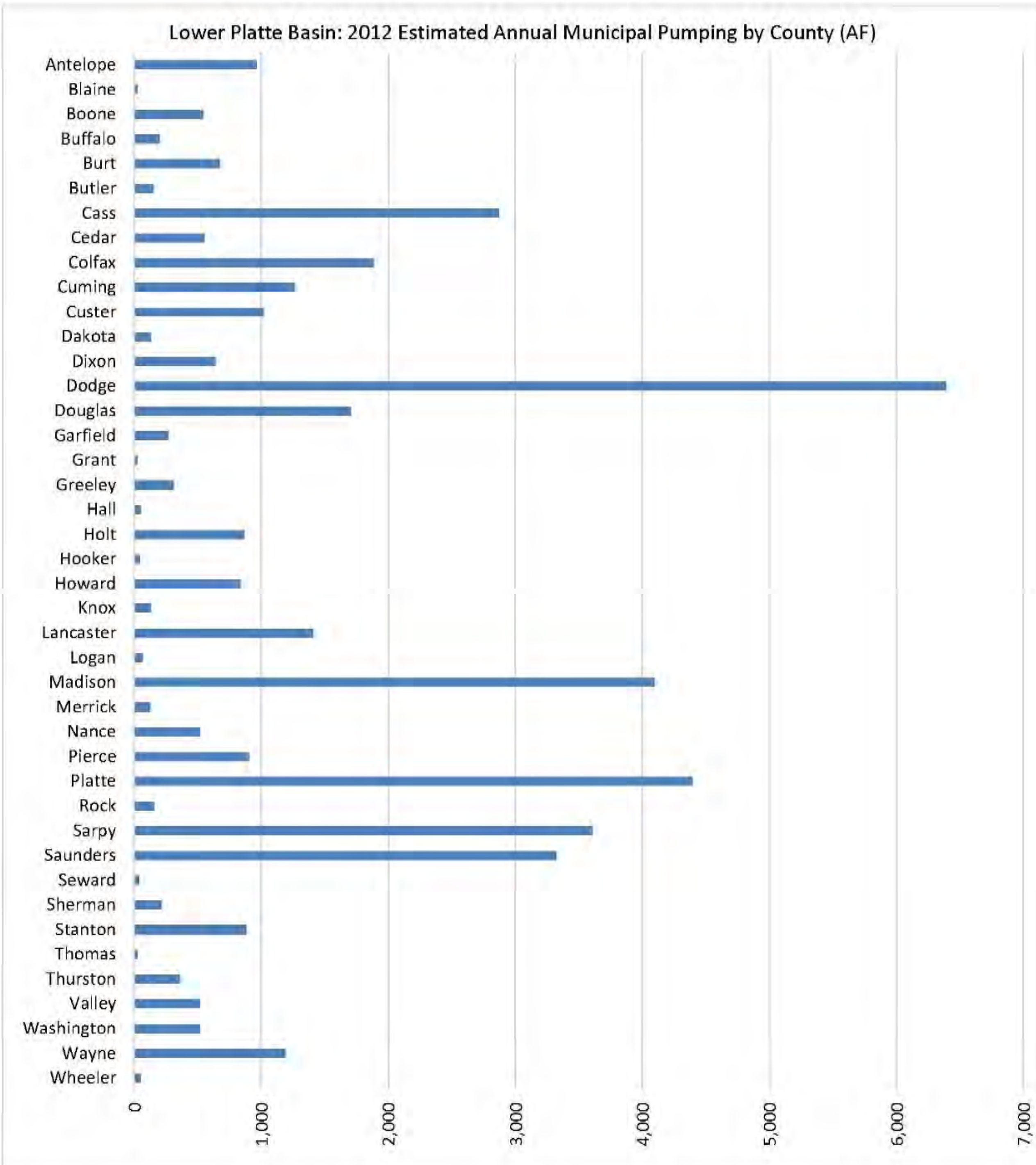
Figure 21: 2012 Estimated Municipal Groundwater Demands by Natural Resources District



Source: Municipal and Industrial Pumping, TFG, January 2014.
Notes: Measurements are in acre-feet. This figure only reflects groundwater demands. This figure does not reflect the Lincoln or MUD well-fields.

Figure 22 shows the same information aggregated by county. It should be noted that the demands are accounted for at the point of extraction, which does not necessarily correspond to the point of use. This figure does not reflect the Lincoln or MUD well-fields.

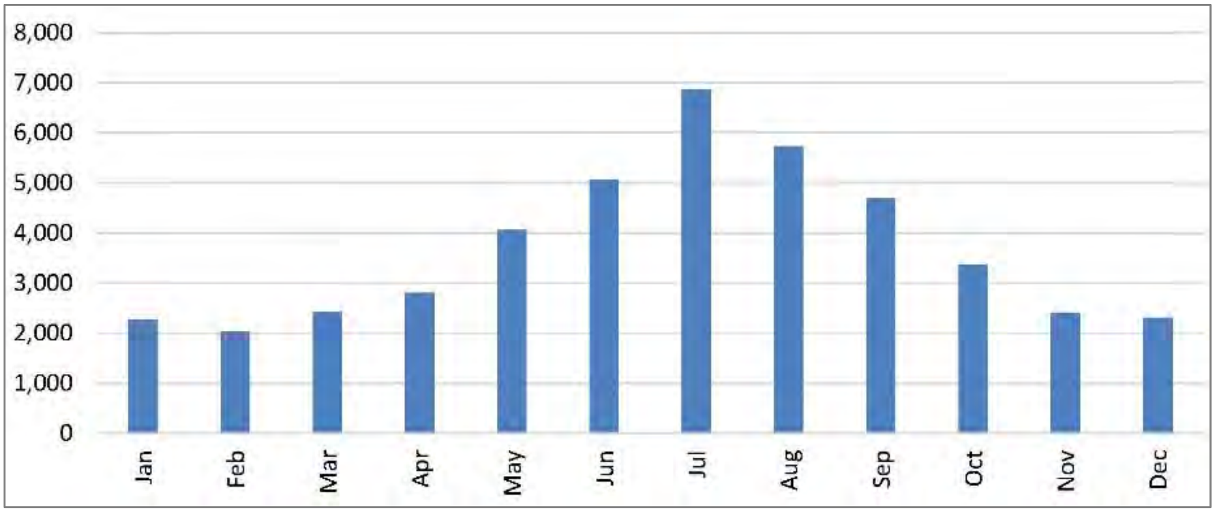
Figure 22: 2012 Estimated Municipal Groundwater Demands by County (Not including Lincoln or MUD well-fields)



Source: Municipal and Industrial Pumping, TFG, January 2014.
Notes: Measurements are in acre-feet. This figure only reflects groundwater demands. This figure does not reflect the Lincoln or MUD well-fields. The Dodge County demand corresponds to the demand for Fremont.

Figure 23 shows the estimated municipal demands as they occur over a calendar year. As expected, the largest demands occur in the summer months when the temperatures are highest and the demand increases for air-conditioning and lawn watering.

Figure 23: 2012 Estimated Municipal Groundwater Demands by Month

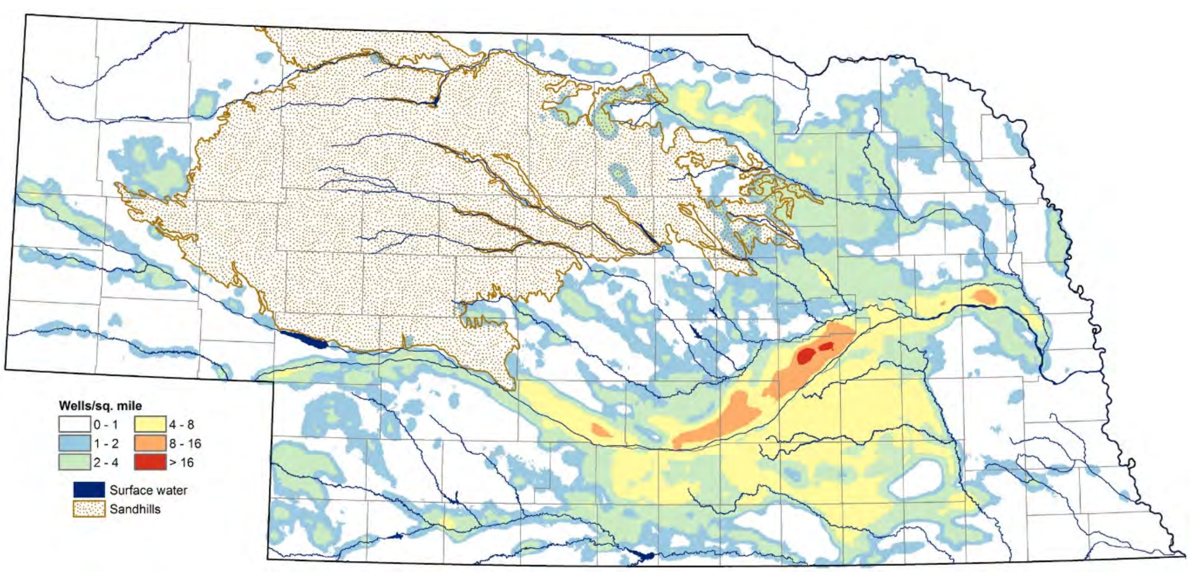


Source: Municipal and Industrial Pumping, TFG, January 2014.
Notes: Measurements are in acre-feet. This figure only reflects groundwater demands. This figure does not reflect the Lincoln or MUD well-fields.

2.7.3.2 Irrigation Groundwater Demands

Figure 24 displays the density of only the irrigation wells (the largest category of groundwater wells).

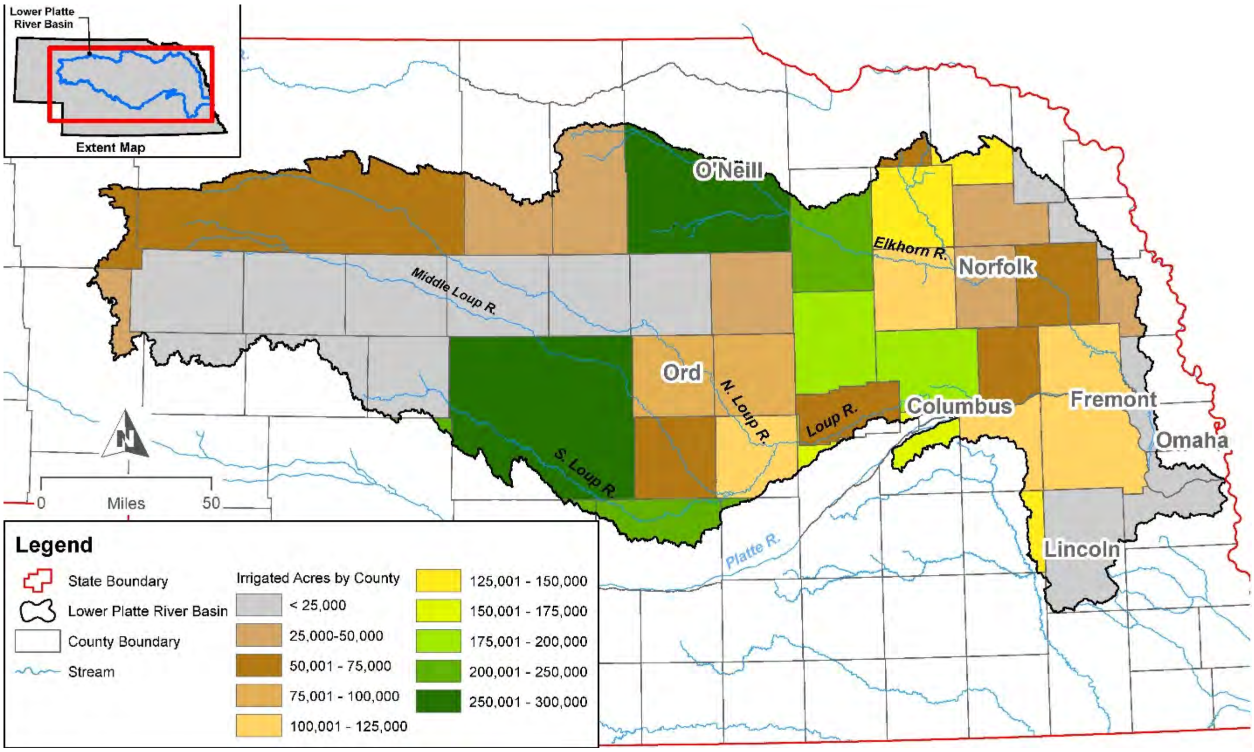
Figure 24: Density of Active Irrigation Groundwater Wells



Source: Nebraska Statewide Groundwater-Level Monitoring Report (University of Nebraska–Lincoln Conservation and Survey Division 2017)

Figure 25 shows irrigated acres by county. It can be seen that there is little to no irrigation in the northwestern portion of the Lower Platte River Basin, which is predominately Sandhills. The bulk of the irrigated acres occurs in the central portions of the Lower Platte River Basin.

Figure 25: Number of Irrigated Acres by County



Source: 2012 Census of Agriculture, U.S. Department of Agriculture, National Agricultural Statistics Service

Table 5: Number of irrigated acres by NRD

NRD	Number of Irrigated Acres				
	Total	Groundwater	Surface Water	Comingled	Wastewater
Upper Loup	82,858	82,858	0	0	--
Lower Loup	1,222,485	1,019,096	155,181	48,209	--
Upper Elkhorn	465,317	465,317	0	0	--
Lower Elkhorn	671,633	626,183	15,807	0	29,643
Lower Platte North	373,433	364,456	4,195	4,782	--
Lower Platte South	3,267	3,267	0	0	--

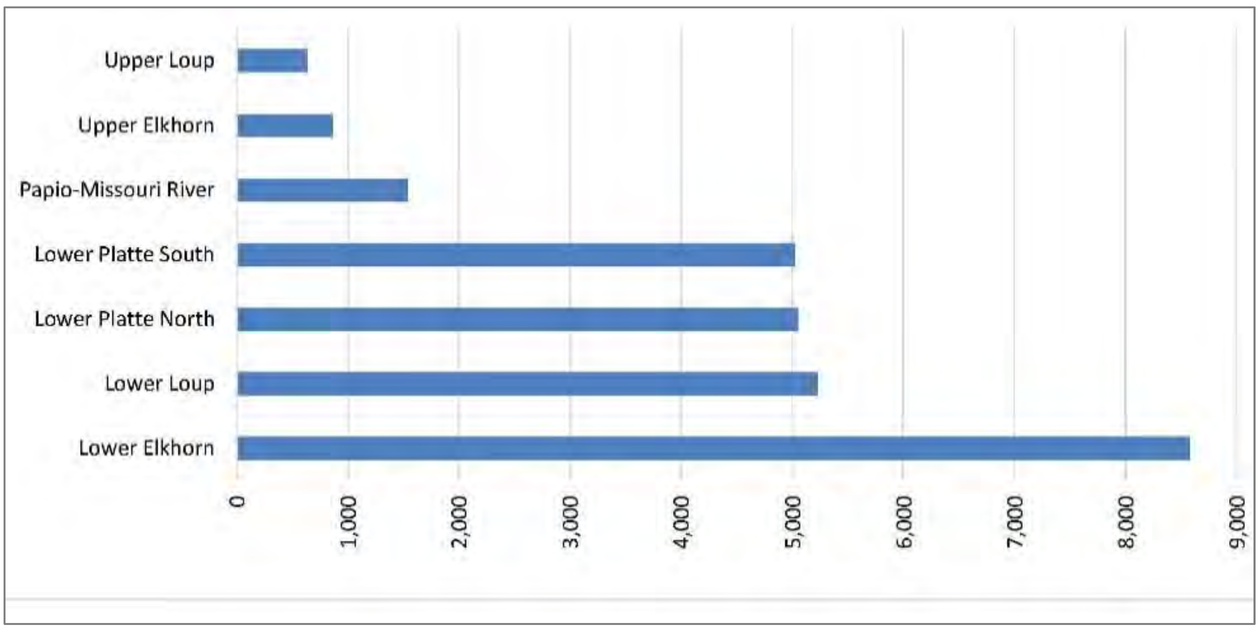
Papio-Missouri River	Estimated 25,000	--	--	--	--

Note: P-MRNRD has not yet completed certifying irrigated acres.
Source: Basin Plan (2017 Annual Reports)

2.7.3.3 Industrial Groundwater Demands

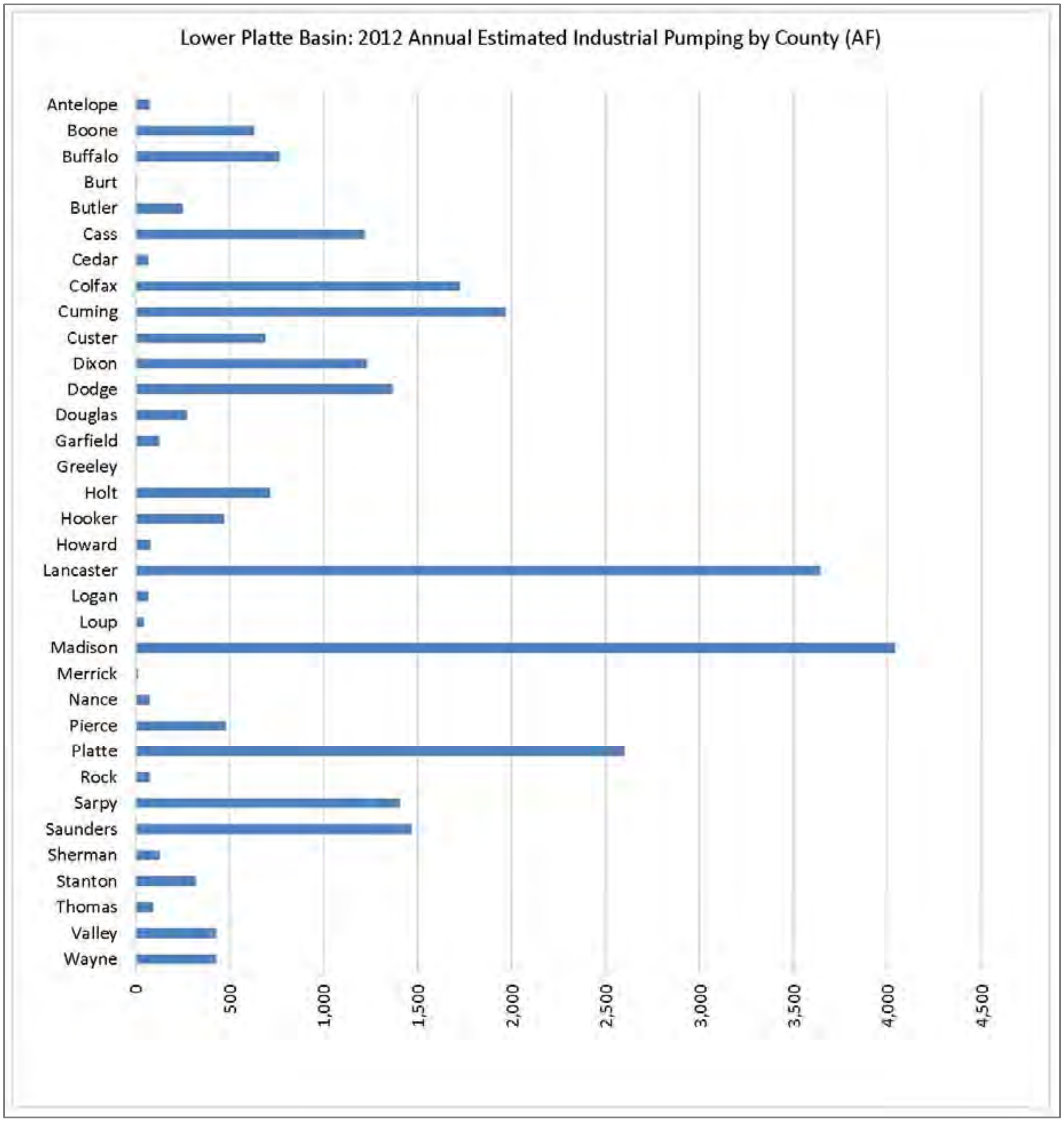
TFG, under contract with NeDNR, estimated self-supplied industrial groundwater use for Nebraska for 2012 using historical and industrial surveys provided by NeDNR. This study does not include industrial uses served by public water supply. The survey results provided water use information for 50 different industrial sites. TFG categorized these industrial sites into 12 industrial classes based on similar types of water use (average annual volume of water usage and the average monthly pumping distribution). Figure 26 shows the estimated industrial groundwater demands for industries served by self-supplied groundwater by NRD. The largest collective industrial use occurs in the Lower Elkhorn NRD followed by the Lower Loup NRD, Lower Platte North NRD, Lower Platte South NRD, Upper Elkhorn NRD, and Upper Loup NRD, respectively. Figure 27 displays the same information for industrial uses aggregated by county.

Figure 26: 2012 Estimated Industrial Groundwater Demands by NRD



Source: Municipal and Industrial Pumping, TFG, January 2014.
Note: Measurements are in acre-feet.

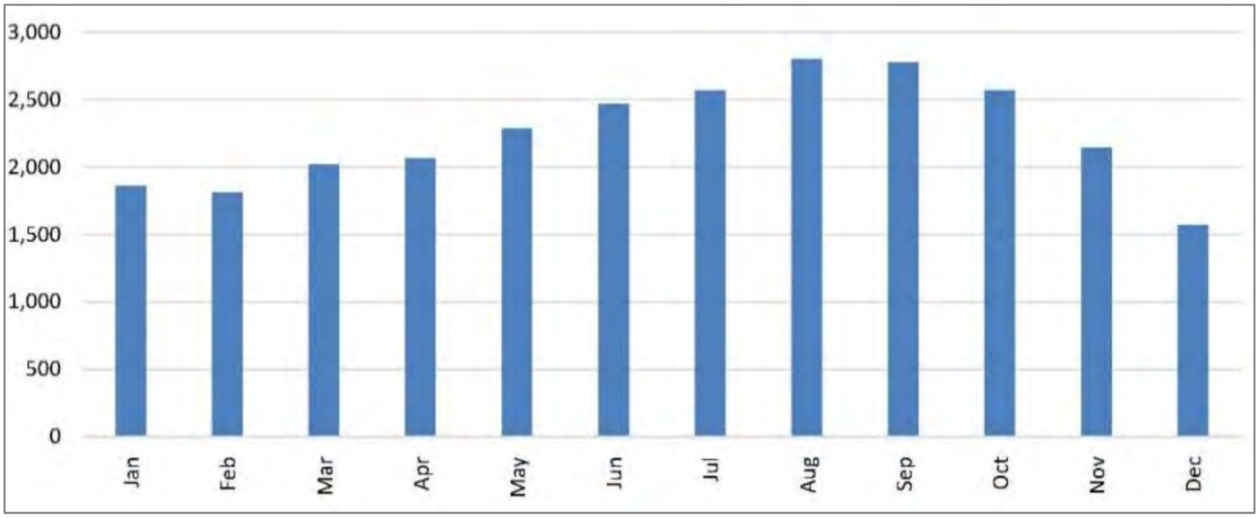
Figure 27: 2012 Estimated Industrial Groundwater Demands by County



Source: Municipal and Industrial Pumping, TFG, January 2014.
Note: Measurements are in acre-feet.

Figure 28 shows the estimated annual distribution of industrial demands. The demand peaks during the summer months but remains relatively stable throughout the year.

Figure 28: 2012 Estimated Industrial Groundwater Demands by Month



Source: Municipal and Industrial Pumping, TFG, January 2014.
Note: Measurements are in acre-feet.

2.8 Non-consumptive use demands

Non-consumptive use demands are demands on the water supply that are available to meet other demands. Examples of non-consumptive use demands are hydropower demands and induced groundwater recharge demands.

The Nebraska Game and Parks Commission holds instream flow appropriations for the protection of fish and wildlife. The instream flow rights have a priority date of November 30, 1993[8]. The instream flow appropriations are measured at the North Bend gage and the Louisville gage, although the appropriations extend to the confluence with the Missouri River. Figure 29 lists the instream flow appropriations by location. Section 5.4.4 discusses in more detail the administration of these instream flow appropriations by the NeDNR.

[8] The instream flow appropriation has a priority date of 11/30/1993; however, it was not approved until 6/26/1998. The NeDNR has placed a priority call on the Lower Platte River for the instream flow right a total of 23 times between 1999 to 2018. See Section 5.4.4.5 for discussion of surface water administration in Nebraska.

Figure 29: Total Platte River instream flow appropriations

Total Platte River Instream Flow Needs
For Purposes of Water Administration
All Quantities in CFS

Central Platte figures in blue (Priority date of 7-25-1990)
Game & Parks figures in red (Priority date of 11-30-1993)
Totals in black

TIME PERIOD	OVERTON GAGE	ODESSA GAGE	GRAND ISLAND GAGE	DUNCAN GAGE	NORTH BEND GAGE	LOUISVILLE GAGE
January	500	500	500	500	1,800	3,100
February	500	500	500	500	1,800	3,700
March	1,100	1,100	1,100	500	1,800	3,700
April 1-14	1,300	1,350 (1,300 + 50)	1,350 (1,300 + 50)	500	1,800	3,700
April 15-30	1,500	1,500	1,500	500	1,800	3,700
May 1-3	1,500	1,500	1,500	500	1,800	3,700
May 4-10	500	1,350 (includes 500)	1,350 (includes 500)	500	1,800	3,700
May 11-31	500	500	500	500	1,800	3,700
June 1-23	500	1,000 (500 + 500)	1,000 (500 + 500)	1,000 (500 + 500)	1,800	3,700
June 24-30	600	1,000 (600 + 400)	1,000 (600 + 400)	1,000 (600 + 400)	1,800	3,700
July 1-31	600	1,000 (600 + 400)	1,000 (600 + 400)	1,000 (600 + 400)	1,800	3,700
August 1-22	600	800 (600 + 200)	800 (600 + 200)	900 (600 + 300)	1,800	3,500
August 23-31	500	800 (500 + 300)	800 (500 + 300)	900 (500 + 400)	1,800	3,500
September	500	500	500	500	1,800	3,200
October 1-11	1,100	1,350 (includes 1,100)	1,350 (includes 1,100)	500	1,800	3,700
October 12-31	1,500	1,500	1,500	500	1,800	3,700
November 1-10	1,500	1,500	1,500	500	1,800	3,700
November 11-30	500	500	500	500	1,800	3,700
December	500	500	500	500	1,800	3,700

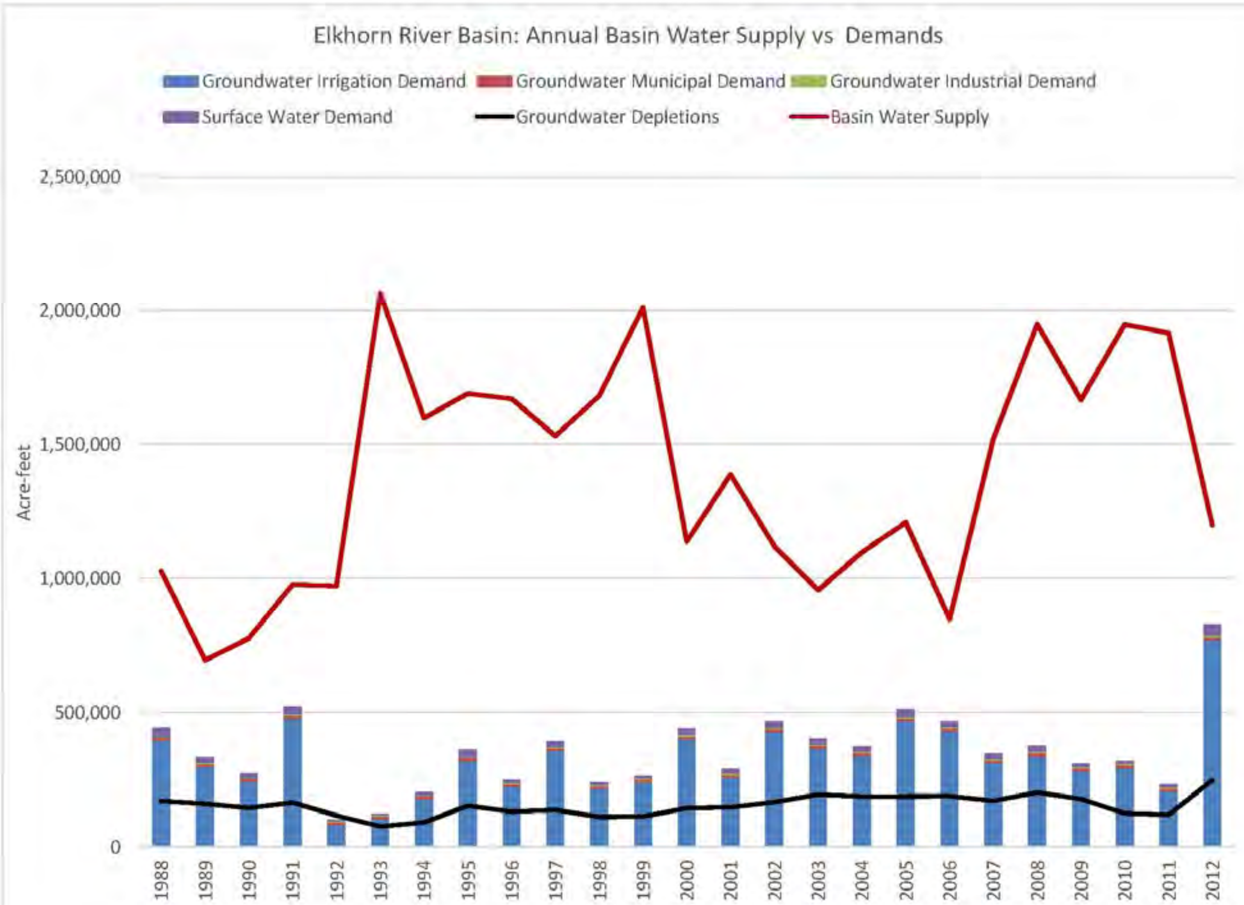
Source: NeDNR

2.9 Supplies versus Demands

As previously mentioned, the Basin Plan quantified basin supplies and basin demands. Section 2.6 described the sources of water supply in the Basin while Section 2.7 discussed each demand component in detail. This section evaluates basin supplies versus demands holistically.

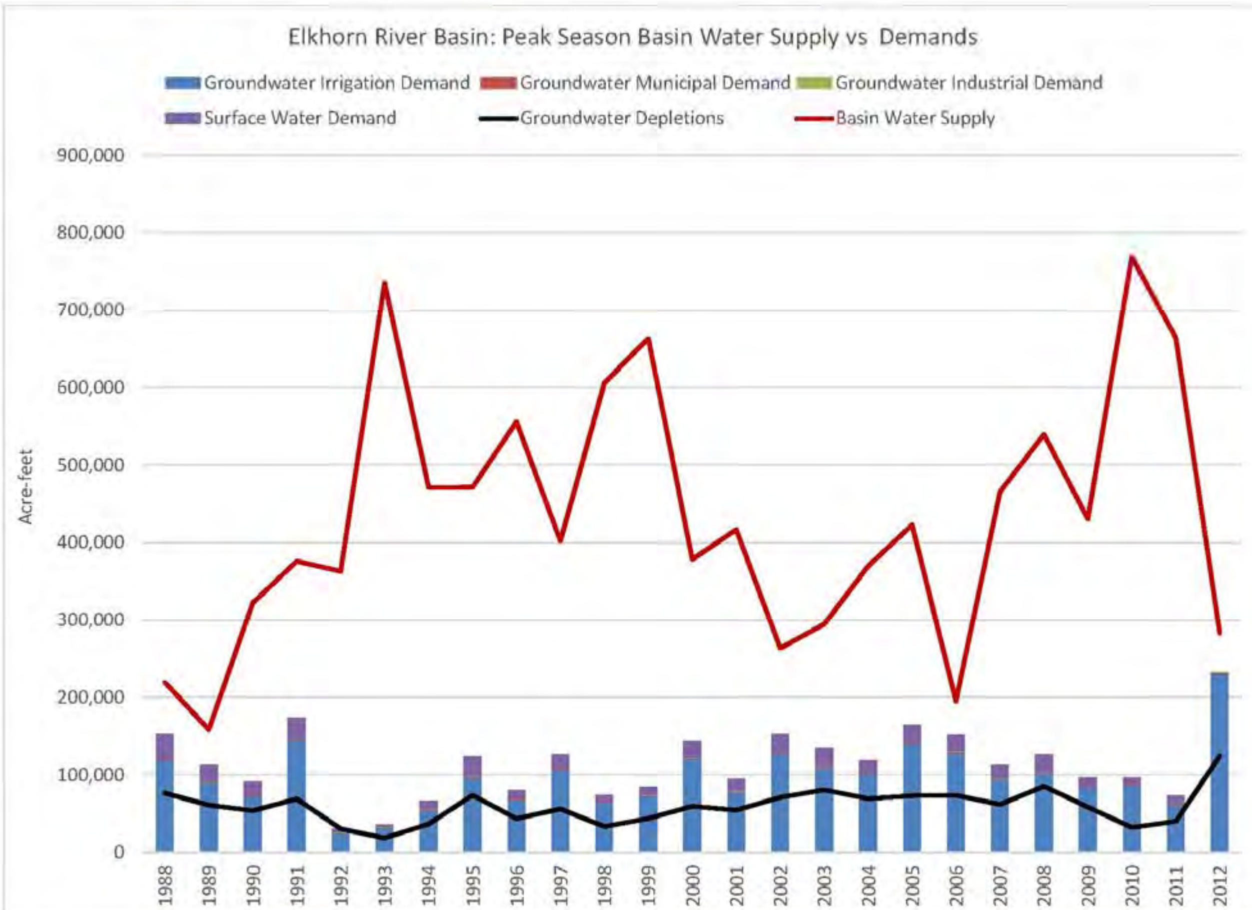
In Figure 30 through Figure 35, basin water supply is inclusive of the historic surface water diversions and groundwater depletions that were realized in the stream to recreate the water supply that was available before these demands were satisfied. This is then compared to full permitted demand (which may be greater than what was historically consumed). In general, basin water supplies are have been historically adequate to meet subbasin demand on a seasonal basis.

Figure 30: Estimated annual supply versus demands in the Elkhorn River Basin (1988-2012)



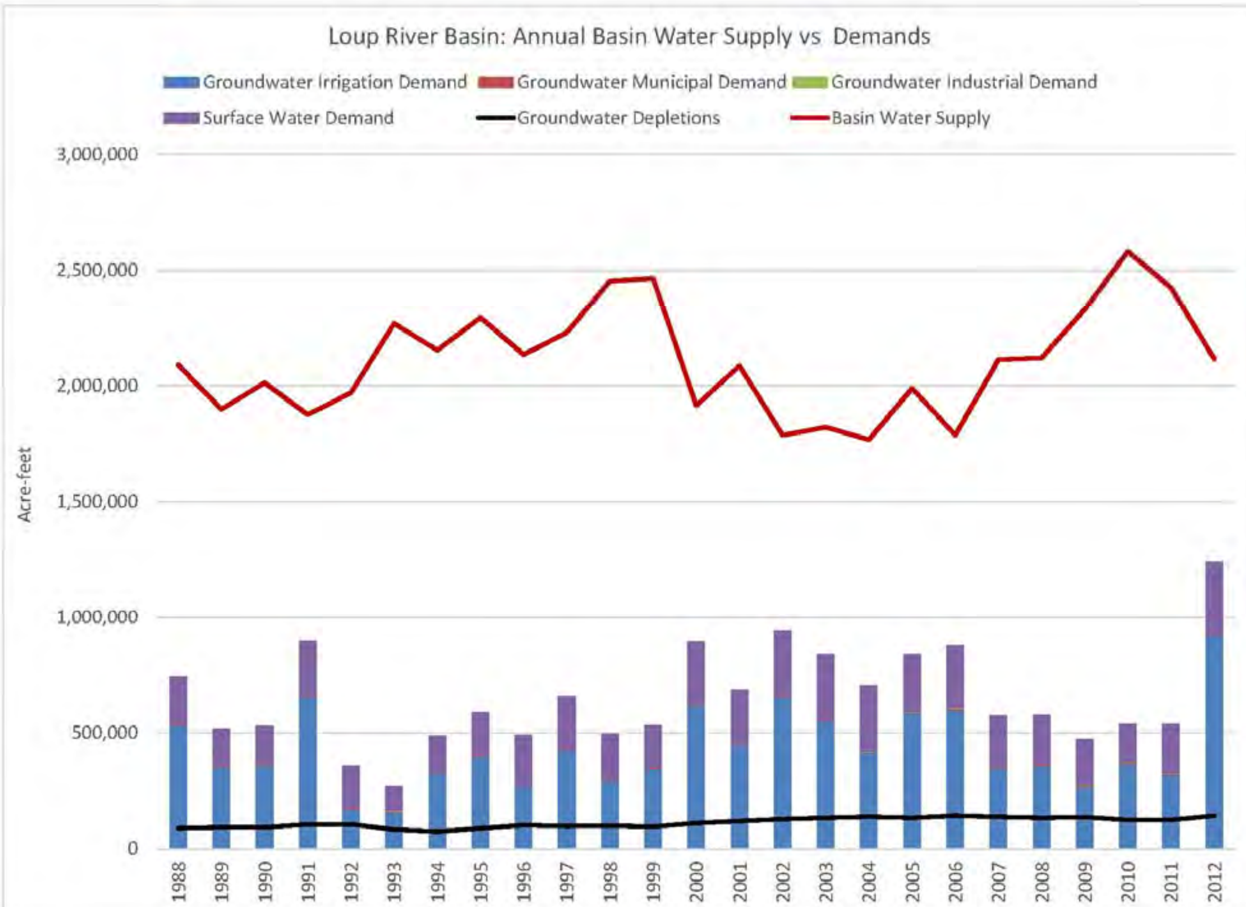
Source: Basin Plan accounting

Figure 31: Estimated peak season supply versus demands in the Elkhorn River Basin (1988-2012)



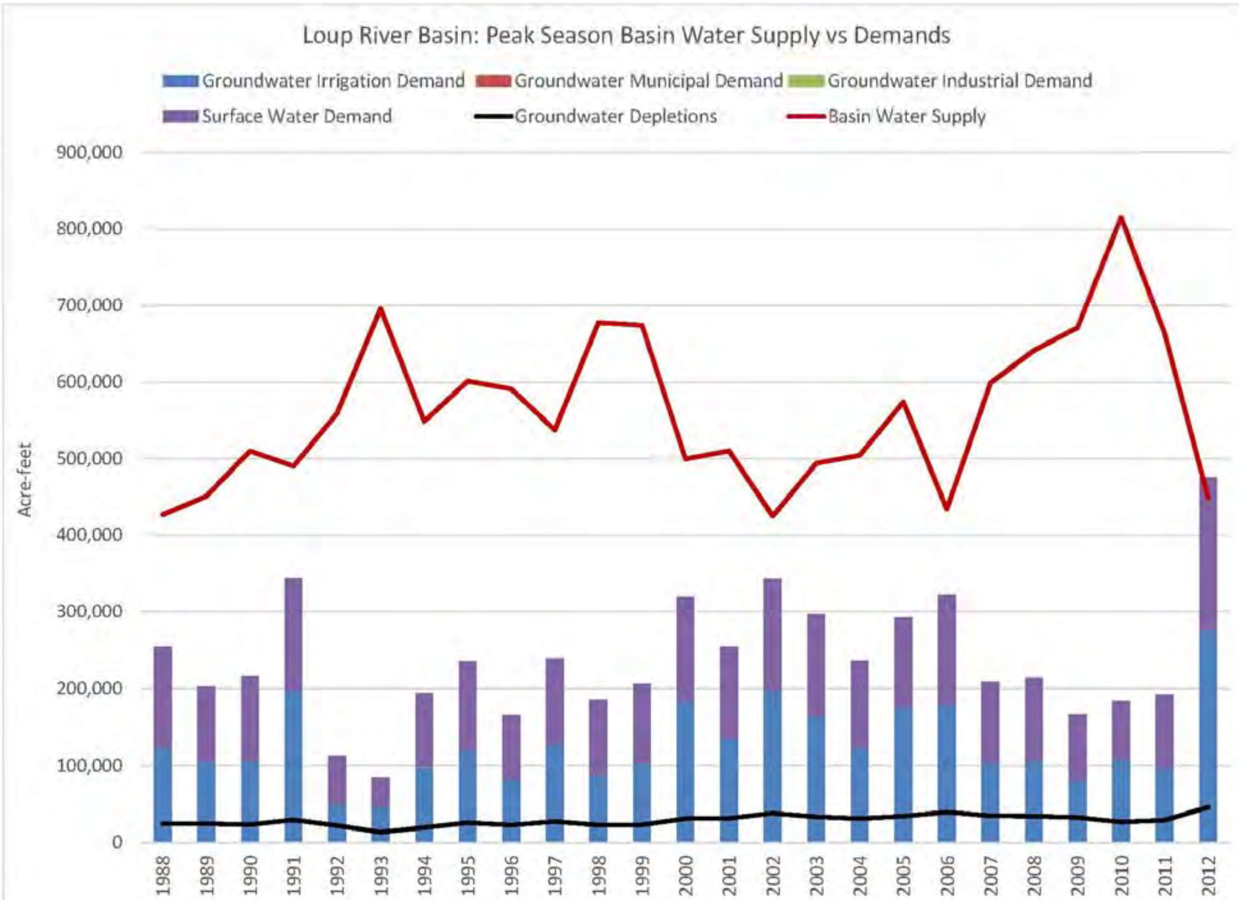
Note: Peak Season corresponds to June 1 through August 31.
Source: Basin Plan accounting

Figure 32: Estimated annual supply versus demands in the Loup River Basin (1988-2012)



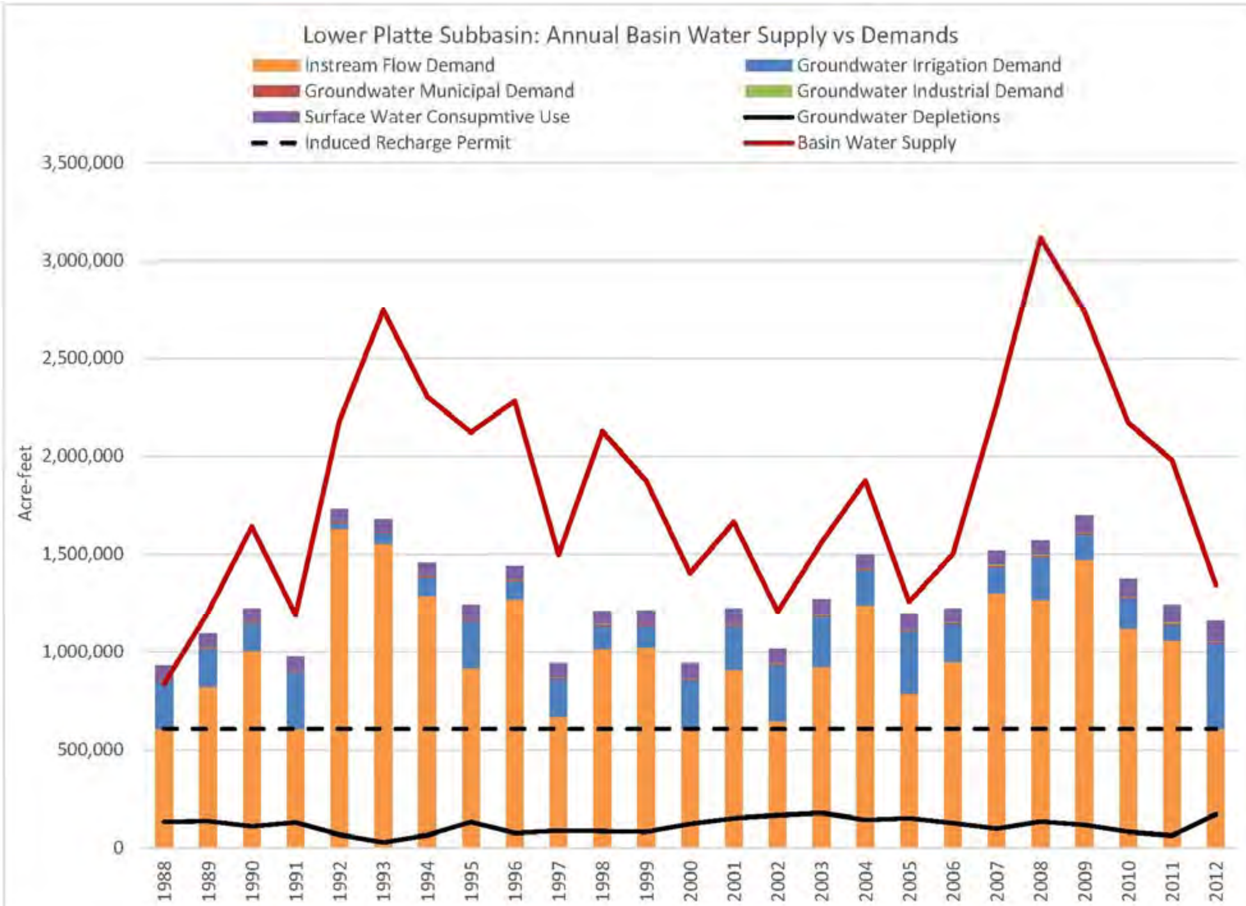
Source: Basin Plan accounting

Figure 33: Estimated peak season supply versus demands in the Loup River Basin (1988-2012)



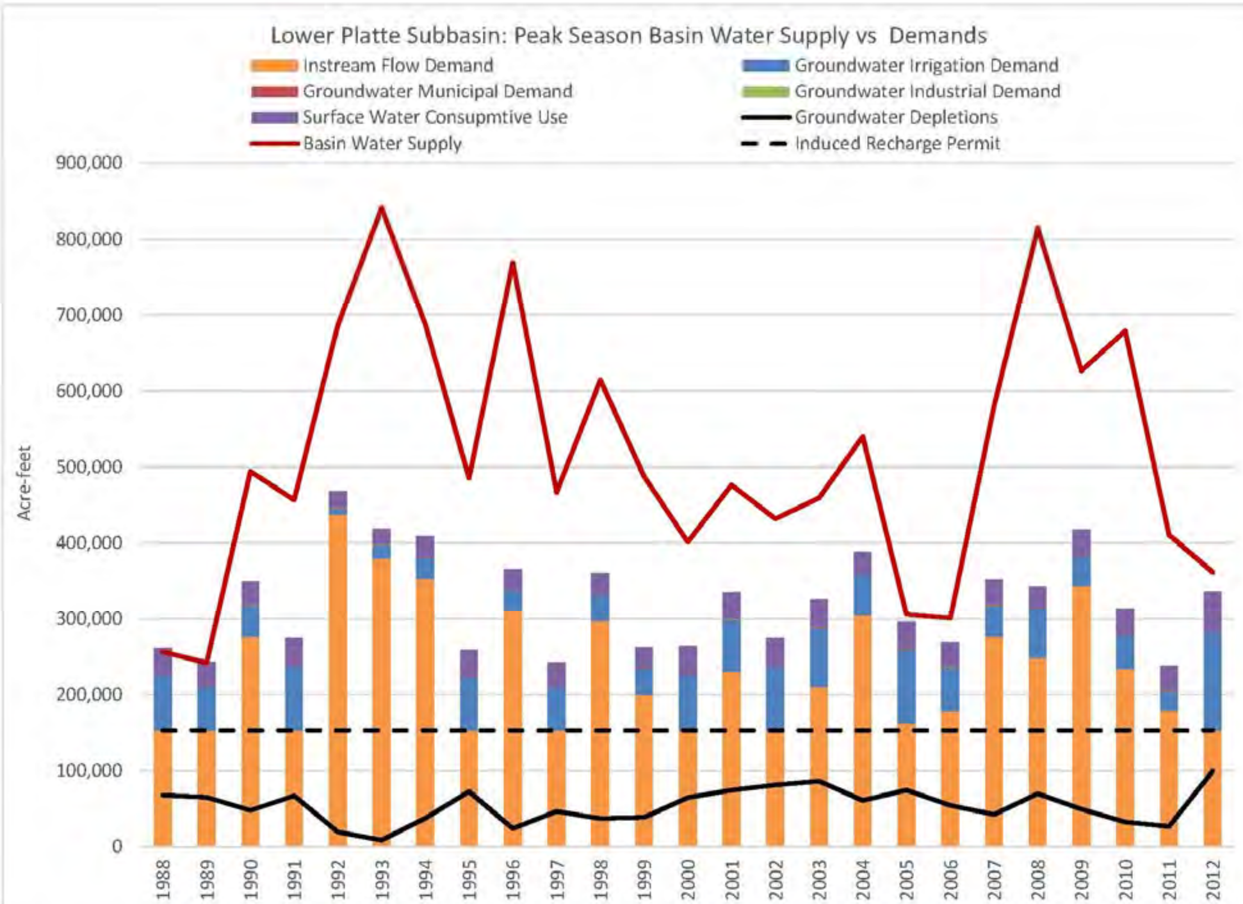
Note: Peak Season corresponds to June 1 through August 31.
Source: Basin Plan accounting

Figure 34: Estimated annual supply versus demands in the Lower Platte River subbasin (1988-2012)



Source: Basin Plan accounting

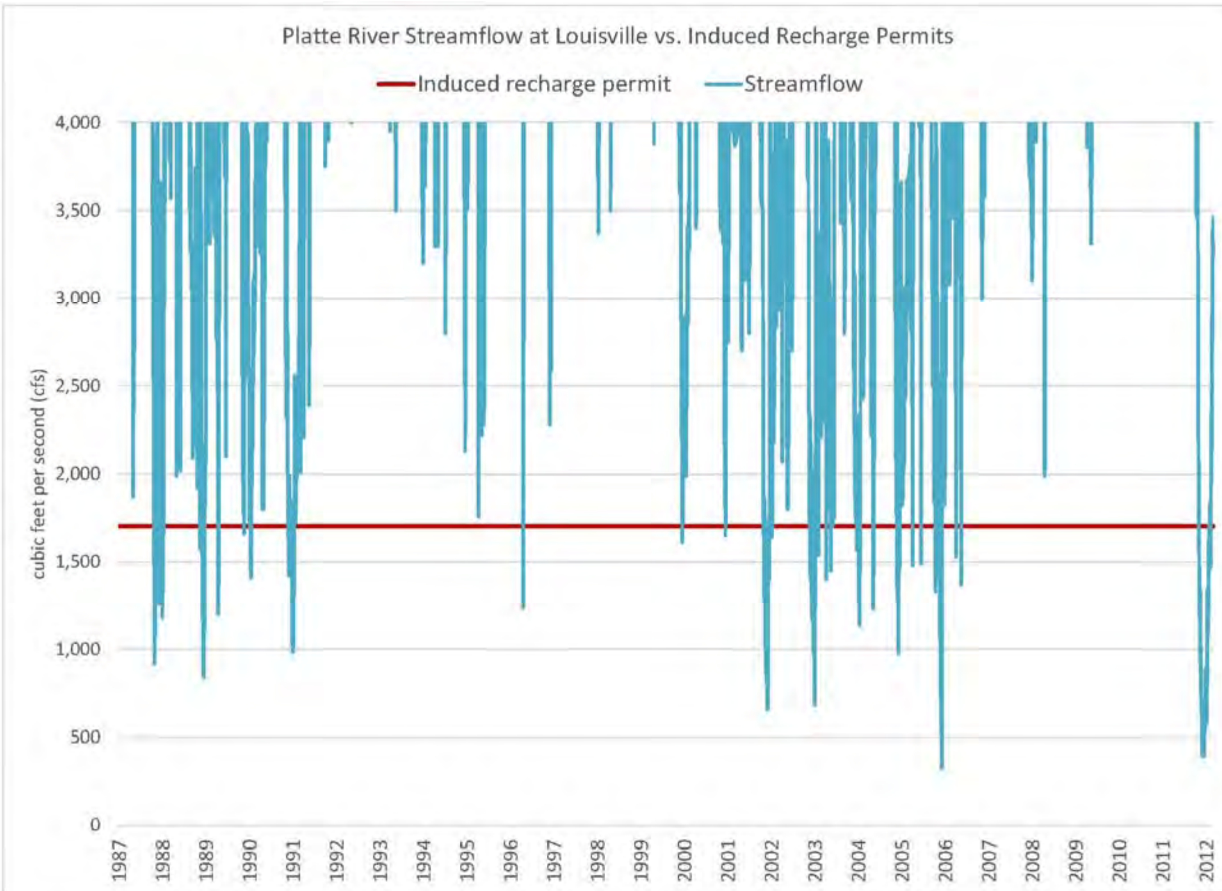
Figure 35: Estimated peak season supply versus demands in the Lower Platte River Subbasin (1988-2012)



Note: Peak Season corresponds to June 1 through August 31.
Source: Basin Plan accounting

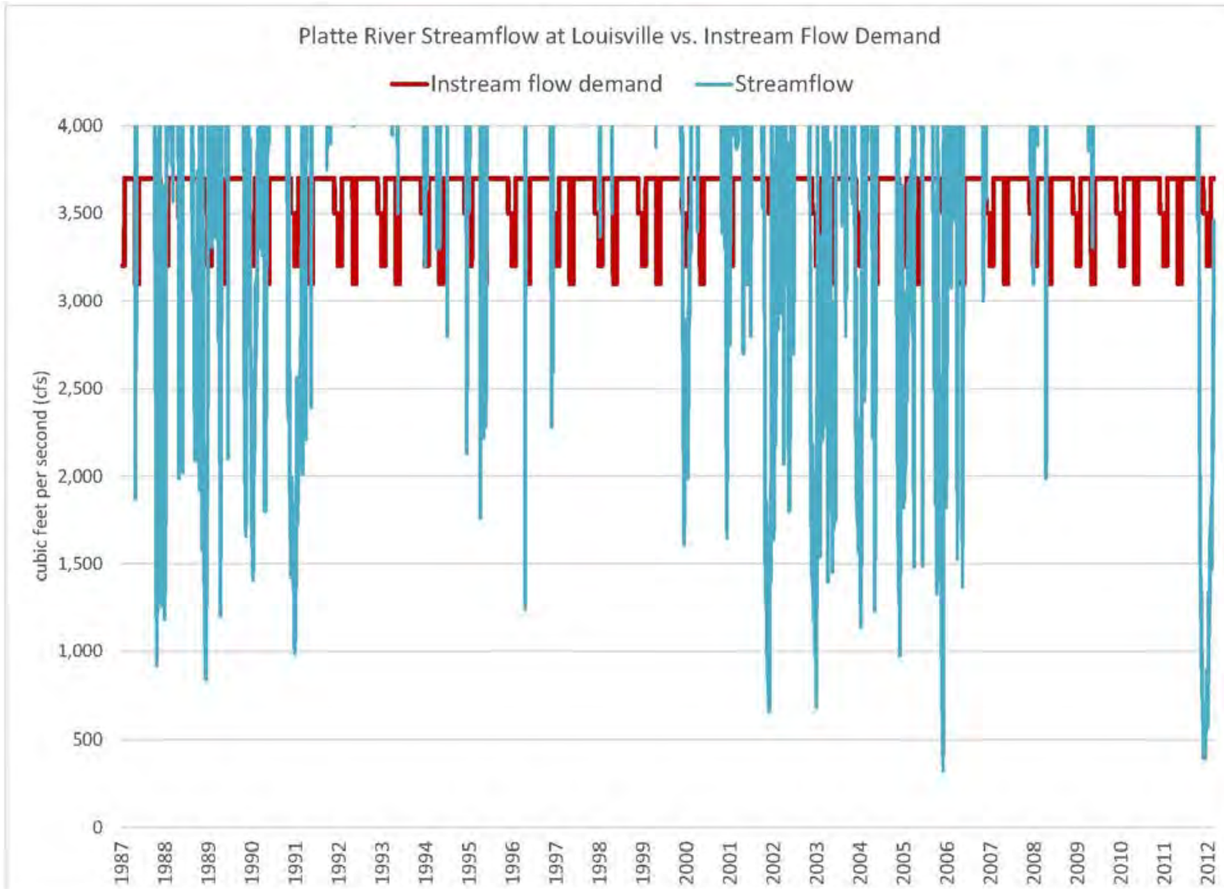
Figure 30 through Figure 35 considered basin water supplies versus demands on a seasonal basis. These plots reveal that, in general, basin supplies are adequate to meet basin demands on a seasonal basis. However, this generalization does not hold when considering supplies versus demands on a daily basis. Figure 36 and Figure 37 compare Platte River streamflow at Louisville against the induced groundwater recharge permit (1,704 cfs/day for MUD Platte West and LWS well fields) and the daily instream flow permit. Comparing streamflow versus demand on a daily basis reveals that the streamflow in the Lower Platte River has not been adequate to meet these instream or well field demands during drought years.

Figure 36: Platte River Streamflow at Louisville versus MUD and LWS induced groundwater recharge permits (1988-2012)



Note: MUD Platte West well field has an induced recharge permit of 1,000 cfs/day. LWS well field has an induced recharge permit of 704 cfs/day.
Source: Louisville daily stream flow was obtained from USGS.

Figure 37: Platte River streamflow at Louisville versus daily instream flow demand (1988-2012)



Source: Louisville daily stream flow was obtained from USGS.

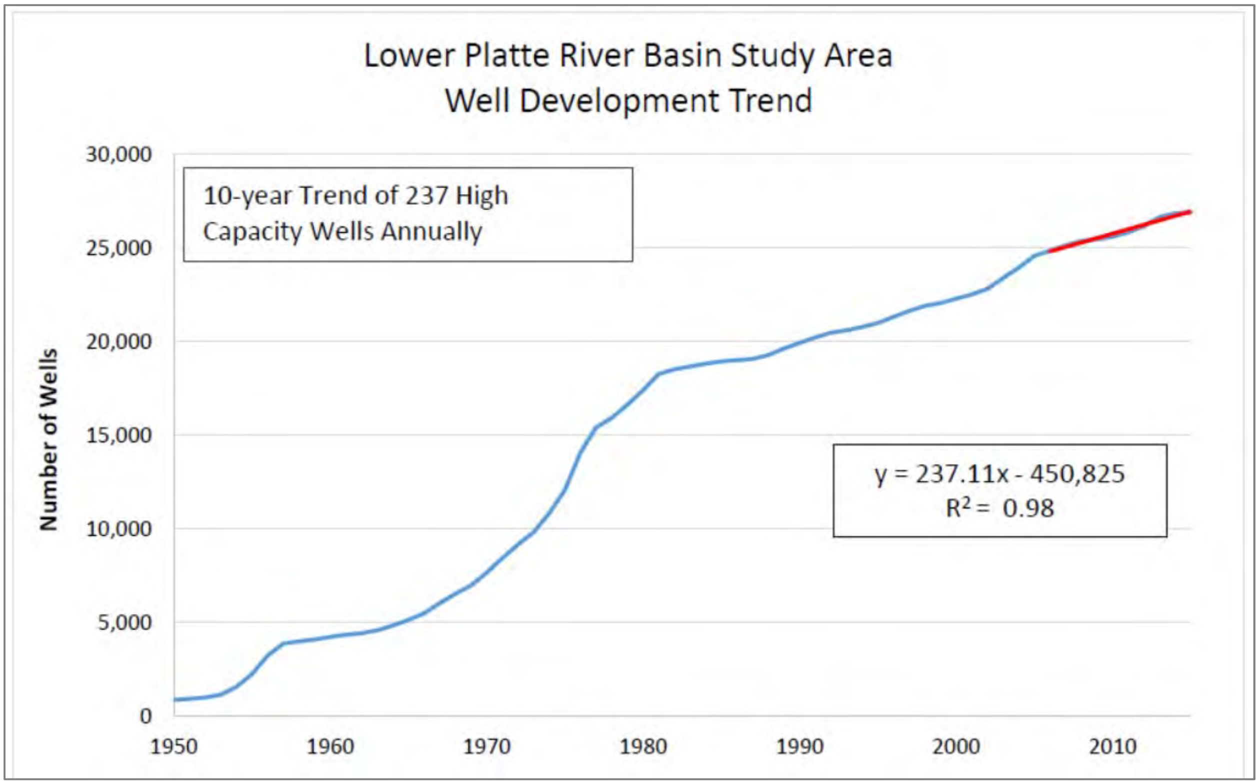
2.10 Consideration of Future Demands

Several factors influence future water demands. Population growth and expansion of irrigated acres are the two largest contributors to growth in new water use demands. In addition, climate change over the next century is project to increase demand for current and future uses.

2.10.1 Estimated Growth of Groundwater Development

Estimates of the number of high capacity groundwater wells (wells pumping greater than 50 gallons per minute [gpm]) that would be completed over the next 25 years, if no new legal constraints on the construction of such wells were imposed, were calculated based on extrapolating the present-day rate of increase in well development into the future (Figure 38). The present-day rate of development is based on the linear trend of the previous 10 years of development. Based on the analysis of the past 10 years of development, the rate of increase in high capacity wells is estimated to be 237 wells per year in the Lower Platte River Basin (NeDNR 2016).[9]

Figure 38: High Capacity Well Development, Lower Platte River Basin



Source: NeDNR Fully Appropriated Basin Report (NeDNR 2017)

2.10.2 Population Growth

Figure 39 includes population ranges for each county located within the Lower Platte River Basin. It should be noted that the populations presented are for the entire county, even though portions of the county may lie outside the boundaries of the Lower Platte River Basin. It is important to understand population trends to understand where growth is occurring, and consequently, increased municipal water use. It is equally important for drought preparedness to understand the population centers. The largest population centers in the Lower Platte River Basin are located in Douglas County, followed by Lancaster and Sarpy Counties.

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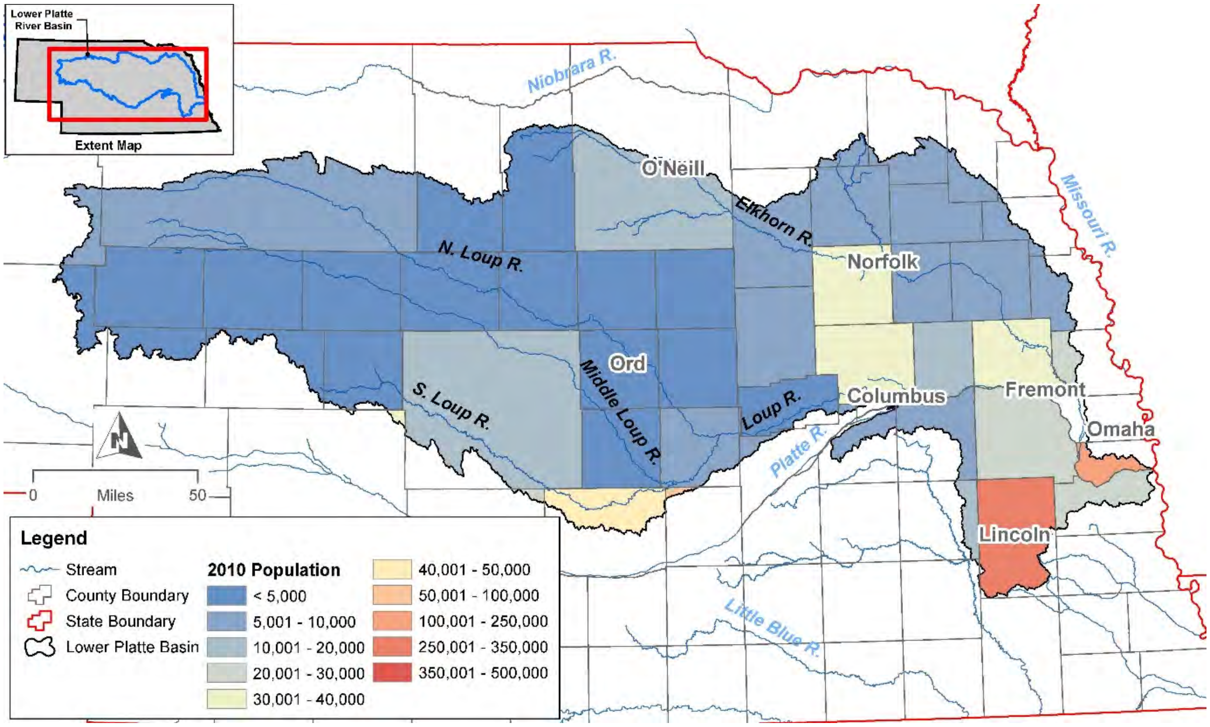
[9] See Section 2.0 on Lower Platte River Basin Coalition Basin Water Management Plan and limits of future groundwater and surface water development in the Lower Platte River Basin.

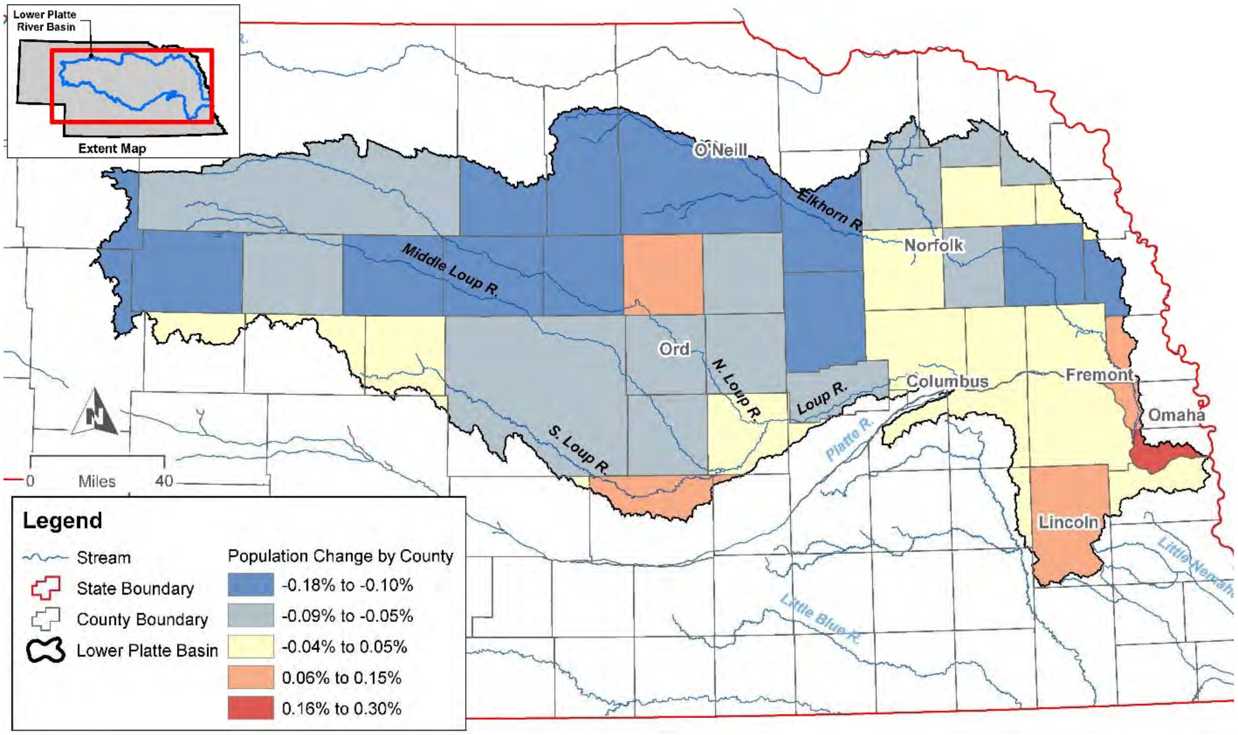
Figure 39: 2010 Population by County



Source: United States Census Bureau

Figure 40 shows the population growth by county between the 2000 and 2010 Census. In general, the rural areas of the Lower Platte River Basin have seen a decline in population (up to a maximum of 18 percent decline in certain areas) and population has increased by as much as 6 to 30 percent around major metropolitan areas (Washington, Douglas, Lancaster, and Sarpy Counties).

Figure 40: 2000 – 2010 Population Change by County



Source: United States Census Bureau

2.10.3 Projected Future Water Change in Lower Platte River Basin

Founded in 1988 by the World Meteorological Organization and United Nations, the Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science related to climate change. In 2007, IPCC published its *Fourth Assessment: Climate Change 2007,* which includes projected future climate change based on various future emission scenarios.

"Projected Freshwater Withdrawals in the United States under a Changing Climate" (Brown, Foti, and Ramirez 2013) utilizes three of these future emission scenarios in their analysis: A-1B, A-2, and B-2. These are described as follows:

- "The A-1B scenario expects a high level of technological change and rapid spread of new and efficient technologies, with a balanced emphasis on all energy sources. This scenario most closely extends historic population and economic growth patterns".
- "The A-2 scenario expects a lower rate of technological change and higher population growth". "Of the three scenarios, the A-2 scenario results in the highest […] atmospheric CO_2 concentration".
- "The B-2 scenario expects slower population growth but also a lower rate of technological change, with more emphasis on environmental protection". Of the three scenarios, […] B-2 [results in] the lowest atmospheric CO_2 concentration".

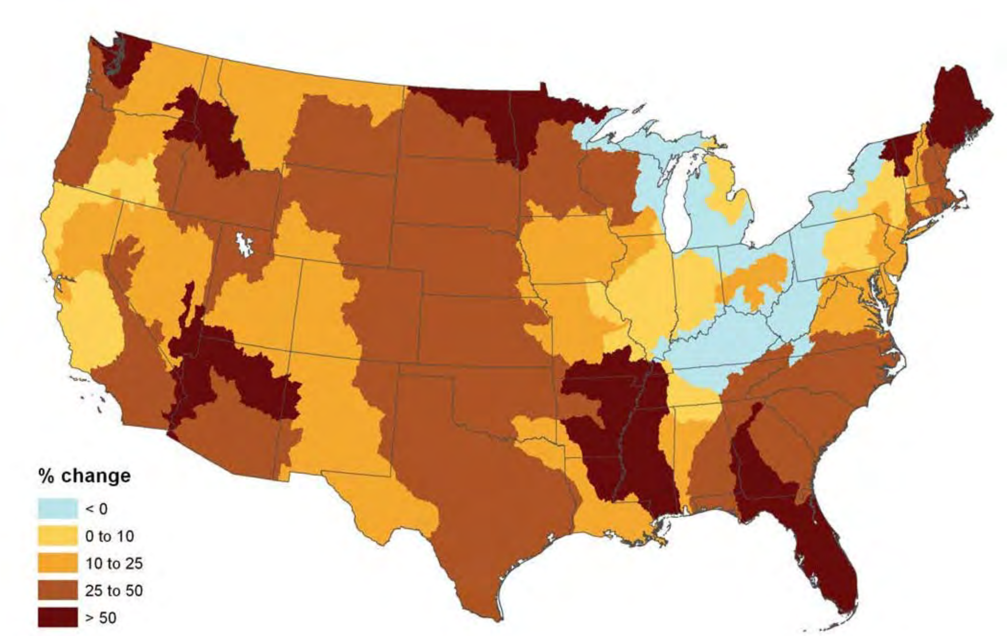
"Projected Freshwater Withdrawals in the United States under a Changing Climate" (Brown, Foti, and Ramirez 2013) investigated the effects of population growth effects on water withdrawals both with and without climate change to isolate plausible impacts from climate change alone.

> This assessment found that despite an expected 70 percent increase in population from 2005 to 2090 with the A-1B scenario, in the absence of future changes in climate, total water withdrawals in the U.S. would increase by only 13 percent, assuming water supply were no more limiting to growth in withdrawal than it has been in the recent past. (Brown, Foti, and Ramirez 2013)

This projection assumes "future gains in water use efficiency and reductions in irrigated area in the west" (2013). However, when climate change is considered, significant increases in water demand occur. "The U.S. withdrawals are projected to increase from 2005 to 2060 by 26 percent, 34 percent, and 5 percent for the A-1B, A-2, and B-2 scenarios, respectively; corresponding increases from 2005 to 2090 are 42 percent, 82 percent, and 12 percent respectively" (2013).

Figure 41 shows the geographic distribution of the projected increases in water withdrawal based on the A-1B scenario. It is shown that the Midwest is expected to have a 25 to 50 percent increase in water withdrawals under this scenario.

Figure 41: Projected Percent Change in Future Water Use in the United States from 2005 to 2060 for the A-1B Climate Scenario



Source: "Projecting Freshwater Withdrawals in the United States Under a Changing Climate" (Brown, Foti, and Ramirez 2013)

The study analyzed the increases isolated to climate change by evaluating effects of increasing temperature (T), decreasing precipitation (P), and increased evapotranspiration (ET_p).

A decrease in precipitation results in increases in agricultural irrigation and landscape watering. "Although specific regions of the U.S. are projected to experience increases or decreases in precipitation, at the national scale, little change in precipitation is projected" (Brown, Foti, and Ramirez 2013). As temperatures increase, there is an "increase[s] in water use at thermoelectric plants to accommodate the electricity needed to satisfy increasing space cooling demands that occur with rising temperatures" (2013). Increasing ET_p (corresponding to increased temperatures) results in increased agricultural irrigation and landscape watering "as plant water use responds to changes in atmospheric demand" (2013).

"The temperature effect is slightly larger than the precipitation effect, reaching 3 percent in 2060 and 5 percent in 2090" (2013). "The ET_p effect is [much larger], reaching 16 percent in 2055 and 23 percent in

2090" (2013). "The combined (temperature, precipitation, ET_p) effect of a changing climate is to increase total withdrawal in the U.S. by about 20 percent in 2060 and by about 30 percent in 2090, as compared to a future without climate change" (2013).

3.0 Vulnerability Assessment

"[V]ulnerability to drought is the product of numerous interrelated factors such as population growth and shifts, urbanization, demographic characteristics, water use trends, social behavior, and environmental susceptibilities" (Commission on Water Resource Management 2003). "The degree to which a population is vulnerable hinges on the ability to anticipate, to deal with, resist, and recover from the drought" (Commission on Water Resource Management 2003).

The effects from drought can be classified as direct and indirect. Direct effects include physical destruction of property, crops, natural resources, as well as public health and safety. Indirect effects are consequences of that destruction, such as temporary unemployment and business interruption (National Academy of Sciences 1999). "The most vulnerable portions of the state in terms of economic impact are cropland, pasture land for animals, recreational areas, and businesses that depend on agricultural industries for the bulk of their business. However, all areas of the state can be impacted by drought events" (Nebraska Emergency Management Agency [NEMA] 2014). Figure 42 summarizes sectors that are affected by drought (both agriculture and non-agriculture).

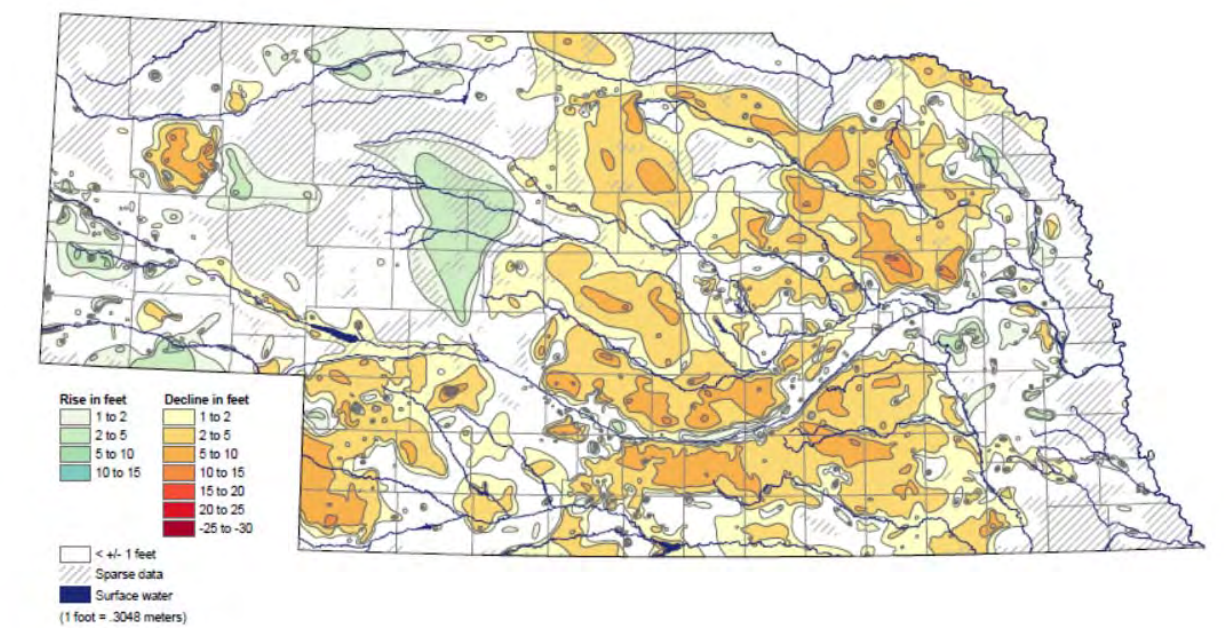
Figure 42: An Overview of Drought Economic Effects

Source: Adapted from Ding, Hayes, and Widhalm 2010

The drought of 2012 was considered the most severe single-year drought on record for Nebraska, with the driest May-to-September on record coupled with extreme heat. From the spring of 2012 to the spring of 2013, most wells in Nebraska experienced declines ranging from 1 foot to more than 20 feet. The increased demand for irrigation water combined with slower rates of recharge resulted in some of the greatest recorded 1-year water-level declines in Nebraska (Young, Burbach, and Howard 2013).

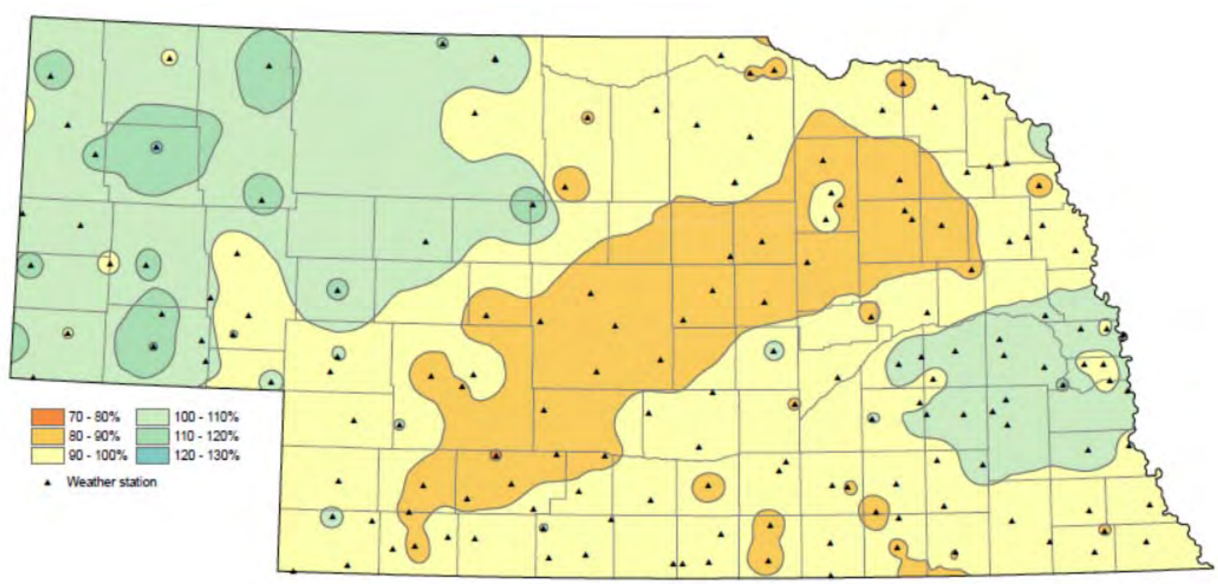
Streamflows respond more quickly to drought than to groundwater. "[T]he lag time between the beginning of a drought and the start of declining ground-water levels is longer than for streamflows. This time-lag pattern continues following the end of a drought when streamflows are returning to normal and ground-water levels may still be declining" (USGS 2005). Figure 43 shows the groundwater-level changes between 2011 and 2016. It can be seen that the groundwater levels in the majority of the Lower Platte River Basin have not fully recovered with groundwater levels 1 to 15 feet below 2011 levels. Figure 44 shows that precipitation for the same period was 70 to 100 percent of normal across the basin.

Figure 43: Groundwater-Level Changes in Nebraska – Spring 2011 to Spring 2016



Source: Nebraska Statewide Groundwater-Level Monitoring Report (Young et al. 2016)

Figure 44: Percent of Normal Precipitation – January 2011 to January 2016



Source: Nebraska Statewide Groundwater-Level Monitoring Report (Young et al. 2016)

3.1 Agricultural Sector

"Crop failures and pasture losses are the primary direct economic impact of drought within the agricultural sector. Drought-induced production losses cause negative food supply shocks, but the amount of incurred economic impacts and distribution of losses depends on the market structure and interaction between the supply and demand of agricultural products" (Ding, Hayes, and Widhalm 2010).

"Drought causes losses in crop yields and quality, insect infestation, disease and wildlife damage, and damage to grazing lands. Irrigated land does not produce as much during drought conditions, while production costs increase. Non-irrigated cropland will produce much less in a drought" (NEMA 2014). Drought causes long-term impacts on perennial crops and livestock productions that can last for years.

"Drought-induced losses are not completely borne by farmers; instead, a portion of the losses [is] passed on to consumers through increased prices. […] Additionally, farmers purchasing crop insurance will get part of their losses compensated by insurance companies, and some eligible farmers may receive direct disaster aid from the government" (Ding, Hayes, and Widhalm 2010). Additional indirect effects include reduced supplies to downstream industries, reduced fertilizer sales, and diminished expenditures (2010).

3.2 Non-agricultural Groundwater Users (Domestic, Commercial, Industrial)

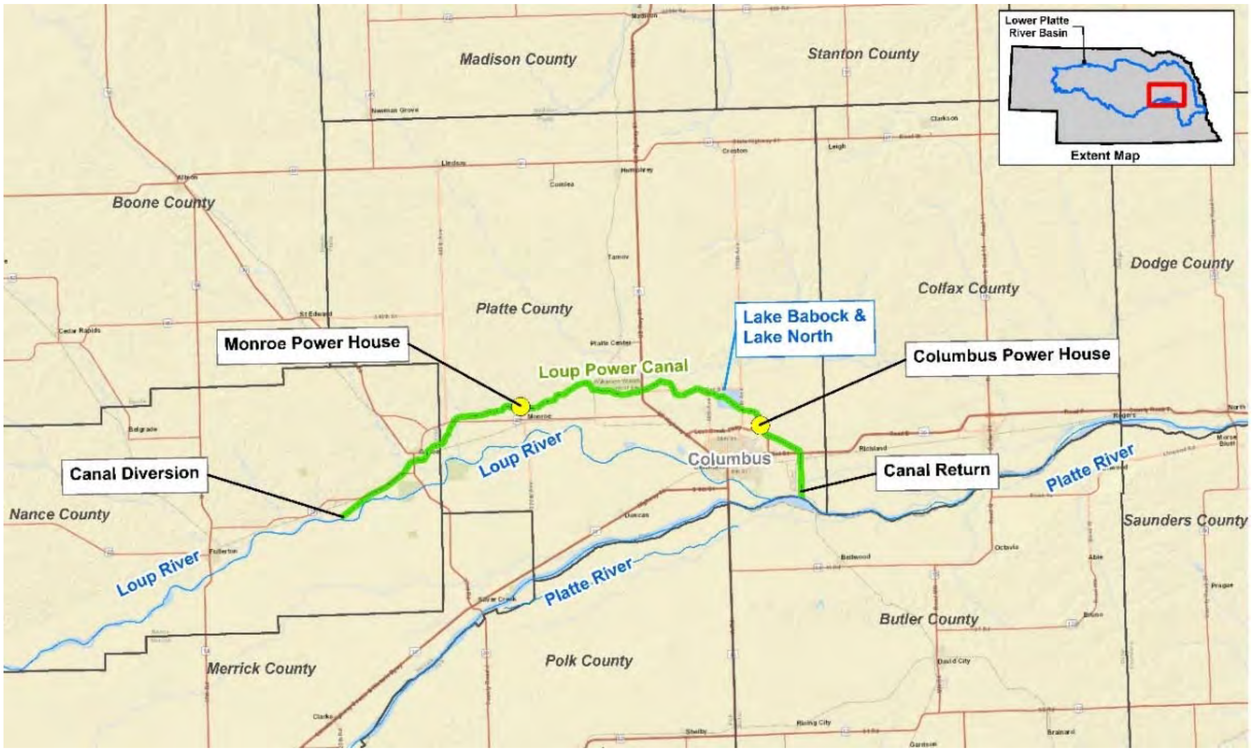
In addition to irrigation, groundwater supplies businesses and industries. The effect of drought on business depends on the importance of water for operations. Businesses such as grocers and food production, nurseries, car washes, and construction can be especially hit hard. For industries, key components of operations are dependent on water at a specific time. Droughts affect production, sales, and operations of these industries. Drought can lead to lost production, lost revenue, and increased costs to consumers.

As these industries increase pumping during a drought, they may cause the groundwater level to be drawn down, which can directly affect domestic groundwater users, potentially drawing the water table below their domestic wells and effectively cutting off their domestic water supply.

3.3 Energy Sector

The Loup River Public Power District, headquartered in Columbus, is a public power electric utility serving Boone, Colfax, Nance, and Platte Counties as well as a small portion of Madison County. Loup River Public Power District's Columbus Powerhouse is one of the largest hydro-generating houses in Nebraska. Loup River Public Power District Hydropower's service area covers approximately 2,028 square miles (Figure 45). Total population within Loup River Public Power District's service area numbers about 50,000. The canal diverts water from the Loup River into the Loup Power Canal to the Monroe powerhouse. The canal then carries water from the Monroe plant to two regulating reservoirs north of Columbus that feed the Columbus powerhouse. These lakes have enough storage capacity for 48 hours of emergency hydro-generation. The Loup Power Canal then returns to the Platte River. Less water flowing to the hydro-generating facilities limits the ability to generate energy.

Figure 45: Loup Public Power Canal System



3.4 Public Water Supply

Public water systems along the Lower Platte River are largely dependent on aquifers hydrologically connected to the river and its tributaries and dependent on streamflow for recharge. Omaha and Lincoln, Nebraska's two largest municipalities, rely heavily on water supplies in the Lower Platte River to support well-field operations adjacent to the river. MUD's water system receives roughly half of its capacity from the Lower Platte River and the other half is received from the Missouri River. The capacity of Lincoln Water Systems' Ashland Well-field is directly dependent on flows in the Lower Platte River adjacent to the well-field. The vulnerability of public water supply during drought is amplified in the Lower Platte River Basin due to the lack of redundant water sources. With the exception of MUD, public water systems along the Lower Platte River rely solely on the aquifers hydrologically connected to the Platte River and reliant on its flows for recharge.

3.4.1 Water Supply Capacity Limitations

The supply capacity of the Lincoln well-field has a maximum instantaneous capacity of between 135 MGD and 145 MGD, depending on streamflow conditions (City of Lincoln 2018). The summer seasonal capacity of the well-field for 60- to 90-day production capacity ranges from 85 to 90 MGD when streamflow in the Platte River at Ashland is less than 1,000 cfs. Figure 19 (Section 2.7.2) relates the projected demand to the river flow-dependent pumping capacity of Lincoln well-field. There is a projected supply deficit with the instantaneous and short-term pumping capacity of the well-field, where it is projected that the well-field may not be able to meet the maximum day demand as early as 2030 during low-flow periods. In addition to water quantity stresses on these well-fields, previous droughts have provided indications that the well-fields may become more vulnerable to water quality issues during these periods of prolonged drought.

MUD has three supply locations: 1) Florence Plant in north Omaha that obtains its water from the Missouri River with a capacity of 160 MGD; 2) Platte West well-field located south of Venice that obtains its water from the Platte River with a capacity of 100 MGD; and 3) Platte South well-field located near La Platte that obtains water from the Platte River with a capacity of 60 MGD. Total system output for MUD from all three facilities is 320 MGD. MUD has the ability to use all three of their facilities interchangeably to meet their demand.

MUD is currently undergoing an analysis of both its Platte West and Platte South well-fields capacities under drought conditions. According to MUD, their system capacity is not expected to be a concern for the foreseeable future. During the 2012 drought, MUD voluntarily reduced operations at Platte West to 30 to 40 MGD and increased operations at the Florence plant.

3.4.1.1 Infrastructure Failure or Needed Upgrades

Extreme heat during drought can cause increased water main breaks due to dry soil conditions and increase water volumes being pumped through the distribution system. In the summer of 2012 (June, July, and August), 217 water main breaks were reported by MUD officials in Omaha. For comparison, the 10-year average from 2007 to 2016 was 118 breaks for the same period. LWS experienced similar increases in 2012 with a record 234 water main breaks for the year, or a 65 percent increase in breaks.

3.4.1.2 Increased Water Treatment Costs

Drought conditions that result in significant declines in groundwater elevations have the potential to negatively affect water quality; specifically related to iron, manganese, and levels in the water supplies.

Salt Creek is a smaller tributary to the Platte River in terms of flow, can affect water quality in the lower reach of the Platte River as it becomes a larger portion of the total streamflow because of large dissolved solids concentrations in shallow groundwater originating from mineralized areas of the Dakota Sandstone.

3.4.1.3 Single-Source Supply and Lack of Redundancy

An additional risk to the water supply in the Lower Platte River Basin is the lack of redundant surface water sources. While Lake McConaughy, a major surface water reservoir, is located in the Upper Platte River Basin, the Platte River often becomes disconnected during times of low-flow (see Section 2.4). Additionally, LWS does not hold a water right to storage water from Lake McConaughy. There are no major surface water supply storage water reservoirs in the Lower Platte River Basin downstream of Duncan. The sole water source for the LWS is the Platte River.

3.5 Recreational and Environmental Sector

Droughts can be detrimental to the recreational and environmental sectors. The result of sustained drought conditions is decreased streamflow. Streamflows support threatened and endangered species that can become vulnerable during drought periods. The endangered species that could be the most affected by drought include the interior least tern, the piping plover, and the pallid sturgeon. Instream-flow targets represent discharge conditions that are intended to result in favorable habitat for pallid sturgeon in the lower Platte River. For the pallid sturgeon, the U.S. Fish and Wildlife Service identified favorable river conditions, including the presence of sandy bottoms, islands or bars, and sediment-rich waters. Factors contributing to the decline in abundance of pallid sturgeon are diverse and in some cases incompletely documented. High water temperatures and loss of connectivity during years of low discharge may be important limiting factors (National Research Council 2005).

“The piping plover is endangered due to the loss of suitable nesting areas. During prolonged droughts, grasses and vegetation can begin growing on the beaches and sandbars along the Platte River making these areas unsuitable for plover nesting. The interior least tern prefers the sandbars along the Platte River for nesting. The same issue that causes a problem for the plover may also present a problem for the least tern” (Ehrman et al. 2015).

Low streamflows are associated with higher water temperatures and degraded water quality that can lead to fish kills and increased water treatment costs. The 2012 drought and extended high air temperatures caused a number of Nebraska’s rivers and stream to be reduced to low-flow, and in some instances, no flow. As a result, a large number of fish kills were caused by thermal stress. These same weather conditions likely caused many of the “low dissolved oxygen” fish kills that were reported in ponds, lakes, and reservoirs (NDEQ 2013).

Lower lake levels are associated with droughts. Lower lake levels have higher water temperatures and are correlated with blue-green algae blooms (NDEQ 2013). Lower lake levels result in decreased boating, fishing, and tourism.

Fish kills in lakes are typically caused by low dissolved oxygen concentrations stemming from eutrophic conditions. Eutrophication is a term that describes water quality conditions as a lake or reservoir ages, which is common during droughts when fresh inflows into the lake or reservoir are limited or non-existent. Lakes or reservoirs that are eutrophic tend to be shallow with high nutrient concentrations and exhibit frequent algae blooms, warmer water temperatures, and lower dissolved oxygen concentrations. “As water warms, its ability to retain dissolved oxygen is lessened. If warm water conditions persist, the demand for oxygen will eventually surpass the supply and a fish kill will occur” (NDEQ 2013).

3.6 Public Health Sector

The public health sector is adversely affected by drought through soil erosion and wildfires, which: degrade air quality; result in toxins in water bodies; increase presence of mosquitos and rodents; and adversely affects public mental health. The Center for Disease Control and Prevention (CDC) has assessed previous droughts and identified the following possible public health implications due to drought (CDC 2012):

- “compromised quantity and quality of drinking water;
- increased recreational risks;
- effects on air quality;
- diminished living conditions related to energy, air quality, and sanitation and hygiene;
- compromised food and nutrition; and
- increased incidence of illness and disease”. (CDC 2012)

During a drought, effects on air quality “make chronic respiratory illnesses worse and increase the risk for respiratory infections like bronchitis and pneumonia” (CDC 2012).

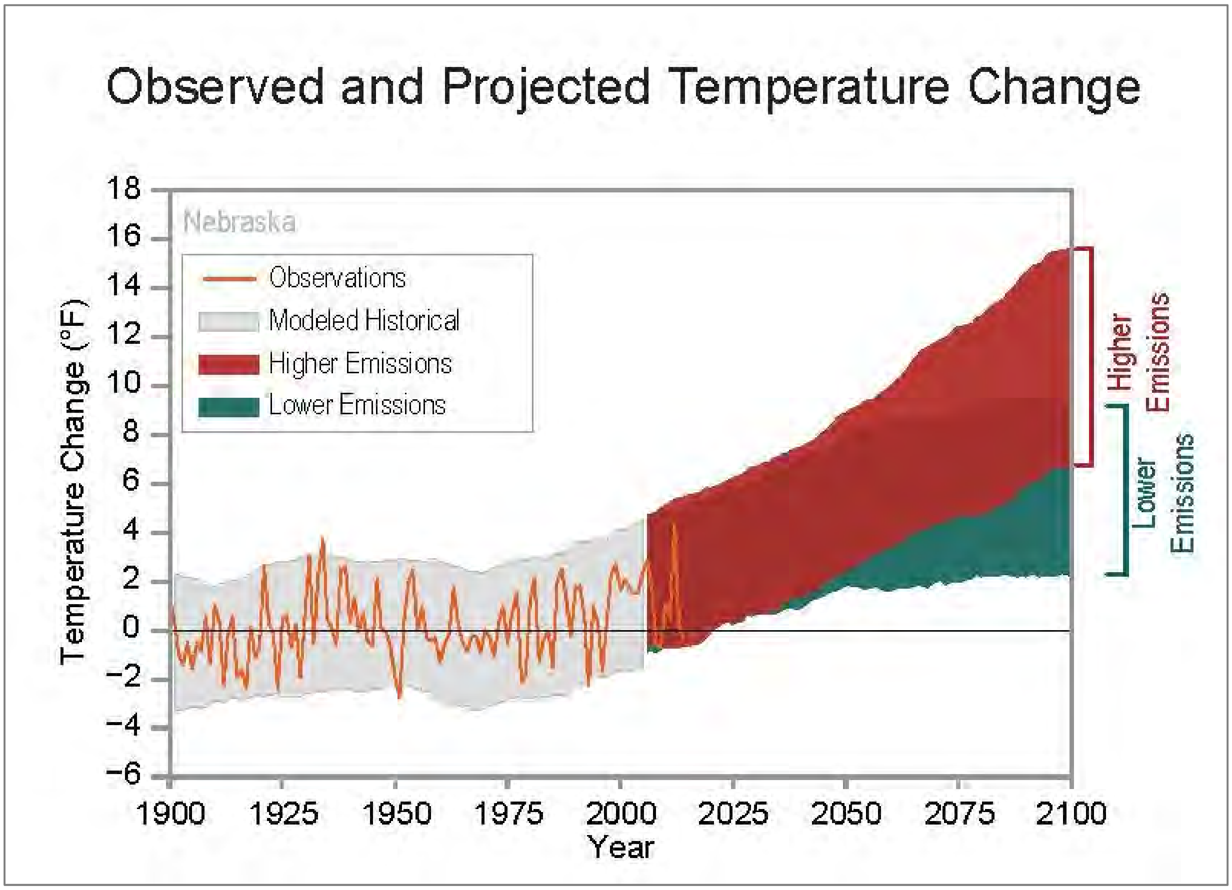
3.7 Potential Future Vulnerabilities attributable to Climate Change

Changes in extreme weather and climate events, such as heat waves and droughts, are the primary way that most people experience climate change. Human-induced climate change has already increased the number and strength of some of these extreme events. Over the last 50 years, much of the U.S. has seen increases in prolonged periods of excessively high temperatures, heavy downpours, and in some regions, severe floods and droughts (Melilo, Richmond, and Yohe 2014).

Section 2.8.3 discusses potential increases in groundwater withdrawals that are attributed to climate change.

Nebraska has experienced an overall warming of about 1 degree Fahrenheit (°F) since 1895. The vast majority of this warming has occurred during the winter months. The 10 warmest years on record have occurred since 1997 (Bathke et al. 2014).

Figure 46: Observed and Projected Temperature Change in Nebraska



Source: NOAA National Centers for Environmental Information 2017.

Figure 46 shows observed and projected changes (compared to 1901-1960 average) in near surface air temperature in Nebraska. Unprecedented warming is projected during the twenty-first century. Less warming is expected under lower emissions future (the coldest years being about as warm as the warmest years in the historical record; shown in green in the figure) and more warming under a higher emissions future (the hottest years being about 11°F warmer than the hottest year on historical record; shown in red in the figure).

A major concern for Nebraska and other central Great Plains states is the current and continued large projected reduction in snowpack for the central and northern Rocky Mountains. This is due to both a reduction in overall precipitation (rain and snow) and warmer conditions, meaning more rain and less snow, even in winter. Summer flows could be greatly reduced in coming years (Bathke et al. 2014).

The study presented in “Why Do Different Drought Indices Show Distinct Future Drought Risk Outcomes in the U.S. Great Plains?” suggests potential for chronic drought across the Great Plains in the future (Feng et al. 2017). Future drought will present a challenge for managing the water resources and agriculture.

While the Drought Plan assesses the vulnerabilities in the Lower Platte River Basin as a whole, the mitigation measures and response actions presented herein are focused on augmenting surface water supplies in the Lower Platte River primarily for public water supplies, while referencing additional drought management resources available through the University of Nebraska, National Drought Mitigation Center, and other sources. It is believed that in addressing the water supply shortages in the Lower Platte River, ancillary benefits to the remaining sectors, including irrigation, power, environmental, and recreational, would be realized.

4.0 Drought Monitoring

Each of the Consortium members has some form of drought monitoring and triggers for response actions. These individual plans are discussed in detail in Appendix A. A summary of the types of drought monitoring available is discussed in the following sections.

4.1 Defining a Drought

There are many definitions for drought, but all definitions include periods of dryness and below average precipitation. The National Drought Mitigation Center (NDMC) lists four types of droughts: meteorological drought, agricultural drought, hydrological drought, and socioeconomic drought. “Meteorological drought is defined usually based on the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period.” “Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and so forth.” “Hydrological drought is associated with the effects of periods of low precipitation events (including snowfall) on surface or subsurface water supply (that is, streamflow, reservoir and lake levels, and groundwater levels). The frequency and severity of a hydrological drought is often defined on a watershed or river basin scale.” “Socioeconomic drought occurs when the demand for an economic good exceeds water supplies available to produce the quantity of economic good needed because of a weather-related shortfall in water supply” (for example, a hydropower plant that relies on streamflow whose production may be limited during low streamflow events) (NDMC 2018) (Figure 47).

Figure 47: Drought Transfer Process and Interactions

Source: Adapted from National Drought Mitigation Center 2018

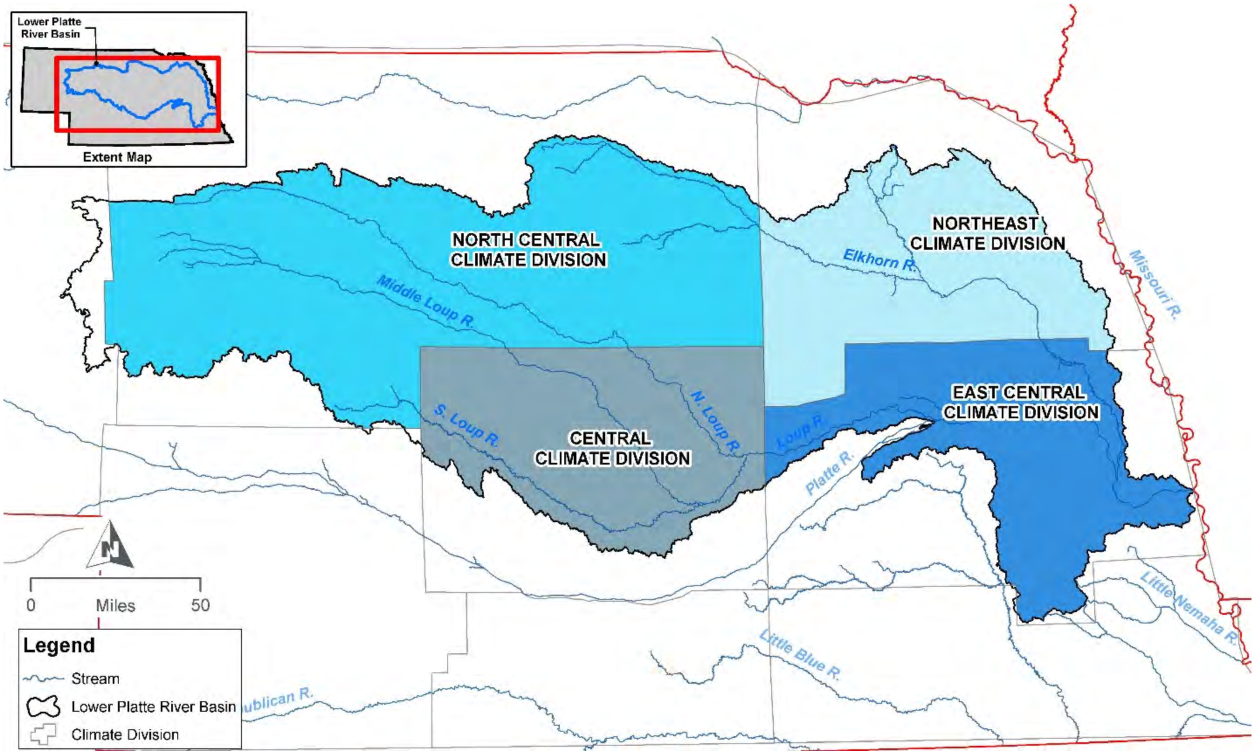
4.2 Hydro Climate Indices

Hydro climate indices assess drought severity using inputs such as precipitation, temperature, streamflow, groundwater and reservoir levels, soil moisture, or snowpack. Indices are essential for tracking and anticipating droughts as well as providing historical reference. Indices provide useful triggers to help direct decision-makers toward proactive risk management. Drought severity is best evaluated based on multiple indicators.

Two hydro climate indices have been selected as appropriate for drought determination in the Lower Platte River Basin. The first index is the Palmer Drought Severity Index (PDSI). Based on USGS streamflow record data, monthly streamflow on the Platte River from Duncan to Louisville, correlated significantly with the monthly PDSI. (USGS 2008) The second index is the Standardized Precipitation Index (SPI). The World Meteorological Organization and the NDMC endorse the SPI as the standard for determining the existence of meteorological drought (Hayes et al. 2011).

The National Oceanic and Atmospheric Administration (NOAA) climate divisions for Nebraska are shown in Figure 48. The Lower Platte River Basin encompasses portions of the North Central, Northeast, Central, and East Central climate divisions. A weighted average of the indices for these four climate divisions should be used for evaluating drought conditions in the Lower Platte River Basin.

Figure 48: National Oceanic and Atmospheric Administration Climate Divisions for Nebraska



Source: Map layer downloaded from Climate Prediction Center 2018.

4.2.1 Palmer Drought Severity Index

The PDSI is calculated weekly by the NOAA Climate Prediction Center (CPC). Zero or near zero PDSI values indicate normal conditions, a negative PDSI value indicates drought, and a positive PDSI value indicates a wet period. Table 6 lists the PDSI classifications for drought.

Table 6: Palmer Drought Severity Index Classifications

Index Value	Description	Index Value	Description
4.0 or above	Extremely wet	-0.99 to -0.5	Incipient dry spell
3.00 to 3.99	Very wet	-1.99 to -1.00	Mild drought
2.00 to 2.99	Moderately wet	-2.99 to -2.00	Moderate drought
1.00 to 1.99	Slightly wet	-3.00 to -3.99	Severe drought
0.5 to 0.99	Incipient wet spell	-4.00 or less	Extreme drought
-0.49 to 0.49	Near normal	---	---

Source: NOAA National Weather Service Climate Prediction Center 2005.
Note: The U.S. Drought Monitor includes one additional category "exceptional drought" for index values less than -5.

4.2.2 Standardized Precipitation Index

The SPI is based on precipitation only, and does not consider soil moisture balance like PDSI. Similar to PDSI, zero or near zero SPI values indicate normal conditions, a negative SPI indicates drought, and a positive value for a wet period. Table 7 lists the SPI classification for drought.

Table 7: SPI Classifications

Index Value	Description	Index Value	Description
2.0 or greater	Extremely wet	-1.49 to -1.00	Moderate drought
1.50 to 1.99	Severely wet	-1.99 to -1.50	Severe drought
1.00 to 1.49	Moderately wet	-2.0 or less	Extreme drought
-0.99 to 0.99	Near normal	---	---

Source: National Oceanic Atmospheric Administration National Weather Service, Climate Prediction Center

The historic PDSI from 1900 to 2017 was compared to the historic 1-month, 3-month, 6-month, and 12-month SPI from the preceding months back through July of the previous year to determine if SPI correlated well with PDSI. These plots, as well as further discussion of how the PDSI and SPI are derived, are found in Appendix B.

4.3 Historic Occurrences of Drought

The Platte River July streamflow at Louisville was plotted as a percentage above or below the median July flow for the period 1953 to 2017 against the historic PDSI to understand the historic droughts. The PDSI value in these plots is a composite of the value for the four climate divisions encompassing the Lower Platte River Basin: East Central, Northeast, Central and North Central divisions; these plots are located in Appendix B.

The U.S. Drought Risk Atlas (a product of the NDMC) summarizes the occurrence of drought by climate division, hydro climate indices, and severity as a percentage of the period-of-record. The historic occurrence of drought for the four climate divisions that encompass the Lower Platte River Basin are shown in Table 8 through Table 11.

Table 8: North Central Climate Division (Division 02): Percent of Time Spent in Drought – 1900 to 2016

PDSI			
Index Value	Percent of Time Spent in Drought	Drought Severity	Recurrence Interval
-2 < PDSI ≤ -1	34%	Mild	1 out of 3 years
-3 < PDSI ≤ -2	21%	Moderate	1 out of 5 years
-4 < PDSI ≤ -3	12%	Severe	1 out of 8 years

PDSI Index Value	Percent of Time Spent in Drought	Drought Severity	Recurrence Interval
PDSI ≤ -4	6%	Extreme	1 out of 17 years

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)
Notes: PDSI = Palmer Drought Severity Index.

Table 9: Northeast Climate Division (Division 03): Percent of Time Spent in Drought – 1900 to 2016

PDSI Index Value	Percent of Time Spent in Drought	Severity	Recurrence Interval
-2 < PDSI ≤ -1	26%	Mild	1 out of 4 years
-3 < PDSI ≤ -2	16%	Moderate	1 out of 6 years
-4 < PDSI ≤ -3	10%	Severe	1 out of 10 years
PDSI ≤ -4	7%	Extreme	1 out of 14 years

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)
Notes: PDSI = Palmer Drought Severity Index.

Table 10: Central Climate Division (Division 05): Percent of Time Spent in Drought – 1900 to 2016

PDSI Index Value	Percent of Time Spent in Drought	Severity	Recurrence Interval
-2 < PDSI ≤ -1	31%	Mild	1 out of 3 years
-3 < PDSI ≤ -2	18%	Moderate	1 out of 6 years
-4 < PDSI ≤ -3	11%	Severe	1 out of 9 years
PDSI ≤ -4	8%	Extreme	1 out 0f 13 years

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)
Notes: PDSI = Palmer Drought Severity Index.

Table 11: East Central Climate Division (Division 06): Percent of Time Spent in Drought – 1900 to 2016

PDSI Index Value	Percent of Time Spent in Drought	Severity	Recurrence Interval
-2 < PDSI ≤ -1	28%	Mild	1 out of 4 years
-3 < PDSI ≤ -2	17%	Moderate	1 out of 6 years
-4 < PDSI ≤ -3	10%	Severe	1 out of 10 years
PDSI ≤ -4	6%	Extreme	1 out of 17 years

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)
Notes: PDSI = Palmer Drought Severity Index.

In general, the PDSI and SPI compare reasonably well; however, the SPI does appear to predict fewer occurrences of severe and extreme droughts than the PDSI. This is likely because the SPI and PDSI tell different stories. The PDSI considers the water balance and gives a more complete representation of conditions; however, the PDSI is a cumulative function, where the PDSI from previous months can affect the PDSI of a current month making it harder to predict flash droughts. The SPI considers only precipitation anomaly compared to historic normal precipitation. Therefore, if precipitation returns to normal conditions, the SPI may indicate the drought is over whereas the PDSI may not.

For these reasons, both the SPI and PDSI should be considered together when evaluating drought conditions.

Analysis of historic PDSI values from 116 years of data reveal that mild, moderate, severe, and extreme droughts can be expected to occur in the Lower Platte River Basin once every three, six, nine, and fourteen years, respectively.

From 1900 to 2016, the most severe droughts occurred in the 1930's, 1950's, 1980's, early 2000's and 2012-2013. Table 12 through Table 15 list the number of months spent in specific drought periods by category.

Table 12: North Central Climate Division (Division 02): Number of Months Spent in Specific Drought Periods

		Number of Months in Drought			
PDSI Index Value	Severity	1933-1941	1953-1958	2002-2004	2012-2014
-2 < PDSI ≤ -1	Mild	101	40	31	12
-3 < PDSI ≤ -2	Moderate	85	28	28	10
-4 < PDSI ≤ -3	Severe	56	24	23	9
PDSI ≤ -4	Extreme	37	19	3	9

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)

Notes: PDSI = Palmer Drought Severity Index.

Table 13: Northeast Climate Division (Division 03): Number of Months Spent in Specific Drought Periods

PDSI Index Value	Severity	Number of Months in Drought 1933-1941	1953-1958	2002-2004	2012-2014
-2 < PDSI ≤ -1	Mild	100	28	11	14
-3 < PDSI ≤ -2	Moderate	93	25	9	12
-4 < PDSI ≤ -3	Severe	62	23	2	10
PDSI ≤ -4	Extreme	44	21	0	9

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)
Notes: PDSI = Palmer Drought Severity Index.

Table 14: Central Climate Division (Division 05): Number of Months Spent in Specific Drought Periods

PDSI Index Value	Severity	Number of Months in Drought 1933-1941	1953-1958	2002-2004	2012-2014
-2 < PDSI ≤ -1	Mild	101	58	29	24
-3 < PDSI ≤ -2	Moderate	83	50	26	19
-4 < PDSI ≤ -3	Severe	75	38	12	14
PDSI ≤ -4	Extreme	68	26	3	8

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)
Notes: PDSI = Palmer Drought Severity Index.

Table 15: East Central Climate Division (Division 06): Number of Months Spent in Specific Drought Periods

PDSI Index Value	Severity	Number of Months in Drought 1933-1941	1953-1958	2002-2004	2012-2014
-2 < PDSI ≤ -1	Mild	100	47	34	15
-3 < PDSI ≤ -2	Moderate	92	40	22	10
-4 < PDSI ≤ -3	Severe	77	26	0	9

		Number of Months in Drought			
PDSI Index Value	Severity	1933-1941	1953-1958	2002-2004	2012-2014
PDSI ≤ -4	Extreme	55	23	0	8

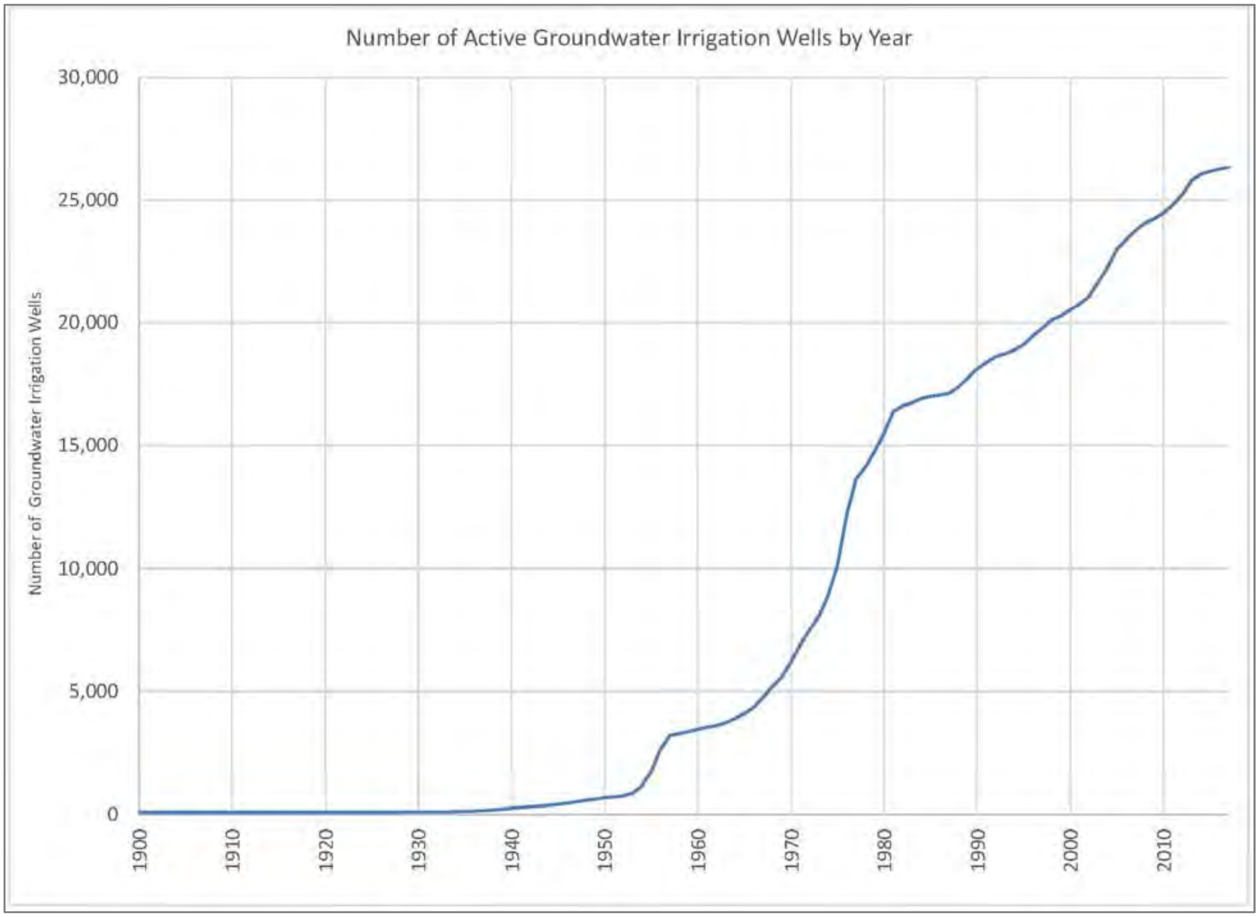
Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)
Notes: PDSI = Palmer Drought Severity Index.

The longest drought post-1900 was the Dust Bowl (1933-1941) that resulted from severe drought and poor farming practices without crop rotation, cover crops, or other erosion control. Deep plowing displaced natural grasses leading to wind erosion and dust storms. Grasshopper infestation and the Great Depression occurred in the same period making it difficult to quantify economic impacts directly attributed to drought. While the drought effects were remembered as agricultural, it also negatively impacted wildlife, plant life, domestic supply, and undoubtedly other sectors. Dust pneumonia claimed the lives of many. The number of farms decreased by 50 percent[10] during the Dust Bowl and millions of people migrated to the west. In response to the drought, Congress passed the Soil Conservation Act of 1935 to combat soil erosion and preserving natural resources, as well as established the Natural Resources Conservation Service (originally named the Soil Conservation Service).

Soil conservation practices such as wind breaks, crop rotation, strip farming, contour plowing, terracing, and other conservation measures were employed. Evaluating historic PDSI values, the drought of the 1950's was "worse" than the Dust Bowl. However, due to improved farming practices and increased reliance on groundwater, the impacts were less severe. Figure 49 shows that the number of irrigation wells dramatically increases post-1950.

[10] https://journalstar.com/news/state-and-regional/nebraska/of-the-deadliest-disasters-in-nebraska-history/collection_6ae50d55-7d8a-5B-6f-B-1c3-b0B-54cfe84f0.html#12

Figure 49: Number of Active Groundwater Irrigation Wells by Year



Source: Groundwater well Map layer obtained from Nebraska Department of Natural Resources (downloaded 2018)

While groundwater irrigation is an invaluable resource during drought, over-pumping can deplete the aquifer and deplete streamflow. The drought of 2012-2013 is considered the worst single year drought in recent history. As of 2016, the groundwater-level changes in the Lower Platte River Basin have not recovered to 2011 levels (CSD 2017).

The drought of 2012 was considered a "flash drought" in that its onset was unusually quick. Crop damages led to corn export prices 128 percent above the 20-year historic average (AghaKouchak et al. 2013). Crop production decreased with hay production down 28 percent, corn production down 16 percent, and soybean production down 21 percent. Ranchers culled their herds by 25-60 percent as forage production was down 28-65 percent of normal (Central Drought Assessment 2012).

4.4 Drought Indicators for the Lower Platte River Basin

Many indicators and indices exist to help identify drought conditions in the Lower Platte River Basin. These include hydroclimate indices, streamflow levels, groundwater aquifer levels, Rocky Mountain snowpack, and Lake McConaughy reservoir storage levels. Additionally, as previously stated, the focus of this first increment of the Drought Plan is on augmenting surface water supplies in the Lower Platte River near Ashland. It is believed that in addressing the water supply shortages in the Lower Platte River, ancillary benefits to the remaining sectors would exist including: irrigation, power, environmental, and recreational. Table 16 identifies four drought levels recommended for the Drought Plan (mild drought, moderate drought, severe drought, and extreme drought) as well as the associated index ranges that define these levels.

Each NRD has some form of drought monitoring and triggers for response actions. Each NRD maintains its own individual groundwater management plans and the intent of this Drought Plan is is not to replace each members' groundwater monitoring and management plans; rather, to provide consistent, basin-scale data and information that can by used by NRDs, while maintaining locally-based management frameworks.. The individual NRD plans are discussed in detail in Appendix A. For this reason, the drought triggers identified for this Drought Plan are triggers associated with surface water supply.

Additionally, as previously stated, the focus of this first increment of the Drought Plan will focus on augmenting surface water supplies in the Lower Platte River near Ashland. It is believed that in addressing the water supply shortages in the Lower Platte River, ancillary benefits to the remaining sectors would exist including irrigation, power, environmental, and recreational.

Table 16: Drought Triggers

Category	Level	Palmer Drought Severity Index (PDSI)	Platte River Stream flow at Ashland
Mild Drought	0	-1.0 to -1.99	
Moderate Drought	1	-2.0 to -2.99	3,000-1,500 cfs
Severe Drought	2	-3.0 to -3.99	1,500-500 cfs
Extreme Drought	3	-4.0 and below	Less than 500 cfs

Notes: PDSI = Palmer Drought Severity Index

The following lists the levels of drought, remaining consistent with the US Drought Monitor definitions of drought.

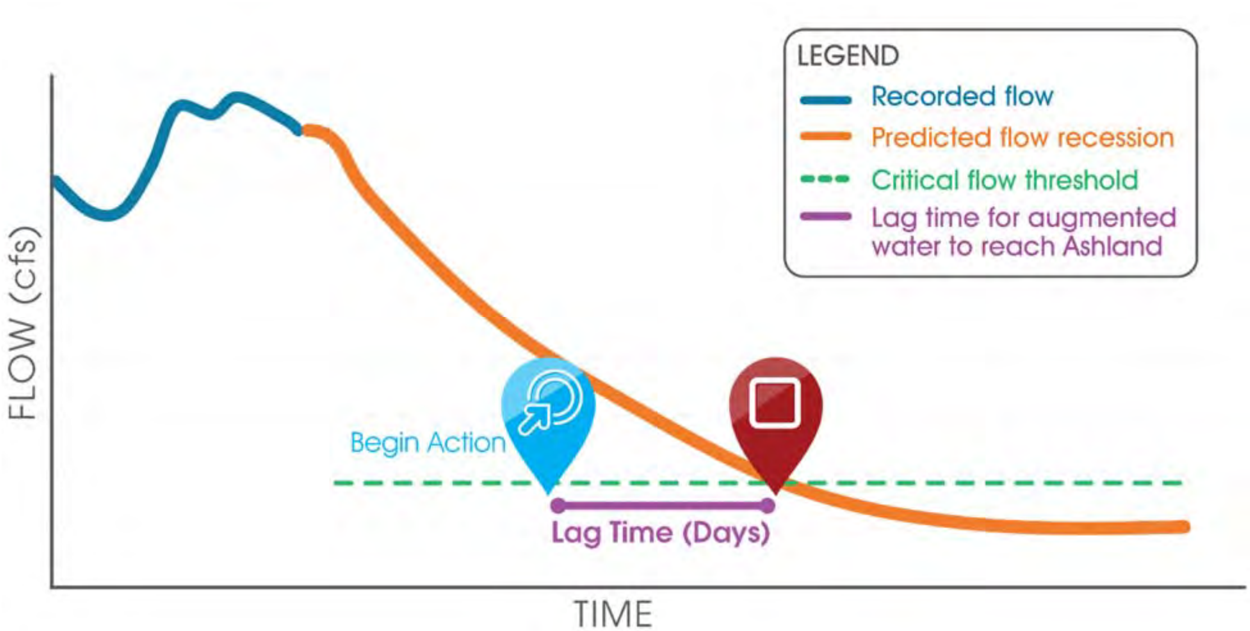
- A Level 0, "Abnormally Dry"[11] indicates an area may be experiencing "short-term dryness slowing planting, growth of crops or pastures" indicating the onset of drought or may be coming out of drought and experiencing lingering effects of drought.
- A Level 1, "Moderate Drought" involves "some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; and voluntary water-use restrictions requested."
- A Level 2, "Severe Drought" means that "crop or pasture losses likely; water shortages common; and water restrictions imposed."
- A Level 3, "Extreme Drought" involves "major crop/pasture losses" and "widespread water shortages or restrictions."

[11] An "Abnormally Dry" classification by the National Drought Monitor corresponds to a PDSI "mild drought" classification.

4.4.1 Platte River at Ashland Recession Tool

Understanding the behavior of the Platte River at Ashland as flows recede is important to the ability of the Consortium to forecast and properly time the implementation of response actions. Using the Platte River at Ashland Recession Tool allows the user to enter the current observed flow in the Platte River at Ashland and predict the flow decay behavior for the next 30 days, assuming no further inputs to the system (precipitation runoff or upstream storage releases). The resulting recession curve can be used to estimate the days until a critical threshold is reached. The development of the Platte River at Ashland Recession Tool is discussed in detail in Appendix E. Figure 50 is a schematic of the functional utility of the Platte River at Ashland Recession Tool in drought forecasting and response.

Figure 50: Platte River at Ashland Recession Tool



4.4.2 U.S. Drought Monitor

The U.S. Drought Monitor is a component of the National Integrated Drought Information System and produced jointly by NOAA, the U.S. Department of Agriculture (USDA), and NDMC. The U.S. Drought Monitor is a weekly product that provides a general summary of current drought conditions: http://www.cpc.ncep.noaa.gov/products/Drought/.

Multiple drought indicators, including various indices, outlooks, field reports, and news accounts are reviewed and synthesized. In addition, numerous experts from agencies and offices across the country are consulted. The result is the consensus assessment presented on the U.S. Drought Monitor map. The U.S. Drought Monitor website can be used as a tool to supplement the drought monitoring by the Consortium. The U.S. Drought Monitor information is usually summarized in the North Central and U.S. Monthly Climate and Drought Summary Outlooks.

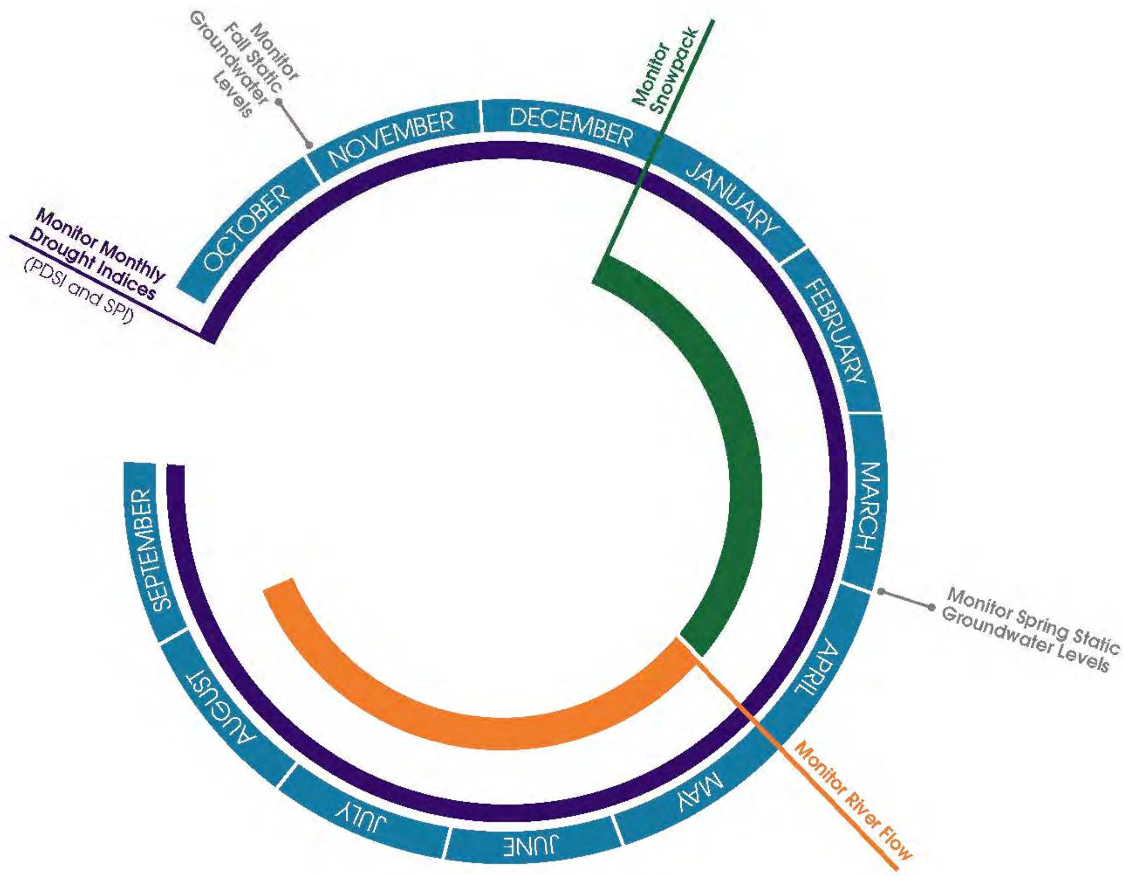
4.4.3 North Central U.S. Monthly Climate and Drought Summary Outlook

NOAA and its climate partners host monthly webinars on the website: https://www.drought.gov/drought/calendar/events/

This monthly briefing covers the region from the Rockies to the Great Lakes. Subject matter includes a summary of past and current conditions in terms of many climate variables such as snowpack, temperatures, and precipitation. In addition, potential and ongoing effects from climate phenomena will be considered across sectors (agriculture, water resources, etc.). Finally, outlook information from 2 weeks to the next few months and seasons are discussed.

As part of its drought monitoring, the Consortium should participate in these monthly webinars to gain expert interpretation of the state of drought and drought predictions.

Figure 51: Drought Monitoring Continuum



The recommended timeline for drought monitoring is displayed in Figure 51. Hydroclimate indices SPI and PDSI should be monitored year round. Groundwater levels are monitored by NRDs in the spring and fall of each year in accordance with their individual groundwater management plans. Snowpack volumes should be monitored from the beginning of the calendar year through the runoff season. Streamflows should be monitored starting in late spring through the summer when water use for irrigation, cooling, and lawn watering is at its peak.

5.0 Drought Management

5.1 Mitigation Alternatives

Drought mitigation measures are actions, programs, and strategies implemented during non-drought periods to address potential risks and effects and reduce the need for response actions; implementation of drought mitigation measures improves long-term resilience.

While the Drought Plan assesses the water supplies, demands, and vulnerabilities in the Lower Platte River Basin as a whole, the focus of this increment of the Drought Plan is on augmenting surface water supplies in the Lower Platte River near Ashland. It is believed that in addressing the water supply shortages in the Lower Platte River, ancillary benefits to the remaining sectors would exist including irrigation, power, environmental, and recreational.

Eight mitigation measures were evaluated as part of the Drought Planning effort to estimate potential increases in regional water supply. These measures include the following:

- Installing an alluvial well-field adjacent to the Missouri River and pumping water to a tributary of the Elkhorn River for availability on demand;
- Purchasing storage in the existing Sherman Reservoir and releasing water on demand;
- A new surface water storage reservoir on Skull Creek near Linwood for releasing water on demand;
- Capture of Middle Loup River water in the non-irrigation season and diversion into the Middle Loup Canal system for intentional recharge and baseflow augmentation;
- Installing a well-field to tap into groundwater aquifers with limited connection to streamflow that can be pumped to the river to augment flows;
- Pumping from alluvial sandpits directly to the river to augment flows; and
- A dry-year-lease agreement with farmers irrigating lands adjacent to the main channel of the Platte River from the alluvial aquifer.

5.1.1 Additional Supply – Missouri River

Streamflow in the Missouri River is regulated by a system of upstream reservoirs to serve a variety of federally authorized purposes. One of the federally authorized purposes is to provide flows adequate for maintaining navigation March through November in the reach from Sioux City to its confluence with the Mississippi River. The full service navigation target at the Omaha gage is 31,000 cfs, while the minimum service navigation target is 25,000 cfs. The system of reservoirs and the authorized purposes they service provide a reliable supply to Missouri River streamflows during periods of drought. As an example, the *2014 Lincoln Water Master Plan* showed the Missouri River would be able to support a 75 million gallons per day demand even during significant drought conditions (City of Lincoln 2014).

Installation of a well-field in the alluvial aquifer adjacent to the Missouri River was investigated as a drought mitigation action. The hydrologic connection of the alluvial aquifer to the Missouri River would provide a reliable source of recharge and maintain its capacity, even during the severest drought periods. The analysis considered delivering 50-100 cfs from the well-field to the Platte River basin on demand. One alternative was a well-field adjacent to the Missouri River near Blair, with a force main extending westward approximately 10 miles over the ridge and into the Bell Creek watershed along existing Highway 91. The second alternative considered a well-field adjacent to the Missouri River near Decatur, with a force main extending westward approximately eleven miles over the ridge and into the upper reaches of the Bell Creek watershed along existing Highway 51. Once discharged flows would be conveyed by tributaries to Bell Creek and the Elkhorn River before eventually reaching the Platte River.

For the alternative near Decatur, an estimated 22 percent conveyance loss occurs between the point of discharge and the Ashland gage on the Platte River under low-flow conditions.

Potential constraints and considerations include location of well-field, obtaining right-of-way for well-field and transmission main, potential utility conflicts/constraints along transmission main alignment, obtaining necessary environmental clearances, and protection of discharged water from use via conveyance appropriation from NeDNR. Project costs would primarily include the well-field, transmission, and discharge infrastructure costs, ROW for project facilities, and annual operating expenses.

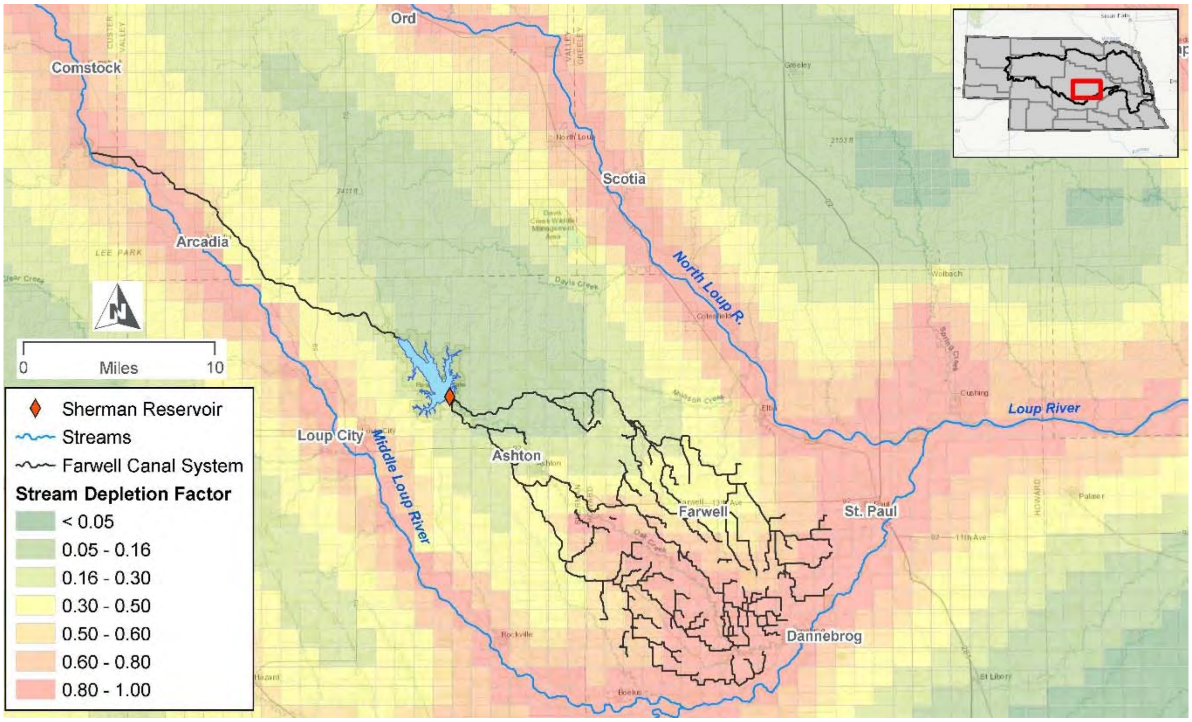
5.1.2 Surface Water Storage Alternatives

Two new surface water storage reservoirs and one existing surface water storage reservoir were considered as mitigations measures to increase water supply to the Lower Platte River Basin during drought conditions.

5.1.2.1 Sherman Storage Reallocation

The Sherman Storage Reallocation would reallocate a portion of stored water in Sherman Reservoir to be managed for re-timing and augmenting streamflows. Sherman Reservoir is owned by the Farwell Irrigation District and stores flows diverted from the Middle Loup River for storage and delivery to its producers during the irrigation season. Reallocating storage in Sherman Reservoir could provide benefits to the Lower Platte River using two operational patterns: 1) the stored water could be actively managed to augment flows during droughts through releases from reservoir storage and conveyance through the canal and natural systems to the Platte River; and 2) the stored water could be released during the non-irrigation season and intentionally recharged using the existing Farwell Irrigation District canal system infrastructure, resulting in increased baseflow accretions passively occurring throughout the year. While this effort focused on Sherman Reservoir, a similar approach could be used on the Davis Creek Reservoir (Figure 52).

Figure 52: Sherman Reservoir and Farwell Canal System



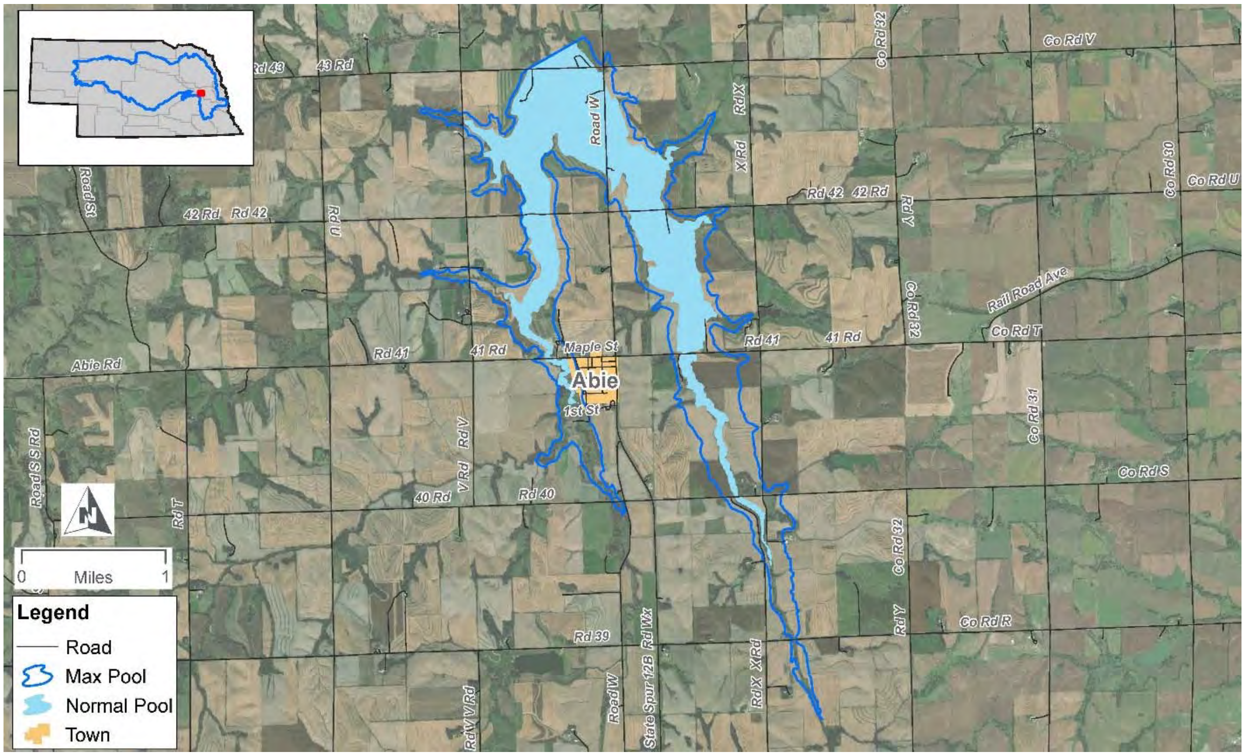
Reallocating or repurposing the upper 3 to 4 feet of Sherman Reservoir's normal storage pool would provide approximately 8,000 to 10,000 acre-feet of water. Active releases would provide 100 percent benefit to streamflow at the point of discharge, with benefits decreasing downstream as conveyance losses are incurred. Estimated conveyance losses from point of release to the Ashland gage on the Platte River is approximately 65 percent during drought conditions.

Potential constraints and considerations include obtaining a storage agreement with owners of Sherman Dam for storage and release of flows for the benefit of the Lower Platte River, adverse effects on current Farwell Irrigation District producers, potential high groundwater tables resulting from intentional recharge activities, and protection of releases from use via conveyance appropriation from NeDNR. Project costs would primarily include the purchase or lease of storage water agreement with the owner and compensatory elements for use of their irrigation infrastructure in the delivery of flows.

5.1.2.2 Skull Creek Reservoir

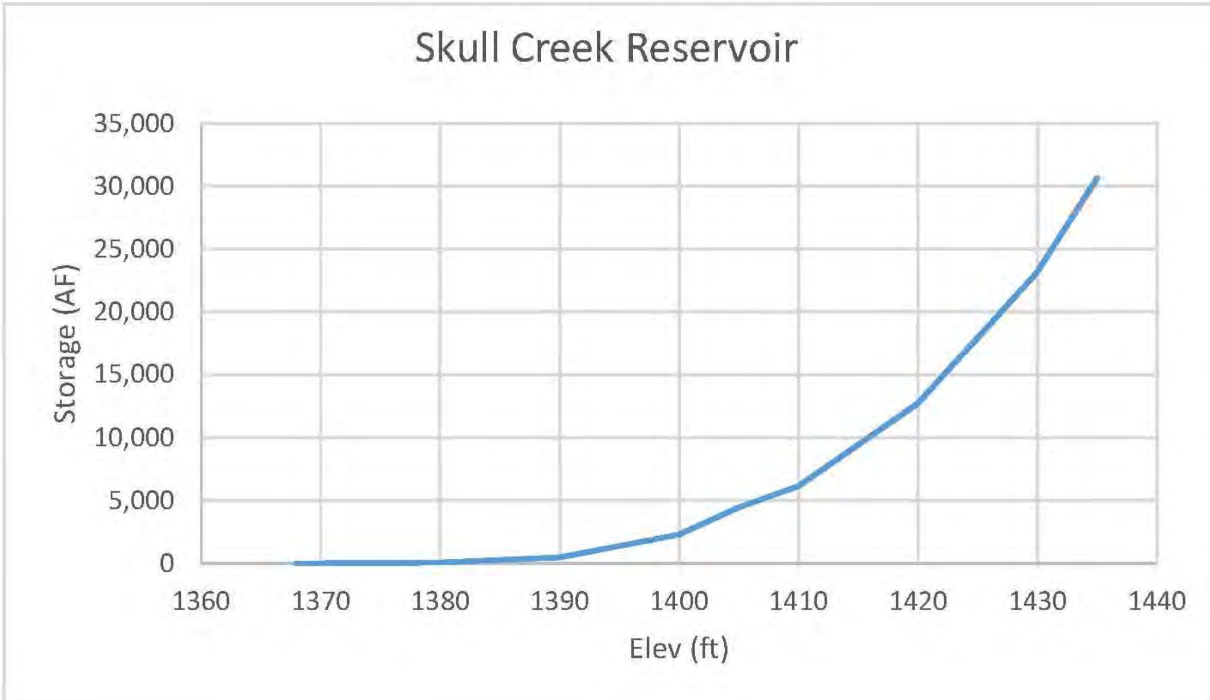
The first new reservoir considered was previously evaluated by the U.S. Army Corps of Engineers in 1965 and again by Lower Platte North NRD in 1985. These analyses investigated multiple locations within the watershed. For purposes of this analysis, the new reservoir considered would be located on Skull Creek (a tributary to the Platte River) near Linwood, Nebraska, located in the Lower Platte North NRD (Figure 53). Other potential sites upstream of this location were previously evaluated; however, upstream locations would reduce the volume for capture and lessen project benefits.

Figure 53: Skull Creek Reservoir Proposed Location



The purpose of the Skull Creek Dam Project would be to store and re-time flows, which are primarily available during the nonpeak season, to be available on demand for release to the Platte River just upstream of North Bend. The area draining to this location is approximately 42,000 acres. The Skull Creek Reservoir investigated would have a top of dam at elevation 1435. The maximum normal pool elevation is 1420 corresponding to a surface area of 880 acres and a volume of approximately 12,700 acre-feet (Figure 54).

Figure 54: Skull Creek Reservoir Stage-Storage



The analysis used a water budget approach and looked at capturing watershed runoff and storing during days when excess flows are available on the Platte River (that is, the instream flow appropriation on the Platte River at both North Bend and Louisville are satisfied). Evaporative and seepage losses were estimated on a daily basis based on reservoir stage and surface area. It then considered a July release for each year to augment Platte River flows. The estimated daily reservoir storage from the routing analysis, both with and without this July release, is shown in Figure 55 and the resultant average monthly volume is shown in Figure 56.

Figure 55: Skull Creek Reservoir Routing

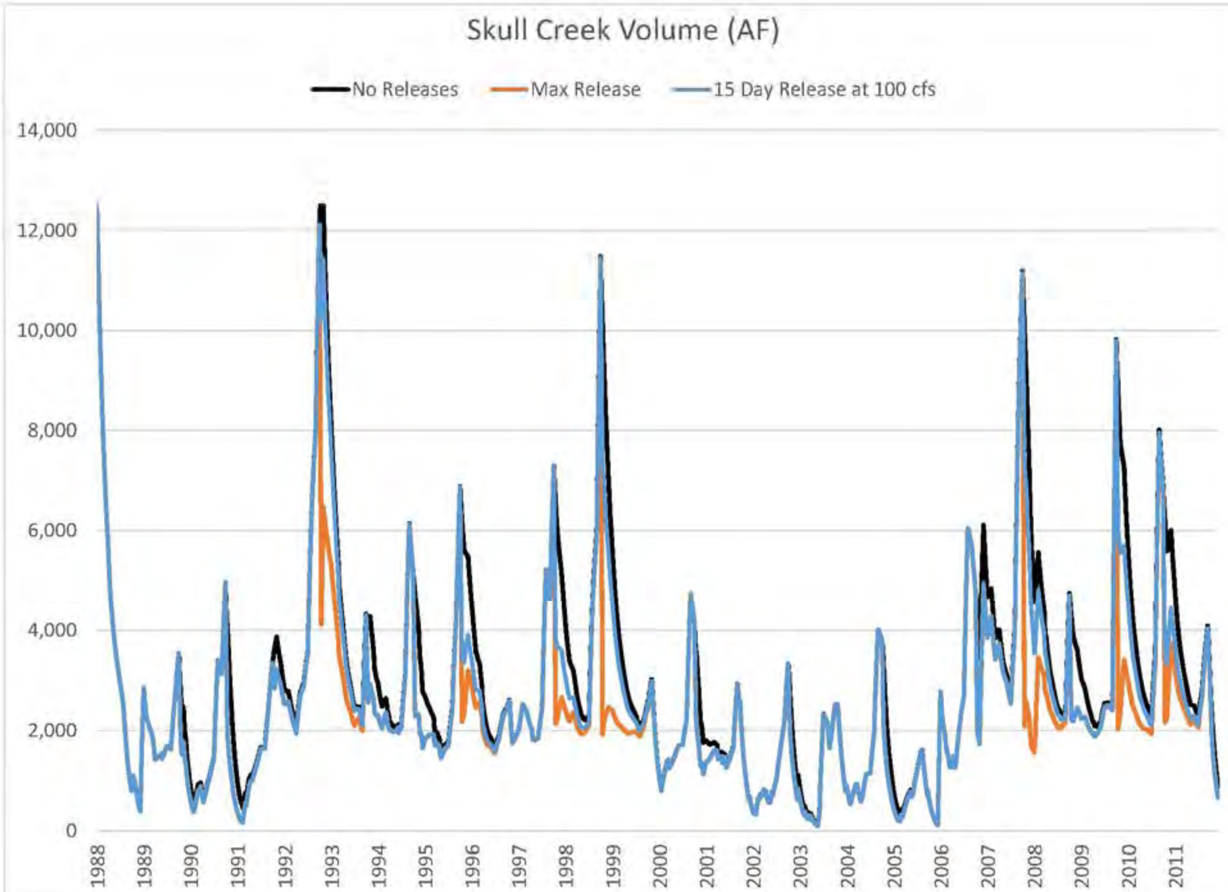
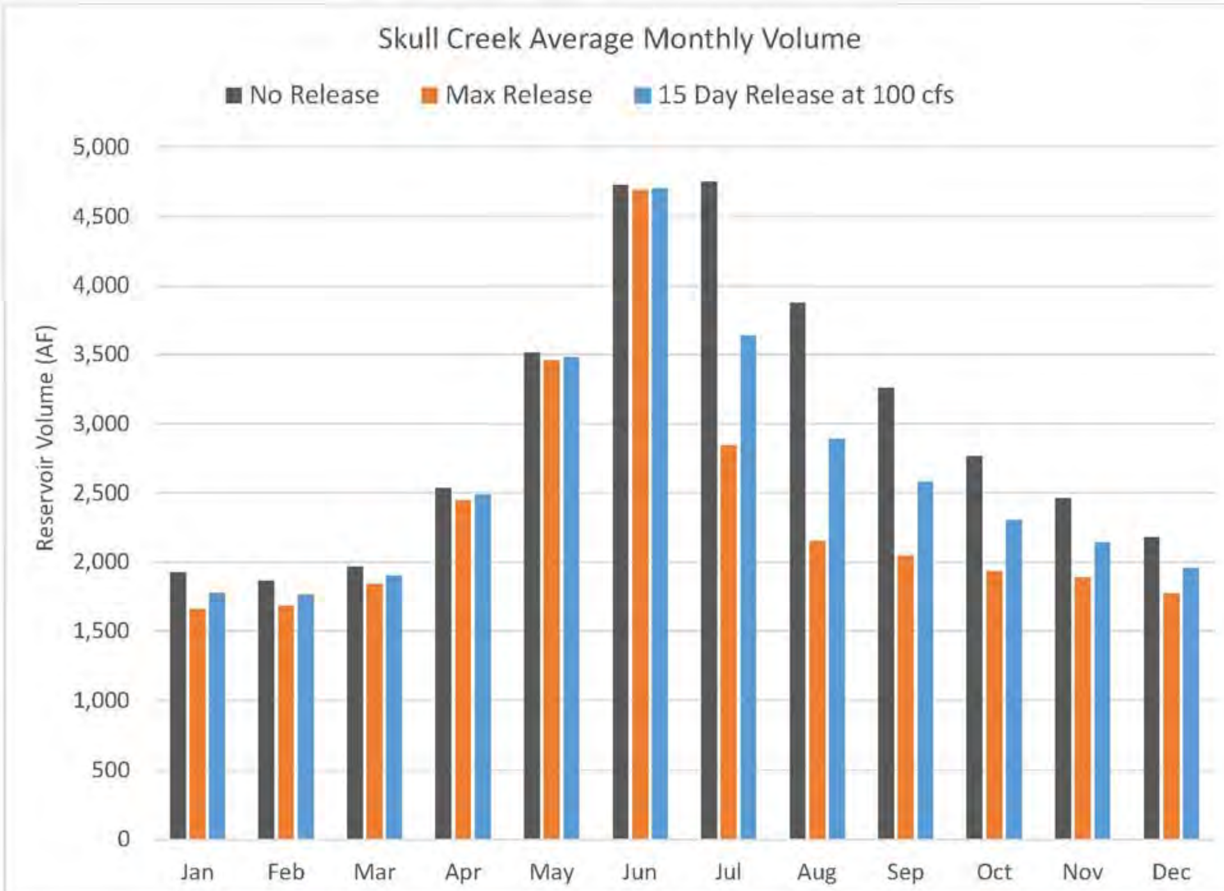


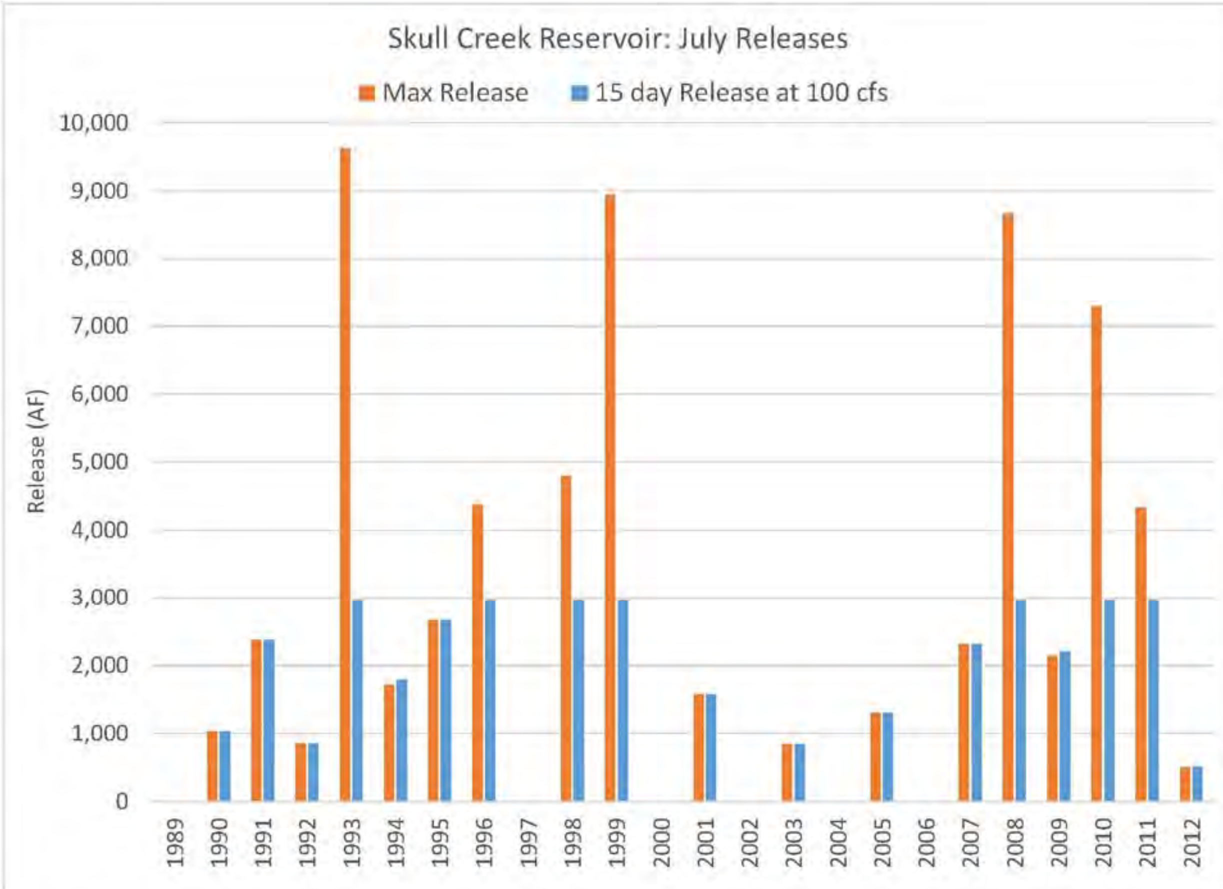
Figure 56: Skull Creek Average Monthly Volume



The estimated annual release that would have occurred during the 1988 to 2011 period is shown in Figure 57Figure 57. A maximum release scenario evacuates all storage above the dead pool (assumed as 10 percent of normal pool) while a 15-day release at 100 cfs was used in this analysis for comparison with other alternatives.

It should be noted that the seepage loss estimates used in the water budget analysis were based on typical permeability values of prevailing soil types present at the site and likely overestimate losses that could be expected once the reservoir is constructed and natural seasoning of the pool area occurs. In addition the runoff values used for inflow were derived from monthly volumes and are not event-based, likely underestimating inflow volumes. The normal pool surface area is approximately two percent of the total drainage area. Reservoirs in eastern Nebraska with pool areas of two percent to four percent of their drainage area are typically sustainable. For these reasons, the routing results produce conservative estimates of expected yield.

Figure 57: Skull Creek Estimated July Releases



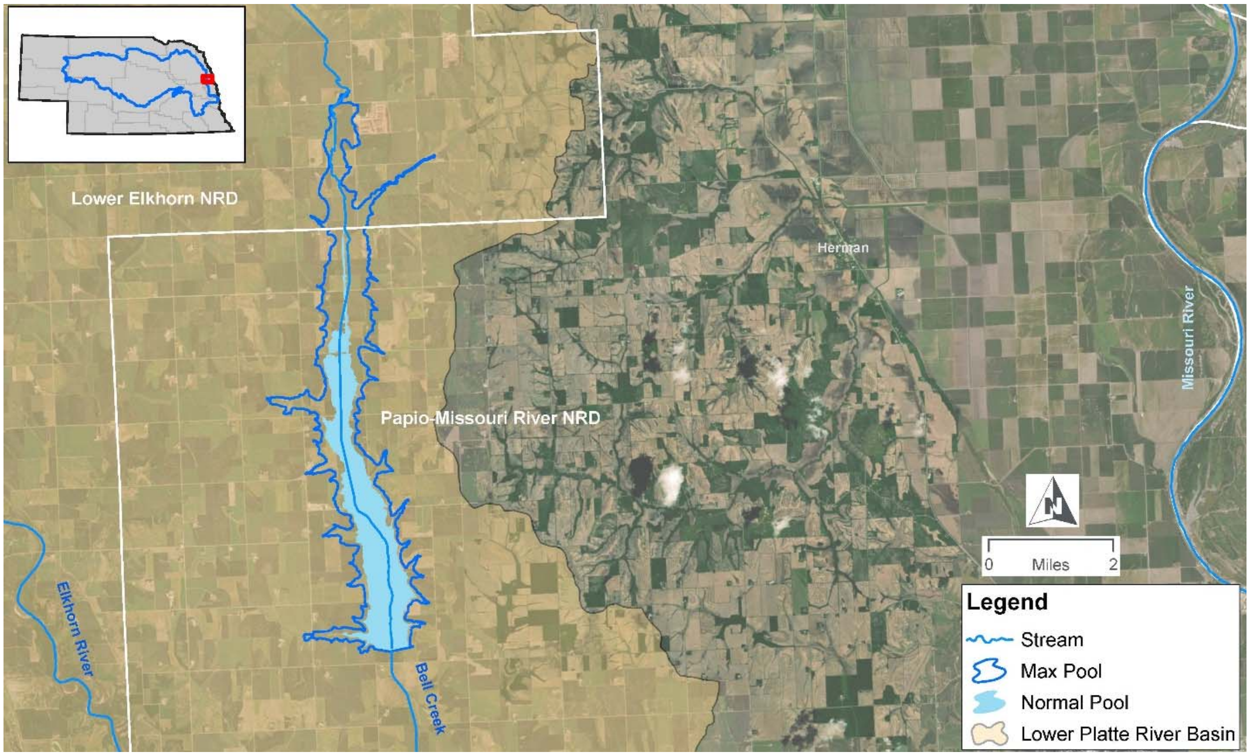
Potential constraints and considerations for a new reservoir include third-party effects due to increased groundwater elevations in the reservoir vicinity, acquisition of land for the reservoir, relocated homes, impacts to roadways adversely affecting connectivity and emergency services, environmental permitting constraints, and managing the reservoir to fulfill multiple project purposes (if necessary).

Project costs would include engineering costs, site construction, land acquisition, mitigation of impacts, and annual operations and maintenance.

5.1.2.3 Bell Creek Reservoir

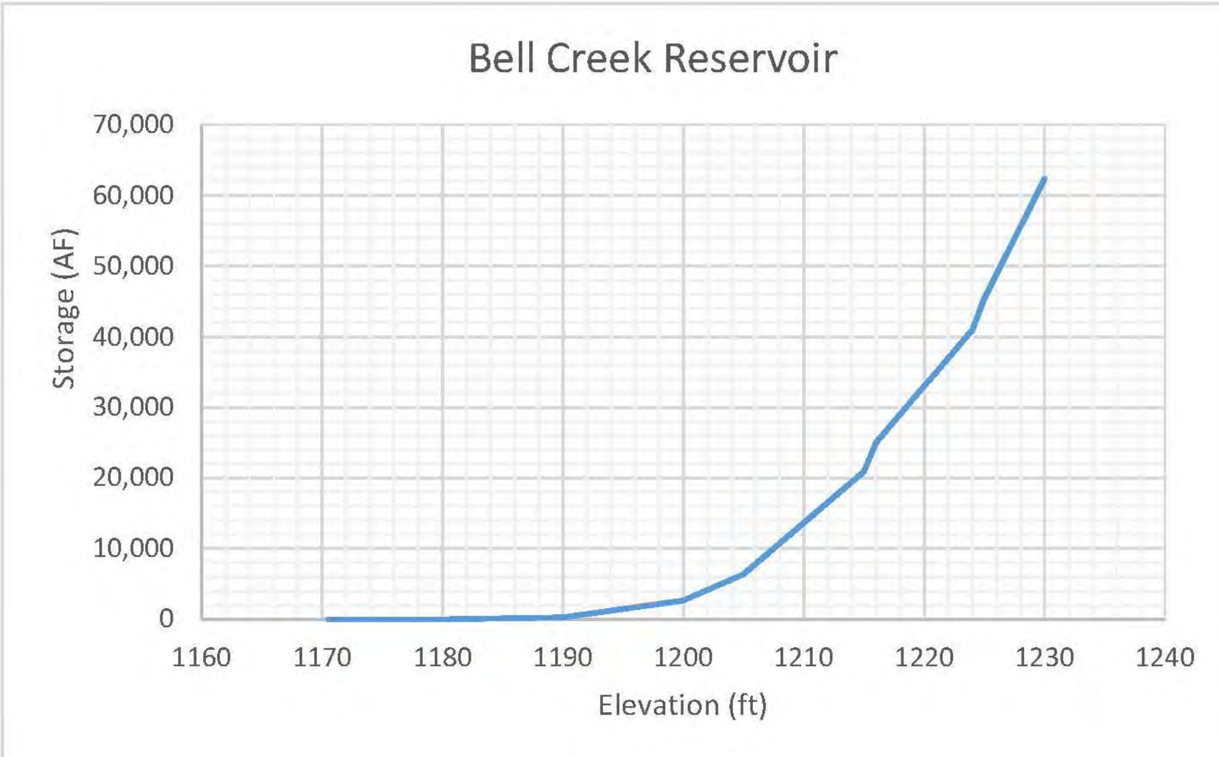
The second potential new reservoir was identified by the 2016 Lower Elkhorn NRD Reservoir Evaluation Project. The new dam would be located on Bell Creek (a tributary to the Elkhorn River) east of Oakland, Nebraska, located in the Papio-Missouri River NRD and extending into the Lower Elkhorn NRD. The location of the potential reservoir for purposes of the Drought Plan is located further downstream than that of the Lower Elkhorn evaluation in order to maximize project benefits (Figure 58).

Figure 58: Bell Creek Reservoir Proposed Location



The purpose of the Bell Creek Dam Project would be to store and re-time flows, which are primarily available during the nonpeak season, to be available on demand for release, joining the Elkhorn River just upstream of Waterloo. The area draining to this location is 85,000 acres. The Bell Creek reservoir investigated would have a top of dam at elevation 1230 corresponding to a normal pool at elevation 1210 with a surface area of 1,720 acres and a volume of approximately 13,600 acre-feet (Figure 59Figure 59).

Figure 59: Bell Creek Reservoir Stage-Storage



The analysis used a water budget approach and looked at capturing watershed runoff during days when excess flows are available on the Platte River (that is, the instream flow appropriation on the Platte River at Louisville is satisfied). Evaporative and seepage losses were estimated on a daily basis based on reservoir stage and surface area. It then considered a July release for each year to augment Platte River flows. The estimated daily reservoir storage from the routing analysis, both with and without this July release, is shown in Figure 60 and the resultant average monthly volume is shown in Figure 61.

Figure 60: Bell Creek Reservoir Routing (Runoff as only inflow)

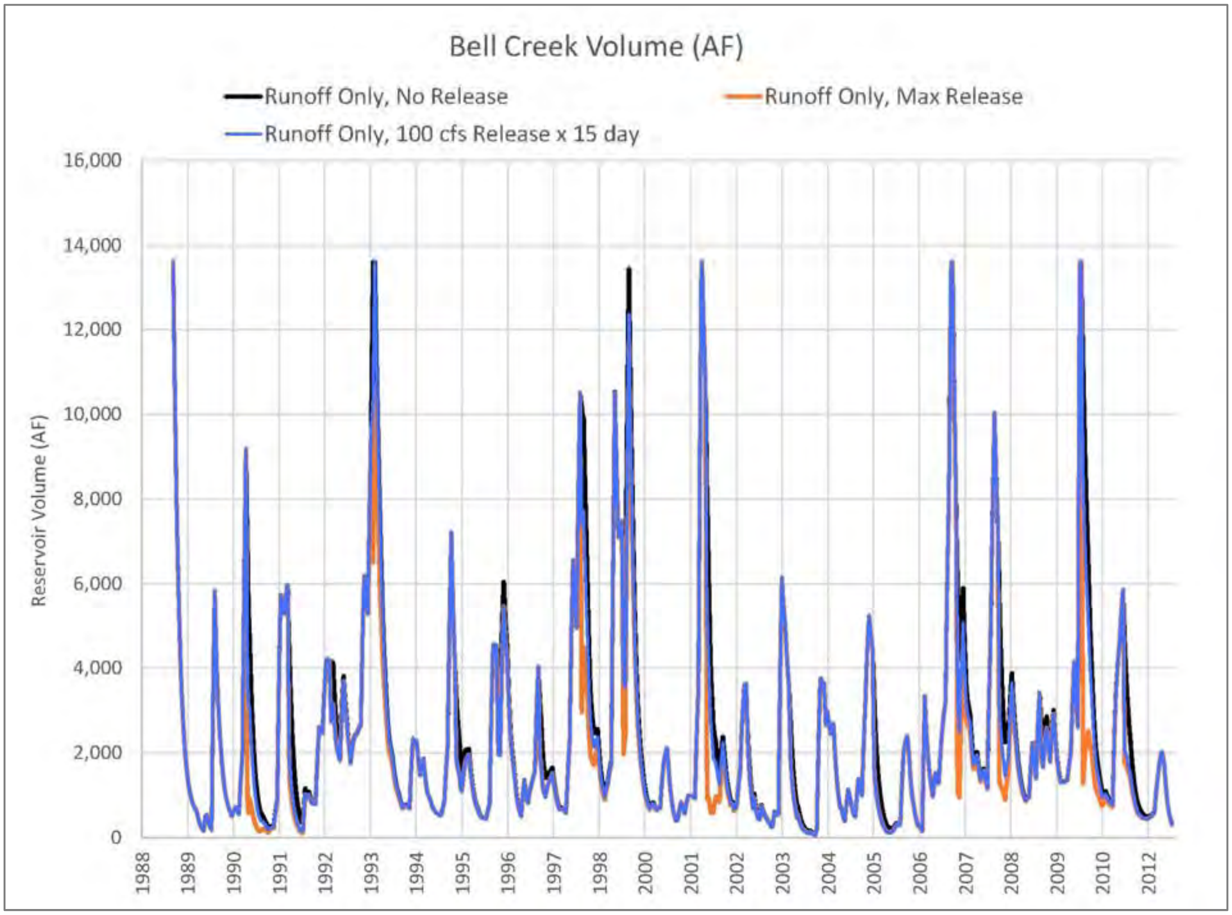
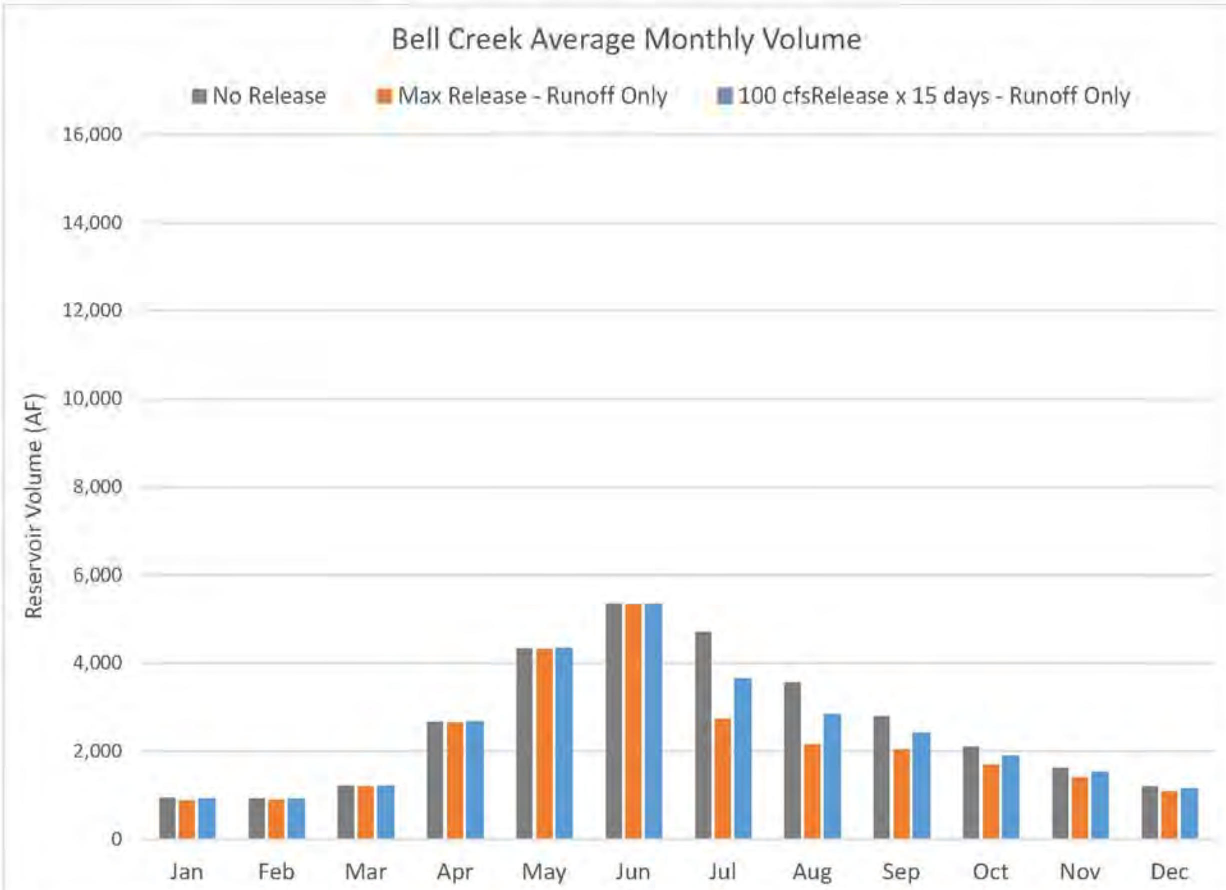


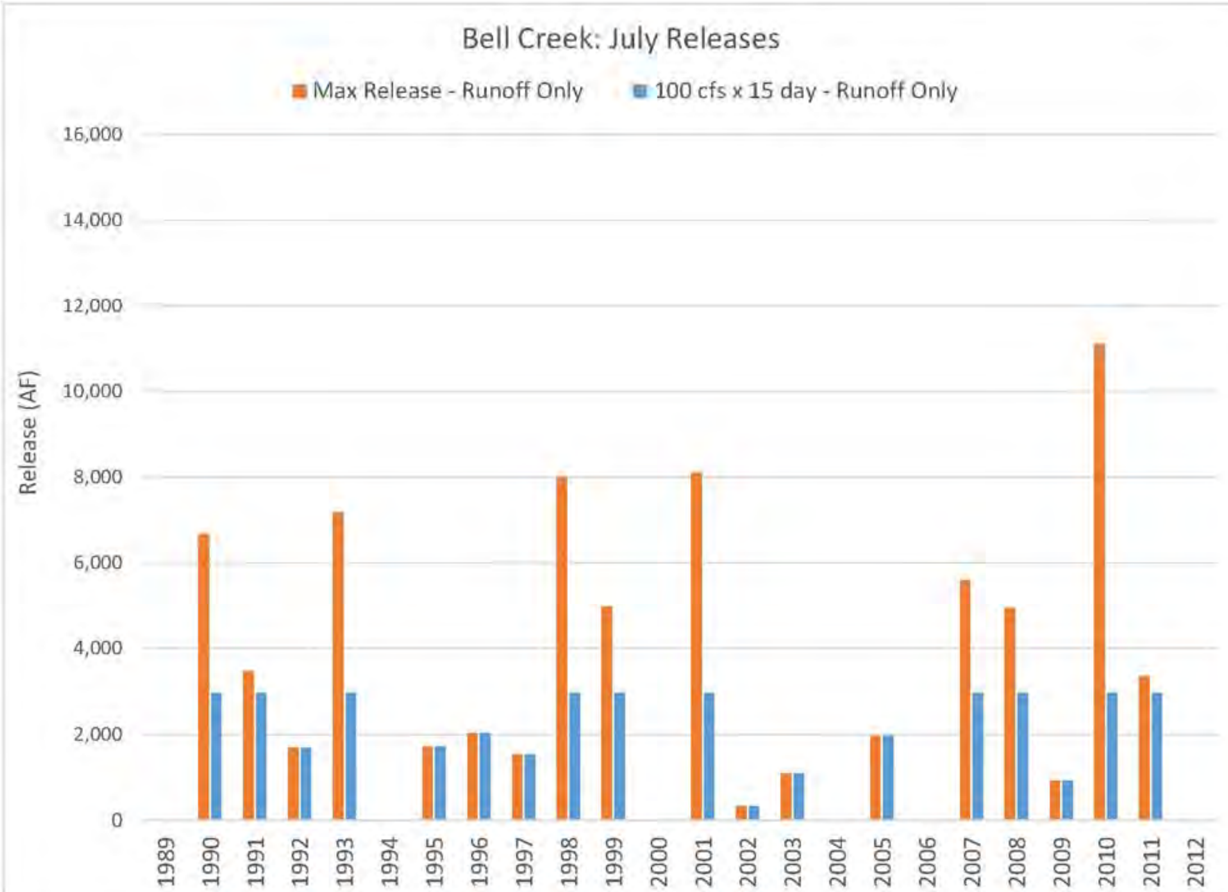
Figure 61: Bell Creek Reservoir Average Monthly Storage Volume based on Runoff



The estimated annual release that would have occurred during the 1988 to 2011 period is shown in Figure 62. A maximum release scenario evacuates all storage above the dead pool (assumes as 10 percent of normal pool) while a 15 day release at 100 cfs was used in this analysis for comparison with other alternatives.

It should be noted that the seepage loss estimates used in the water budget analysis were based on typical permeability values of prevailing soil types present at the site and likely overestimate losses that could be expected once the reservoir is constructed and natural seasoning of the pool area occurs. In addition the runoff values used for inflow were derived from monthly volumes and are not event-based, likely underestimating inflow volumes. The normal pool surface area is approximately 2 percent of total drainage area. Reservoirs in eastern Nebraska with pool areas of 2 percent to 4 percent of their drainage area are typically sustainable. For these reasons, the routing results produce conservative estimates of expected yield.

Figure 62: Bell Creek Estimated July Releases (Runoff as only inflow)



As shown in Figure 60, Figure 61, and Figure 62, capturing runoff and baseflow alone provides a limited volume for release. Therefore, an analysis for a reservoir on Bell Creek was considered in conjunction with the alternative of importing water from the Missouri River. It then considered a July release for each year to augment Platte River flows.

The estimated daily reservoir storage volume for this combined alternative, both with and without a July release, is shown in Figure 64 and the resultant average monthly volume is shown in 55.

Figure 63: Bell Creek Reservoir Routing (importing Missouri River water)

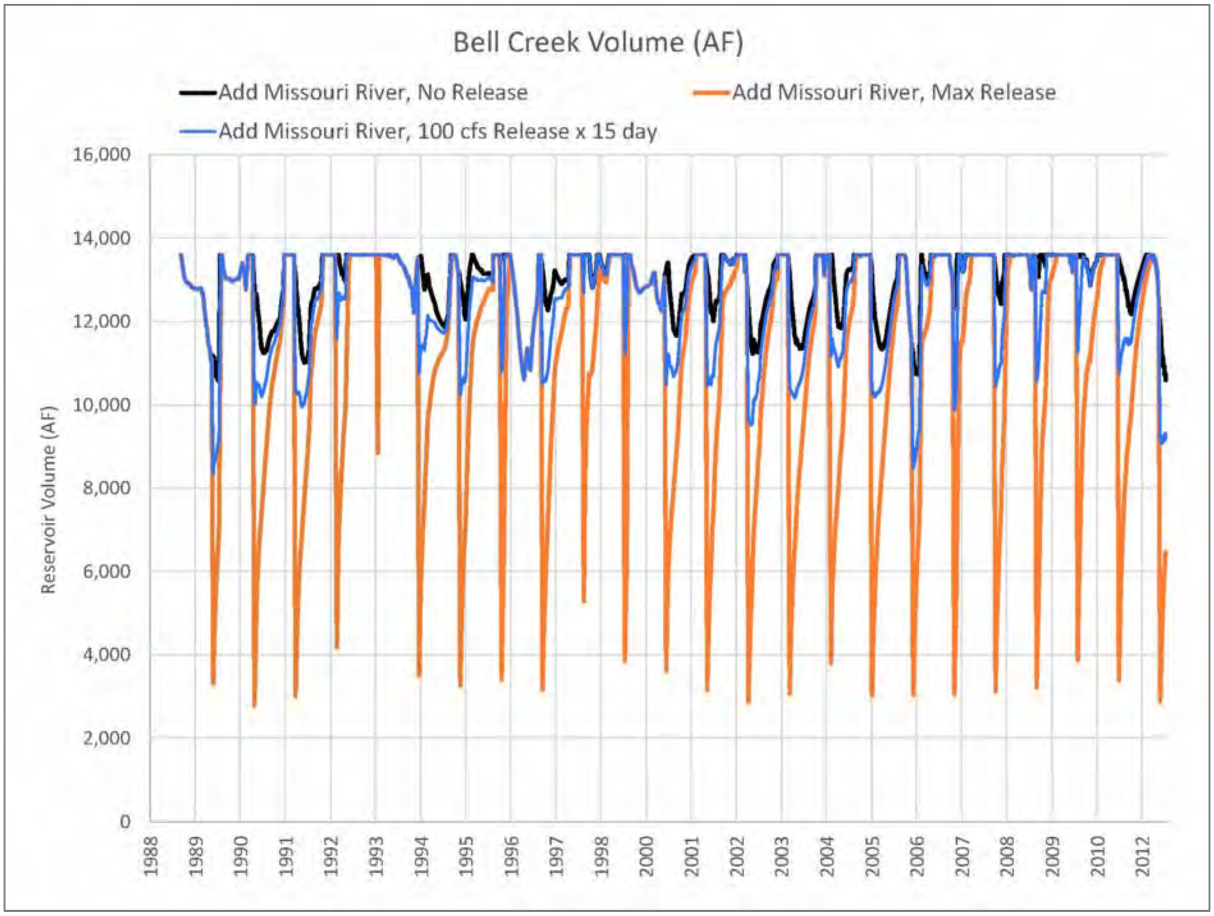
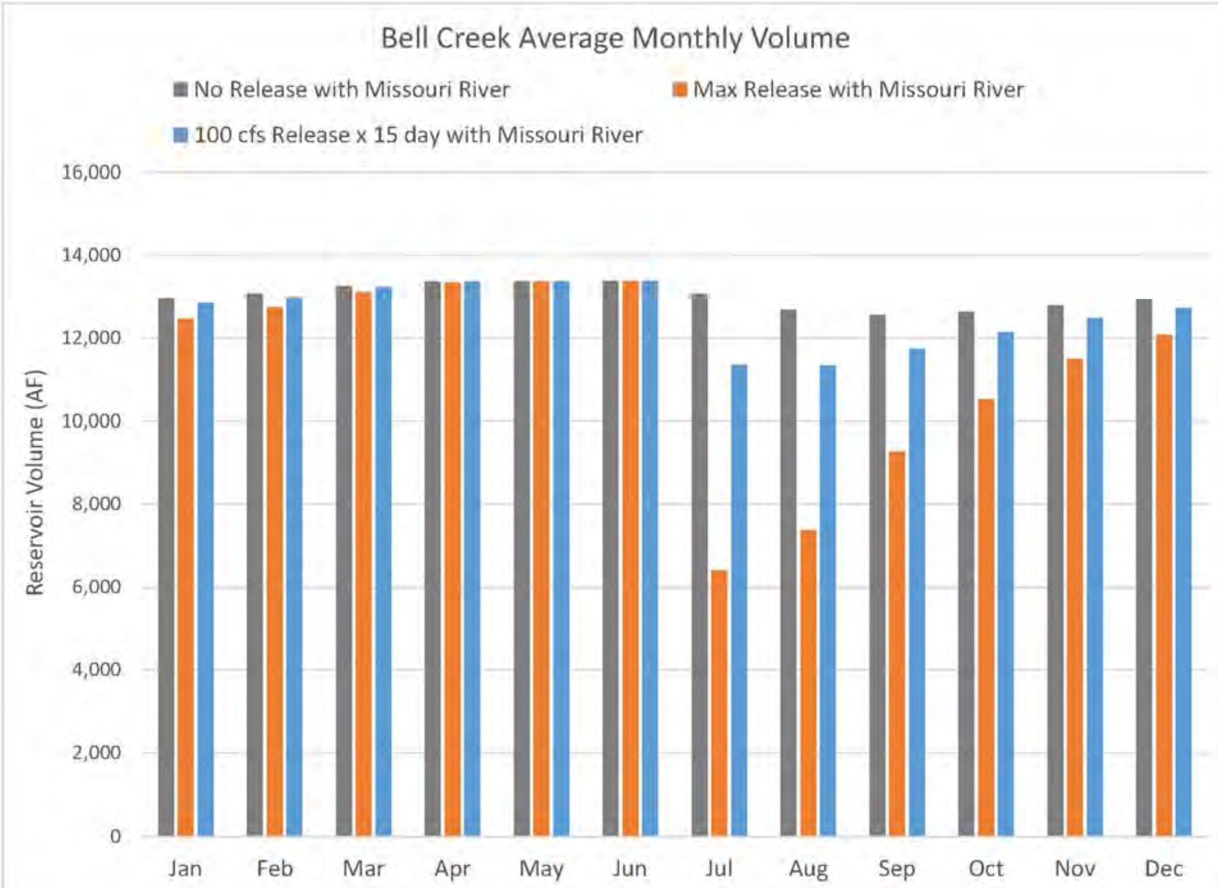
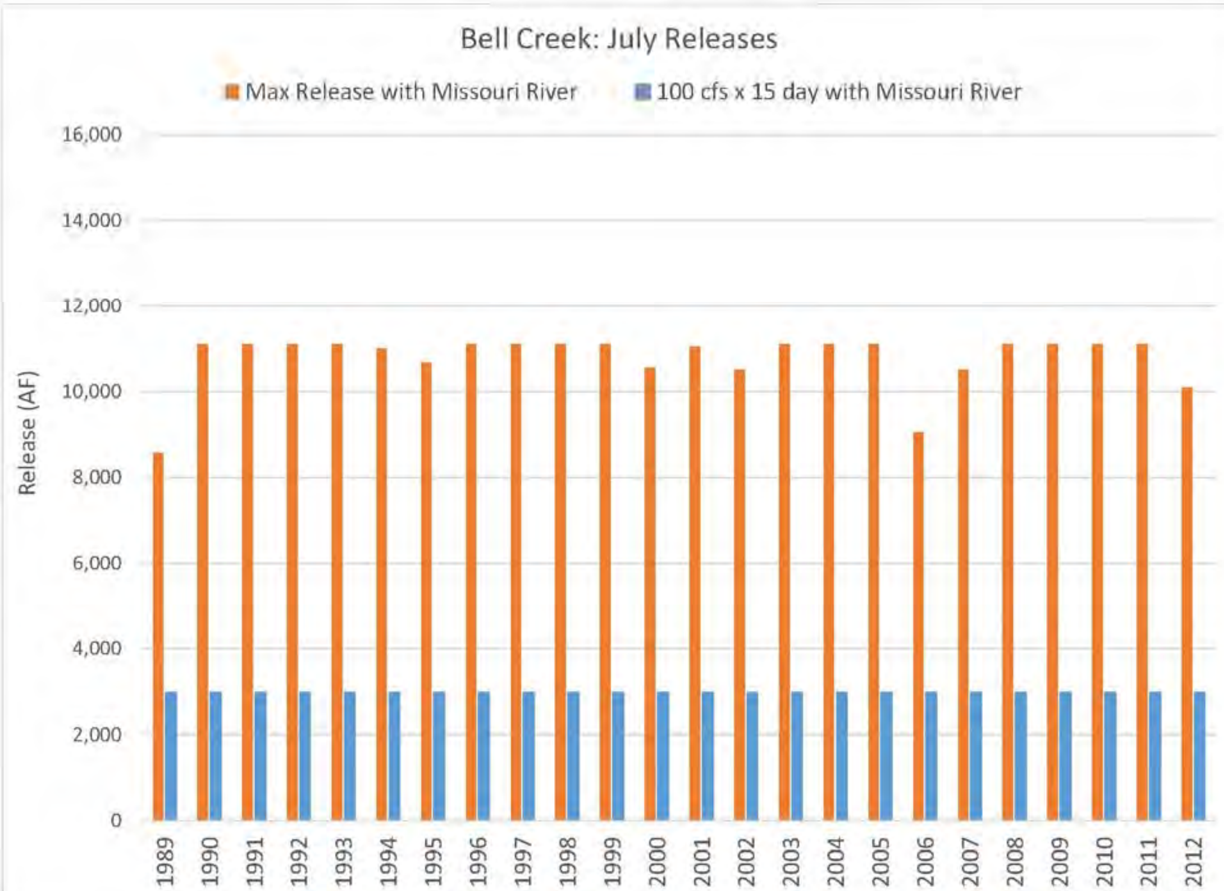


Figure 64: Bell Creek Average Monthly Volume importing Missouri River water



The estimated annual release that would have occurred during the 1989 to 2011 period is shown in Figure 65. A maximum release scenario evacuates all storage above the dead pool (assumes as ten percent of normal pool) while a 15-day release at 100 cfs was used in this analysis for comparison with other alternatives

Figure 65: Bell Creek Estimated July Releases (importing Missouri River water)



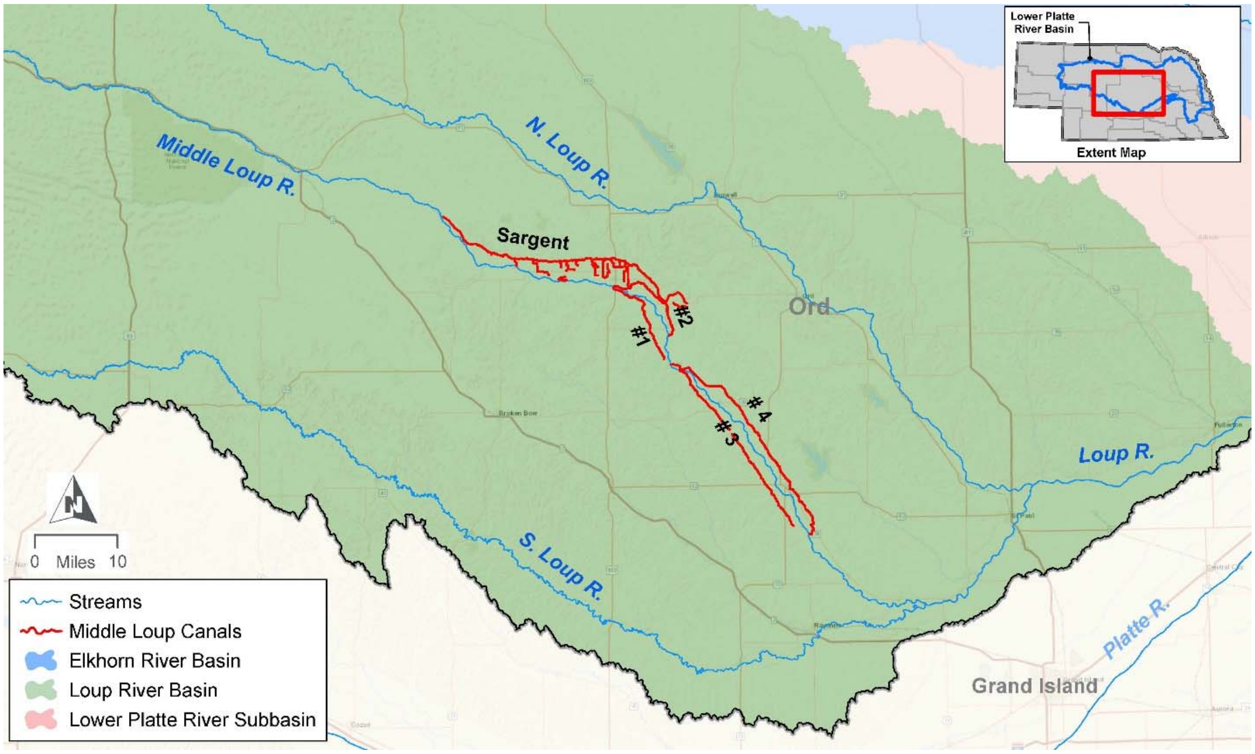
Potential constraints and considerations for a new reservoir include third-party effects due to increased groundwater elevations in the reservoir vicinity, acquisition of land for the reservoir, relocated homes, impacts to roadways adversely affecting connectivity and emergency services, environmental permitting constraints, and managing the reservoir to fulfill multiple project purposes (if necessary).

Project costs would include engineering costs, site construction, land acquisition, mitigating impacts, and annual operations and maintenance.

5.1.3 Canal Recharge through Canal Seepage

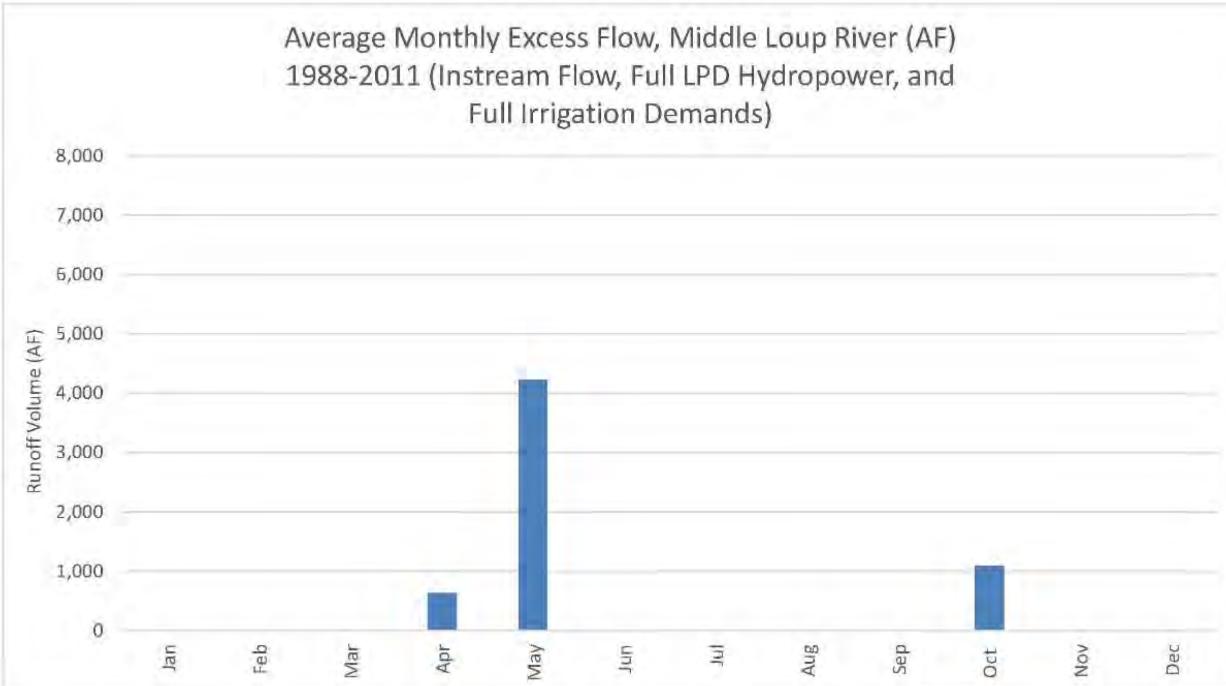
A potential mitigation measure considered the use of existing surface water infrastructure on the canal system in the Middle Loup River basin for intentional recharge of excess flows (Figure 66). Excess flow is defined as the quantity of surface water in excess of the existing state protected flows. An excess flow analysis is useful in determining the location, duration of excess flows, and frequency of excess flows on a monthly time-step when evaluating the volume of water available for capture in support of potential conjunctive management projects.

Figure 66: Middle Loup Canals



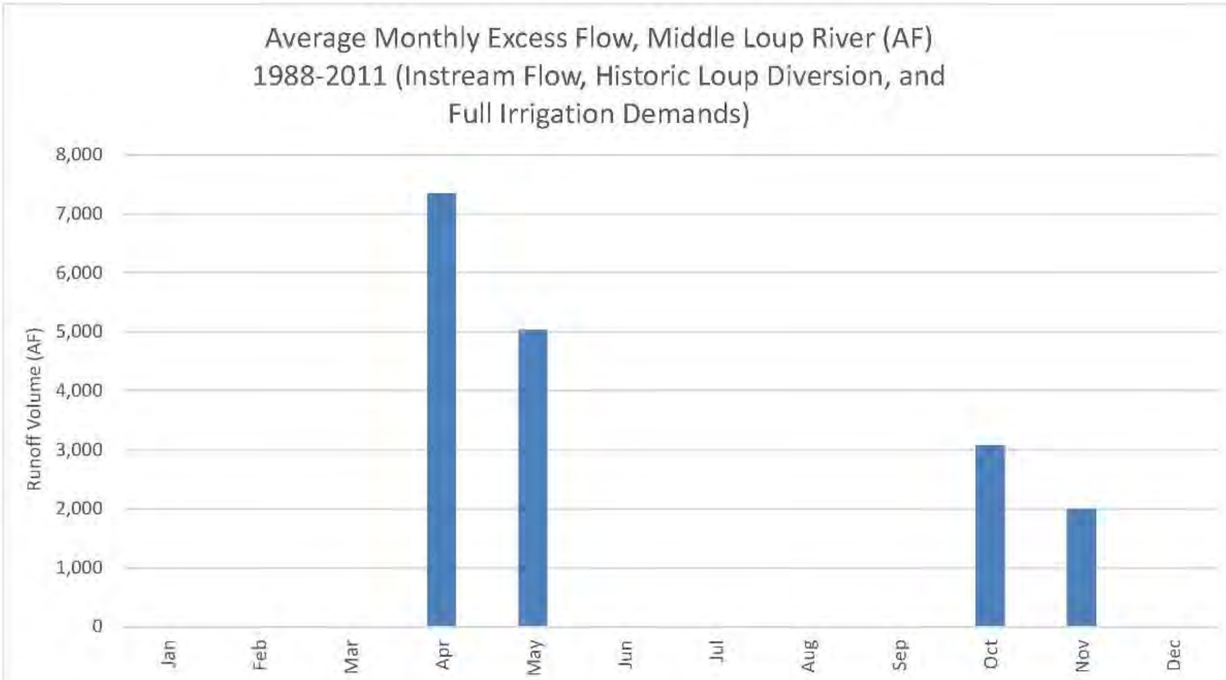
An excess flow evaluation was conducted for the Loup River system that first evaluated excess flows in the Lower Platte River, then working upstream into the Loup River basin. Two demand scenarios were considered when evaluating available excess flows in the Loup River. The first demand scenario considers the full Loup River Public Power District hydropower appropriation placed on the Loup subbasin. The average monthly flow available for diversion on the Middle Loup River for this demand scenario is shown in Figure 67.

Figure 67: Average Middle Loup River Excess Flow (based on Loup Power Surface Water Appropriation)



The second demand scenario considers the historic Loup Power Canal diversion. This demand scenario is considered the historic demand that was actually placed on the basin. The average monthly flow available for diversion on the Middle Loup River for this demand scenario is shown in Figure 68.

Figure 68: Average Middle Loup River Excess Flow (based on historic Loup Power Canal diversion)



Canal recharge alternatives that were considered would re-time flows during the non-peak season (times of low demands) to be available in the peak season (times of high demand) by diverting excess flows from the Middle Loup River into existing canals (Sargent Canal and Middle Loup Canals 1, 2, 3, and 4) during the months of April, May, October, and November. Return flows will passively accrete to the Middle Loup River throughout the year and will be available for use.

Figure 69 shows that when considering historic Loup Canal Diversions, approximately 450,000 acre-feet would have been available for capture and diversion between 1988 and 2011 in the months of April, May, October, and November. The seepage would return to the river naturally throughout the calendar year, with only a portion of this water returning during the peak summer months when drought effects are most severe.

Figure 69: Cumulative Middle Loup Canal Diversions versus Cumulative Returns to Middle Loup River (assuming historic Loup Power Canal diversion)

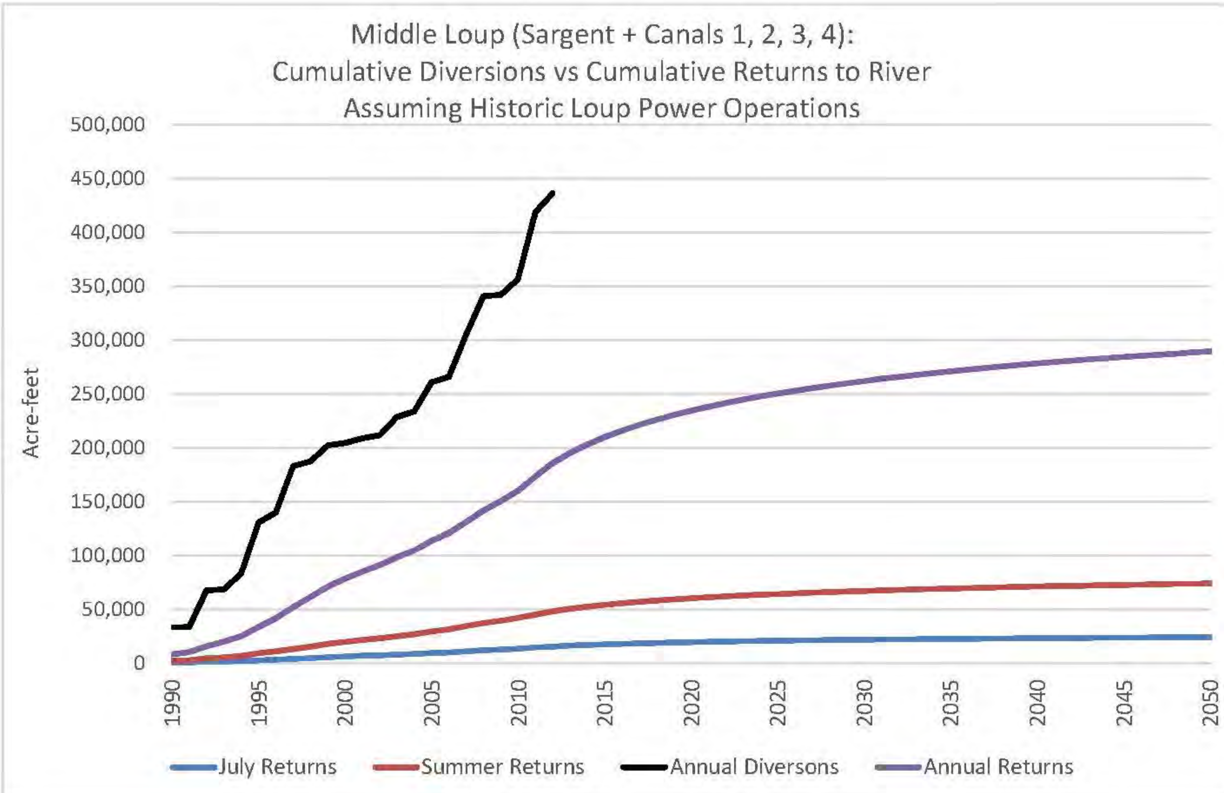
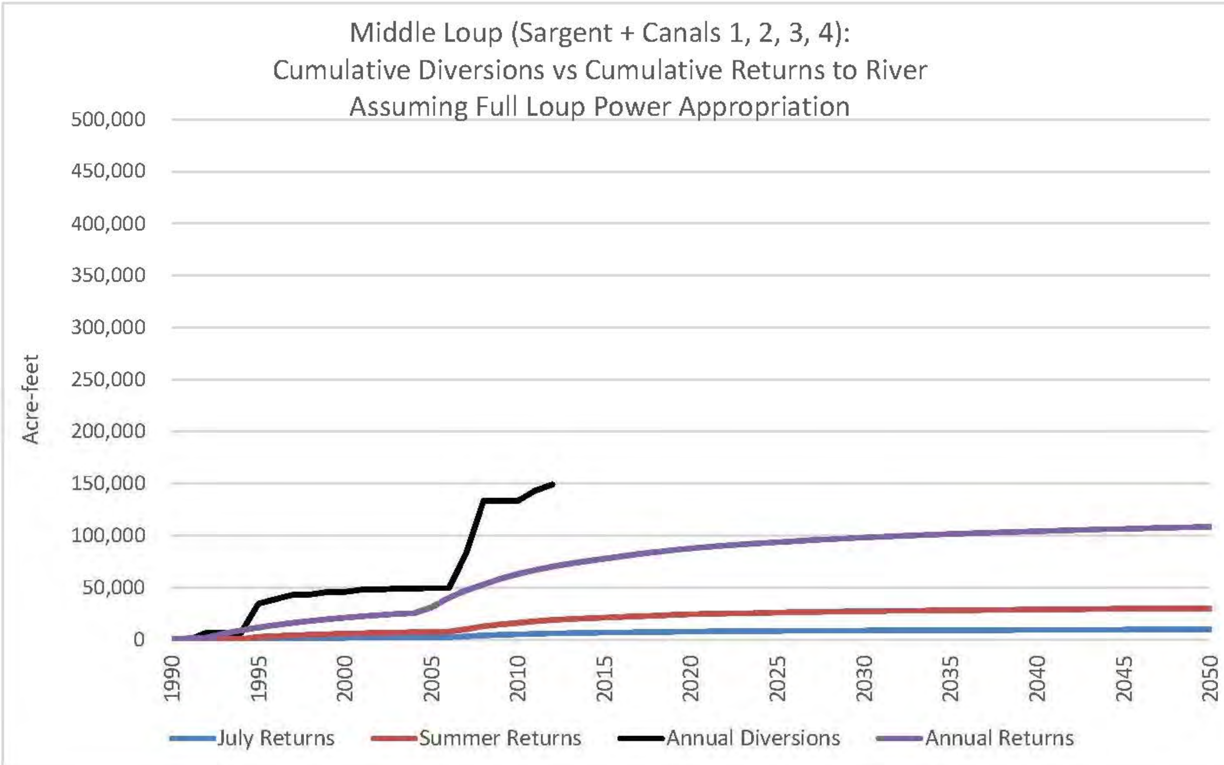


Figure 70 shows that when considering the full Loup River Public Power District hydropower appropriation, a much smaller volume of water is available for capture and diversion (approximately 150,000 acre-feet).

Figure 70: Cumulative Middle Loup Canal Diversions vs Cumulative Returns to Middle Loup River (assuming Loup Power Surface Water Appropriation)



In general, 20 percent of the seepage recharge on the Middle Loup system would return in the first year, 40 percent after 5 years, 60 percent after 20 years, and 80 percent after 90 years. After 20 years of operation, the average summer accretion to the river is 12-15 cfs per day (target season) while the annual accretion to the river is estimated to be over 9,000 AF; improving supply to the stream year-round.

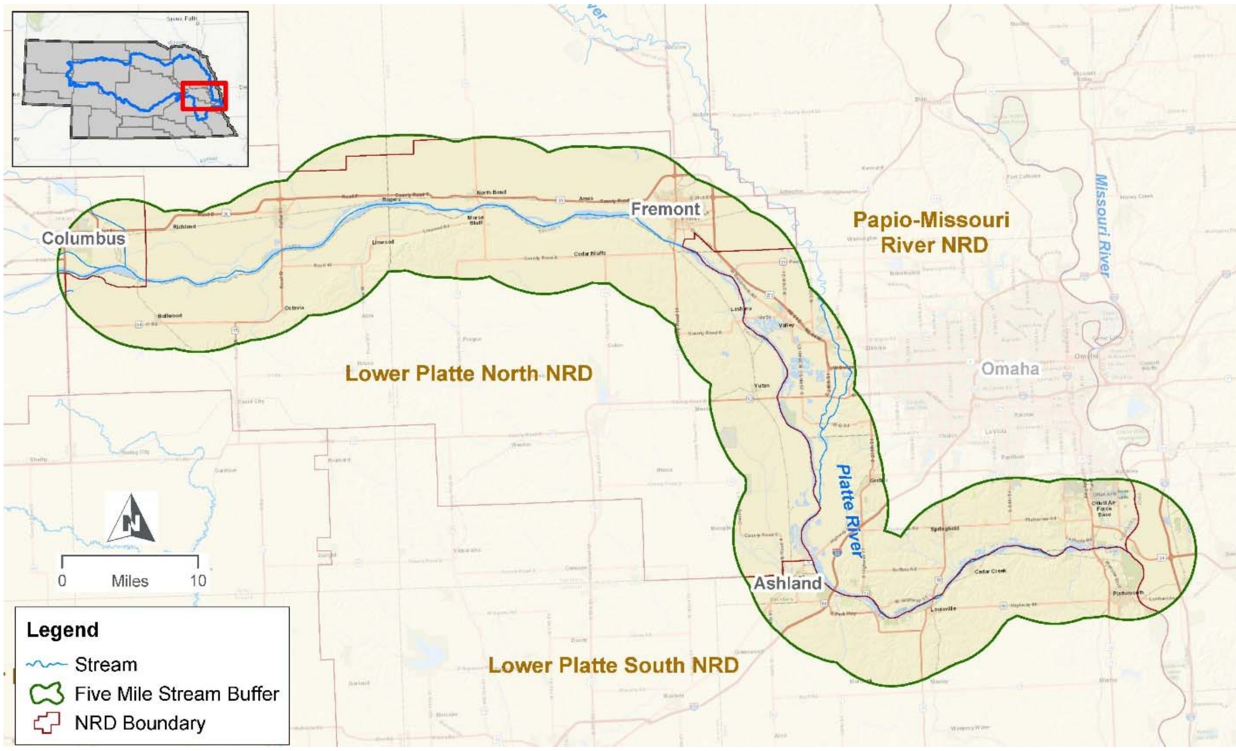
Potential constraints and considerations include third-party effects due to elevated groundwater elevations, coordination with annual canal maintenance activities, and existing operations and agreements amongst existing surface water irrigation districts on the Middle Loup River that may affect the ability to operate the system for intentional recharge in the non-peak season.

Project costs would include the increased operation and maintenance costs of the canal system and compensation through leasing agreements to use the existing canal facilities.

5.1.4 Dry-year Lease Option

The dry-year lease option would limit irrigation in areas adjacent to the Platte River during drought conditions. A rapid response area was defined in the Lower Platte River below the Loup River confluence by placing a 5-mile buffer on either side of the main channel of the Platte River (Figure 71). Irrigation wells in the alluvial aquifer of this area are most directly connected to streamflow in the Platte River and therefore have the quickest and largest depletive effects.

Figure 71: Platte River – Five Mile Buffer – Columbus to Louisville



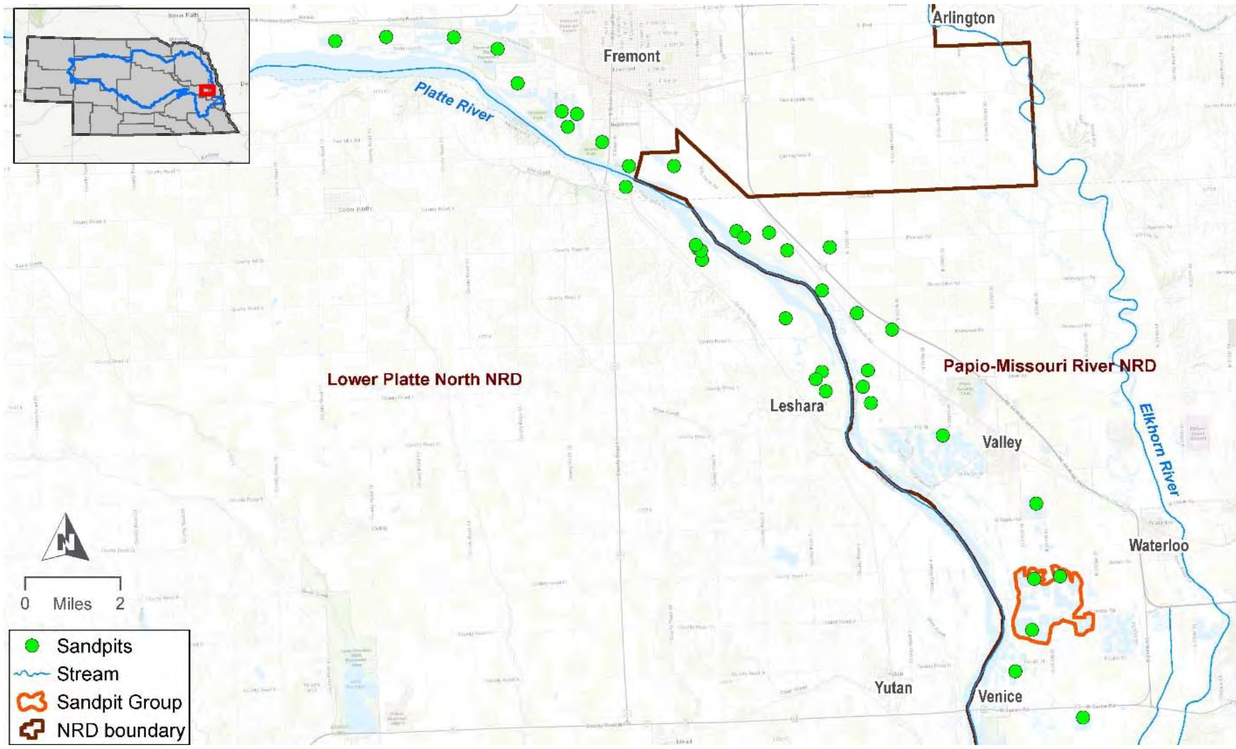
Approximately 310,000 irrigated acres are located within this area, served by over 3,000 wells according the NeDNR well registration database. Average annual pumping during the irrigation season is approximately 167,500 acre-feet. Analytical analysis using current estimates of stream depletion factors for the area estimates an average daily increase in Lower Platte River flows of approximately 25-30 cfs per day during July and August.

Implementing the dry-year lease option would require agreements with existing producers to forego irrigation in exchange for financial compensation. Typical format and content of these types of agreements vary, but may include a required lead time for notifying producers of intent to exercise the dry-year lease option and a limit on number of times option may be exercised during the agreement term. Financial terms may include a set annual compensation, or an annual retainer with an escalator clause when option is exercised. The escalator may also vary based on the lead time of notice, as producers may be able to adjust crop type or production inputs accordingly if sufficient lead time is provided.

5.1.5 Alluvial Groundwater Pumping

Alluvial groundwater pumping would involve use of wells to augment streamflow during times of shortage, with aquifer levels recovering during the non-peak season through natural recharge from river flows. The wells may pump surface water from sandpits located adjacent to the river, or from the alluvial aquifer near the river – both have similar depletive effects to streamflow in the Platte River (Figure 72). For analyzing this option, pumping of surface water from adjacent sandpits was investigated.

Figure 72: Platte River Alluvial Sandpits



A series of four small, interconnected sandpits in western Douglas County adjacent to the Platte River was evaluated to estimate project benefits. The total area of the system of sandpits is approximately 1,150 acres. This option would include financial compensation for the ability to drawdown the sandpit 4-ft in the event of a drought, yielding approximately 4,600 AF of water (equivalent to 100 cfs of augmented flows for a duration of 23 days). It is noted that this option would have an operational constraint to be considered. Because of the proximity and high degree of connection to the river, depletive effects of augmentation pumping would begin to be reflected in Platte River streamflow in a matter of days or weeks. Therefore, use of this option early in the peak season during a drought (June or July, for example), could potentially exacerbate drought conditions and decrease streamflow in the Platte River later in the peak season (August, for example).

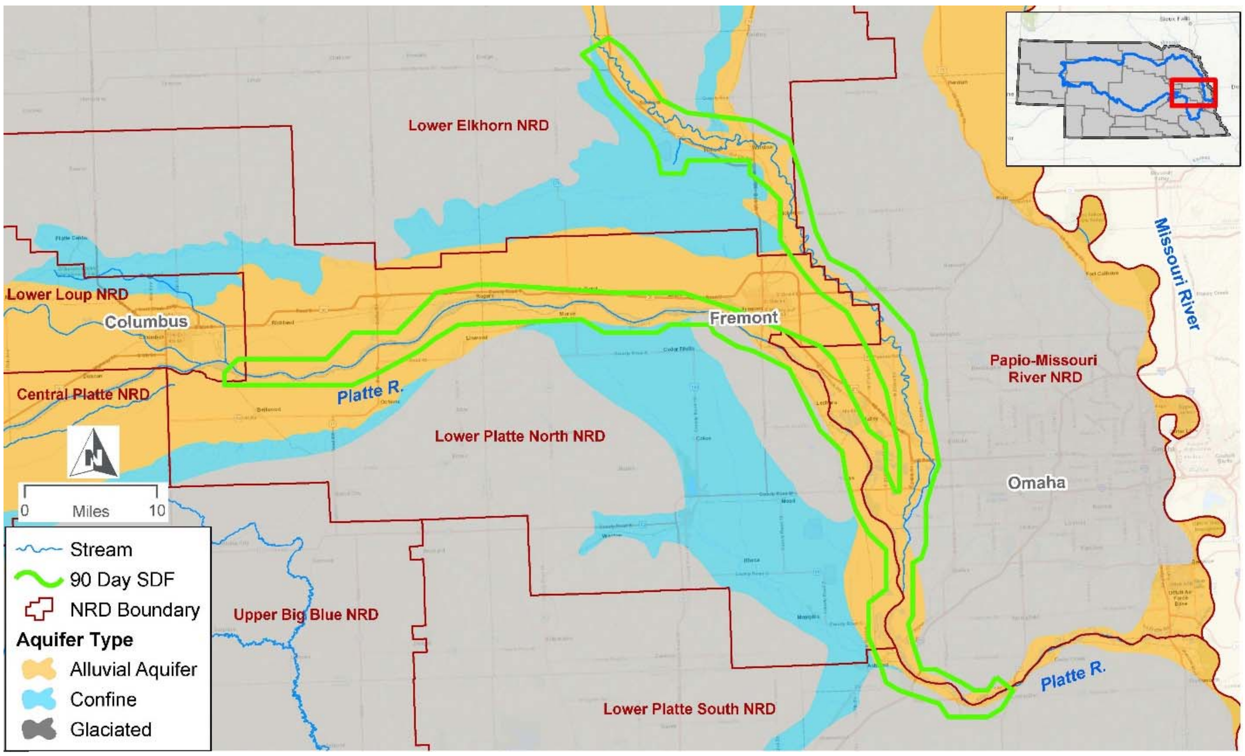
Costs associated with this option would include financial compensation to sandpit owners for the right to use the water from the sandpits as well as capital and O&M costs for the infrastructure to pump and deliver water to the river.

5.1.6 Groundwater Well-field Augmentation Project

The purpose of a well-field augmentation project would be to develop a well-field at a location with significant and accessible groundwater supplies, preferably at a considerable distance from the stream (low connectivity). New wells would draw water primarily from the aquifer, so as not to rely on induced recharge from the nearby surface water sources in the short term. This requires balancing the distances of the new wells from the river with the infrastructure costs for delivery (if pipe is used for conveyance) or conveyance losses (if natural channel conveyance is used). Ideally, new wells would be spread out to minimize interference with neighboring wells. The well-field could be used to pump water on demand that could be delivered to augment surface water flows, primarily for short durations during times of low-flows.

While specific sites were not investigated in detail, potential locations for a well-field augmentation project include the alluvial aquifers of the Platte and Elkhorn River systems (located outside the 90-day stream depletion factor (SDF) line); and in the Todd Valley in the Lower Platte River area. Figure 73 depicts the 90-day SDF line, which corresponds to the offset from the stream at which effects of pumping would take 90 days to deplete streamflow. This lag effect should be considered when locating any potential augmentation well sites. Sites should be located outside of this 90-day SDF line to delay depletion of the streamflow until the peak demand summer months have passed.

Figure 73: 90-Day Stream Depletion Factor Line



Potential constraints and considerations include third-party effects due to well-field pumping, well interference, discharge capacity of the receiving tributary (should one be used in lieu of direct conveyance to the river), and managing depletive effects of well-field pumping so as not to exacerbate low-flow conditions.

Project costs would include the development of the wells and well-field infrastructure, conveyance infrastructure, right-of-way, and annual operation and maintenance expenses.

5.2 Evaluation of Potential Mitigation Measures

Drought mitigation measures are actions, programs, and strategies implemented during non-drought periods to address potential risks and effects and to reduce the need for response actions; implementation of drought mitigation measures improves long-term resilience and reliability of the regional water supply.

Eight mitigation measures, and variations or combinations thereof, were evaluated in the Drought Plan that could increase regional water supply reliability. These include the following and are summarized in **Error! Reference source not found.**A and Table 17B:

- Installing an alluvial well-field adjacent to the Missouri River and pumping water to a tributary of the Elkhorn River for availability on demand (two alternatives considered in **Error! Reference**

source not found.A and Table 17B: one that discharges directly into Bell Creek and a second that discharges into the proposed Bell Creek Reservoir);
- Purchasing storage in the existing Sherman Reservoir and releasing water on demand (two release volumes considered in **Error! Reference source not found.**A);
- A new surface water storage reservoir on Skull Creek near Linwood for releasing water on demand;
- A new surface water storage reservoir on Bell Creek east of Winslow for releasing water on demand;
- Capture of Middle Loup River water in the non-irrigation season and diversion into the Middle Loup Canal system for intentional recharge and increase baseflow (two demand scenarios evaluated in **Error! Reference source not found.**A and Table 17B: one that considers the historic Loup hydropower operations downstream and a second that considers the full Loup hydropower appropriation downstream);
- Installing a well-field to tap into groundwater aquifers with limited connection to streamflow that can be pumped to the river to augment flows;
- Pumping from alluvial sandpits directly to the river to supplement flows; and
- A rapid response area/dry-year-lease agreement with farmers irrigating lands adjacent to the main channel of the Platte River from the alluvial aquifer.

Conceptual design of infrastructure requirements and anticipated operational characteristics were defined for each mitigation measure. In addition, the estimated project yield to the Lower Platte River at the Ashland gage was determined. For projects upstream in the basin, a routing tool was used to estimate the losses that occur during conveyance to the Ashland gage. This routing tool utilizes historic reach loss data during low-flow periods to estimate conveyance losses (see Appendix D). As part of this planning effort, continuous recording monitoring wells paired with stage recorders were installed to foster a better understanding of losses in the Lower Platte River under varying hydrologic conditions.

For comparison of alternative costs and benefits, a 20-year period was evaluated to reflect the relative reliability of water from the mitigation action, i.e. for some mitigation actions water will not be available every year. A 15-day operation period, targeting the typical late-July/early-August critical low-flow period in the Lower Platte River was assumed for project operations. For developing cost/acre-foot estimates included in **Error! Reference source not found.**A, costs were estimated over a 20-year period without using a discount rate or otherwise accounting for the time value of money. Benefits were based on acre-foot of water estimated to be delivered at the Ashland gage during the 15-day target period over the 20-yr period. Assumptions for each mitigation action are described in Appendix C.

Table 17A: Evaluation of Potential Mitigation Measures (cost estimate versus volume of water added)

Alternative	Volume Added at Source: Cumulative AF/15 days	Volume Added at Source: Ave Daily cfs	Where Added	Volume Increase at Ashland: Cumulative AF/15 days	Volume Increase at Ashland: Ave Daily cfs	Cost Estimate	Cost per acre-foot added at Ashland
Import Missouri River Water to Bell Creek (via alluvial well-field ; no reservoir)	59,400	100	Waterloo	46,300	80	$76,572,840	$1,654
Sherman Release (400 cfs at St Paul)	47,520	400	St. Paul	15,720	132	$9,628,000	$612
Sherman Release (250 cfs at St. Paul)	29,700	250	St. Paul	9,800	83	$6,955,000	$710
Skull Creek Res. Rel. (100 cfs at Linwood)	59,400	100	Linwood	46,300	80	$32,630,000	$705
Bell Creek Reservoir (Release 100 cfs at Waterloo)	59,400	100	Waterloo	46,300	80	$81,520,000	$1,761
Pump Missouri River water (via alluvial well-field) into Bell Creek Reservoir	59,400	100	Waterloo	46,300	80	$129,564,000	$2,798
Middle Loup Canal Recharge (Historic Loup Canal Operations)	7,525	13	Arcadia	2,525	4	$16,360,000	$6,478
Middle Loup Canal Recharge (Full Hydropower Right downstream)	2,034	3	Arcadia	634	1	$5,225,000	$8,238
Alluvial sandpit pumping	14,850	100	Leshara	14,850	100	$5,980,000	$403
Augmentation Well-field	59,400	100	TBD	59,400	100	$81,008,040	$1,364
Rapid Response Area/ Dry-year Lease	4,000	33	Columbus to Louisville	4,000	33	$248,500,800	$62,125

Notes: AF = acre-feet; cfs = cubic feet per second; 20-year period evaluated to reflect relative reliability of each measure; Fifteen-day operating period, targeting late July/early August critical low-flow period; Routing tool used to estimate reach gains/losses; Cost per acre-foot based on water that makes it to Ashland (common point). Reach losses for evaluation assume 66% loss from the Loup River to Ashland, 20% loss from the Elkhorn River to Ashland, and 20% loss from North Bend to Ashland.

Table 18B: Evaluation of Potential Mitigation Measures (advantages, disadvantages, and uncertainties)

Alternative	Advantages	Disadvantages	Uncertainties
Import Missouri River Water (via alluvial well-field to Bell Creek/no reservoir)	• Secondary source of water outside of Platte River basin increases supply reliability. • Operational every year & year-round	• Larger construction cost than many alternatives • Implementation - 5-10 years	• Future regulation on Missouri River • Well field siting
Sherman Release (400 cfs at St Paul)	• Utilizes existing facilities (no construction cost) • Produces large volume of water on-demand • Historically Loup River supply adequate to fill reservoir every year. • Implementation: 1-2 years	• Likely limitation on frequency of call on storage water • Significant conveyance losses from release point to Lower Platte River	• Requires cooperation and agreements with existing facility owners. • Negotiations will dictate price. • Cost estimates based on similar agreements in state.
Sherman Release (250 cfs at St. Paul)			

Alternative	Advantages	Disadvantages	Uncertainties
Skull Creek Res. Rel. (100 cfs at Linwood)	• Available every year & year-round • Produces large volume of water on demand • Potential for multi-purpose facility	• Larger construction cost than many alternatives • Land requirements, involving multiple landowners • Implementation: 5-10 years	• Runoff volume varies year to year • Land use impacts on runoff • Implementation (permitting, land purchase, etc.)
Bell Creek Reservoir (Release 100 cfs at Waterloo)			
Pump Missouri River water (via alluvia well-field) into Bell Creek Reservoir	• Secondary source of water outside of Platte River basin increases supply reliability. • Operational every year & year-round. • Importing into Bell Creek Reservoir requires a lower capacity system for importing water - saving $$	• Larger costs associated with combining alternatives that require both land and infrastructure. • Implementation: 5-10 years	• Future regulation on Missouri River • Well field siting • Implementation (permitting, land purchase, etc.)
Middle Loup Canal Recharge (Historic Loup Canal Operations)	• The canal recharge and dry-year lease projects are passive mitigation measures whose benefits (passive baseflow returns) accrue throughout the year, adding supply reliability to the overall system. • Existing infrastructure – no initial construction costs • Implementation: 1-2 years	• Unavailable to release a pulse of water volume "on-demand". • Takes time for the full benefit to be realized in river (lag effect) and some attenuation	• Requires cooperation and agreements with existing facility. • Negotiations will dictate price. • Cost estimates based on similar agreements in state. • Amount of improvement of overall system supply from year around accretions
Middle Loup Canal Recharge (Full Hydropower Right downstream)			
Alluvial sandpit pumping	• Minimal infrastructure costs (pumps from existing sandpits) • Utilizes existing sandpits (no construction costs) • Implementation: 1-2 years	• Limited operation window as pumping this close to the river may cause depletions to the stream (lag effect) that amplify impacts during extended drought • Likely limitation on the number of calls allowed in a 20-year period	
Augmentation Well-field	• Available every year & year-round • Can be located closer to critical reach to reduce losses compared to alternatives producing similar volumes upstream in the Basin.	• Land & infrastructure costs make this one of the more expensive alternatives. • Adds to overall depletions • Implementation: 5-10 years	• Siting to avoid interference with existing wells. • Long-term reliability of aquifer
Rapid Response Area/ Dry-year Lease	• No infrastructure or construction necessary.	• Logistics of securing agreements with thousands of producers • Likely limitation on the number of calls allowed in a 20-year period • Most expensive of all the alternatives by an order of magnitude based on assumptions.	• Negotiations will dictate price. • Cost estimates based on similar agreements in state, and factors such as cost differential between irrigated and dry land rental rates. • Uncertain how many producers would participate (benefits assume 100% participation which is unlikely)

5.3 Response Actions

Drought response actions are near-term actions triggered during specific stages of drought to manage the limited supply and decrease the severity of immediate effects. Response actions can be quickly implemented and can provide rapid benefits.

In this first increment of the Drought Plan, potential mitigation measures (**Error! Reference source not found.**) have been evaluated, but preferred measures have not been determined or constructed; therefore, the primary drought response action available to the Consortium at this time is communication and outreach.

Consistent and coordinated messaging to basin water users (municipal, industrial, domestic, irrigation, etc.), as well as the general public, raises awareness of the current water supply conditions, allows water users to proactively alter their demand and usage based on limited water supplies, and defines expectations of forecasted conditions and potential actions in response to the drought.

5.3.1 Coordinated Public Messaging Effort

Consistent and coordinated messaging to basin water users (municipal, industrial, domestic, irrigation, etc.), as well as the general public, raises awareness of the current water supply conditions, allows water users to proactively alter their demand and usage based on limited water supplies, and defines expectations of forecasted conditions and potential actions in response to the drought.

The internet and other digital sources capture a wide audience and it is important that the right information out. The Consortium website should include drought stage, an explanation of the drought stage, links to water efficiency and conservation information, and a link to drought plan.

The Consortium should maintain directions for directing media inquiries. A list of media contact is provided in Table 19. A draft press release follows.

Table 19: Media Contact Information

Contact Information	
Washington County Pilot-Tribune & Enterprise Mark Rhoades PO Box 328, Blair, NE 68008 (402) 426-2121 editor@enterprisepub.com	Columbus Telegram & Fremont Tribune Vincent Laboy 1254 27th Ave, Columbus, NE 68601 (402)753-9000 vincent.laboy@lee.net
Lincoln Journal Star Dave Bundy 926 P Street, Lincoln, NE 68508 (402) 473-7334 dbundy@journalstar.com	Norfolk Daily News Cristina Anderson 525 Norfolk Ave, Norfolk, NE 68701-0977 (402) 371-1020 canderson@norfolkdailynews.com
Omaha World Herald Jeff Hartley 1314 Douglas Street, Omaha, NE 68102 (402) 444-1000 Jeff.hartley@owh.com	Wahoo Newspaper Lisa Brichacek 564 N. Broadway Street, Wahoo, NE 68066 (402) 443-4162 Lisa.brichacek@wahoonewspaper.com
Bilingual Media Contacts	

El Perico Clay Seaman PO Box 7360, Omaha, NE 68107 (402) 341-6967 clay@el-perico.com	Buenos Dias Nebraska (online) Oscar Erives 120 W. 3rd St, Grand Island, NE 68801 (308) 381-7777 oscarerives@yahoo.com
KBBX Radio (97.7 FM) J. Timm 11128 John Galt Blvd, Omaha, NE 68137 (402) 884-0968 jtimm@connoisseurmedia.com	KHUB PO Box 669, Fremont, NE 68025 (402) 721-5012 khub@nrgmedia.com

Press Release Template:

For Immediate Release

Contact: Name, phone, email

Headline (7-10 words that describe major point of the release)

City, Date

Main Paragraph (quickly answers who, what, where is it taking place, when and why is this important of the story)

Quote (from pre-determined spokesperson. Quote should say action Consortium is taking, tell people what actions they should be taking, etc.)

Key Message 1 (supporting points)

"The Lower Platte River Basin has been experiencing an extended period of drought conditions which results in declining levels .. . . In accordance with Drought Contingency Plan, once the [drought indicator], drought condition declared.

Key Message 2 (supporting points)

- Level 1, "Moderate Drought:" This level of drought involves "some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; and voluntary water-use restrictions requested," according to the monitor.
- Level 2, "Severe Drought:" This level means that "crop or pasture losses likely; water shortages common; and water restrictions imposed," the monitor states.
- Level 3, "Extreme Drought:" This is the second-highest level of drought, with "major crop/pasture losses" and "widespread water shortages or restrictions."

Key Message 3 (supporting points)

The situation continues to evolving and may change (better or worse) depending on future weather conditions. Update as new information becomes available.

More information (Name, phone, web site, other ways to get information)

In order to maintain consistent public messaging, a scripted message template is included.

Table 20: Scripted Message Template

NOTE: Direct all media inquiries to ________________ (or his/her designee):

Phone:

Email:

Revised: (date)

Contact/Target Audience	Sample Question	Consortium Response
General Public	"When will water flow return to normal?"	
	"Is my water use restricted now? When will the restrictions be lifted?"	
	"What are you doing to prevent this from happening again?"	
Government Regulator	"What are the impacts?"	
Elected Official	"What is the impact on the community? The environment? The economy?"	
News Media	"What are the current water supply conditions?"	
	"What is the status of the community demand reduction response?"	
	"What is the status of conservation measures?"	
	"What is the estimated loss?"	
	"What caused the incident?"	
	"What are you going to do to prevent this from happening again?"	

5.4 Additional Drought Resources

In addition to the specific monitoring, mitigation, and response actions identified in development of this plan, additional resources and actions of national, state, and local programs exist to aid in preparing for and responding to drought conditions. While not part of this plan's actions, the programs and actions described in this section are available to the Consortium and its constituents to aid in times of drought.

5.4.1 National Drought Mitigation Center

The NDMC website (https://drought.unl.edu/droughtplanning/PlanningHome.aspx) provides a wealth of information and actions to take before, during, and after a drought for a variety of impacted water users. In addition, the University of Nebraska Institute of Agricultural and Natural Resources has specific drought information and resources for Nebraska at the following website: (https://droughtresources.unl.edu/)

5.4.2 Nebraska Soil and Water Conservation Program

The Nebraska Soil and Water Conservation Program, established in 1977, provides state financial assistance to Nebraska landowners for the installation of approved soil and water conservation measures that improve water quality, conserve water, and help control erosion and sedimentation. Among the eligible practices for cost-share assistance are; terraces, terrace outlets (grassed or mechanical), irrigation reuse pits, grade stabilization structures, dams, diversions, grassed waterways, control basins, pasture and range seeding, planned grazing systems, irrigation water management, and windbreaks and windbreak renovations.

The Nebraska Natural Resources Commission determines the list of eligible practices, establishes operating procedures for the fund, and allocates the funds annually among the State's 23 NRDs. The USDA Natural Resources Conservation Service (NRCS) provides the technical assistance needed in planning and installing the approved conservation measures. Each NRD is responsible for the administration of the program at the local level including accepting applications from landowners, setting priorities, and working with the landowners and contractors to complete the practices.

Table 21: Nebraska Soil and Water Conservation Program – Drought Relevant Practices

Practice ID	Practice Name	Purpose
NC-1	Constructing Terrace Systems	To control erosion on cropland, to conserve water and to reduce pollution
NC-3	Constructing Water Impoundment Dams	To impound runoff, conserve water, prevent erosion, prevent pollution, and to enhance groundwater recharge
NC-5	Constructing Irrigation Tailwater Recovery Pits with or without Underground Return Pipe	To impound runoff from irrigated fields for reuse; hence, conserving groundwater
NC-6	Constructing Diversions	To divert water from areas where it is in excess to sites where it can be used or disposed of safely
NC-8	Constructing Water-and-Sediment-Control Basins	To reduce on-site erosion, reduce sediment, reduce sediment content in water, intercept and conduct surface runoff through subsurface conduits to stable outlets, reduce peak rate or volume of flow at downslope locations, reform the land surface, and improve farmability

Practice ID	Practice Name	Purpose
NC-9	Constructing Dugouts for Livestock Water (runoff collection only)	To create an impoundment for livestock water use by excavating to collect runoff in grassland.
NC-10	Pasture Planting or Range Seeding (land use conversions)	To establish grass on land being converted from other uses or the renovation of existing pasture or range
NC-11	Critical Area Planting (grass)	To stabilize the soil, reduce damage from sediment and runoff to downstream areas
NC-12	Windbreaks	To establish a stand of trees to conserve soil and moisture and to prevent erosion
NC-13	Constructing Underground Return Pipe from Irrigation Tailwater Recovery Pits	To provide a permanent conveyance facility for water impounded by an approved tailwater recovery pit to the water supply that created the tailwater.
NC-14	Planned Grazing Systems	To reduce erosion and improve water quality by maintaining or improving plant cover for increased forage production, enhanced wildlife habitat, grazing uniformity and water use efficiency
NC-16	Windbreak Renovation	To provide for the restoration of farmstead or field windbreaks that have been rendered substantially ineffective due to the death of trees or other windbreak plantings as a result of weather, disease, or other natural causes
NC-17	Irrigation Water Management	To conserve groundwater and surface water by improving water use efficiency on irrigated lands
NC-19	Repair of Practices	To repair the following practices or practice elements when the damage to the practice is due to natural cause(s) rather than improper or inadequate maintenance; terraces, dams, diversions, grade stabilization structures, and livestock water supply pipelines. Any repair work must return the practice to a condition that meets technical specifications of the NRCS.

5.4.3 Education Programs

Many NRDs participate in school outreach programs to help teach children about the importance of conserving natural resources and ways they can contribute to a safe, clean environment. Elementary students attend water and natural resources festivals across the state, while older students benefit from outdoor classroom development, contests for land, range, and soil judging, and other activities.

Many NRDs help teachers develop tools to pass the conservation message on to the next generation. NRDs assist universities and colleges in developing natural resources opportunities. Workshops for farmers and urban landowners provide practical information on a variety of ways to care for natural resources.

5.4.4 Administrative Actions

5.4.4.1 MUD Shift Operations to utilize Missouri River

The MUD Platte West well-field is designed to operate at 100 MGD. In 2012, MUD shifted operations to its Florence plant (Missouri River surface water source), reducing pumping at the Platte West well-field in August. The coordination framework provided by the Consortium will help facilitate the desire to implement this type of action in future droughts. When dealing with future drought conditions there are a myriad of factors MUD would need to consider before again shifting water production between its three water treatment plants. These factors include, but are not limited to: plant capacities, water quality, streamflow on both the Platte and Missouri River, customer demand and/or operational efficiencies.

5.4.4.2 MUD and LWS Interconnection

At the time of this plan development, MUD and LWS are independently investigating the feasibility of an interconnection between their finished water systems. Conceptually this interconnection would provide LWS treated water from MUD's system originating from the Missouri River. Access to imported water from the Missouri River would provide LWS access to a second water source largely unaffected by drought conditions. The interconnection may also provide water for future growth in demands on the LWS system.

5.4.4.3 Urban Water Use Restrictions

Many water utilities implement water use restrictions during various stages of drought. MUD and LWS both implement voluntary and mandatory water use restrictions during various stages of drought. These restrictions are described in detail in Appendix A.

5.4.4.4 Urban Water Rate Pricing

In combination with water use restrictions, many water utilities implement inclining block rates. LWS has an inclining block rate structure in place year round. More recently, LWS implemented a "water shortage rate" policy whereby the rate blocks are further increased to curtail outdoor water use. MUD's inclining block rate structure is utilized during summer months only. LWS and MUD implement water rate pricing as described in Appendix A.

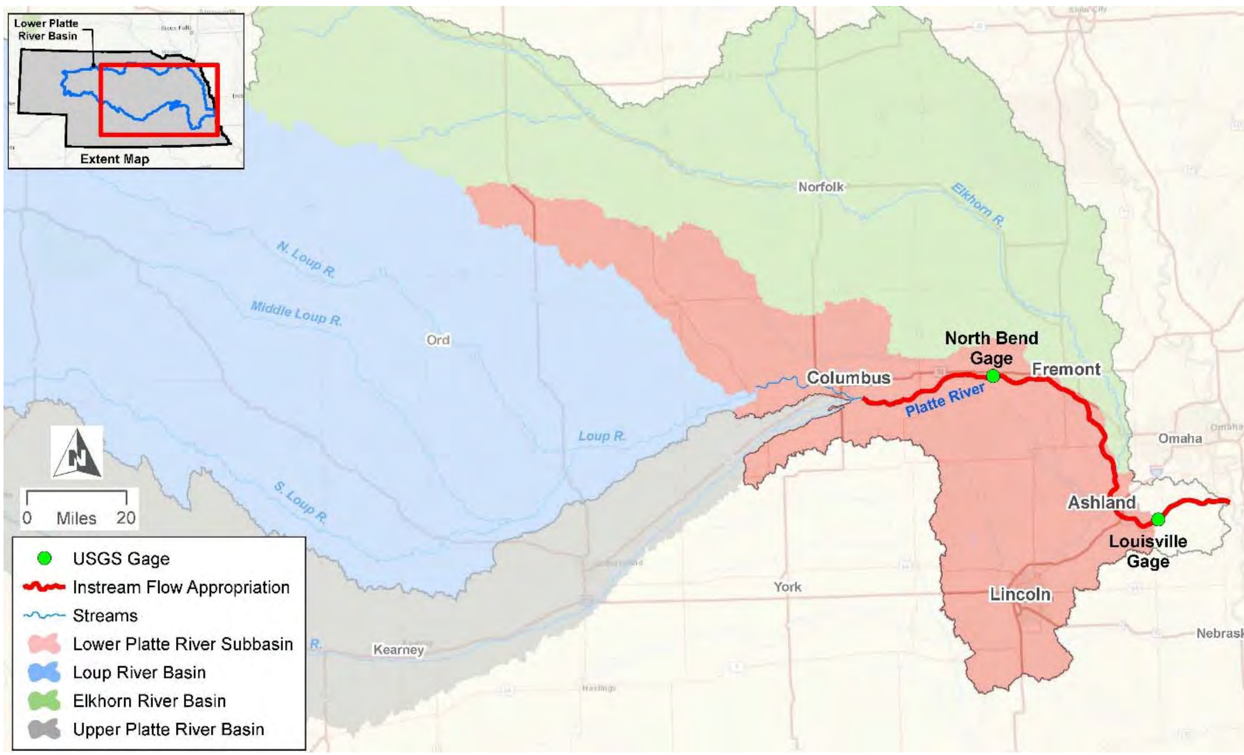
5.4.4.5 Surface Water Right Administration

Nebraska surface waters are governed by the prior appropriation (first-in-time, first-in-right) doctrine, which allows diversion of water from the surface waters of the state based on the date the water right was obtained. This system protects those who received their water rights first during periods when the overall water supply is insufficient to meet all appropriated water rights. Thus, the entity with the earliest priority date (first-in-time) is entitled to their full appropriation (first-in-right) before a later priority date entity receives any water. An exception to the priority doctrine is preferences. Under Nebraska appropriation law, domestic surface water use is considered to be superior to all other uses, and agriculture is inferior to domestic but superior to industry. If a junior superior user takes water from a senior inferior user, the senior must be paid for the water.

One of the mitigation measures available to the City of Omaha (MUD) and the City of Lincoln (LWS) during periods of drought is to exercise a priority call on the Lower Platte River, affecting hundreds of upstream junior irrigation appropriations, likely during peak irrigation demand periods. This disruption to irrigation supplies would leave many of those junior irrigation users vulnerable to crop loss during a prolonged drought. Regulation or interference with these irrigation demands can be costly should this type of priority call be necessary.

The Nebraska Game and Parks Commission holds instream flow appropriations for the protection of fish and wildlife. The instream flow rights have a priority date of November 30, 1993. The instream flow appropriations are measured at the North Bend gage and the Louisville gage, although the appropriations extend to the confluence with the Missouri River. When instream flow appropriations are not met at the North Bend gage, all junior surface water appropriations above that gage, including those in the Loup River subbasin, are closed to diversion. When instream flow appropriations are not met at both the North Bend and the Louisville gages, all junior surface water appropriations above both gages, including those in both the Loup and Elkhorn River subbasin, are closed to diversion. In circumstances where the instream flow appropriation is being met at the North Bend gage but not at the Louisville gage, all junior appropriations above the Louisville gage, including those in both the Loup and Elkhorn River subbasins, are closed to diversion (NeDNR 2016) (Figure 74).

Figure 74: Instream flow Trigger Locations



5.4.5 Rural Water Supply

Each rural water agency is required to provide the Nebraska Department of Health and Human Services (DHHS) with a Water Shortage Emergency Response Plan. Each plan must identify stages and criteria of a water shortage, alternate or emergency water sources, a communication plan, and water shortage response actions.

For those domestic users who use self-supplied domestic groundwater wells, *NebGuide* “G1536” makes recommendations for storing an emergency supply of water. Recommendations include the following (Skipton, Dvorak, and Albrecht 2010):

- Replace pressure tanks with larger tanks or using supplemental tanks to provide additional storage.
- Reduce demand during high water use periods by storing water extracted during low use periods
- Deepen existing well or drill new well
- Bottle or haul water from near-by public water supply

5.4.6 Agricultural Sector Response Actions

5.4.6.1 Groundwater Controls

The Nebraska Legislature, under Nebraska Revised Statutes 46-701 to 46-754 of the Nebraska Groundwater Management and Protection Act, grants the NRDs authority to protect the quantity and quality of water, and to resolve conflicts between surface water and groundwater users. The NRD may adopt one or more controls, which may include the following:

- Allocations of the amount of groundwater users may withdraw
- System of rotation for use
- Well spacing requirements
- Well meter requirements
- Reduction of irrigated acres
- Limits on or prevention of expansion of irrigated acres or beneficial use of water
- NRD approval of transfer of groundwater off overlaying land
- NRD approval of transfer of rights to use groundwater that result from NRD-imposed allocations or other NRD restrictions
- Prevention of adverse effects on other groundwater or surface water users

Each NRD maintains a Groundwater Management Plan with water quality area designation criteria and water quantity area designation criteria, which include use well spacing, allocations, and stays on new development depending on which phase is triggered.   These plans are summarized in Appendix A.

5.4.6.2 National Drought Mitigation Center

The NDMC provides guidance for ranchers during drought including pasture management, finding feed, reducing feed demand, and lessening risk of heat stress: http://drought.unl.edu/ranchplan/DuringDrought.aspx.

5.4.6.3 University of Nebraska–Lincoln CropWatch

CropWatch provides guidance for managing crop production during drought conditions, including articles related to corn, sorghum, soybeans, dry beans, forages, silage, and wheat production. It also provides information on farm management during drought, harvest, storage, irrigation practices, soil management, and weed management: https://cropwatch.unl.edu/crop-management-drought

6.0 Operational and Administrative Framework, and Plan Update Process

The Consortium will have two scheduled meetings each year to: (1) prepare for the monitoring and evaluation effort for the current year; (2) discuss evolving needs in the region, any triggers, and issues to be addressed; (3) evaluate and prioritize identified mitigation projects to implement as future funding opportunities arise; (4) identify funding needs and sources for the following year's activities, and develop a plan to pursue identified funds; and (5) discuss progress and results of the Drought Plan monitoring and evaluation effort, other items brought forth by the Consortium, and review content from the updated Drought Plan (every 5 years). These two scheduled meetings will be concurrent with the fall and spring monitoring meetings illustrated in Figure 75. The Consortium chairperson is the NeDNR representative who will be responsible for setting the agenda, public noticing the meetings, and conducting the meetings. The chairperson will house and maintain the files and information of the Consortium.

6.1 Plan Implementation

On an ongoing basis and at the approximate frequency illustrated in Figure 75, the Consortium shall monitor indicators and indices for trigger levels that may indicate the onset of drought conditions. **Error! Not a valid bookmark self-reference.**Table 22 lists the drought monitoring roles and responsibilities assigned to each Consortium member.

Table 22: Drought Monitoring Roles/Responsibilities

Drought Indicator	Consortium Member	Contact
Website Hosting/Maintenance	Lower Platte South NRD	General Manager
PDSI/SPI	NeDNR	Water Planning Division Manager
Streamflow & recession tool	NeDNR	Water Planning Division Manager
Snowpack/Reservoir Levels	NeDNR	Water Planning Division Manager
Monthly climate webinars & review US Drought Monitor website	LWS	Superintendent of Water Production
Groundwater Levels	Each entity individually in accordance with their groundwater management plans (NRDs) and aquifer monitoring protocol (LWS/MUD)	Lower Platte North NRD- Water Resources Manager Papio-Missouri River NRD- Ground Water Management Engineer Lower Platte South NRD- Water Resources Specialist MUD-Director, Water Production & Pumping LWS- Superintendent of Water Production NeDNR-Water Planning Division Manager

Drought Indicator	Consortium Member	Contact
Notification drought triggers reached	NeDNR will notify Consortium members when drought triggers have been reached; Consortium will initiate response actions according to drought level.	NeDNR -Water Planning Division Manager

Figure 75: Lower Platte River Drought Contingency Plan Implementation Actions

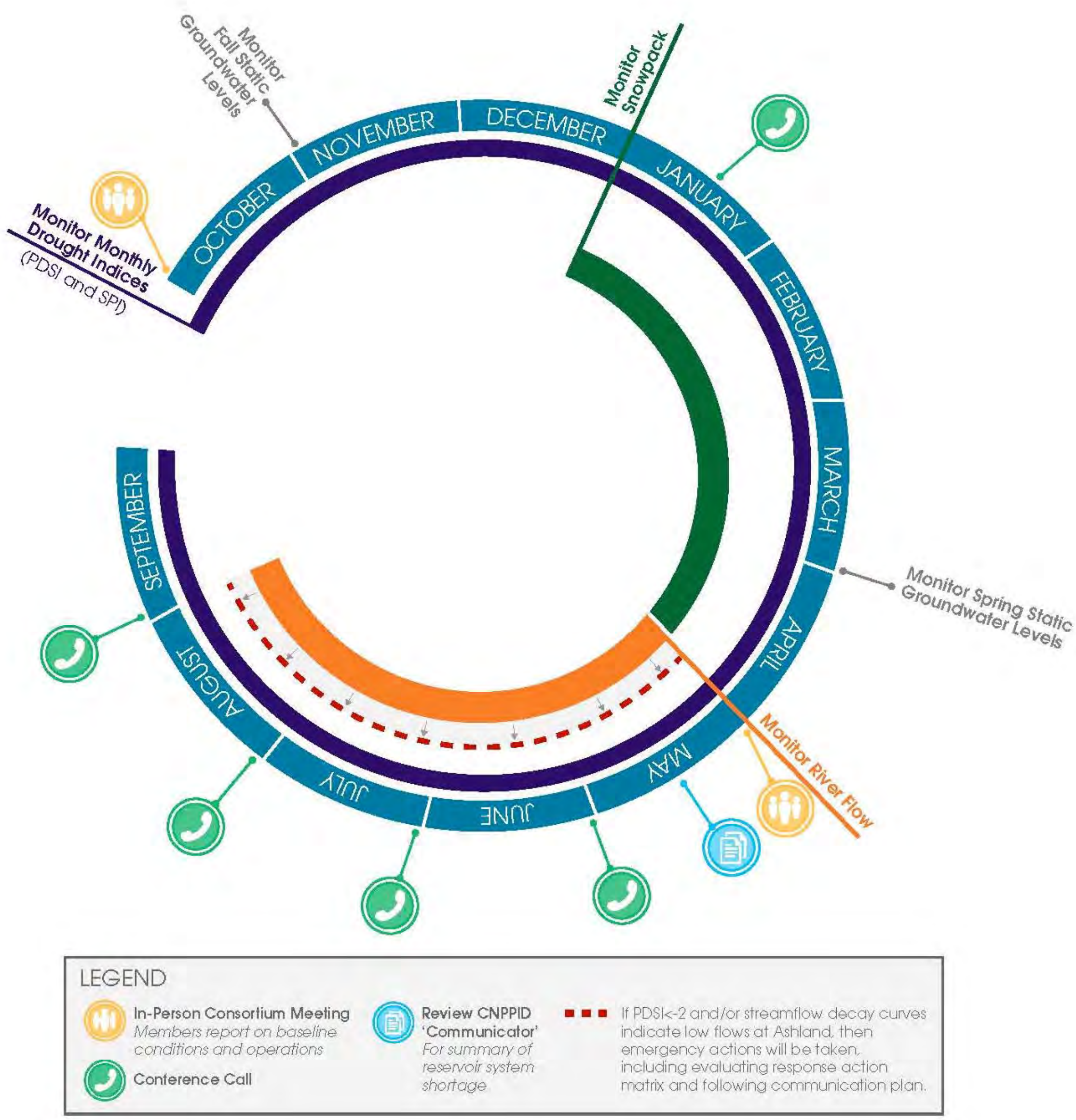


Table 23 lists the implementation plan actions over the calendar months.

Table 23: Drought Monitoring Continuum

Month	Activities
November - March	Monitoring: - PDSI/SPI indices - Mountain and plains snowpack - CNPPID operating plan - River flows
April/May meeting	Meeting to review following: - PDSI/SPI indices - Mountain and plains snowpack - NRD Spring static aquifer levels - Upper Platte River/Loup River reservoir storage - River flows - CNPPID operating plan - Well-field aquifer levels - Conveyance tool projections
June/July/August/September	Monitoring and potentially meetings, depending on conditions: - PDSI/SPI indices - River flows - Well-field aquifer levels - Conveyance tool projections - Response actions
October/November meeting	Post-peak season evaluation meeting. Items for review/discussion: - Past season operations - Well-field aquifer levels - NRD fall static aquifer levels - PDSI/SPI indices - Upper Platte River/Loup River reservoir storage

6.2 Plan Update Process

The Drought Plan and associated planning are meant to be part of an adaptive process that is routinely updated to reflect the needs of the Lower Platte River Basin and its water users. The Consortium will evaluate the need for updating the Drought Plan every five years, or as conditions warrant (such as implementation of a response action project).

- On an annual basis, the Consortium will gather information and make any necessary updates to the Vulnerability Assessment.
- On an annual basis, the Consortium will review any changes in the Vulnerability Assessment, determine the need for new and revised actions, and update the status of existing actions and add new actions (as needed).
- The Consortium may identify planning and technical efforts outside those anticipated that need to be undertaken based on changed conditions or a potential need.

- Every five years, the Consortium will assess the need for and prepare an updated Drought Plan (as needed).

6.3 Continued Communication and Outreach

In addition to internal plan maintenance and implementation, it important that the Consortium maintains a relationship with stakeholders and the public and serves as a resource to water users in the Lower Platte River. The following communication and outreach activities have been identified:

- The Consortium will keep the project website updated to keep interested stakeholders informed of meetings, new materials, and other information related to the Drought Plan and its implementation. An email distribution list of interested stakeholders will be maintained and used for distribution of information and notices of website content updates.
- Each individual agency will be responsible for informing its constituents, customers, and the public of any actions initiated and related progress and results.
- Coordination and information sharing with other ongoing efforts will be beneficial to both the Drought Plan and the other drought monitoring and planning efforts (Missouri Basin Plan, NEMA, etc.). At this time there is no set protocol or timing identified for this coordination efforts, rather it is anticipated this coordination will occur on an as needed basis.

7.0 Glossary of Terms

Term	Definition
Accretion	Addition of streamflow that results from an offset or mitigation measure or project.
Acre-Foot (AF)	Volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot, equivalent to 325,851 gallons.
Appropriation	See Surface Water Appropriation
Aquifer	A geological formation or structure of permeable rock or unconsolidated materials that stores and/or transmits water, such as to wells and springs.
Baseflow	The portion of streamflow that is not runoff and results from seepage of water from the ground into a channel slowly over time.
Cubic feet per second (cfs)	The rate of discharge representing a volume of 1 cubic foot passing a given point during one second. It is equivalent to 7.48 gallons per second, or 4,448.8 gallons per minute.

Term	Definition
Drought	There are many definitions for drought, but all definitions include periods of dryness and below average precipitation. The National Drought Mitigation Center (NDMC) lists four types of droughts: meteorological drought, agricultural drought, hydrological drought, and socioeconomic drought as described in Section 4.1. For this Drought Plan, the three drought levels identified remain consistent with NDMC definitions of "moderate", "severe", and "extreme" droughts: • A Level 0, "Abnormally Dry" or "Mild Drought" indicates an area may be experiencing "short-term dryness slowing planting, growth of crops or pastures" indicating the onset of drought or may be coming out of drought and experiencing lingering effects of drought. • A Level 1, "Moderate Drought" involves "some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; and voluntary water-use restrictions requested." • A Level 2, "Severe Drought" means that "crop or pasture losses likely; water shortages common; and water restrictions imposed." • A Level 3, "Extreme Drought" involves "major crop/pasture losses" and "widespread water shortages or restrictions."
Depletion	See Groundwater Depletion
Evapotranspiration (ET)	The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.
Excess Flow	The historic quantity of surface water in the Lower Platte River Basin in excess of the state protected flows in the Platte River.
Fully Appropriated	From Nebraska Revised Statutes 46-713, subsection (3): "A river basin, subbasin, or reach shall be deemed fully appropriated if NeDNR determines based upon its evaluation conducted pursuant to subsection (1) of this section and information presented at the hearing pursuant to subsection (4) of section 46-714 that then current uses of hydrologically connected surface water and groundwater in the river basin, subbasin, or reach cause or will in the reasonably foreseeable future cause (a) the surface water supply to be insufficient to sustain over the long term the beneficial or useful purposes for which existing natural-flow or storage appropriations were granted and the beneficial or useful purposes for which, at the time of approval, any existing instream appropriation was granted, (b) the streamflow to be insufficient to sustain over the long term the beneficial uses from wells constructed in aquifers dependent on recharge from the river or stream involved, or (c) reduction in the flow of a river or stream sufficient to cause noncompliance by Nebraska with an interstate compact or decree, other formal state contract or agreement, or applicable state or federal laws".
Gallon per capita per day (gpcd)	A term generally used to approximate the average amount of water used per day, per person, in one year.
Groundwater	Water which occurs in or moves, seeps, filters, or percolates through ground under the surface of the land, and shall include groundwater which becomes commingled with waters from surface sources.

Term	Definition
Groundwater Depletion	Reduction to streamflow that results from a new use of either groundwater or surface water.
Groundwater Recharge	The addition of water to the zone of saturation. Infiltration of precipitation and its movement to the water table is one form of natural recharge.
Hydraulic Conductivity	A property of vascular plants, soils and rocks, that describes the ease with which a fluid (usually water) can move through pore spaces or fractures. It depends on the intrinsic permeability of the material, the degree of saturation, and on the density and viscosity of the fluid.
Hydrologically Connected	Describes a geographic area designated by the NeDNR where the existing amount of groundwater and surface water each has significant influence on the other and where appropriate regulation exists.
Induced Groundwater Recharge	An indirect method of artificial recharge involving pumping from an aquifer hydrologically connected with surface water such as perennial streams. The heavy pumping lowers the groundwater level and a cone of depression is created. Lowering of water levels induces the surface water to replenish this groundwater. This method is effective where a streambed is connected to aquifer by sandy formation.
Instream flow Demand	Demands for streamflow taking place within the stream and is not withdrawn from a surface water source. These demands are based on current appropriations held by the Nebraska Game and Parks Commission or any local Natural Resources Districts.
Integrated Management Plan (IMP)	A plan cooperatively developed by NeDNR and individual NRDs for a specific area. The objective of an integrated management plan is to manage such river basin, subbasin, or reach to achieve and sustain a balance between water uses and water supplies for the near and long term.
LB 483	On December 12, 2008, the NeDNR reached a preliminary determination that the Lower Platte River Basin was fully appropriated. Subsequent to this determination, NeDNR reached a final determination that the Lower Platte River Basin was not fully appropriated. Following this reversal, on April 6, 2009 the Legislature passed LB 483 which requires that when a basin status change occurs, the affected NRDs must adopt rules and regulations that: 1) allow a limited number of total new groundwater irrigated acres annually; 2) are created with the purpose of maintaining the status of not fully appropriated based on the most recent determination; 3) be for a term of not less than four years; and 4) limit the number of new permits so that total new groundwater irrigated acres do not exceed the number set in the rules and regulations.
LB 962	A bill passed by Nebraska Legislature in 2004 that allows leases of surface water, changes administration of surface water rights, establishes a proactive approach to the integrated management of hydrologically connected groundwater and surface water and creates funds to direct money towards data gathering, research, conservation and implementation of integrated management plans in fully and overappropriated basins.

Term	Definition
Lower Platte River Basin	The Lower Platte River Basin is defined as all surface areas that drain into the Lower Platte River, including those areas that drain into the Loup River and the Elkhorn River, and all aquifers that impact surface water flows of the basin.
Lower Platte River Basin Coalition (Coalition)	Formed through an Interlocal Cooperation Act agreement among the NeDNR and the following seven Natural Resources Districts (NRDs) that encompass the Lower Platte River Basin: Upper Loup NRD; Lower Loup NRD; Upper Elkhorn NRD; Lower Elkhorn NRD; Lower Platte North NRD; Lower Platte South NRD; Papio-Missouri River NRD
Lower Platte River Consortium (Consortium)	Beginning in 2016, the Lower Platte South NRD, Papio-Missouri River NRD, Lower Platte North NRD, Metropolitan Utilities District (MUD), Lincoln Water System (LWS), and Nebraska Department of Natural Resources (NeDNR), collectively referred to as the Lower Platte River Consortium (Consortium), embarked on an effort to develop a drought contingency plan for the Lower Platte River Basin in Nebraska.
Lower Platte River Drought Contingency Plan (Drought Plan)	The purpose of the Drought Plan is to refine the collective understanding of drought vulnerabilities, while developing more robust monitoring and forecasting tools coupled with timely triggers, new mitigation strategies and responsive actions to create a sound operational framework and improve critical water supply needs of the area through drought periods.
Million gallons per day (MGD)	A rate of flow of water equal to 133,680.56 cubic feet per day, or 1.5472 cubic feet per second, or 3.0689 acre-feet per day.
Natural Resources District (NRD)	A political subdivision of the State that governs the natural resources within the subdivision.
Nebraska Department of Natural Resources (NeDNR)	Nebraska Department of Natural Resources; a State Agency.
Ogallala Aquifer	A shallow water table aquifer surrounded by sand, silt, clay and gravel located beneath the Great Plains in the United States. One of the world's largest aquifers, it underlies an area of approximately 174,000 sq mi in portions of eight states (South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas). The aquifer is part of the High Plains Aquifer System, and rests on the Ogallala Group, which is the principal geologic unit underlying 80% of the High Plains.

Term	Definition
Overappropriated	From 46-713, subsection (4a): A river basin, subbasin, or reach shall be deemed overappropriated if, on July 16, 2004, the river basin, subbasin, or reach is subject to an interstate cooperative agreement among three or more states and if, prior to such date, NeDNR has declared a moratorium on the issuance of new surface water appropriations in such river basin, subbasin, or reach and has requested each natural resources district with jurisdiction in the affected area in such river basin, subbasin, or reach either (i) to close or to continue in effect a previously adopted closure of all or part of such river basin, subbasin, 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, subbasin, or reach.
Palmer Drought Severity Index (PDSI)	The Palmer Drought Severity Index (PDSI) uses readily available temperature and precipitation data to estimate relative dryness. It is a standardized index that spans -10 (dry) to +10 (wet). It has been reasonably successful at quantifying long-term drought.
Sandhills	A region of mixed-grass prairie on grass-stabilized sand dunes in north-central Nebraska, covering just over one quarter of the state. The dunes were designated a National Natural Landmark in 1984.
Saturated Thickness	The vertical thickness of the hydrogeologically defined aquifer unit in which the pore spaces are filled (saturated) with water.
Streamflow	The discharge that occurs in a natural channel of a surface stream course.
Standardized Precipitation Index (SPI)	A widely used index to characterize meteorological drought on a range of timescales. It quantifies observed precipitation as a standardized departure from a selected probability distribution function that models the raw precipitation data.
Surface Water	Water that occurs or moves on the surface of the planet such as in a stream, river, lake, wetland, or ocean.
Surface Water Appropriation	A permit granted by NeDNR to use surface water for a beneficial use in a specific amount, purpose and location, and is based on first-in-time, first-in-right
Transfer	To allow for the historic consumptive use of water to be changed, in location and/or purpose. Impacts of a transfer may include an increase in depletions to the river or an impact to existing surface water or groundwater uses.
Upper Platte River Basin	The Upper Platte River Basin includes the North Platte River, South Platte River, and Platte River from the confluence to Duncan.

8.0 References

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Appendix A: Current Drought Monitoring and Drought Plans

This appendix summarizes the existing drought monitoring efforts, existing drought plans, or other relevant local plans that address water supply management.

A.1 State of Nebraska Current Monitoring and Response Actions

Established in 1991 by Legislative Bill (LB) 274 to replace the Drought Assessment and Response Team (DART), the Nebraska Climate Assessment Response Committee (CARC) serves as a steering committee for the state's *Drought Mitigation and Response Plan* and other climate-related activities. CARC membership consists of the U.S. Department of Agriculture (USDA), Nebraska Department of Natural Resources (NeDNR), Nebraska Health and Human Service (NHHS) System – Office of Regulation and Licensure, Nebraska Emergency Management Agency (NEMA), University of Nebraska–Lincoln (UNL) Cooperative Extension Service, UNL Conservation and Survey Division (CSD), and Governor's Policy Research Office. By statute, NEMA is charged with responding to emergencies, such as drought or floods, at the direction of the Governor.

Nebraska's *Drought Mitigation and Response Plan* was last updated in June 2000 (revised May 2004). Presently, Nebraska (through NEMA) is in the process of updating its *Hazard Mitigation Plan*, of which the Drought Plan will become a component. Going forward, the *Hazard Mitigation Plan* will replace the 2000 *Drought Mitigation and Response Plan*. The *Hazard Mitigation Plan* is scheduled to be completed and submitted to the Federal Emergency Management Agency (FEMA) in the spring of 2019. NEMA will collaborate with the National Drought Mitigation Center (NDMC), CARC, and USDA to update the drought component of the *Hazard Mitigation Plan*. The *Hazard Mitigation Plan* will include a drought assessment, vulnerabilities assessment, triggers and strategic actions, response actions and mitigation measures, research, technical assistance, and workshops.

Table A-1: 2004 Nebraska Drought Mitigation and Response Plan – Planned Mitigation Activities

Prioritized Impacts	Prioritized Planned Actions	Assistance Agencies
Due to drought, many public water supply systems experience potable water demand problems.	Emphasize, and evaluate, long and short-term drought contingency plans for all systems. Emphasize indoor and outdoor water conservation measures. Maintain list of "problem systems", with history or potential for drought-related problems. Develop programs to educate the public on the potential uses of wastewater. Develop partnerships with utility companies and others who can help distribute drought-related information.	NHHS, League of Municipalities, NRDs, Nebraska Rural Water Association, NDEQ, AWWA, CED/UNL
Many rural water districts and small public water systems (under 10,000 population) develop operational (mechanical) problems when operating for extended periods of drought.	Maintain a list of "problem systems" with history or potential for drought-related problems. Continue work with systems to develop a plan of long-term drought mitigation and short-term drought response actions. Maintain communication means and use Nebraska Rural Water Associations (NeRWA) newsletter and training sessions to address drought-related issues. Explore, as needed, emergency funds.	NRWD, NEMA, Nebraska Section of AWWA, Nebraska Department of Economic Development (NDED), USDA Rural Development, League of Municipalities, NHHS, Midwest Assistance Program, NDEQ, UNL Extension, NRDs, Groundwater Foundation, Nebraska Department of Natural Resources, NeRWA, EPA
Due to drought, private wells experience water quality and quantity problems.	Encourage NRDs to evaluate situation. Emphasize indoor and outdoor water conservation measures.	NRDs, CSD/UNL, CED/UNL

Prioritized Impacts	Prioritized Planned Actions	Assistance Agencies
Increased irrigation may overdraft available aquifer and affect municipal and rural water supplies during drought.	Promote groundwater-metering efforts and establish an emergency allocation program. Encourage statewide water level measurement program to effectively monitor aquifer levels.	NRDs, Bureau of Reclamation, DOE, CSD/UNL, CED/UNL, USGS.
Drought induced mental anguish of farmers and ranchers resulting in increased suicides, social and family problems.	Use local TV and radio outlets to implement public information program directed at reducing drought-induced mental stress. Implement and/or maintain farm/crisis hotline(s). Develop working partnerships with local ministerial alliances and local health office as to develop social counseling and support programs. Public service announcements for hotline numbers and mediation services.	NHHS, local health offices, local ministerial alliances, CED/UNL, NEDA, Centers for Rural Affairs, national public health services, Mediation Service, Farm Crisis Council
Increased presence of large, industrial, independent water users may overdraft available aquifers during drought.	Maintain a list of large, industrial, independent water users. Enhance communication between large, independent water users and municipal suppliers to implement water conservation measures and drought-preparedness guidelines.	NRDs, NDED, CSD/UNL, Nebraska Department of Natural Resources, League of Municipalities, CED/UNL
Increased health problems for residents of areas experiencing blowing dust problems for drought-affected agricultural lands.	Communicate with state medical allergy and asthma experts to develop recommendations. Establish education programs to increase awareness of dust-related respiratory problems and how soil and land conservation practices can improve air quality. Develop funded initiatives to explore mitigation of health effects.	NHHS, UNMC, CED/UNL, NRDs, NRCS, Nebraska Emergency Management Agency (NEMA), local health offices, environmental health fund.
Drought-induced temperature extremes produce extreme living conditions for both rural and urban residents. Increased electrical usage may create overloads on available electrical grid network.	Develop information program to provide living guidelines and alternatives to enable residents to cope with extreme conditions. Develop working partnerships with local urban and rural power suppliers to cooperate in providing energy and water conservation guidelines to public. Develop an education program. Learn about electrical bill assistance programs. Learn about fan distribution programs.	NHHS, HUD, CED/UNL, Nebraska Energy Office, Salvation Army, League of Women Voters, medical professionals, local utility companies, Nebraska Rural Electric Association, Nebraska Power Association, Nebraska Energy Office, League of Municipalities.
General Impacts	Promote the use of water efficient plumbing fixtures and appliances.	AWWA, League of Municipalities, Builders and Plumbers Associations, EPA.

Source: Nebraska Drought Mitigation and Response Plan, Appendix A

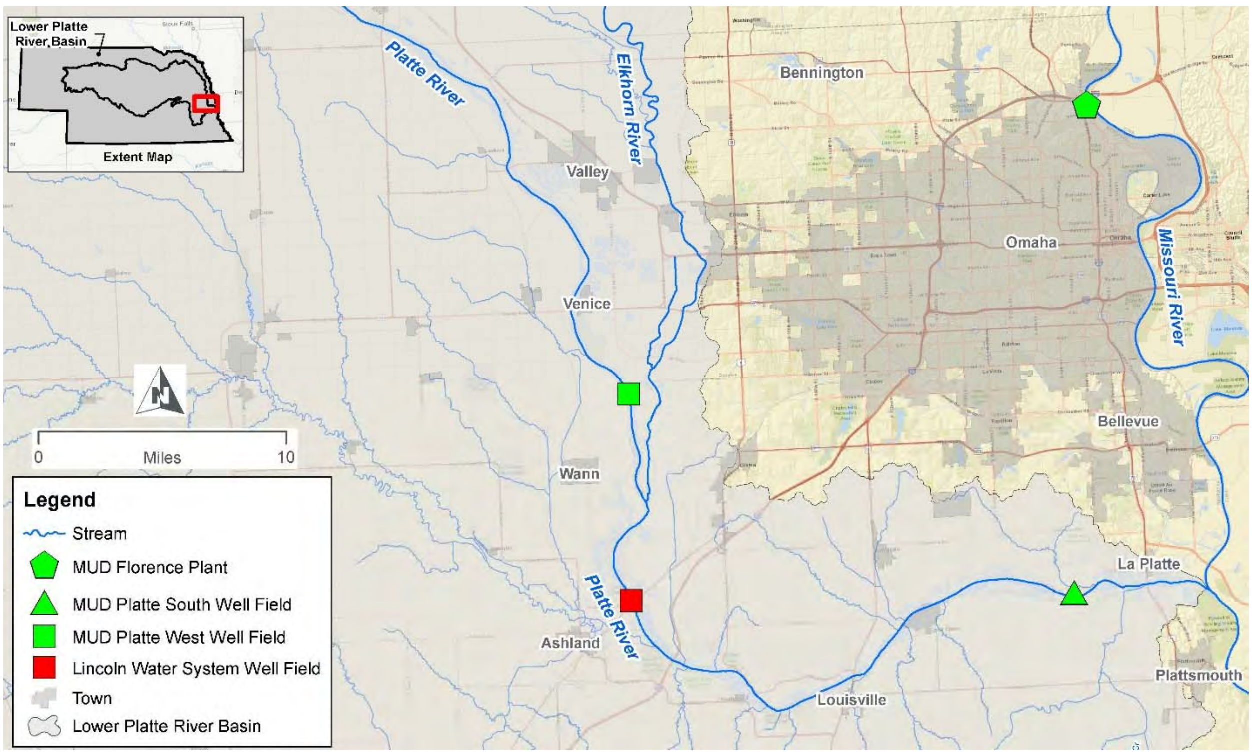
Notes: AWWA = American Water Works Association; CED/UNL = Cooperative Extension Division – University of Nebraska-Lincoln; CSD/UNL = Conservation and Survey Division- University of Nebraska – Lincoln; NDED = Nebraska Department of Economic Development; NDEQ = Nebraska Department of Environmental Quality; DOE = Department of Energy; EPA = Environmental Protection Agency; HUD = Housing and Urban Development; NEDA = Nebraska Department of Agriculture; NEMA = Nebraska Emergency Management Agency; NHHS = Nebraska Health and Human Services; NRCS = Natural Resource Conservation Service; NRDs = Natural Resource Districts; NRWD = Nebraska Rural Water Districts; UNMC = University of Nebraska Medical Center; USGS = United States Geological Survey.

A.2 Metropolitan Utilities District Current Monitoring and Response Actions

The Metropolitan Utilities District (MUD) has three supply intake locations: 1) Florence Plant in north Omaha, Nebraska, that obtains its water from the Missouri River with a capacity of 160 million gallons per day (MGD); 2) Platte West well-field located south of Venice, Nebraska, that obtains its water from the Platte River with a capacity of 100 MGD; and 3) Platte South well-field located near La Platte, Nebraska, that also obtains water from the Platte River with a capacity of 60 MGD. Total system output for MUD from all three facilities is 320 MGD. MUD has the ability to use all three of their facilities interchangeably to meet their demand.

The induced recharge right for the Platte West well-field is 1,000 cubic feet per second (cfs) and for Platte South is 500 cfs. MUD is currently undergoing an analysis of both its Platte West and Platte South well-field capacities under drought conditions. According to MUD, their system capacity is not expected to be a concern for the foreseeable future. During the 2012 drought, MUD voluntarily reduced operations at Platte West to 30 to 40 MGD and increased operations at the Florence plant.

Figure A-1: Municipal Well-field Locations



MUD maintains a water conservation and emergency plan on the MUD website (Table A-2). The water conservation and emergency plan includes voluntary and mandatory conservation measures, which have not been imposed since the early 2000s and have not been imposed since the Platte West well-field was constructed. MUD imposes conservation measures when consecutive days have a demand at or above 300 MGD.

Table A-2: MUD Water Alert Levels

Alert Level	Trigger	Action
Level 1: Voluntary Alternate Day Watering	Water consumption reaches 95 percent (about 300 million gallons per day) of available supply or system capacity, or any of the water storage reservoirs cannot be refilled from day to day, or low pressure jeopardizes fire fighting or causes numerous customer complaints.	Press release to notify public of alert. Press release will include basic list of water conservation tips. Limit hydrant flushing and main filling, comply with alternate day water restrictions, and shut down decorative fountains at the Florence Plant and the Headquarters Building. All customers asked to voluntarily adhere to alternate day watering. Customers told what to expect if Level 2 Alert issued. All customers asked to voluntarily discontinue hosing down driveways, shut off decorative fountains, discontinue filling swimming pools, and other actions deemed appropriate by MUD City of Omaha and other municipalities served by MUD asked to voluntarily comply with alternate day watering restrictions; curtail sewer flushing, lake filling, firefighting drills, street washing and other non-essential uses of water. Enforcement: None
Level 2: Voluntary No Watering Days	Specified no-watering days will allow MUD to fill water system reservoirs. Trigger: Water consumption reaches 95 percent of available supply or system capacity, or any of the water storage reservoirs cannot be refilled from day to day, or low pressure jeopardizes fire fighting or causes numerous customer complaints.	Press release to notify public of alert. Press release will include basic list of water conservation tips. Limit hydrant flushing and main filling, comply with alternate day water restrictions, and shut down decorative fountains at the Florence Plant and the Headquarters Building. All customers asked to voluntarily discontinue all outdoor water use on days determined by MUD. Customers told what to expect if Level 2 Alert issued. All customers asked to voluntarily discontinue hosing down driveways, shut off decorative fountains, discontinue filling swimming pools, and other actions deemed appropriate by MUD City of Omaha and other municipalities served by MUD asked to voluntarily comply with alternate day watering restrictions; curtail sewer flushing, lake filling, firefighting drills, street washing and other non-essential uses of water. Enforcement: None
Level 3: Water Alert	Water consumption meets or exceeds available supply or system capacity, or useable water storage has been reduced 50 percent, or there are widespread pressure problems.	Issue press release to notify public that voluntary requirements of Level 1 or Level 2 alerts have become mandatory. Stop hydrant flushing and main filling, comply with designated restrictions, including shut down of decorative fountains at the Florence Plant and the Headquarters Building. All customers required to adhere to water restrictions. All customers required to discontinue hosing down driveways, shut off decorative fountains, discontinue filling swimming pools, and other actions deemed appropriate by MUD. City of Omaha and other municipalities served by MUD will be required to comply with water restrictions, stop sewer flushing, lake filling, firefighting drills, street washing and other non-essential uses of water. Enforcement: Customers who do not comply with water restrictions will be subject to having their water shut off until mandatory restrictions are lifted. The current turn-on fee will be charged to restore service. Exceptions: Exceptions may be made for new sod less than three weeks old and other circumstances deemed appropriate by MUD

Alert Level	Trigger	Action
Level 4: Water Emergency	Water use exceeds production or distribution capacity due to emergency situations.	Issue press release to notify public a Water Emergency is in effect. All non-sanitary, non-essential use must be discontinued. Enforcement: Customers who do not comply with water restrictions will be subject to having their water shut off until mandatory restrictions are lifted. The current turn-on fee will be charged to restore service.
Level 5: Water Emergency (Water Quality)	Water quality for human consumption cannot be assured due to a contamination or suspected contamination.	Issue press release to notify public that water cannot be consumed safely unless it is boiled or cannot be consumed safely at all. This will include water used in food preparation. MUD, in cooperation with DHHS, will take action to make water safe for consumption and conduct tests to assure it is safe. Issue press release to inform customers water is safe for consumption. Enforcement: None

Source: MUD Water Alert Emergency Plan, Rev. 2012

In combination with water use restrictions, MUD implements inclining block rates as described in Table A-3.

Table A-3: MUD Commodity Charges

cubic feet	Nov-May ($ per 100 cubic feet)	Jun-Oct ($ per 100 cubic feet)
0 to 900	1.2632	1.2632
901 to 3,000	1.2632	1.7685
Over 3,000	1.2632	2.2738

Source: Provided by MUD 2018

A.3 City of Lincoln Current Monitoring and Response Actions

Lincoln Water System (LWS) updated its *Water Management Plan* in 2013. This plan manages water use to maintain consumption within the system's production, pumping, and delivery capacities. When water use cannot be maintained within the system's capacity, the plan defines procedures and provides guidance for imposing water restrictions. The plan includes phases for management of the City of Lincoln, Nebraska, water supplies through various circumstances, including drought conditions or other catastrophic events that would result in a water shortage.

The extent to which drought restrictions are implemented is primarily based on the flows in the Lower Platte River at Ashland, Nebraska, and water usage. Watering restrictions are implemented through the City of Lincoln's Municipal Code. The various phases of watering restrictions start as voluntary and then increase to mandatory as the severity of the drought increases. Tiered water shortage rates are applied during periods when *Water Management Plan* restrictions are implemented. The water shortage rates were developed on the basis that customers practicing conservation techniques would see little or no increase in their summer water bills. The water shortage rates begin with the voluntary restrictions and are increased if stricter plan phases are enacted.

Table A-3: City of Lincoln Drought Phases

Phase	Signal River Flow	Signal Water Use	Possible Action
Moderate Shortage	3,000 – 1,500 cubic feet per second (cfs)	Greater than 75 million gallons per day (MGD)	Voluntary restrict certain water use activities to three (3) designated days per week
Severe Shortage	1,500 – 200 cfs	Greater than 65 MGD	Certain water use activities may be mandatorily restricted to three (3) designated days per week
Critical Shortage	Less than 200 cfs	Greater than 55 MGD	In addition to restricted imposed under severe shortage, also limits outdoor water use; may result in either mandatorily restricting certain water use activities to two (2) or one (1) designated day or no outside water use

Source: City of Lincoln's Water Management Plan 2013

Reduced water usage equates to reduced sales. Reduced sales equates to reduced revenues to cover costs of water treatment and delivery, and costs of infrastructure repair and replacement.

The City of Lincoln monitors several sources in an attempt to monitor impending drought conditions. Through the winter and spring months, LWS monitors aquifer levels, National Oceanic Atmospheric Administration (NOAA) 90-day precipitation and temperature forecasts, the NOAA Seasonal Drought Outlook, the U.S. Drought Monitor and previous 90-day precipitation and makes a Phase 1, Phase 2, or No Restriction recommendation to the Mayor on May 15 of each year as described in Table A-4.

Table A-4: City of Lincoln Drought Indicators – Spring (prior to May 15)

Indicator	No Restriction	Phase 1	Phase 2
Remaining Operational Volume	>80%	60%-80%	40%-60%
NOAA 90-day precipitation forecast (% probability below normal)	Equal chance (above, below, normal)	33%-40% (below normal)	33%-40% (below normal)
NOAA 90-day temperature forecast (% probability above normal)	Equal chance (above, below, normal)	33%-40% (above normal)	33%-40% (above normal)
NOAA Seasonal Drought Outlook	None predicted-improvement	On-going	Intensify
U.S. Drought Monitor Rating	No Rating-moderate	Severe	Extreme
Previous 90 day precipitation (from High Plains Regional Climate Center) (% of normal)	>90%	70%-90%	50%-70%

Source: City of Lincoln's Water Management Plan, 2013

After May 15, and throughout the summer months, LWS switches to NOAA 30-day outlooks and previous 30-day precipitation totals to designate drought phases as well as adds a Phase 3 category for very extreme drought conditions, as summarized in Table A-5. LWS implements conservation measures based on the designated drought phases. The existing conservation measures focus almost entirely on reducing outdoor water use.

Table A-5: City of Lincoln Drought Indicators – May 15 through September

Indicator	No Restriction	Phase 1	Phase 2	Phase 3
Remaining Operational Volume	>80%	60%-80%	40%-60%	<40%

Indicator	No Restriction	Phase 1	Phase 2	Phase 3
NOAA 30-day precipitation forecast (% probability below normal)	Equal chance (above, below, normal)	33%-40% (below normal)	33%-40% (below normal)	>40% (below normal)
NOAA 30-day temperature forecast (% probability above normal)	Equal chance (above, below, normal)	33%-40% (above normal)	33%-40% (above normal)	>40% (above normal)
NOAA Seasonal Drought Outlook	None predicted-improvement	On-going	Intensify	Intensify
U.S. Drought Monitor Rating	No Rating-moderate	Severe	Extreme	Exceptional
Previous 30 day precipitation (from High Plains Regional Climate Center) (% of normal for Lower Platte River Basin)	>90%	70%-90%	50%-70%	<50%

Source: City of Lincoln's Water Management Plan 2013

LWS implements accelerated water shortage rates during periods when *Water Management Plan* restrictions are implemented, beginning with Phase 1 and increasing if stricter plan phases are enacted (Tables A-6 and A-7). Water shortage rates were developed on the basis that customers choosing to practice water conservation techniques, primarily targeted at outdoor water use reduction, may see little or no increase in their rates.

If a natural disaster, such as a tornado, fire, blizzard, ice, or flood, or catastrophic failure of LWS facilities occurs, the City of Lincoln will enact restrictions under the Catastrophic Water Shortage Levels, separate from Phase 1 through Phase 3. Such restrictions would be based on the varying circumstances as adjudged necessary and appropriate by the Mayor and the Director of Public Works and Utilities Department.

Table A-6: Residential Water Shortage Charges for 2016

	Normal Water Conditions (no rate increase)	Voluntary Restrictions Phase 1	Mandatory Restrictions Phase 2	Mandatory Restrictions Phase 3	Mandatory Restrictions Catastrophic
Demand Goal	0%	Up to 10%	10% - 20%	20% - 30%	30% - 50%
Block 1: 0 – 8 CCF **(up to 6,000 gallons)**	$1.344	$1.344	$1.559	$1.855	$2.873
Block 2: 8 – 23 CCF **(6,000 – 17,200 gallons)**	$1.911	$2.624	$2.771	$3.726	$5.446
Block 3: Over 23 CCF **(over 17,200 gallons)**	$2.961	$4.587	$5.635	$7.249	$10.393

Source: Lincoln Water System 2017.

Table A-7: Non-Residential Water Shortage Charges for 2016

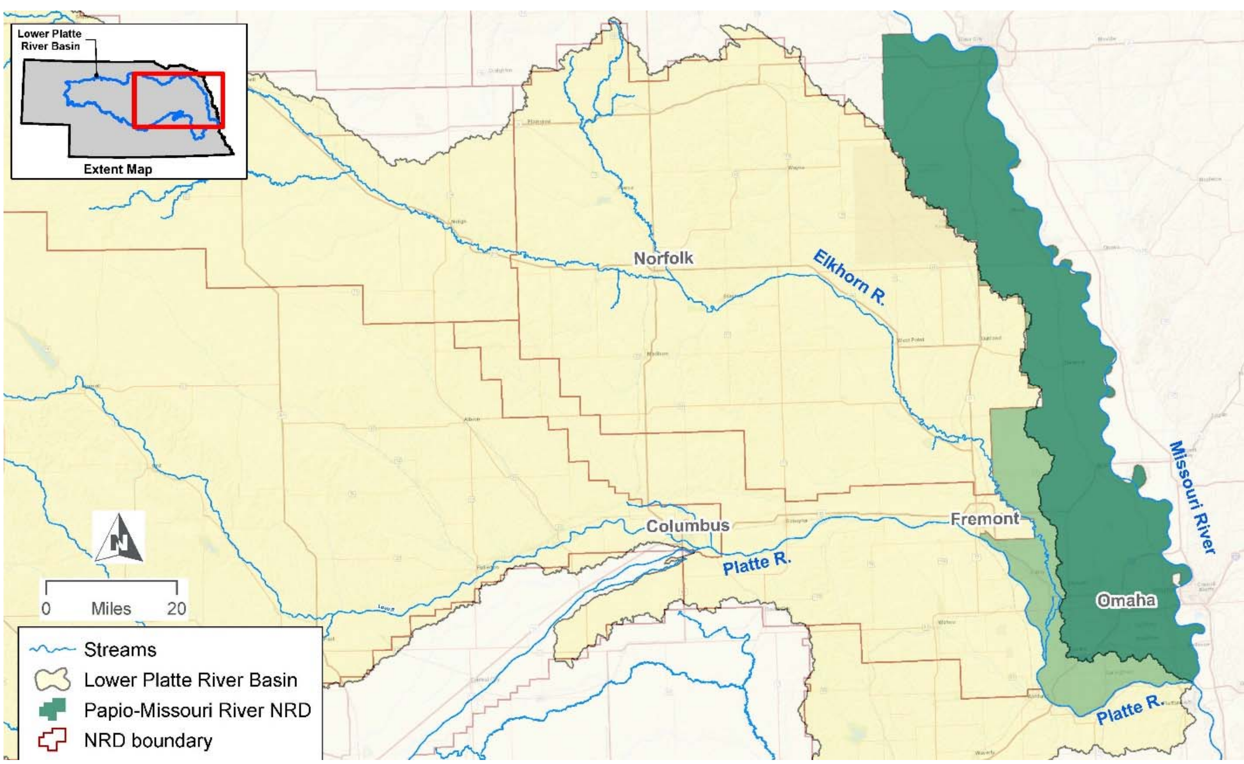
	Normal Water Conditions (no rate increase)	Voluntary Restrictions Phase 1	Mandatory Restrictions Phase 2	Mandatory Restrictions Phase 3	Mandatory Restrictions Catastrophic
Demand Goal	0%	Up to 10%	10% - 20%	20% - 30%	30% - 50%
Block 1: 0 – 80 CCF	$1.344	$1.496	$1.688	$1.934	$2.714
Block 2: Over 80 CCF	$1.911	$2.128	$2.400	$2.750	$3.858

Source: Lincoln Water System 2017.

A.4 Papio-Missouri River Natural Resources District Current Monitoring and Response Actions

The Papio-Missouri River Natural Resources District (NRD) has a biannual static groundwater level monitoring program to establish a baseline and to continue monitoring the groundwater levels in the aquifer areas of the Papio-Missouri River NRD. Trigger levels for each alluvial monitoring well are in the process of being developed using the recommendations presented in an analysis conducted by a collaboration of Papio-Missouri River NRD, the other five NRDs, and cooperating agencies including NeDNR, UNL-CSD, and USGS (Papio-Missouri River NRD 2017). In accordance with the report, the current water levels are compared to a running average baseline with a standard deviation value. This method of comparing to running average baselines is consistent with surrounding NRD's in developing a groundwater level triggers as a basis for evaluating and responding to drought conditions. Triggers for confined aquifers will be developed as monitoring data becomes available.

Figure A-2: Papio-Missouri River Natural Resources District



The following levels have been established for the unconfined areas of the Papio-Missouri River NRD for drought response action:

- A Level I Groundwater Management Area (GMA) is currently established for the entire NRD. Require well permits for all pumps over 50 gallons per minute (gpm).
- A Level II GMA is established if an average of 10 percent decline in saturated thickness of an unconfined aquifer in 50 percent of the wells occurs for 3 consecutive years. Require water meters on wells that pump over 50 gpm.
- A Level III GMA will be established if an average of 15 percent decline in saturated thickness of an unconfined aquifer in 50 percent of the wells occurs for 3 consecutive years. Annual allocations to be set by the Board of Directors.

Although currently there are no areas with significant groundwater level declines, the 2017 Papio-Missouri River NRD *Groundwater Management Plan* recommends response actions based on Water Quantity Program Level designation as shown in Table A-8.

Table A-8: Papio-Missouri River Natural Resources District Water Controls Based on Declines

Water Quantity Control Descriptions	Level I (Entire NRD)	Level II Average 10% decline in saturated thickness of an unconfined aquifer	Level III Average 15% decline in saturated thickness of an unconfined aquifer
Offer water conservation education for rural and urban users	X	X	X
Cost-share water meters and encourage annual water use reporting	X	X	X
Require irrigation acre certification per IMP requirements	X	X	X
Limit expansion of irrigated acres per IMP requirements	X	X	X
Require minimum well spacing (600 feet from registered domestic well)	X	X	X
Require high-capacity well evaluations and permits for wells pumping greater than 300 acre-feet per year	X	X	X
Enable water banking transactions through basin-wide plan	X	X	X
Enforce irrigation runoff rules	X	X	X
Encourage water conservation through support of urban and rural cost-share programs	X	X	X
Require well permits for new wells that pump greater than 50 gpm	X	X	X
Require irrigation management certification		X	X

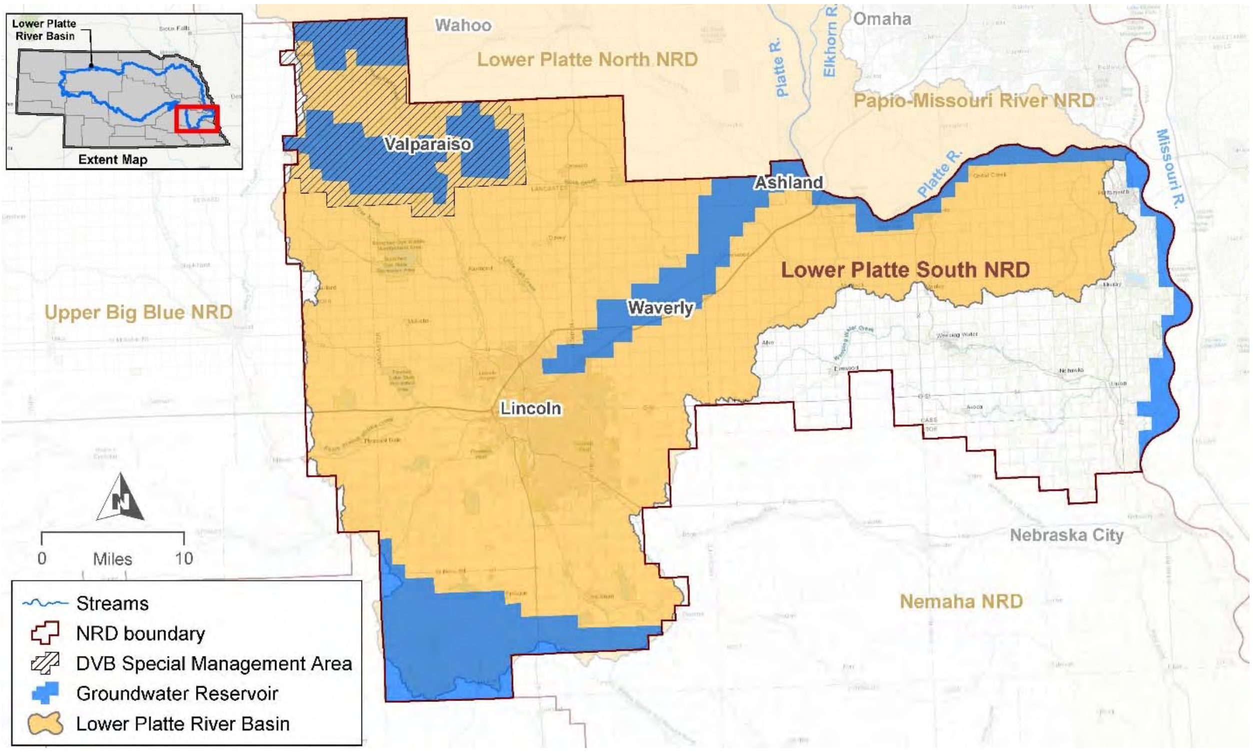
Water Quantity Control Descriptions	Level I (Entire NRD)	Level II Average 10% decline in saturated thickness of an unconfined aquifer	Level III Average 15% decline in saturated thickness of an unconfined aquifer
Require water meters and annual water use report		X	X
Evaluate effects of reducing irrigated acres		X	X
Encourage implementation of rural and urban BMPs		X	X
Require acre-inch allocations and eliminate use of end-guns on pivots			X
Require reduction of irrigated acres in selected areas			X
Require implementation of two water efficiency BMPs			X

Source: Papio-Missouri River NRD 2017

A.5 Lower Platte South Natural Resources District Current Monitoring and Response Actions

The Lower Platte South NRD's *Groundwater Management Plan* specifies three types of areas in which Lower Platte South NRD can pursue various drought management activities. These three types of areas include Groundwater Reservoirs (GWRs), the Remaining Area (RA), and Community Water Supply Protection Areas (CWSPAs).

Figure A-3: Lower Platte South Natural Resources District Groundwater Reservoirs



Source: Adapted from Ehrman et. al. 2015

The Lower Platte South NRD has designated five major GWRs, as shown in Figure A-3, within the NRD with the remainder of the district designated as the RA, which generally corresponds to areas that are variable in both groundwater quality and quantity. The Lower Platte South NRD monitors the well levels in each of the GWRs.

- Lower Platte South NRD's groundwater rules and regulations have the entire NRD designated as a Phase I Quality and Quantity Groundwater Management Area.
- A Phase II Groundwater Quantity Area is triggered when spring static water elevations in 30 percent of monitoring network wells have declined from the established upper elevation of the saturated thickness to an elevation that represents greater than or equal to a percent reduction in saturated thickness and has remained below that elevation for 2 consecutive years.
- A Phase III Groundwater Quantity is triggered when spring static water elevations in 50 percent of the monitoring network wells have declined from the established upper elevation of the saturated thickness to an elevation that represents greater than or equal to a percent reduction in saturated thickness and has remained below that elevation for 2 consecutive years."(Ehrman et al. 2015).

Table A-9 summarizes targeted reductions in pumping associated with each phase.

Table A-9: Lower Platte South Natural Resources District Phase II and Phase III pumping reduction triggers based on Groundwater Reservoir based on reduction in saturated thickness

Groundwater Reservoir	Phase II (water level decline in 30% of the wells)	Phase III (water level decline in 50% of the wells)
Lower Salt Creek	15%	30%

Groundwater Reservoir	Phase II (water level decline in 30% of the wells)	Phase III (water level decline in 50% of the wells)
Missouri River	8%	15%
Platte River	8%	15%
Crete-Princeton	8%	15%
Dwight Valparaiso	8%	15%
Remaining Area	8%	15%

Source: Lower Platte South NRD, Groundwater Rules and Regulations 2017
Note: Lower Platte South NRD's groundwater rules and regulations have the entire NRD designated as a Phase I Quality and Quantity Groundwater Management Area.

The Lower Platte South NRD includes CWSPAs around the groundwater supply wells for the 30 public water suppliers within their jurisdiction. CWSPA boundaries correspond with the Wellhead Protection Area boundaries as delineated by the Nebraska Department of Environmental Quality (NDEQ), and are defined as the area that encompasses the 20-year time-of-travel zone around a given well-field. Lower Platte South NRD samples each public water supplier at least annually for water quality.

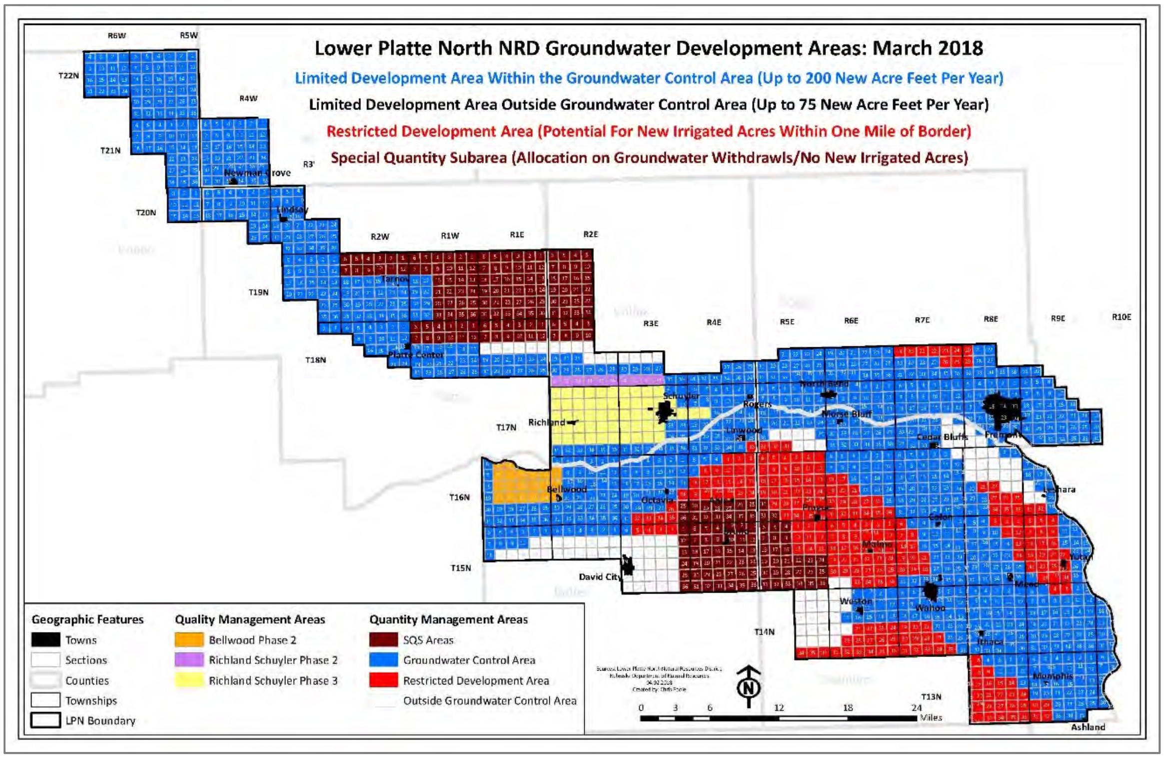
As a response to the drought conditions of 2012 and 2013, the Lower Platte South NRD created the Dwight-Valparaiso-Brainard (DVB) Special Management Area (SMA), shown in Figure A-3, and drafted new rules and regulations for the area including a stay on new irrigated acres, allocations on irrigation, required certification classes for irrigators, establishment of cost-share programs, new well depth requirements as well as formed an advisory group to evaluate progress of the SMA. The groundwater allocations on irrigated acres included 21 acre-inches per 3 years with a maximum of 9 inches applied in any 1 year for pivots or sprinklers and 30 acre-inches per 3 years with a maximum of 12 acre-inches applied in any 1 year for gravity/flood irrigation.

A.6 Lower Platte North Natural Resources District Current Monitoring and Response Actions

The Lower Platte North NRD may designate a Special Quantity Subarea (SQS) for the protection of groundwater quantity in a portion of the district where additional controls are deemed necessary. Additional controls in these areas may include stays on new irrigation wells, allocations, mandatory education classes for irrigators, well metering for all wells pumping greater than 50 gpm, mandatory acre certification, and static level measurements semi-annually (spring and summer).

There are currently two SQS areas in the Lower Platte North NRD, Butler/Saunders County SQS and Colfax/Platte County SQS; both of which have groundwater allocations based on a 3-year Rolling Allocation (Figure A-4). The Rolling Allocation shall specify the total number of acre-inches of irrigation water per irrigated acre for the rolling term. If the Lower Platte North NRD Board of Directors fails to adopt a Rolling Allocation by December of any given year, the Rolling Allocation for the following 3-year term shall be 27 acre-inches per irrigated acre. The Board may establish timing or rotation restrictions for the SQS.

Figure A-4: Lower Platte North Natural Resources District Special Quantity Subareas



Source: Map provided by Lower Platte North NRD (obtained 2018)

Additionally, the Lower Platte North NRD maintains a groundwater management plan (Lower Platte North NRD 2018). This groundwater management plan sets criteria for establishing Level 1, 2, and 3 areas based on groundwater trigger levels.

Level I Criteria

Level I aquifer management areas are designated for the entire Lower Platte North NRD. As more information becomes available, subareas shall be further refined. Any changes in water use, location of water use, number of gallons pumped, or changes in water source shall be reviewed and approved by the Lower Platte North NRD before those changes can take effect. Due to hydrologic conditions, Lower Platte North NRD monitoring wells are not to be located on municipal well-field property.

Level II Criteria

Confined Aquifer

- Unconfined aquifer management subareas are to be designated within the Lower Platte North NRD's when conditions indicate a 10 percent drop in the saturated thickness of the aquifer.
- Assessment of percentage drop will be calculated using the spring readings of Lower Platte North NRD monitoring wells over a consecutive 3-year period assessed against the 1987 baseline groundwater levels or a more recent baseline year groundwater level, adopted by the Lower Platte North NRD Board of Directors and revised in the Groundwater Management Rules and Regulations.
- When greater than 50 percent of the area within a subarea has reached, or exceeded the trigger level, then a Level II management area can be established. Assessment of the percentage of a

sub-area will be determined by applying an area-weighting method to Lower Platte North NRD groundwater monitoring wells.
- After the establishment of a Level II Area, if groundwater levels should recover, two consecutive spring readings below the trigger levels are needed before the Groundwater Quantity Management Area could be placed as a Level I management area.

Unconfined Aquifer

- Confined aquifer management subareas are to be designated within the Lower Platte North NRD when conditions, indicate a 7 percent drop in potentiometric-aquifer thickness.
- Assessment of percentage drop will be calculated using the spring readings of Lower Platte North NRD’s monitoring wells over a consecutive3-year period assessed against the 1987 baseline groundwater levels or a more recent baseline year groundwater level, adopted by the Lower Platte North NRD Board of Directors and revised in the Groundwater Management Rules and Regulations.
- When greater than 50 percent of the area within a subarea has reached, or exceeded the trigger level, then a Level II management area can be established.
- Assessment of the percentage of a sub-area will be determined by applying an area-weighting method to Lower Platte North NRD’s groundwater monitoring wells.
- After the establishment of a Level II Area, if groundwater levels should recover, two consecutive spring readings below the trigger levels are needed before the Groundwater Quantity Management Area could be placed as a Level I management area.

Level III Criteria

Unconfined Aquifer

- Unconfined aquifer management subareas are to be designated within the Lower Platte North NRD when conditions indicate a 15 percent drop or greater in the saturated thickness of the aquifer.
- Assessment of percentage drop will be calculated using the spring readings of Lower Platte North NRD’s monitoring wells over a consecutive 3-year period assessed against the 1987 baseline groundwater levels or a more recent baseline year groundwater level, adopted by the Lower Platte North NRD Board of Directors and revised in the Groundwater Management Rules and Regulations.
- When greater than 50 percent of the area within a subarea has reached or exceeded the trigger level, then a Level III management area can be established. Assessment of the percentage of a sub-area will be determined by applying an area-weighting method to Lower Platte North NRD groundwater monitoring wells.
- After the establishment of a Level III Area, if groundwater levels should recover, two consecutive spring readings below the trigger levels are needed before the Groundwater Quantity Management Area could be placed as a Level II or Level I management area.

Confined Aquifer

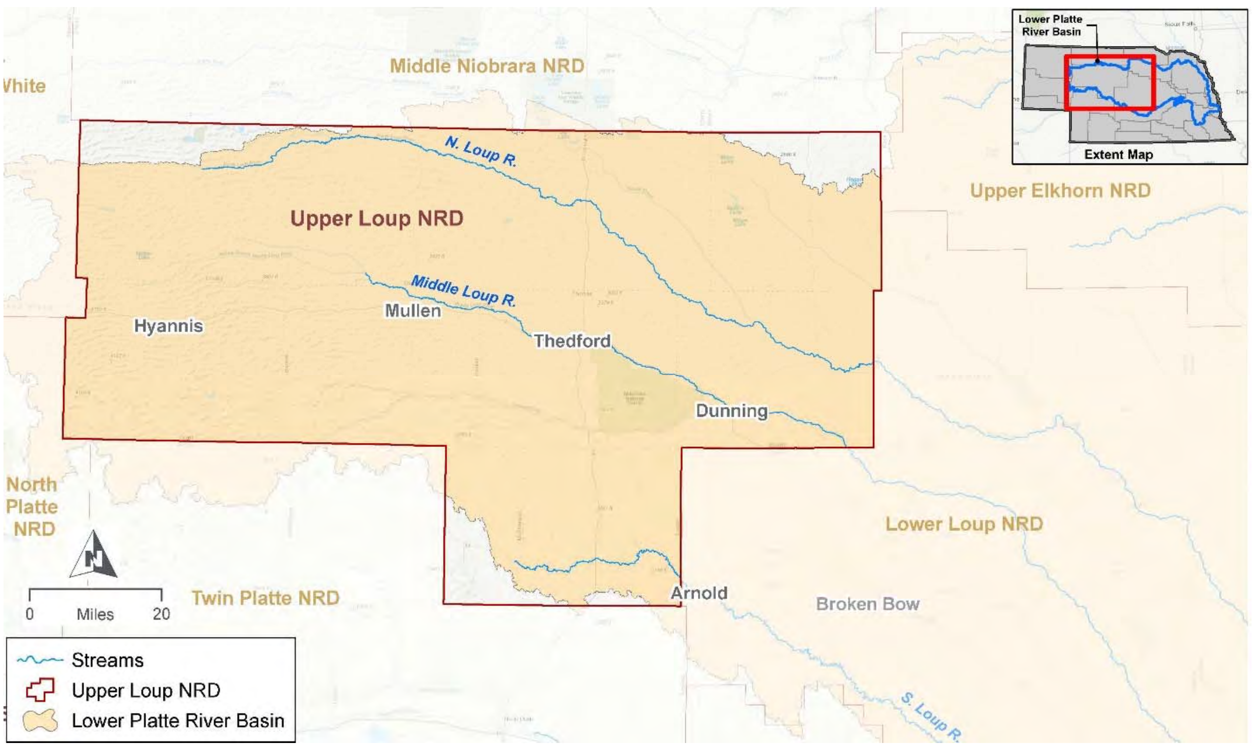
- Confined aquifer management subareas are to be designated within the Lower Platte North NRD when conditions, indicate a 10 percent or greater drop in the potentiometric-aquifer thickness.
- Assessment of percentage drop will be calculated using the spring readings of Lower Platte North NRD monitoring wells over a consecutive 3-year period assessed against the 1987 baseline groundwater levels or a more recent baseline year groundwater level, adopted by the Lower Platte North NRD Board of Directors and revised in the Groundwater Management Rules and Regulations.

- When greater than 50 percent of the area within a subarea has reached or exceeded the trigger level, then a Level III management area can be established. Assessment of the percentage of a sub-area will be determined by applying an area-weighting method to Lower Platte North NRD groundwater monitoring wells.
- After the establishment of a Level III Area, if groundwater levels should recover, two consecutive spring readings below the trigger levels are needed before the Groundwater Quantity Management Area could be placed as a Level II or Level I management area.

A.7 Upper Loup Natural Resources District Current Monitoring and Response Actions

The Upper Loup NRD is located in the Sandhills and there is very little irrigation within the Upper Loup NRD. The Upper Loup NRD has an active groundwater quality monitoring program and has the ability to designate an area with impacted water quality as a Phase 1, Phase 2, or Phase 3 area depending on severity.

Figure A-5: Upper Loup Natural Resources District



The Upper Loup NRD monitors groundwater quantity through a monitoring well network. Network wells are measured each spring. The Upper Loup NRD has the ability to implement the following measures to protect groundwater quantity; however, no specific triggers have been identified to trigger these actions:

1. Establish a sub-area;
2. Temporary moratorium on new irrigated acres in the established sub-area; and
3. Initiate a study during which, as a minimum, water levels in surrounding wells will be measured to determine the severity, the geographical extent, and the boundaries of the affected area.

The Upper Loup NRD will offer workable solutions and/or voluntary controls, by which any water quantity problems may be addressed. Solutions may include but not limited to the following:

- irrigation scheduling,

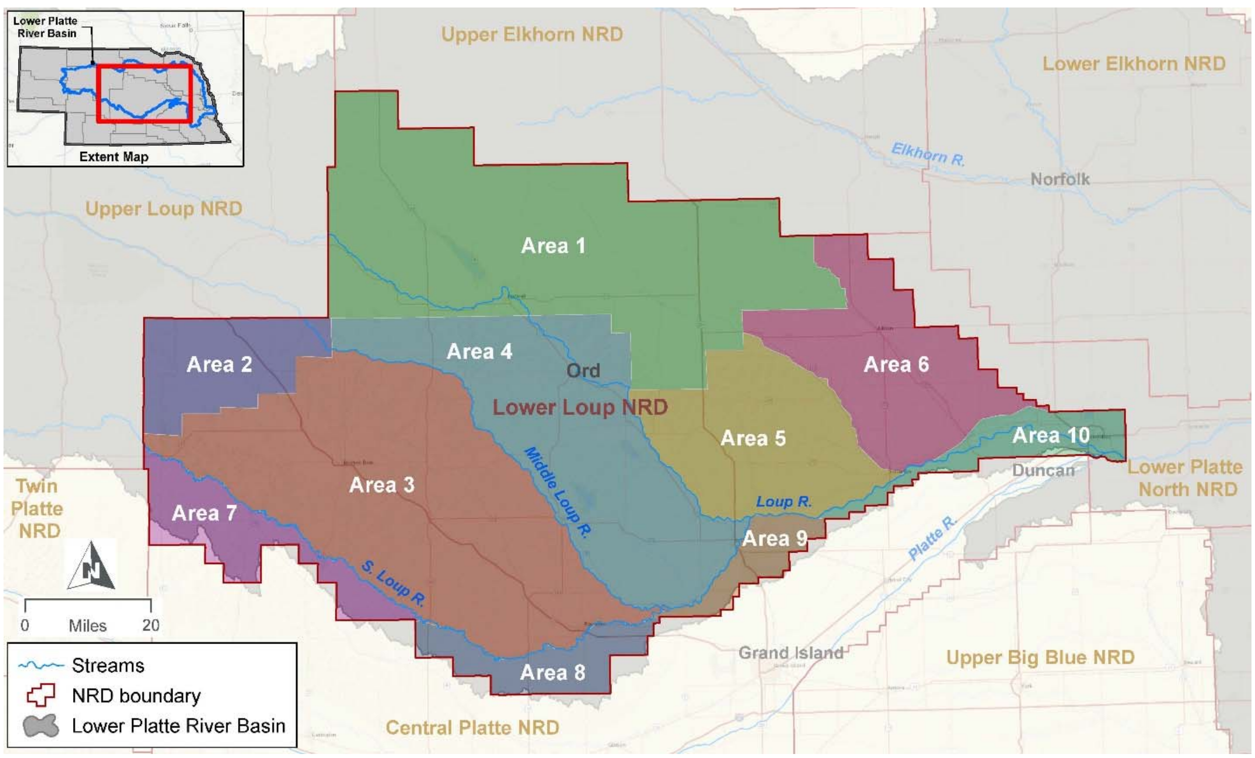
- reduction of irrigated acres,
- adopt a system of rotation of use of groundwater,
- allocate groundwater withdraw on an acre-inch basis, and
- any other reasonable regulations to protect the quantity of groundwater in the sub-area.

A.8 Lower Loup Natural Resources District Current Monitoring and Response Actions

The Lower Loup NRD is divided into 28 Groundwater Quality Management Sub-Areas. Each Sub-Area may be subject to water quality controls in three separate Phases. Each phase is dependent on median nitrate nitrogen levels. Prior to any Sub-Area entering a higher or lower water quality control phase, a public hearing shall be held by the Board of Directors. The entire Lower Loup Natural Resources District Groundwater Management Area is a designated Phase I.

The Lower Loup NRD is divided into 10 Groundwater Quantity Management Sub-Areas (Figure A-6). The criteria for groundwater management is established in the Lower Loup NRD Groundwater Management Plan of 1985.

Figure A-6: Lower Loup NRD Water Quantity Areas



Source: Adapted from Lower Loup NRD Groundwater Management Plan 1985

As part of the Lower Loup NRD Groundwater Management Plan (Lower Loup NRD 1985):

1. The Lower Loup NRD adopted the Spring 1982 static water levels as the base line top of the groundwater reservoir;
2. Adopted 10 subdivisions as areas in which management plans will be implemented under declining conditions;

3. Continue monitoring within the Lower Loup NRD. In the event any well or group of wells has maintained a 10-foot decline below the Spring 1982 base line for 3 consecutive years, it shall be designated as a critical well or wells;
4. In all areas with a designated critical well, the Lower Loup NRD will expand the static well monitoring program to provide needed data for management area designation;
5. The Lower Loup NRD will simultaneously, with #3 notify water users within a 36 square mile area projecting 3 miles in all directions of the critical well or wells of the conditions. The Lower Loup NRD shall then assess the land use, water usage, number of active irrigation wells, and any other pertinent factors to make recommendations on voluntary water conservation practices;
6. In any groundwater reservoir that has a saturated thickness of less than 100 feet, the trigger to begin the process in #3 shall be 10 percent of the saturated thickness;
7. In the case of #3 or #5, if declines continue at the rate to equal 30 percent of the initial decline in the critical well and in other wells within the 36 square mile area over a 3-year period, the Lower Loup NRD shall establish a groundwater management area. Said management area shall extend not less than an area projecting 9 miles in all directions from any critical well or wells. In no case will management area boundaries cross into adjacent subdivisions or NRDs. Boundaries greater than 9 miles in radius can be adopted at the Lower Loup NRD's discretion;
8. In the case where declines appear to cross NRD boundaries, the affected NRDs shall be notified of the conditions and the Lower Loup NRD's actions;
9. Once a groundwater management area has been established, through due process, the Lower Loup NRD may require a combination of any of the following options:
    a. Well spacing
    b. Require water meters and report usage
    c. Develop an allocation system for groundwater withdrawal
    d. Adopt a system of rotation among groundwater users
    e. Initiate complaints for improper runoff
    f. With concurrence from the Nebraska Department of Natural Resources, establish groundwater control areas with the possibility of invoking well drilling moratoriums
10. Management area designations for subdivisions 7, 8, 9, and that part of 10 south of the Loup River will be established through coordination with the Central Platte NRD. The Lower Loup NRD reserves the right to exercise independent judgment if it determines that the management options proposed are too lenient or severe;
11. At any time it becomes apparent to the Lower Loup NRD that a management area designation will not bring declines into conformance with the goals of their Groundwater Management Plan, the Lower Loup NRD will take appropriate actions to create a control area in accordance with the appropriate statutes.

A.9 Lower Elkhorn Natural Resources District Current Monitoring and Response Actions

The Lower Elkhorn NRD manages groundwater through its 2015 Groundwater Management Plan. Additionally, Lower Elkhorn NRD published its Drought Management Plan in 2017.

The Lower Elkhorn NRD Drought Management Plan includes Drought Monitoring using the Palmer Drought Severity Index (PDSI) and Standardized Precipitation Index (SPI) in addition to monitoring streamflows at specific locations and groundwater levels through its monitoring program.

Streamflow locations are USGS gages for Elkhorn River at West Point, Elkhorn River at Norfolk, Logan Creek near Uehling, and North Fork Elkhorn River near Pierce, Nebraska. Historical data from each stream as collected and measurements were separated by month in order to establish drought indicators. Percentiles were calculated by month to account for the rivers' natural fluctuation throughout the year and period of record.

Lower Elkhorn NRD monitors groundwater quantity by measuring the depth of the groundwater in approximately 240 privately owned irrigation wells each spring in addition to transducers deployed in the Lower Elkhorn NRD monitoring well network. Historical groundwater level data from Lower Elkhorn NRD's transducers was collected and separated by month. Monthly percentiles were calculated in order to account for the typical fluctuation in groundwater levels throughout the calendar year.

Table A-10 shows the drought categories and criteria used by the Lower Elkhorn NRD.

Table A-10: Lower Elkhorn Natural Resources District Drought Monitoring Tool

Drought Level	PDSI	SPI 1, 3, 6, 12	Streamflow (West Point, Norfolk, Uehling, and Pierce)	Groundwater
Drought Watch	-2.00 to -2.99	<-1.0 and >-1.5 for all timescales	Streamflows between the 25th and 10th percentile	Groundwater level between the 25th and 10th percentile
Drought Warning	-3.00 to -3.99	<-1.5 and >-2.0 for all timescales	Streamflows between the 10th and 5th percentile	Groundwater level between the 10th and 5th percentile
Drought Emergency	-4.00 and below	<-2.0 for all timescales	Streamflows below the 5th percentile	Groundwater level below the 5th percentile

Source: Lower Elkhorn NRD 2017

PDSI = Palmer Drought Severity Index; SPI = Standardized Precipitation Index.

The current Groundwater Management Plans existing triggers do not provide protection of in-season groundwater level declines.

Lower Elkhorn NRD's Groundwater Management Plan provides guidance for managing both groundwater quantity and quality as described in the following sections.

Groundwater Quantity Management

Triggers for groundwater quantity protection consist of several phases, called action levels, which respond to worsening conditions with increasingly rigorous corrective measures. Each action level has its own triggering mechanism, so that changing conditions will trigger new action levels.

Flexibility has been built into the triggers and action levels because of the complex hydrogeology of the district. The current triggers and actions are used for the entire district, which may be too protective in some areas and may under-protect other areas. As our knowledge of the district's hydrogeology increases, the triggering mechanisms and actions will be 'fine-tuned' to improve the effectiveness of our groundwater quantity protection efforts. The Lower Elkhorn NRD will develop unique triggers and actions for different regions of the district as more local hydrogeologic information becomes available.

Action Level 1: The Lower Elkhorn NRD will initiate the following actions when, in 2 years of any 3-year period, the spring groundwater level of any well in the routine groundwater quantity monitoring program drops 15 or more feet below predevelopment estimates for groundwater levels in that area. When this trigger is actuated, the Lower Elkhorn NRD will take the following actions:

1. Intensify educational efforts in the area including, but not limited to, information concerning:
    a. Groundwater conservation practices;
    b. Potential regulatory actions of the 2nd and 3rd Action Levels (see below);
    c. The status of the groundwater supply in the area.
2. Formation of a local citizen's advisory committee.
3. Increase the number of wells monitored in the area to determine the extent of the problem, to serve as a basis for triggering Action Level 2, and to obtain the hydrogeologic information necessary to delineate a management area. The intensified monitoring program described below applies to the entire district. The actual monitoring program for each problem area may vary according to the local hydrogeologic characteristics of the area.

The district will determine a rudimentary area to be monitored. The shape and size of the area may change as more information is gathered. A minimum area of 9 square miles will be monitored.

a. The minimum number of monitoring sites will be 50 percent of the number of registered irrigation wells in the area that are suitable for use as groundwater level observation wells (taking into account criteria such as quality of well construction and screened intervals). The district will also consider using registered industrial, livestock, monitoring, observation, public water supply, and domestic wells that would be suitable as monitoring sites.
b. The intensified monitoring will begin no later than the spring after the trigger was actuated for Action Level 1.
c. If, after 5 years of the intensified monitoring, the trigger for Action Level 2 has not been actuated, the district may return to the routine groundwater level monitoring program for the area.

4. Determine the necessary control measures, rules, and regulations for Action Levels 2 and 3.

Action Level 2: An area will be placed into Action Level 2 when the spring groundwater levels in 80 percent of the wells monitored in the intensified monitoring program conducted in Action Level 1 drop 15 or more feet below predevelopment estimates for groundwater levels in those wells for 3 years out of any 4-year period of time. The area affected by this drop must be a minimum of 9 square miles in size.

a. The Lower Elkhorn NRD will actively seek public opinion while developing the rules and regulations for the area.
b. The district will require volume metering of wells used for any or all of the following categories of groundwater use: domestic, agricultural, manufacturing, commercial, or industrial.
c. The district will also require owners of these wells to submit an annual report to the district.

Additionally, the district will choose at least one of the following authorized controls:

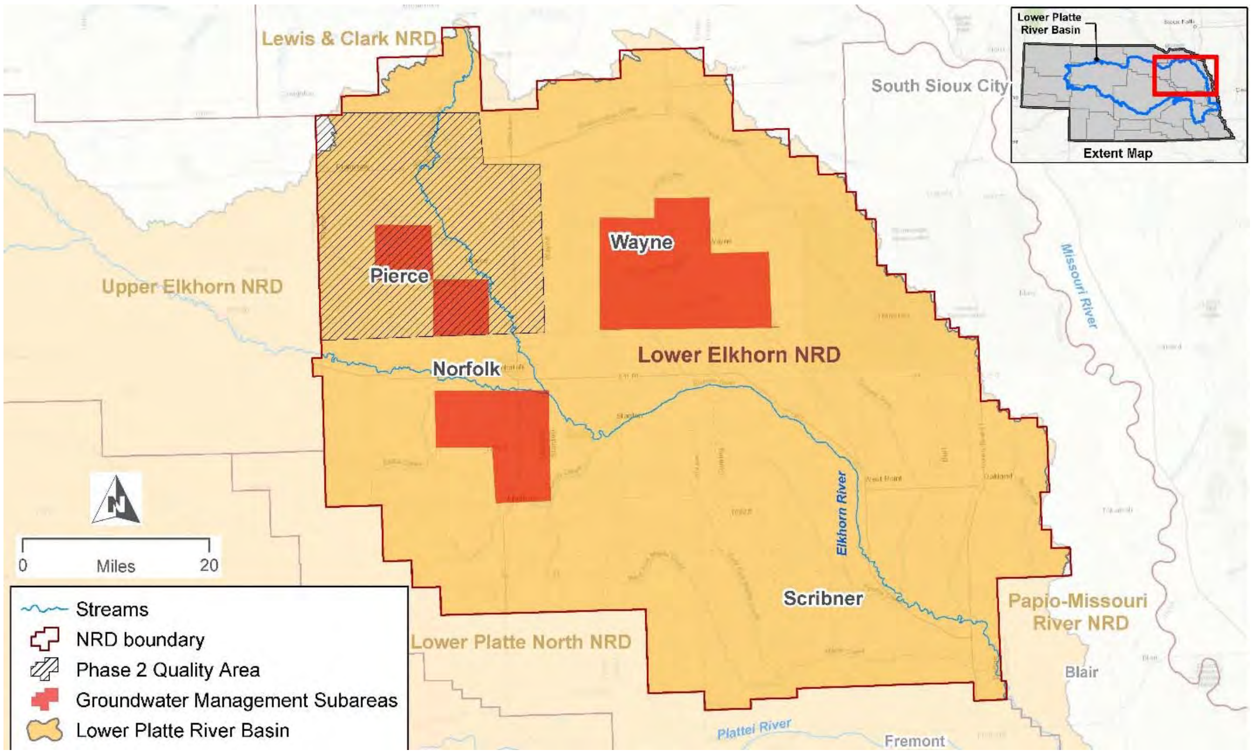
a. Allocate groundwater withdrawal on an acre-inch basis, specifying the total number of acre-inches of irrigation water per irrigated acre per year or an average number of acre-inches of irrigation water per irrigated acre over any reasonable period of time not to exceed 5 years.
b. Adopt a system of rotation of use of groundwater by utilizing a recurring series of use and nonuse of irrigation wells on an hourly, daily, weekly, or monthly basis or of irrigated acres on an annual basis.
c. Adopt well spacing requirements
d. Require the reduction of irrigated acres, where the nonuse of irrigated acres will be a uniform percentage reduction of each landowner's irrigated acres.
e. Require the use of flow meters on wells.
f. Require best management practices including irrigation scheduling.
g. Require groundwater users to submit annual reports to the district. The district will also continue the educational efforts and the groundwater level monitoring of Action Level 1.

Action Level 3: An area will be placed into Action Level 3 when the spring groundwater levels in 80 percent of the wells monitored in Action Level 2 drop 20 or more feet below predevelopment estimates for groundwater levels in those wells for 3 years out of any 4-year period of time. The area affected must be a minimum of 9 square miles in size. In addition to any of the controls of Action Level 2, the district may require any of the following controls for an Action Level 3 area:

a. Require the use of tensiometers, soil moisture blocks, or other irrigation scheduling devices.
b. Require annual reports with water level measurements and quantifying the total withdrawal from wells.

c. Close the area to the issuance of any additional new well permits for a period of one year. The district will also continue the educational efforts and the groundwater level monitoring of the first two Action Levels.
d. The Lower Elkhorn NRD has three (3) Quantity Subareas with allocations: 1) Eastern Madison County Quantity Subarea; 2) Wayne County Quantity Subarea; and 3) Pierce County.

Figure A-7: Lower Elkhorn Natural Resources District Groundwater Management Areas



Source: Adapted from Lower Elkhorn NRD Groundwater Management Plan (LENRD 2015)

Groundwater Quality Management

The Lower Elkhorn NRD maintaining a network of 81 irrigation wells for the district-wide groundwater quality monitoring that are on a 5-year sampling cycle. Specialized monitoring is also performed to evaluate local conditions on a concentrated basis.

The Lower Elkhorn NRD groundwater quality portion of the management area will be divided into subareas to more effectively manage areas where different conditions exist (such as areas with high or low groundwater contamination concentrations, different soil types, or different land uses). Borders for these subareas will be determined primarily, but not exclusively, by groundwater contamination concentration. These subareas will be referred to as phases. An area may move from one phase to another (either up or down) according to groundwater concentration and/or any of the listed additional criteria that are deemed appropriate by the Board. Borders for the subareas will follow either natural or political boundaries. NRDs are required to address all nonpoint source contaminants in their groundwater management plans. Because of the diversity of potential nonpoint source contaminants that the management area could address, the controls listed in this section are somewhat generic. This is so that contaminants other than nitrate-nitrogen may be addressed if necessary.

For those contaminants that have an established Maximum Contaminant Level, the following criteria and controls will be used to delineate and treat subareas (the subareas will be called 'phases'):

Phase 1 Area: Areas that are not designated as either Phase 2 or Phase 3.

a. Persons installing new wells must obtain a permit from the NRD in accordance with § 46-659.
b. The district will encourage operators to attend educational programs sponsored by the district concerning the contaminant (such as fertilizer and irrigation water management), to perform deep soil testing for the contaminant(s), to test irrigation water for the contaminant(s) and to submit an annual report (similar to the report required in phases 2 and 3) to the district.

Phase 2 Area: Areas that have from 50 percent to 90 percent of the Maximum Contaminant Level for a contaminant. An area will be placed into a Phase 2 area when at least 20 percent of the registered wells in an area are at or above the trigger level and the contamination is the result of nonpoint source groundwater contamination. Phase 2 areas must be a minimum of 9 square miles in size.

a. Persons installing new wells must obtain a permit from the NRD in accordance with § 46-659.
b. All operators applying fertilizer or (other possible sources of contaminants that the management area is addressing) must attend educational programs sponsored by the district.
c. Soil must be tested for residual quantities of the contaminant(s) (such as nitrate-nitrogen).
d. Irrigation water must be tested for the contaminant(s) (such as nitrate-nitrogen).
e. All operators applying fertilizer or (other possible sources of contaminants that the management area is addressing) must periodically submit reports to the district that will include soil test results, irrigation water test results, and other information required by the Board of Directors.
f. Contaminants other than nitrate-nitrogen may require controls that are different from those listed above for Phase 2 areas.

If these controls will not be effective in preventing or remediating groundwater contaminant(s) other than nitrate-nitrogen, the Board of Directors may choose to not use some or all of the controls listed above.

Phase 3 Area: Areas with greater than 90 percent of the Maximum Contaminant Level for a contaminant. An area will be placed into a Phase 3 area after being in a Phase 2 area for a minimum of 5 years, and when 50 percent of the registered wells in the area are at or above the trigger level. Phase 3 areas must be a minimum of 9 square miles in size.

a. Persons installing new wells must obtain a permit from the NRD in accordance with § 46-659.
b. All operators applying fertilizer or (other possible sources of contaminants that the management area is addressing) must attend educational programs sponsored by the district.
c. Soil must be tested for residual quantities of the contaminant(s) (such as nitrate-nitrogen).
d. Irrigation water must be tested for the contaminant(s) (such as nitrate nitrogen).
e. All operators applying fertilizer or (other possible sources of contaminants that the management area is addressing) must submit a report to the district that includes soil test results, irrigation water test results, and other information required by the Board of Directors annually.
f. All irrigation wells must have the volume output certified by the district.
g. All irrigators must employ some form of irrigation scheduling
h. Contaminants other than nitrate-nitrogen may require controls that are different from those listed above for Phase 3 areas.

If these controls will not be effective in preventing or remediating groundwater contaminant(s) other than nitrate-nitrogen, the Board of Directors may choose to not use some or all of the controls listed above.

Additional criteria: The district Board of Directors, at its discretion, may designate an area as, or include an area in, either Phase 2 or Phase 3, when the triggers are not met, under the following conditions:

1) Areas with similar soil and land use conditions as an existing Phase 2 or Phase 3 area.
2) Areas that may be vulnerable to groundwater contamination.
3) Areas that have vadose zone contamination that indicates a potential for groundwater contamination.
4) Areas that are within Public Water Supply Wellhead Protection Areas.
5) Other areas deemed necessary by the Board of Directors consistent with the Groundwater Reservoir Life Goal and the Nebraska Groundwater Management and Protection Act.

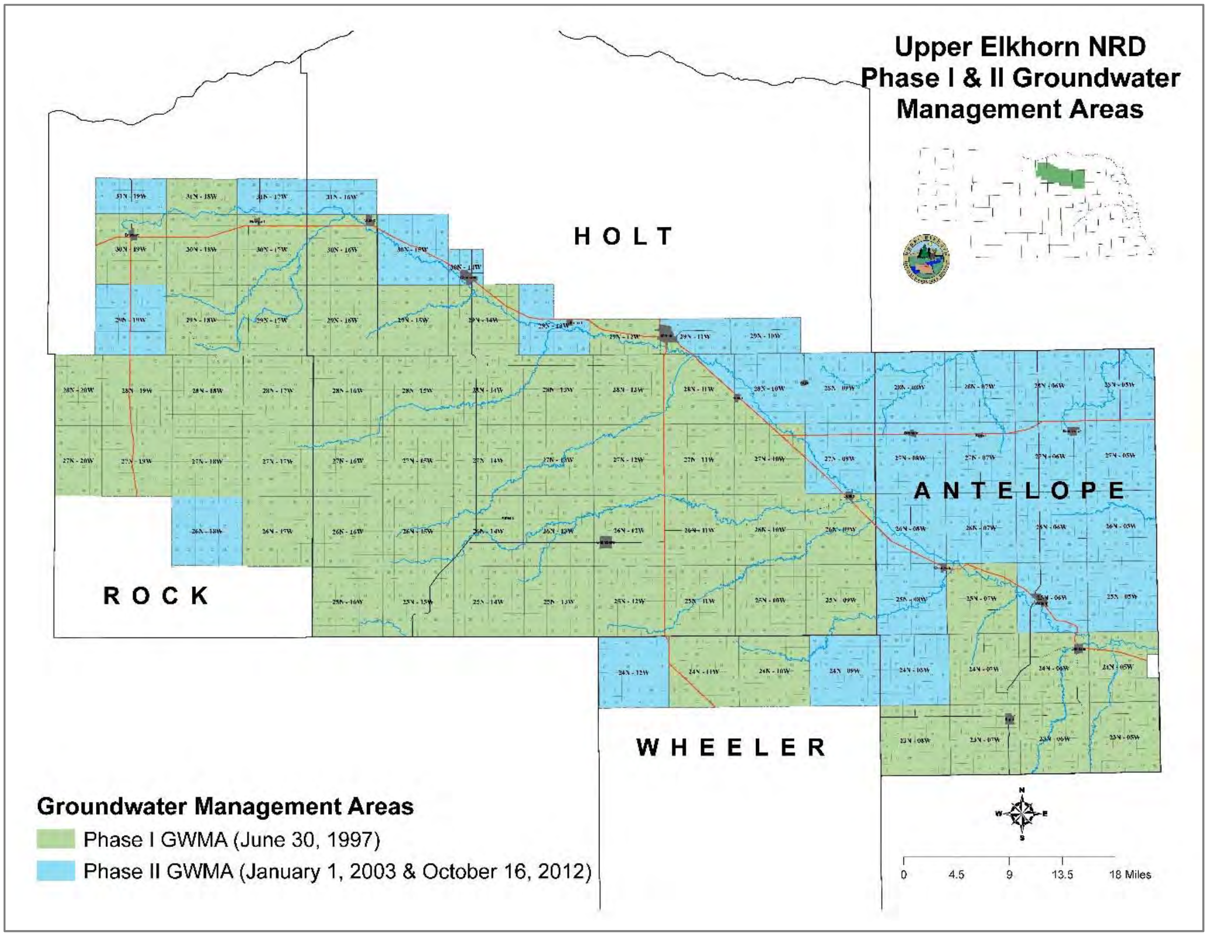
Additional Controls: Any of the following controls may be required by the Board of Directors in a Phase 1, Phase 2, or Phase 3 area if deemed necessary to fulfill the Groundwater Reservoir Life Goal:

a. All operators applying fertilizer or (other possible sources of contaminants that the management area is addressing) must attend educational programs sponsored by the district.
b. Soil must be tested for residual quantities of the contaminant(s) (such as nitrate-nitrogen).
c. Irrigation water must be tested for the contaminant(s) (such as nitrate nitrogen).
d. Using realistic yield goals
e. Irrigation water scheduling.
f. Meter irrigation water application volume.
g. Ban fall and/or winter fertilizer application.
h. Require the use of nitrification inhibitors.
i. Allowing nutrient credit for legume crops.
j. Performing chemical and/or physical analysis of contaminant sources being land applied (such as manure, compost, sewage sludge, and other waste products).
k. Allowing nutrient credit for manure, compost, sewage sludge, and other waste products.
l. Performing nutrient analysis of manure, compost, sewage sludge, and other waste products. Confined animal production facilities must prepare and implement a plan for the disposal of animal wastes that determines the amount of manure that will be land applied, the area of land required for that amount of manure (complying with UNL recommendations), and the location(s) of that area of land.

A.10 Upper Elkhorn Natural Resources District Current Monitoring and Response Actions

The Upper Elkhorn NRD measures the static water level in approximately 380 wells annually to keep track of water quantity across the NRD. The Upper Elkhorn NRD also has an extensive water quality monitoring network throughout the NRD. The Upper Elkhorn NRD samples approximately 600 irrigation wells annually for nitrate-nitrogen, and 58 dedicated monitoring wells for nitrate-nitrogen and selected pesticides.

Figure A-8: Upper Elkhorn Natural Resources Phase II Management Areas



Source: Upper Elkhorn NRD Phase II Area Map (downloaded 2018)

Groundwater Quality

The Upper Elkhorn NRD manages groundwater quality through the three phases that are based on nitrate-nitrogen levels. The entire Upper Elkhorn NRD was designated a Phase I Groundwater Quality Management Area.

Groundwater Quantity

The Upper Elkhorn NRD has developed sub-districts throughout the Upper Elkhorn NRD management area to manage groundwater. As part of such management, Upper Elkhorn NRD has determined a baseline static water level within each of the sub-districts, which will be the lowest static water level reading prior to 2014.

Triggering Mechanisms:

1) When spring static water levels within a sub-district are determined to be between 24 inches and 12 inches above the lowest spring reading, the following shall occur:
    a) The Upper Elkhorn NRD will conduct an informational and educational campaign for landowners that own and operate irrigation distribution systems that are supplied by individual or commingled high capacity wells yielding more than 50 gpm. Landowners will be informed within that sub-district that this level has been reached and upon subsequent spring static water level readings, additional regulations may be warranted the following year.

   b) Historical certified irrigated acres that were not being irrigated by groundwater prior to this trigger will not be allowed to be developed for irrigation as long as these criteria are met.
2) When spring static water levels in a sub-district are determined to be within 12 inches above the lowest spring static reading, the following shall occur:
   a) Flowmeters will be required on 10 percent of the landowner's irrigation distribution systems within that sub-district that are supplied by individual or commingled high capacity wells yielding more than 50 gpm.
   b) Installation of flowmeters must be installed to manufacturer's specifications. A legal description must be submitted to Upper Elkhorn NRD and flowmeters must be installed by December 31 of the current year of meeting the above static water level.
   c) If the groundwater irrigation distribution system owner owns less than 10 groundwater irrigation distribution systems, they will be required to install one flowmeter if the above criteria is met.
   d) If the groundwater irrigation distribution system owner already has 10 percent of their groundwater irrigation distribution systems equipped with flowmeters within this sub-district, this requirement will be satisfied.
   e) Flowmeter readings will need to be submitted to Upper Elkhorn NRD by December 31 each year on forms developed by Upper Elkhorn NRD and may be spot-checked for compliance.
   f) Any groundwater irrigation distribution system that is currently equipped or is to be equipped with a flowmeter must certify their irrigated acres if they have not already been certified.
   g) Historical groundwater certified irrigated acres that were not being irrigated prior to this trigger will not be allowed to be developed for irrigation as long as the above criteria is met.
3) When spring static water levels in a sub-district remain and are determined to be within 12 inches above the lowest spring static reading in subsequent or non-subsequent years, the following shall occur:
   a) Flowmeters will be required on an additional 10 percent of the landowner's irrigation distribution systems within that sub-district that are supplied by individual or commingled high capacity wells yielding more than 50 gpm.
   b) Installation of flowmeters must be installed to manufacturer's specifications. A legal description must be submitted to Upper Elkhorn NRD and flowmeters must be installed by December 31 of the current year of meeting the above static water level.
   c) If the groundwater irrigation distribution system owner owns less than 10 groundwater irrigation distribution systems, they will be required to install an additional flowmeter within this sub-district.
   d) Flowmeter readings will need to be submitted to Upper Elkhorn NRD by December 31 each year on forms developed by Upper Elkhorn NRD and may be spot-checked for compliance.
   e) Historical groundwater certified irrigated acres that were not being irrigated prior to this trigger will not be allowed to be developed for irrigation as long as the above criteria is met.
4) When spring static water levels in a sub-district are determined to be 12 inches above the lowest reading, the flowmeter installation requirement will discontinue until the spring static water levels are determined to be within 12 inches above the lowest static water level reading.
5) When spring static water levels in a sub-district are determined to be within 12 inches below the lowest spring static water level reading, the following shall occur:

   a) Flowmeters will be required on 60 percent of the landowner's irrigation distribution systems within that sub-district that are supplied by individual or commingled high capacity wells yielding more than 50 gpm.

   b) Installation of flowmeters must be installed to manufacturer's specifications. A legal description must be submitted to Upper Elkhorn NRD and flowmeters must be installed by December 31 of the current year of meeting the above static water level.

c) Flowmeter readings will need to be submitted to Upper Elkhorn NRD by December 31 each year on forms developed by Upper Elkhorn NRD and maybe spot-checked for compliance.

d) Historical groundwater certified irrigated acres that were not being irrigated prior to this trigger will not be allowed to be developed for irrigation as long as the above criteria is met.

6) When spring static water levels in a sub-district remain and are determined to be within 12 inches below the lowest spring static reading in subsequent or non-subsequent years, the following shall occur:

   a) Flowmeters will be required on 100 percent of the landowner's irrigation distribution systems within that sub-district that are supplied by individual or commingled high capacity wells yielding more than 50 gpm. No allocation will be implemented at this time.

   b) Installation of flowmeters must be installed to manufacturer's specifications. A legal description must be submitted to Upper Elkhorn NRD and flowmeters must be installed by December 31 of the current year of meeting the above static water level.

7) When the spring static water levels in a sub-district are determined to be below 12 inches of the lowest spring static water level reading, then an allocation system will be implemented within that sub-district and the following shall occur:
   a) Flowmeters will be required on 100 percent of the landowner's irrigation distribution systems within that sub-district that are supplied by individual or commingled high capacity wells yielding more than 50 gpm.
   b) Installation of flowmeters must be installed to manufacturer's specifications. A legal description must be submitted to Upper Elkhorn NRD and flowmeters must be installed by December 31 of the current year of meeting the above static water level.
   c) Variances may be granted upon a demonstration of good cause.
   d) Allocations will be allotted the following year of the spring reading reaching this static water level. Each groundwater certified irrigation distribution system will be allocated for a period of 5 years and receive 75 acre inches.
   e) Flowmeter readings will need to be submitted to Upper Elkhorn NRD by December 31 each year on forms developed by Upper Elkhorn NRD and may be spot-checked for compliance.
   f) Historical groundwater certified irrigated acres that were not being irrigated prior to this trigger will not be allowed to be developed for irrigation as long as the above criteria is met.
8) When spring static water levels in a sub-district are determined to be below 12 inches of the lowest spring static water level in one spring static water level measuring cycle, the following shall occur:
   a) Flowmeters will be required on 100 percent of the landowner's irrigation distribution systems within that sub-district that are supplied by individual or commingled high capacity wells yielding more than 50 gpm and an allocation will be enforced on all groundwater irrigation distribution systems within the sub-district.
   b) Allocations will be allotted the following year of the spring reading reaching this static water level.
   c) Allocations will be maintained for a minimum of 5 years. Any time within this period the Upper Elkhorn NRD board of directors reserves the right to adjust the allocation amount based on static water levels, trend lines, and weather conditions.
   d) Flowmeter readings will need to be submitted to Upper Elkhorn NRD by December 31 each year on forms developed by Upper Elkhorn NRD and may be spot-checked for compliance.
   e) Historical groundwater certified irrigated acres that were not being irrigated prior to this trigger will not be allowed to be developed for irrigation as long as the above criteria is met.
9) Upon static water levels reaching Subpart 8 above:
   a) Expansion of groundwater irrigated acres will not be allowed.

b) Each groundwater certified irrigation distribution system will be allocated for a period of 5 years and receive 75 acre inches.
c) New helper wells will not be allowed once a sub-district has been determined to be triggered.
d) Transfers of historical or active groundwater irrigated acres will not be allowed.
e) Inactive certified historical acres that are not currently irrigated upon a sub-district being triggered will not receive an allocation.
f) Historical certified irrigated acres that began irrigating within the five years prior to being triggered will only receive 15 acre inches multiplied by the number of years documented by Farm Service Agency or County Assessor records. (For example, if documentation demonstrates land was irrigated 3 out of the previous 5 years, such land would receive only 45 acre inches for the 5-year allocation starting the year it was triggered.)
g) Situations where groundwater historical irrigated acres are utilized to complete circle or add to a certified irrigation distribution system will be calculated as such. I. (For example, if 5 acres were added to a 127-acre pivot and 3 years' worth of documentation are available, 5 acres x 45 inches = 225 acre inches. 127 acres have 75 acre inches, or 9,525 acre inches. So, add (225 acre in + 9,525 acre in) /132 acres = 73.86 acre inches for the 5-year allocation.)
h) Balance of allocations will be based on an annual allocation of 15 acre inches.
i) Once levels rise two feet above the lowest level, the Upper Elkhorn NRD Board will decide as to whether a sub-district can sustain more consumptive use and determine if groundwater historical acres that are not being currently irrigated will be allowed to be irrigated.
j) Allocation Carry-Over:
    i) Any unused allocation at the end of the 5-year period would only be allowed to carry 5 acre inches into the next allocation. (Starting with a new 75 acre inch allocation + 5 acre inches of carry over = 80 acre inches for next 5-year time period.)
    ii) Landowners would have to notify on a form provided by Upper Elkhorn NRD the amount and location where a portion of an allocation is to be moved. This notification would have to occur by January 15 of each year.
    iii) Moving of allocation as stated above would only be allowed when:
        (1) Properties are within the same ownership;
        (2) Within sub-districts developed by Upper Elkhorn NRD; and
        (3) Are to a lower stream depletion factor within the same hydrologic unit code (HUC) within the same sub-district. Allocation would be allowed to move within 2 miles of adjacent HUC meeting above criteria.
k) Penalties:
    i. At the end of the 5-year allocation, any amount of groundwater used over the 75 acre inch allocation will be rounded to the next consecutive inch, multiplied by 5, and subtracted from the next new subsequent allocation.
    ii. If the district removes the sub-district from an allocation, those groundwater irrigation distribution systems that was to be penalized by a reduction will remain with an allocation for another year. This 1-year allocation will be based on the annual 15 acre inch allocation minus the penalty. (For example, if a landowner used 1.2 acre inches more than the 75 acre inch allocation, 1.2 acre inches rounded to 2 acre inches times 5 equals 10 acre inches. 15 acre inches (annual) minus 10 acre inches (penalty) = 5 acre inches for year 6.)
    iii. Acres that are being irrigated that have not been certified by the groundwater irrigation distribution owner with Upper Elkhorn NRD will have their allocation reduced on their certified groundwater irrigated acres for that groundwater distribution irrigation system. Certified irrigated acres will be reduced by a multiplier of 10. (For example, landowner has 127 acres and irrigated 3 acres more that was not certified as irrigated. Landowner would be penalized 3 (acres) x 10 (multiplier) = 30 acres of reduction on that impacted irrigation distribution system for a minimum of 1

year. If this violation occurs during an allocation period, penalty will carry on for completion of existing allocation period and on to next full allocation. If allocation for that subbasin is removed then the penalty will be enforced for 1 year.

Appendix B: Evaluation of Hydroclimate Indices

B.1 Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) is calculated weekly by the National Oceanic Atmospheric Administration (NOAA) Climate Prediction Center (CPC). The PDSI reflects recent precipitation and the soil moisture balance. PDSI does not consider human impacts on the water balance, such as irrigation. Zero or near zero PDSI values indicate normal conditions, a negative PDSI value indicates drought and a positive value for a wet period.

Table B-1: PDSI Classifications

Index Value	Description	Index Value	Description
4.0 or above	Extremely wet	-0.99 to -0.5	Incipient dry spell
3.00 to 3.99	Very wet	-1.99 to -1.00	Mild drought
2.00 to 2.99	Moderately wet	-2.99 to -2.00	Moderate drought
1.00 to 1.99	Slightly wet	-3.00 to -3.99	Severe drought
0.5 to 0.99	Incipient wet spell	-4.00 or less	Extreme drought
-0.49 to 0.49	Near normal	---	---

Source: NOAA National Weather Service Climate Prediction Center 2005.
Note: The U.S. Drought Monitor includes one additional category "exceptional drought" for index values <-5

Mathematically, the PDSI is calculated as follows:

$$PDSI_i = \sum_{m=0}^{i} \frac{0.897^m}{3} Z_{i-m} \qquad \text{Equation (B-1)}$$

where *i* and *i-1* indicate current and previous months at some arbitrary time, respectively, and $PDSI_0 = 0$. The Z_i in Equation (B-1), called the monthly Z-index, is defined as

$$Z_i = (Kd)_i \qquad \text{Equation (B-2)}$$

where K is a coefficient and

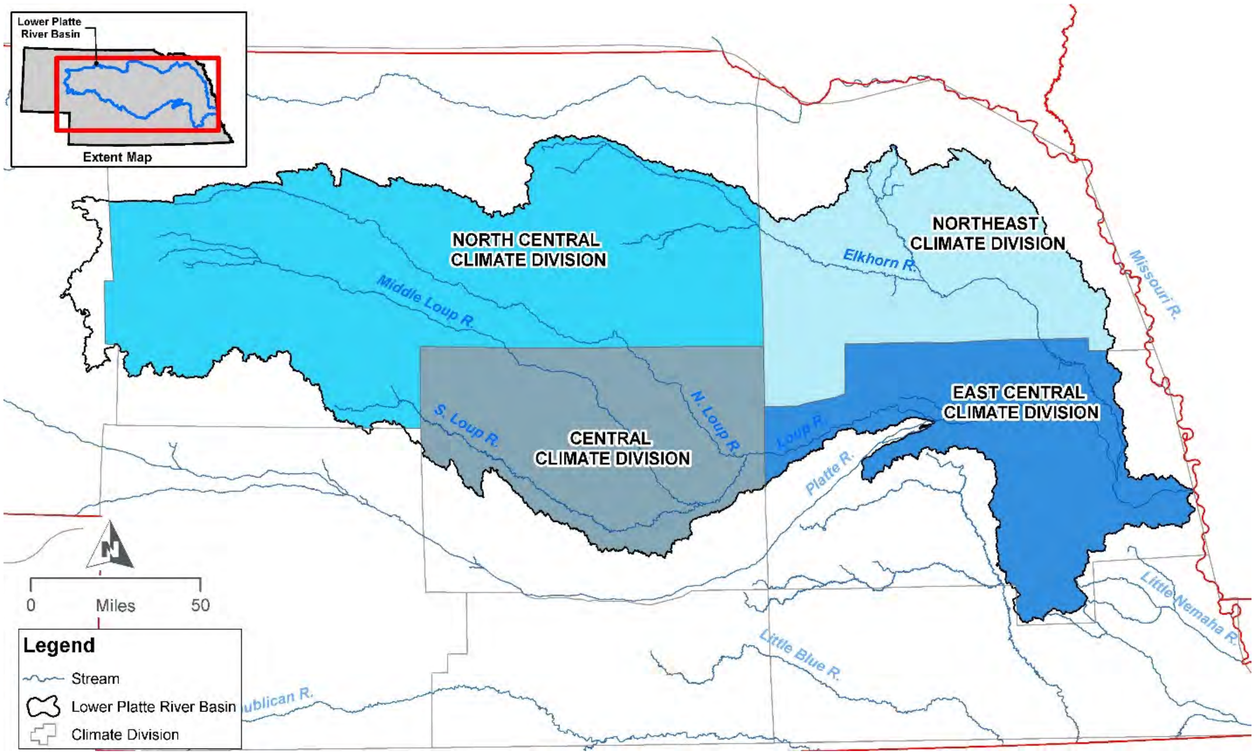
$$d = P - (\alpha_i PE + \beta_i PR + \gamma_i PRO - \delta_i PL) \qquad \text{Equation (B-3)}$$

where $\alpha_i = \overline{ET}_i/\overline{PE}_i,\ \beta_i = \bar{R}_i/\overline{PR}_i,\ \gamma_i = \overline{RO}_i/\overline{PRO}_i,\ \delta_i = \bar{L}_i/\overline{PL}_i$

In Equation (B-3), P is actual monthly precipitation. The terms in the parenthesis on the right-hand-side of Equation (B-3) combine to yield monthly 'climatologically appropriate rainfall'. In particular, PE is potential evapotranspiration, PR is potential water recharge to soil, and PRO potential runoff. Wayne C. Palmer used a two-layer soil model consisting of a surface layer, 'plow layer', and underlying layer, 'root zone', and defined PL as the sum of soil water of the two layers available for evapotranspiration. He called this term 'potential loss of soil water to evapotranspiration' (Palmer 1965).

Equation (B-1) is a cumulative formula, the PDSI from previous months affects the current month. As the number of months increase, the effect of previous months gradually decrease. However, because previous months affect the PDSI of a current month, there could be a lag in the PDSI identifying rapidly emerging droughts. Based on USGS streamflow record data, monthly streamflow on the Platte River from Duncan to Louisville, Nebraska, correlated significantly with the monthly PDSI (USGS 2008). The NOAA climate divisions for Nebraska are shown in Figure B-1.

Figure B-1: NOAA Climate Divisions for Nebraska



Source: Map layer downloaded from Climate Prediction Center 2018.

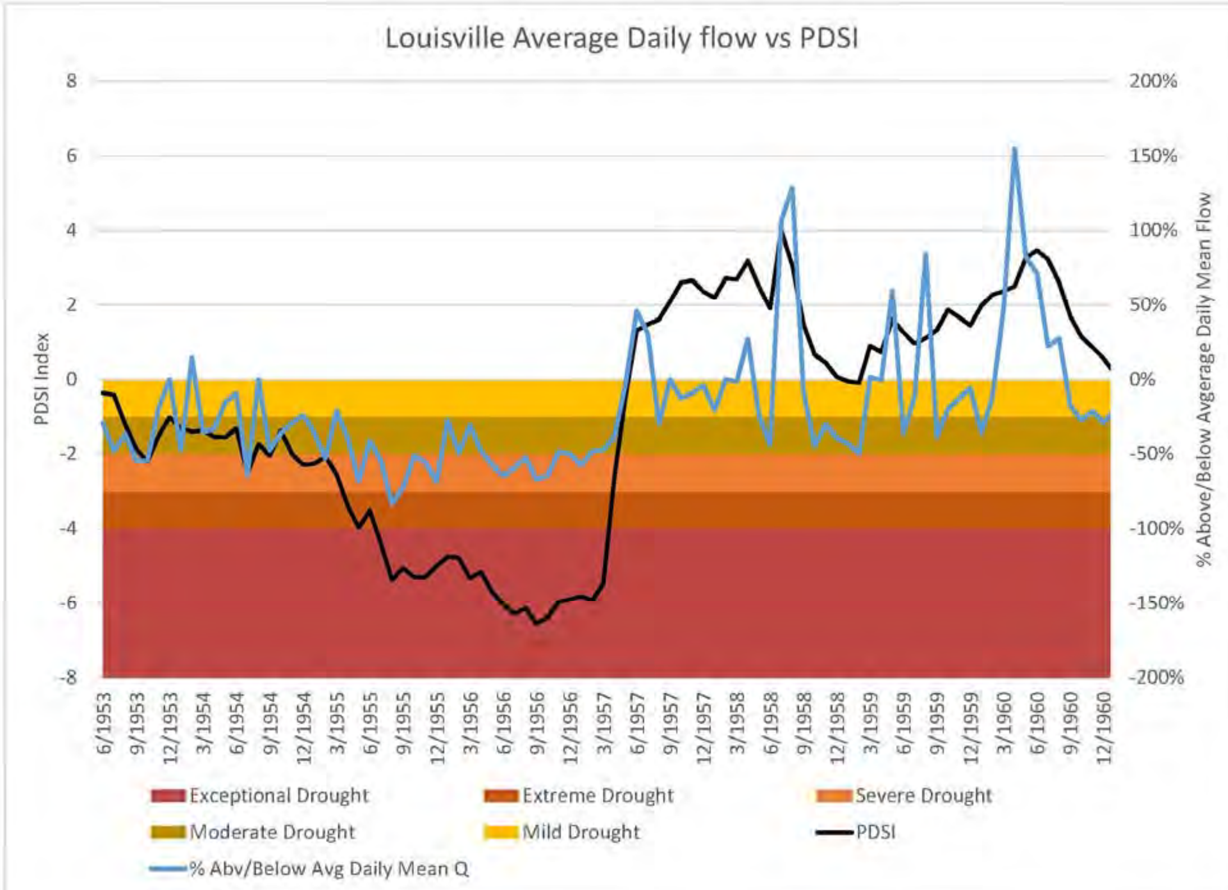
Figures B-1 through B-8 plot the Platte River July streamflow at Louisville as a percentage above or below the median July flow for the period 1953 to 2017 (Table B-2) against the historic PDSI to understand the historic droughts. The PDSI value in these plots is a composite of the value for the four climate divisions encompassing the Lower Platte River Basin: East Central, Northeast, Central, and North Central divisions).

Table B-2: Platte River at Louisville – 50 percent flow exceedance values by month

Month	50% Exceedance Flow (cfs)	Month	50% Exceedance Flow (cfs)
January	4,309	July	4,994
February	6,922	August	3,149
March	9,287	September	3,523
April	8,292	October	4,490
May	8,033	November	5,062
June	9,287	December	4,629

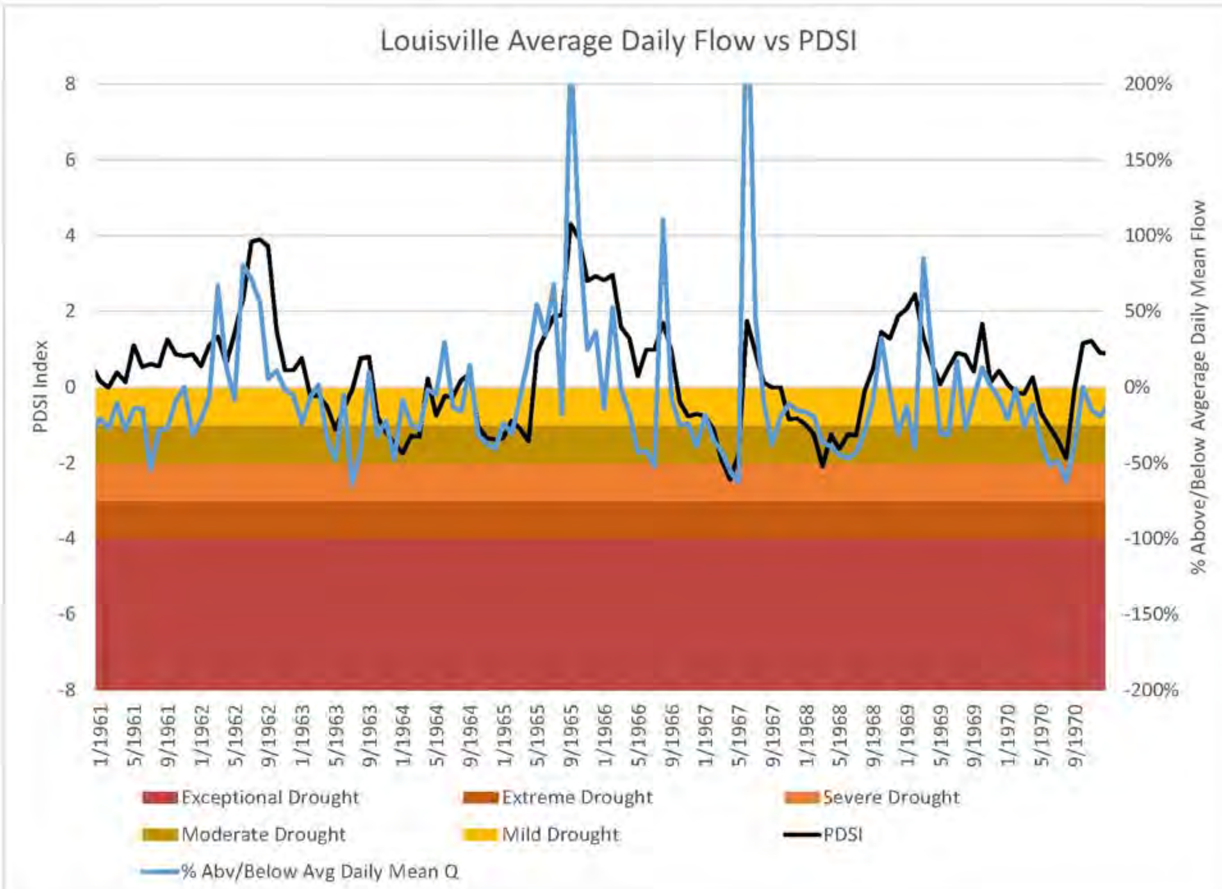
Note: Based on USGS gage #06805500 Platte River at Louisville, Nebr. (6/1953 to 12/2017 mean daily flow)

Figure B-2: Composite PDSI versus Above/Below Average Flow at Louisville – 1953 to 1960



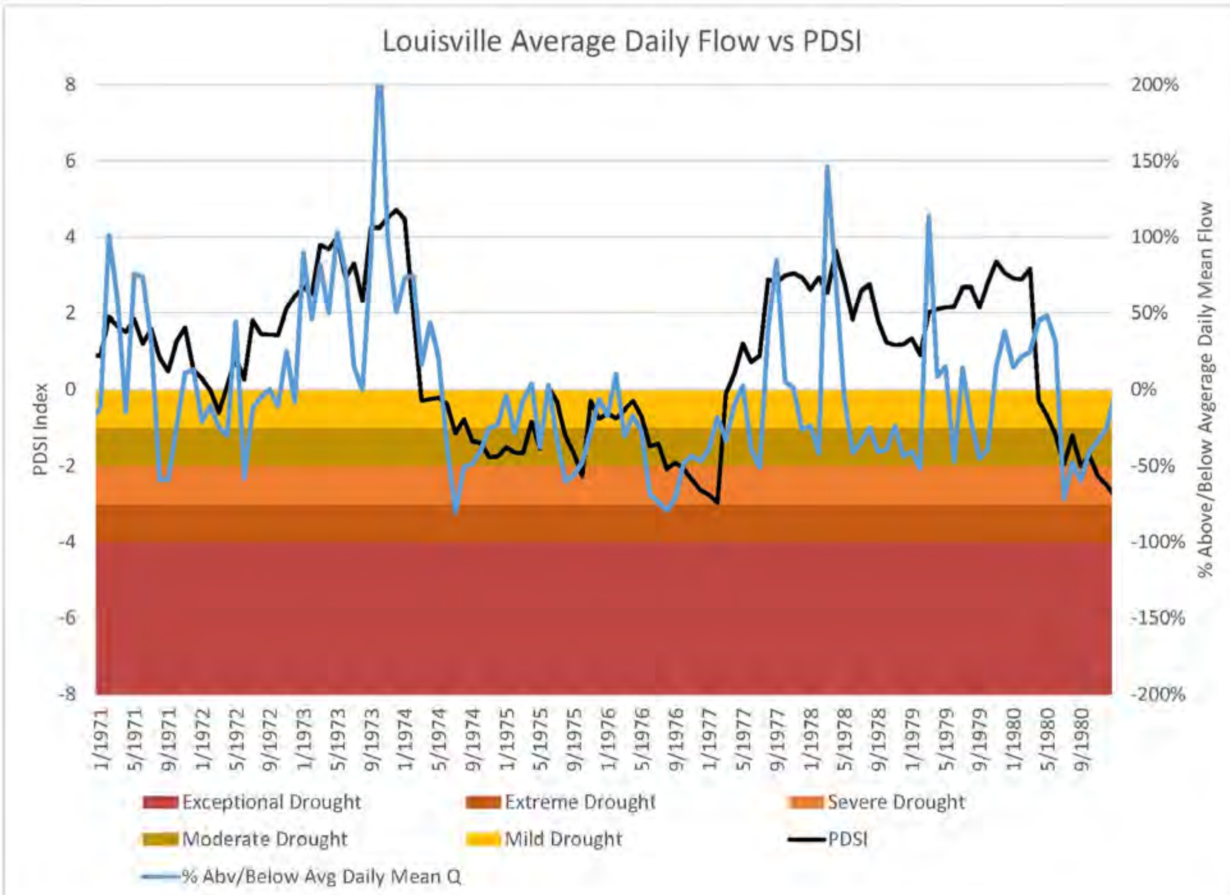
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-3: Composite PDSI versus Above/Below Average Flow at Louisville – 1961 to 1970



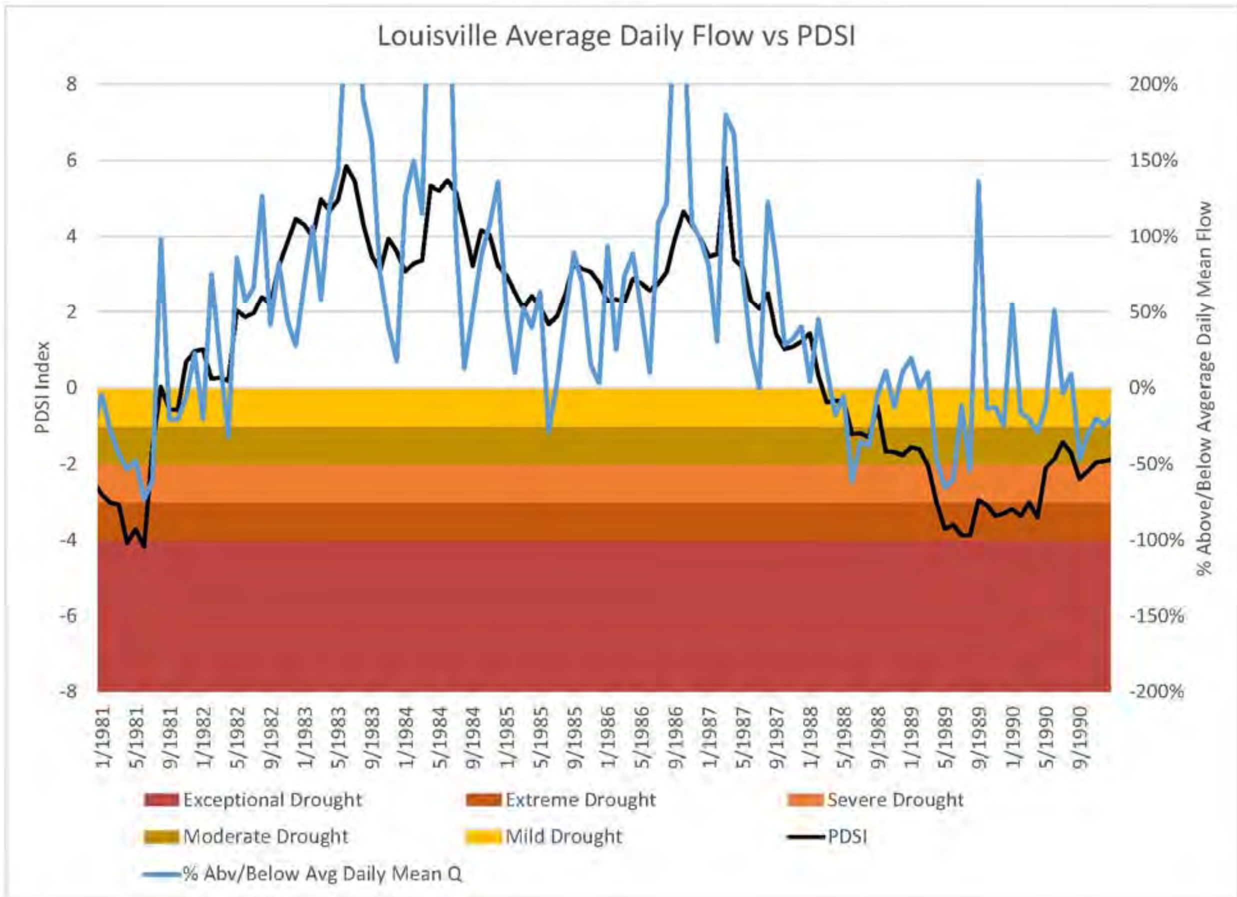
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-4: Composite PDSI versus Above/Below Average Flow at Louisville – 1971 to 1980



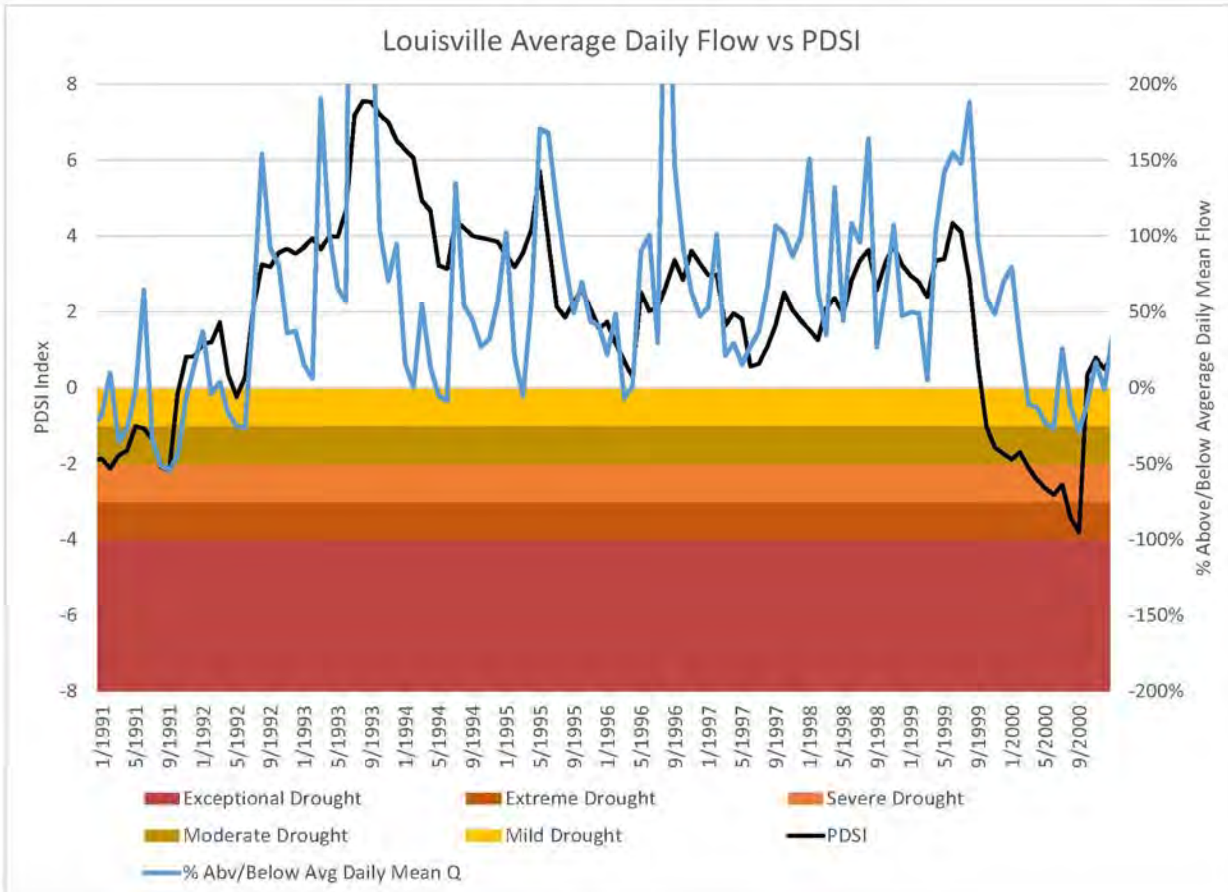
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-5: Composite PDSI versus Above/Below Average Flow at Louisville – 1981 to 1990



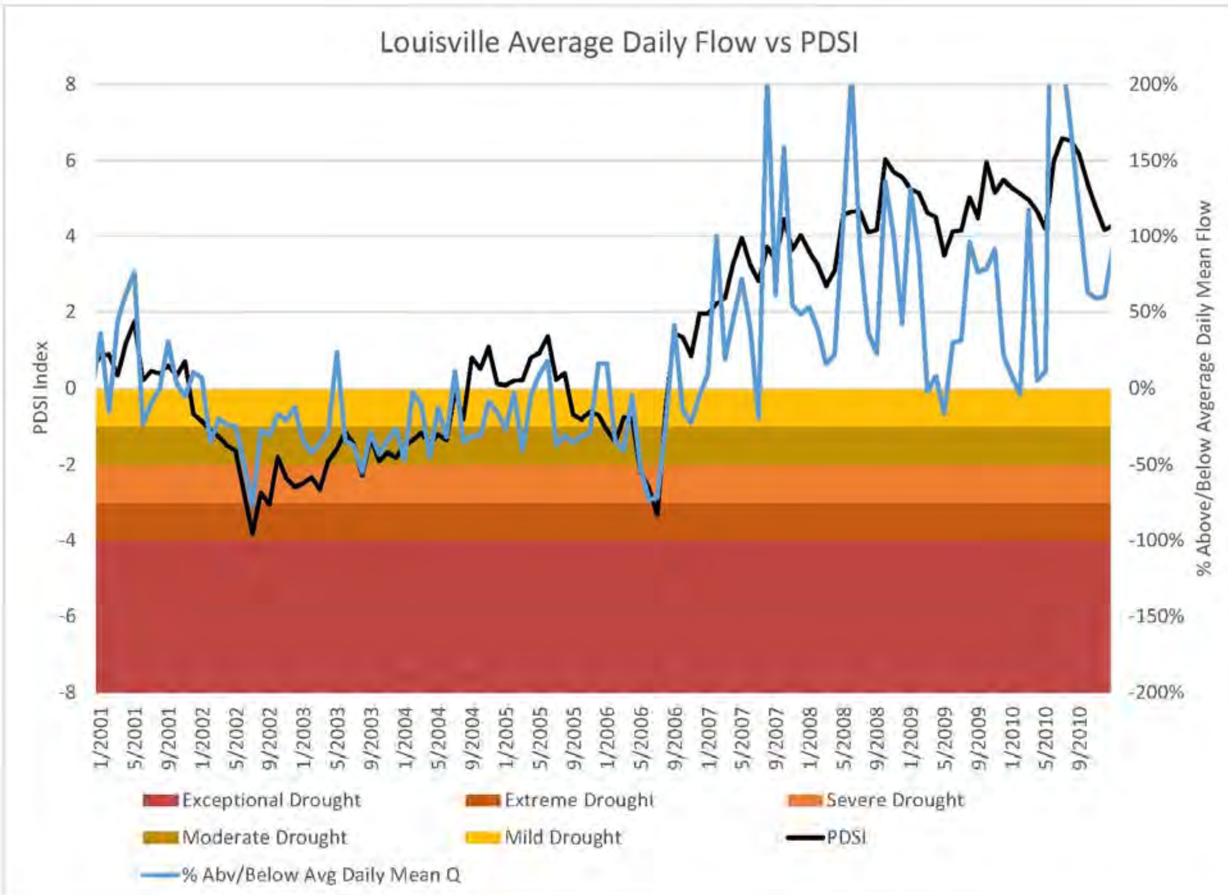
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-6: Composite PDSI versus Above/Below Average Flow at Louisville – 1991 to 2000



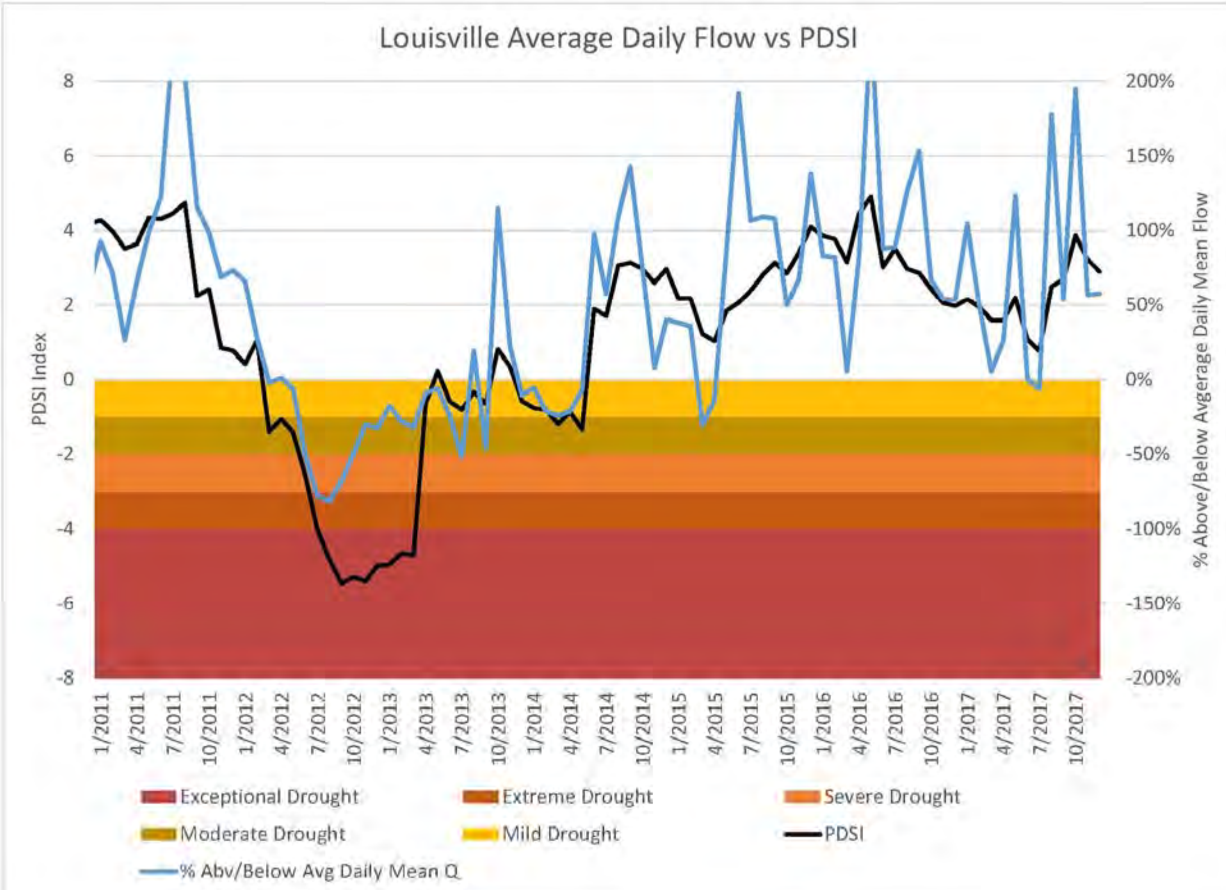
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-7: Composite PDSI versus Above/Below Average Flow at Louisville – 2001 to 2010



Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-8: Composite PDSI versus Above/Below Average Flow at Louisville – 2011 to 2017



Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

B.2 Standardized Precipitation Index

The Standardized Precipitation Index (SPI) is the internationally preferred index for meteorological drought (Hayes et al. 2011). Similar to PDSI, Zero or near zero SPI values indicate normal conditions, a negative SPI indicates drought and a positive value for a wet period. Table B-3 lists the SPI classification for drought.

Table B-3: SPI Classifications

Index Value	Description	Index Value	Description
2.0 or greater	Extremely wet	-1.49 to -1.00	Moderate drought
1.50 to 1.99	Severely wet	-1.99 to -1.50	Severe drought
1.00 to 1.49	Moderately wet	-2.0 or less	Extreme drought
-0.99 to 0.99	Near normal	---	---

Source: NOAA National Weather Service Climate Prediction Center 2005.

The SPI is based on precipitation only, and does not consider soil moisture balance like PDSI. The SPI uses historical precipitation records for any location to develop a probability of precipitation that can be computed at any number of timescales, from 1 month to 48 months or longer.

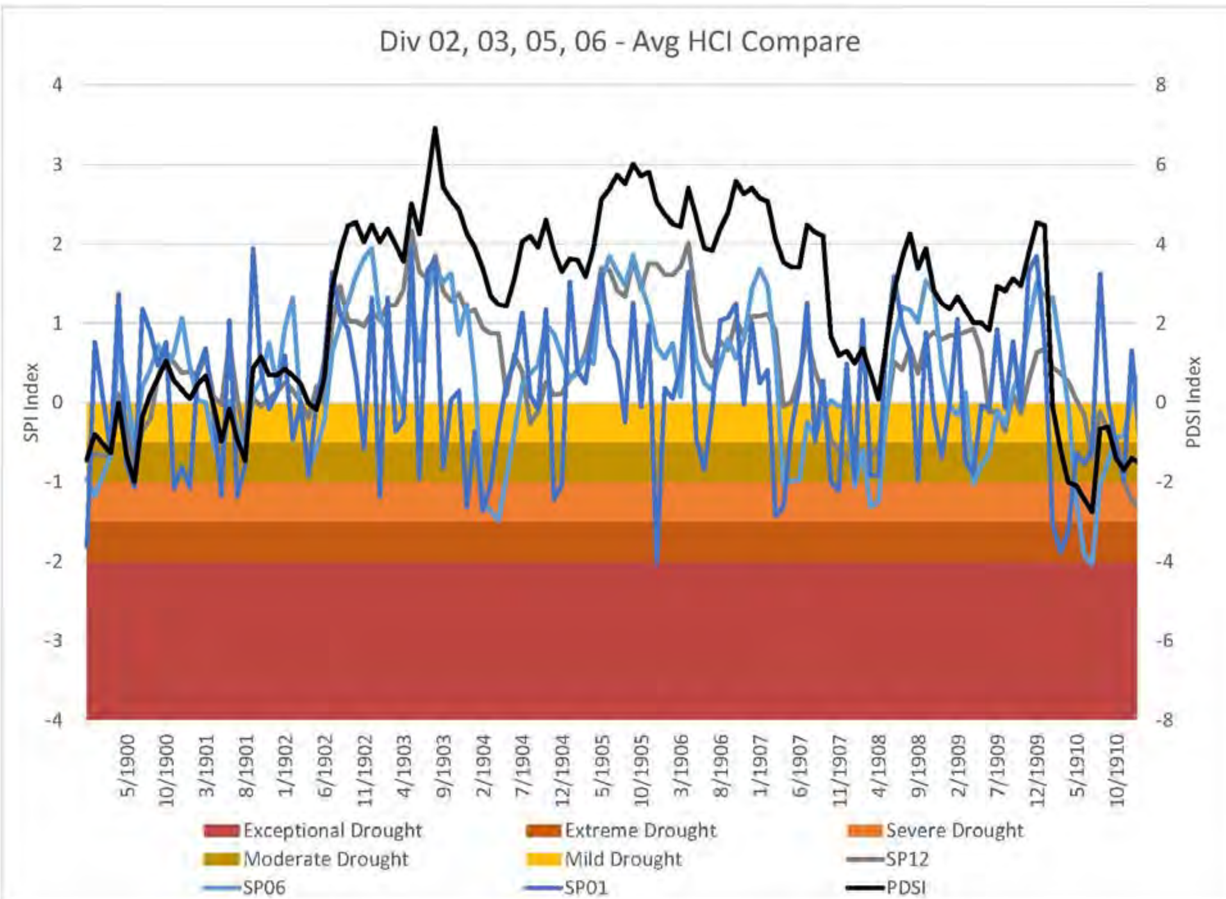
With precipitation as the only input, SPI is deficient when accounting for the temperature component, which is important to the overall water balance and water use of a region. This drawback can make it more difficult to compare events of similar SPI values but different temperature scenarios. Mathematically, the SPI is calculated as follows:

$$SPI = (P - P^{*})/\sigma_p \qquad \text{(Equation B-4)}$$

where P = precipitation, P* = mean precipitation, and σ_p = standard deviation of precipitation.

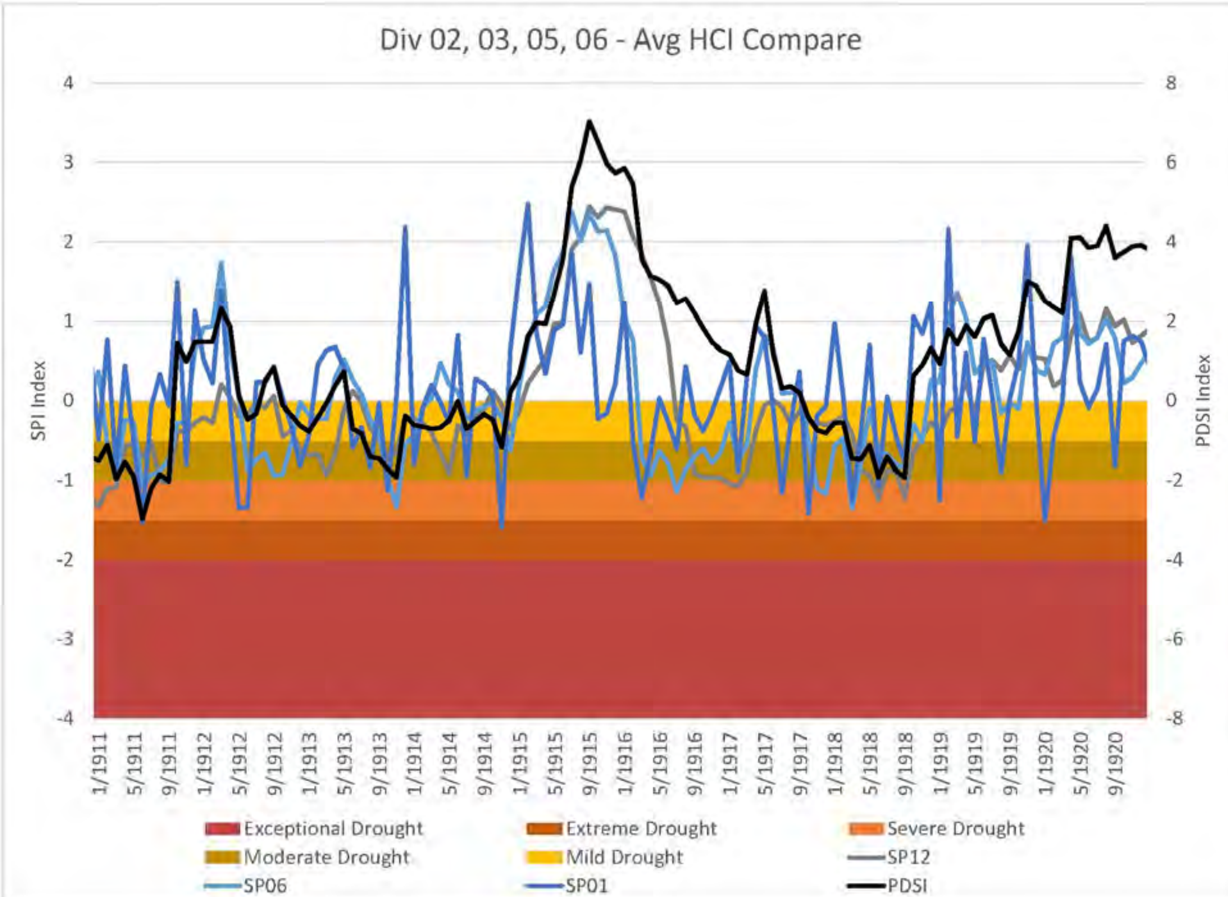
To compare historic SPI to historic PDSI, the composite of each (North Central, Northeast, Central, and East Central climate divisions) were plotted in Figures B-9 through B-20 for the period-of-record 1900 – 2017.

Figure B-9: Composite SPI Index versus Composite PDSI Index – 1900 to 1910



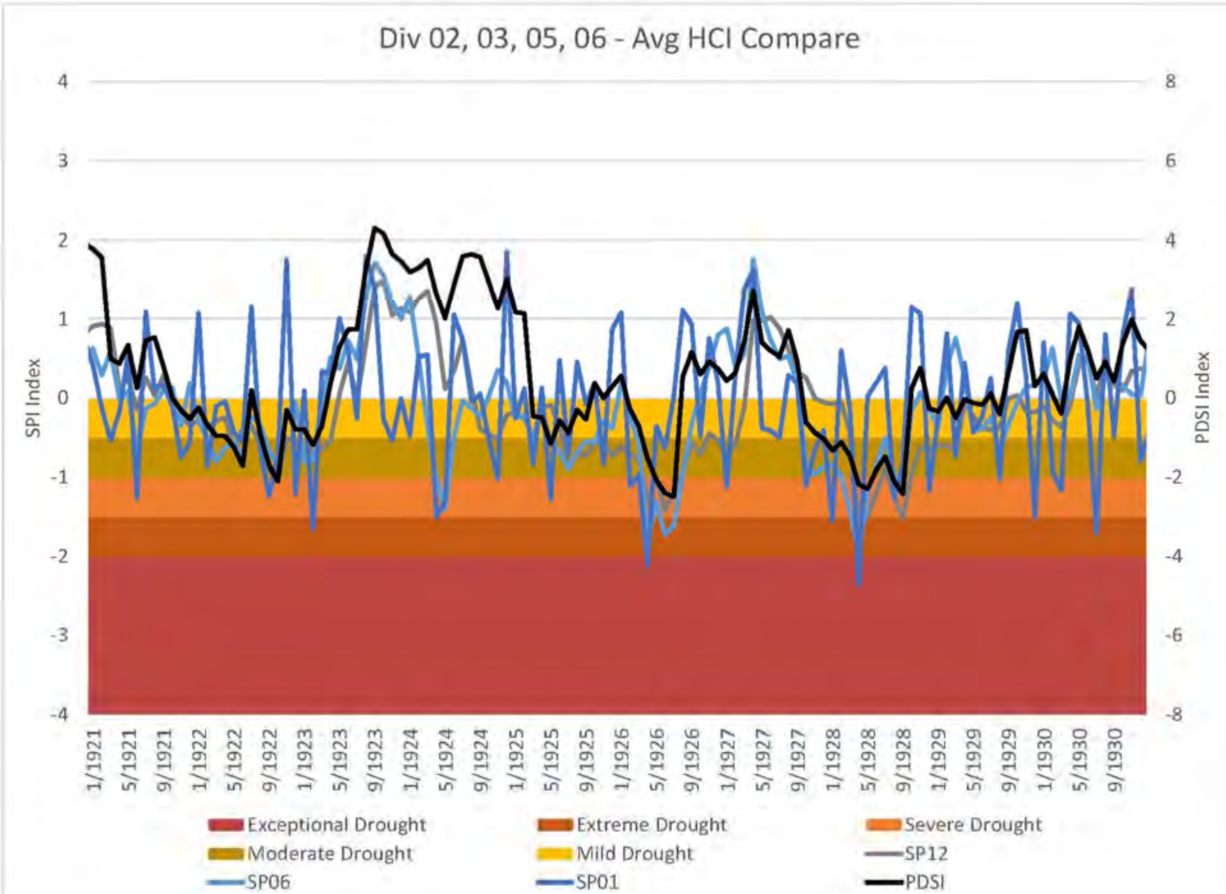
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-10: Composite SPI Index versus Composite PDSI Index – 1911-1920



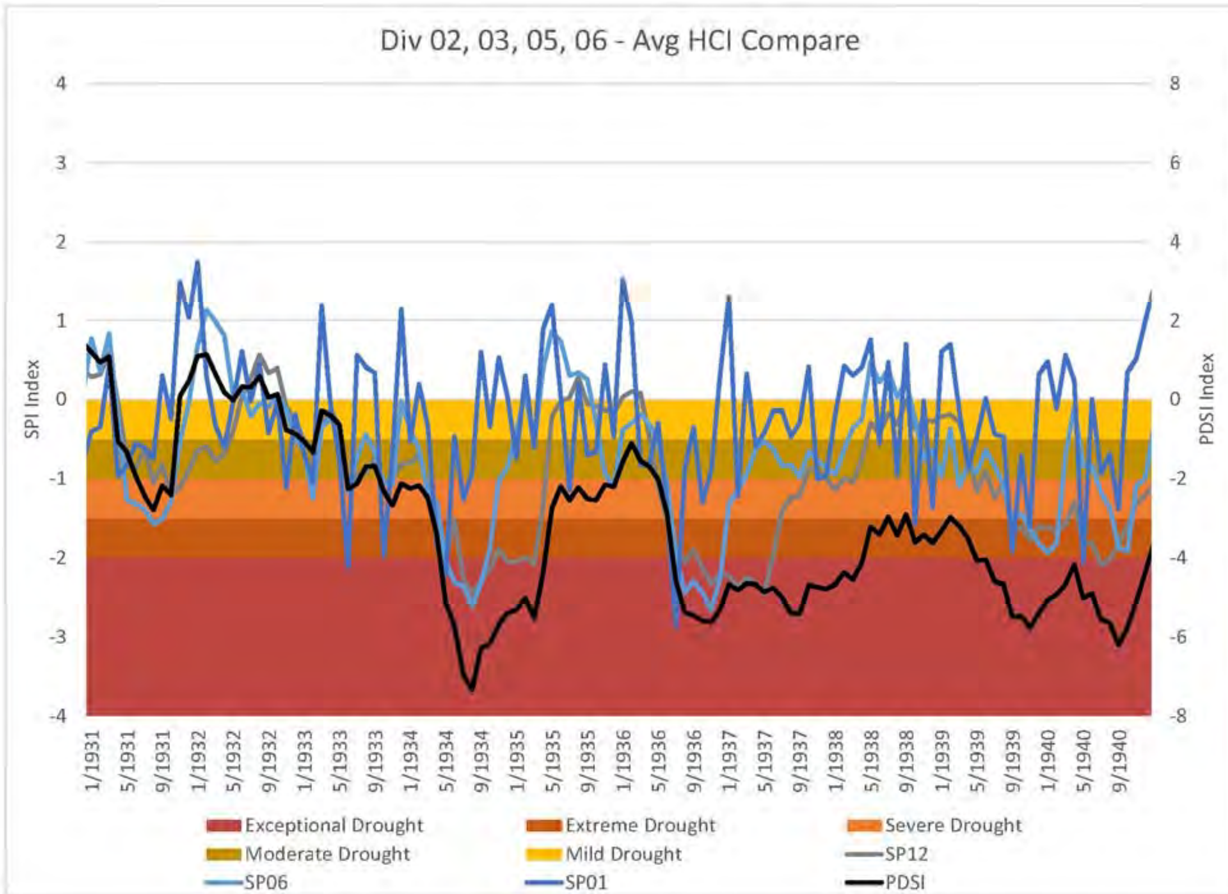
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-11: Composite SPI Index versus Composite PDSI Index – 1921 to 1930



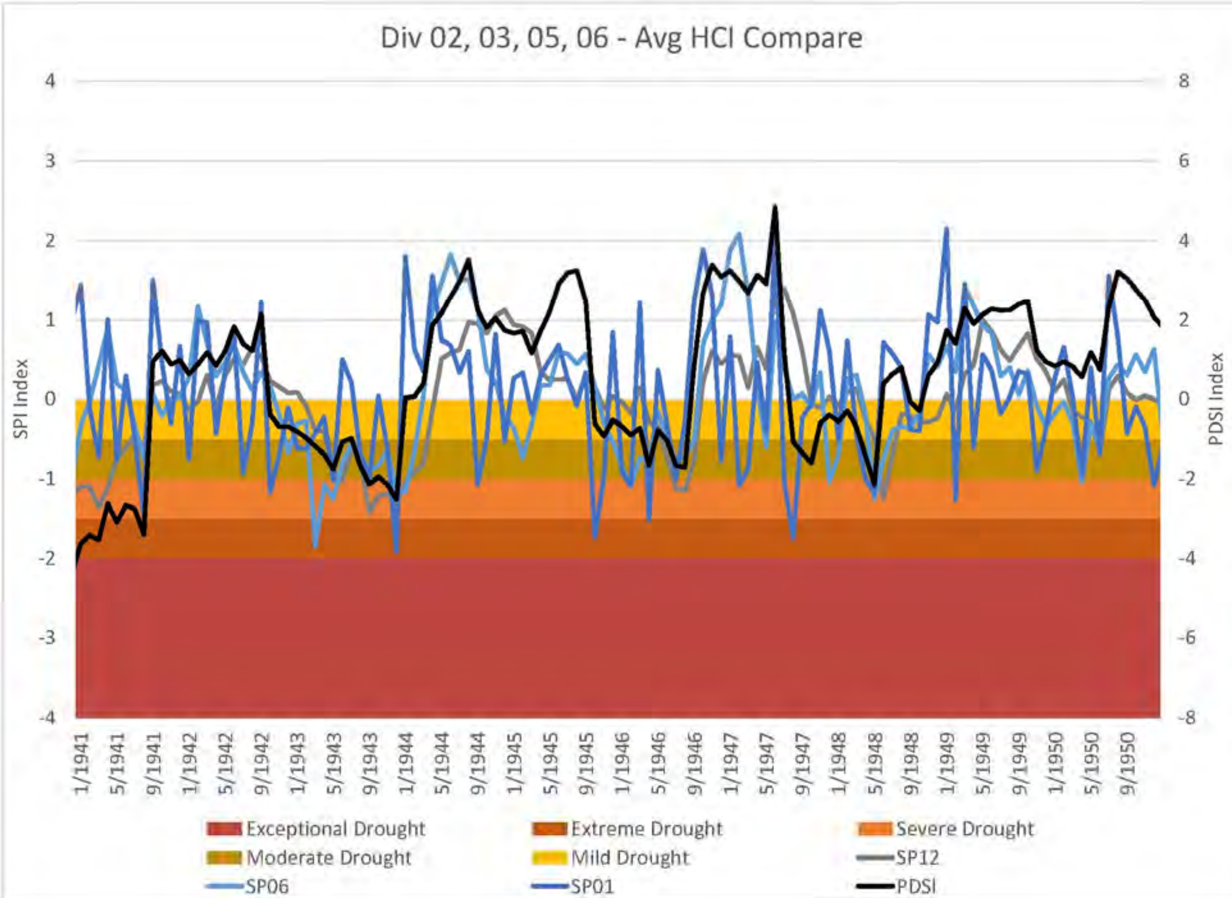
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-12: Composite SPI Index versus Composite PDSI Index – 1931 to 1940



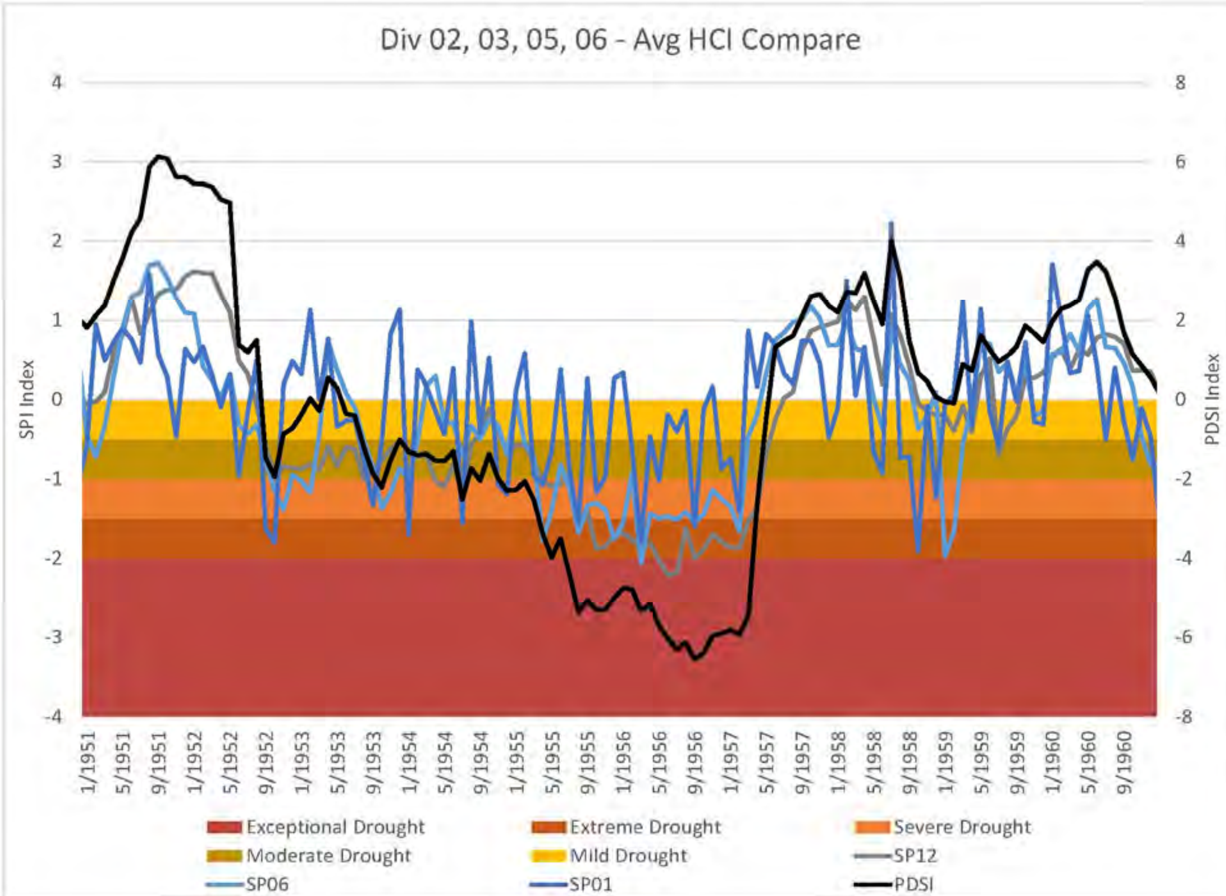
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-13: Composite SPI Index versus Composite PDSI Index – 1941 to 1950



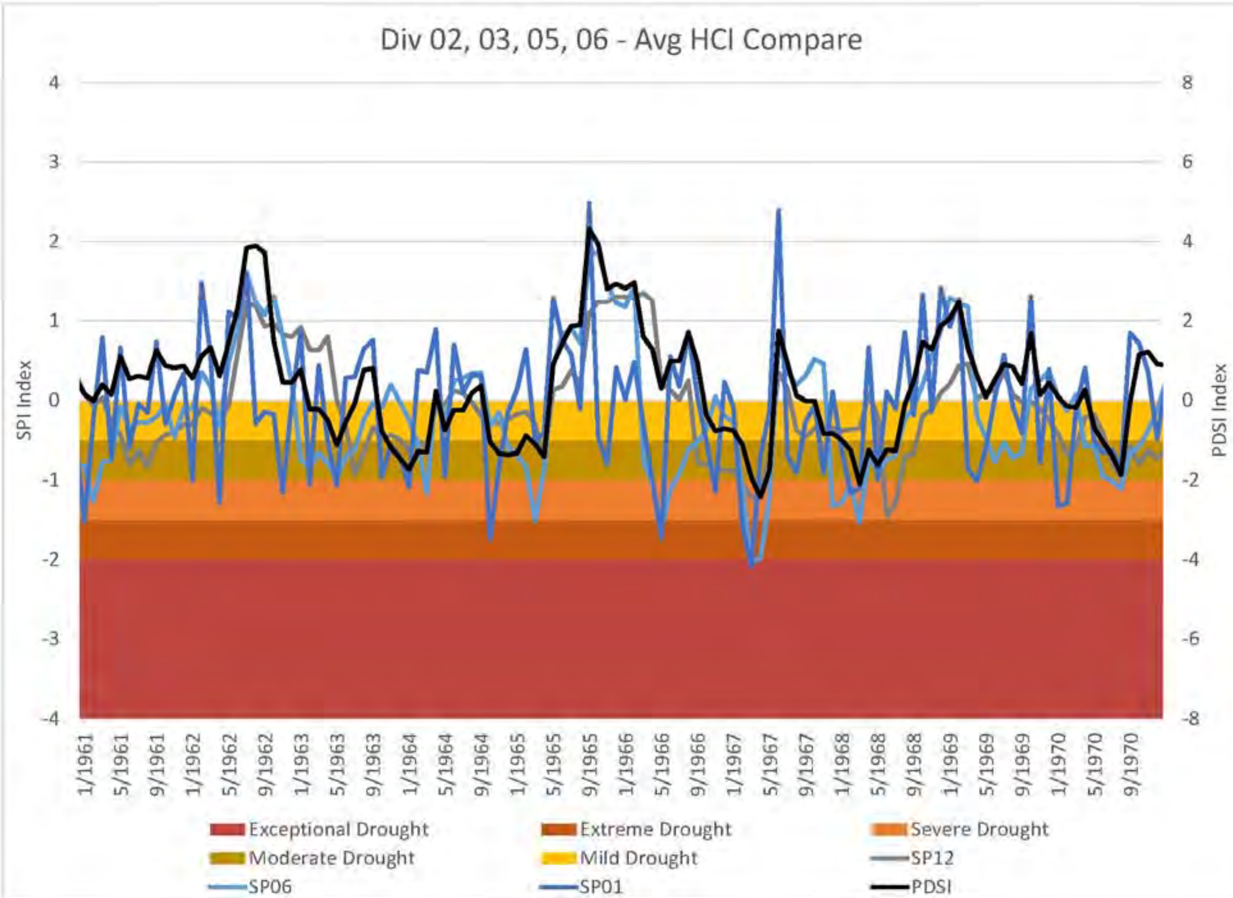
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-14: Composite SPI Index versus Composite PDSI Index – 1951 to 1960



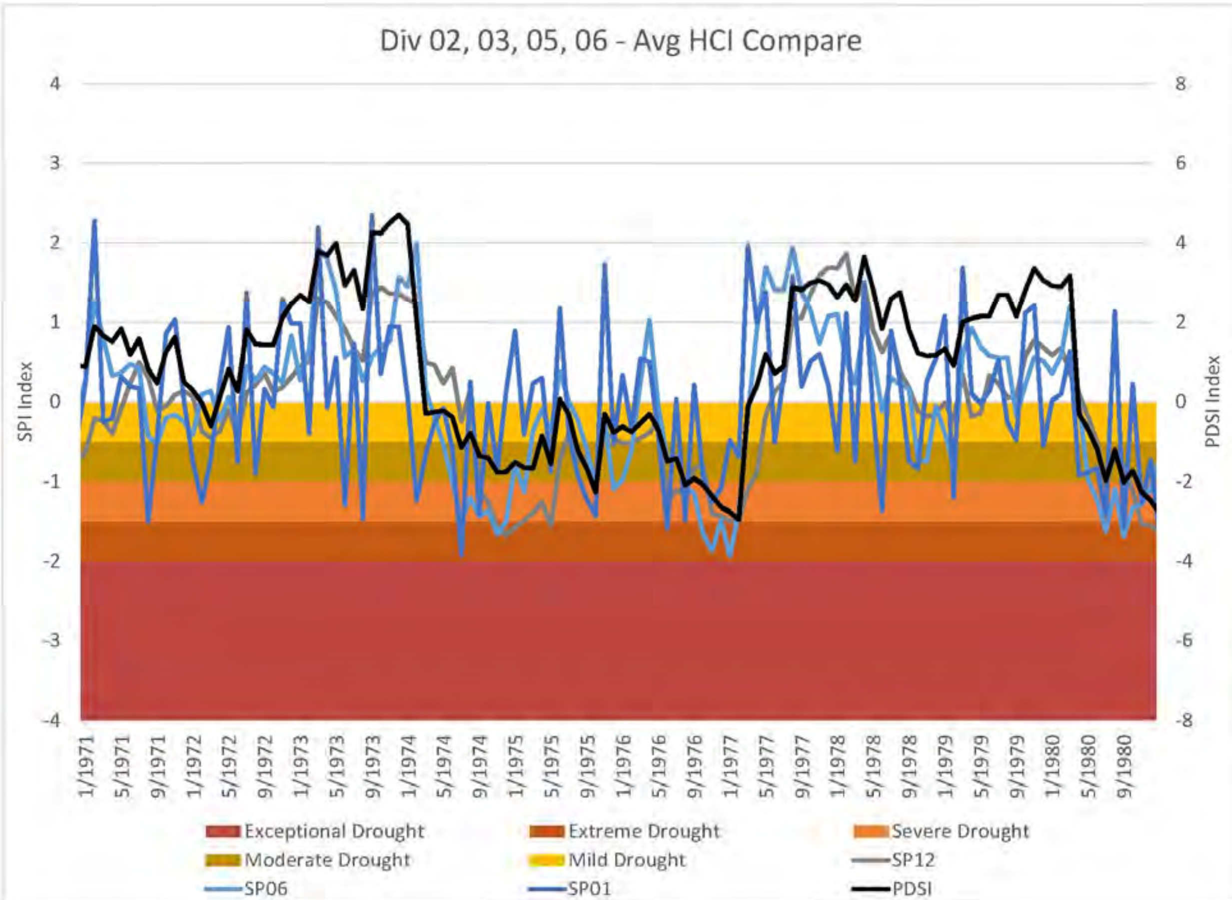
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-15: Composite SPI Index versus Composite PDSI Index – 1961 to 1970



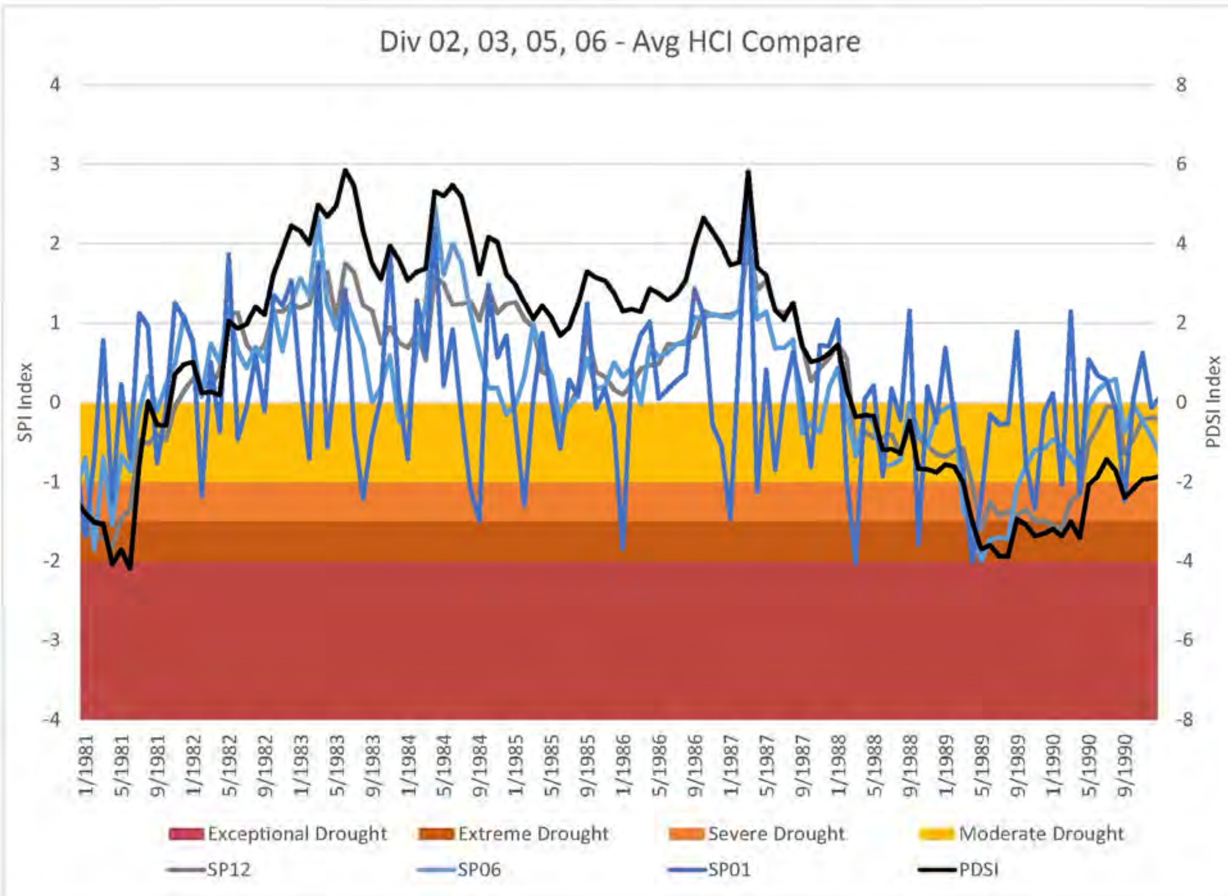
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-16: Composite SPI Index versus Composite PDSI Index – 1971 to 1980



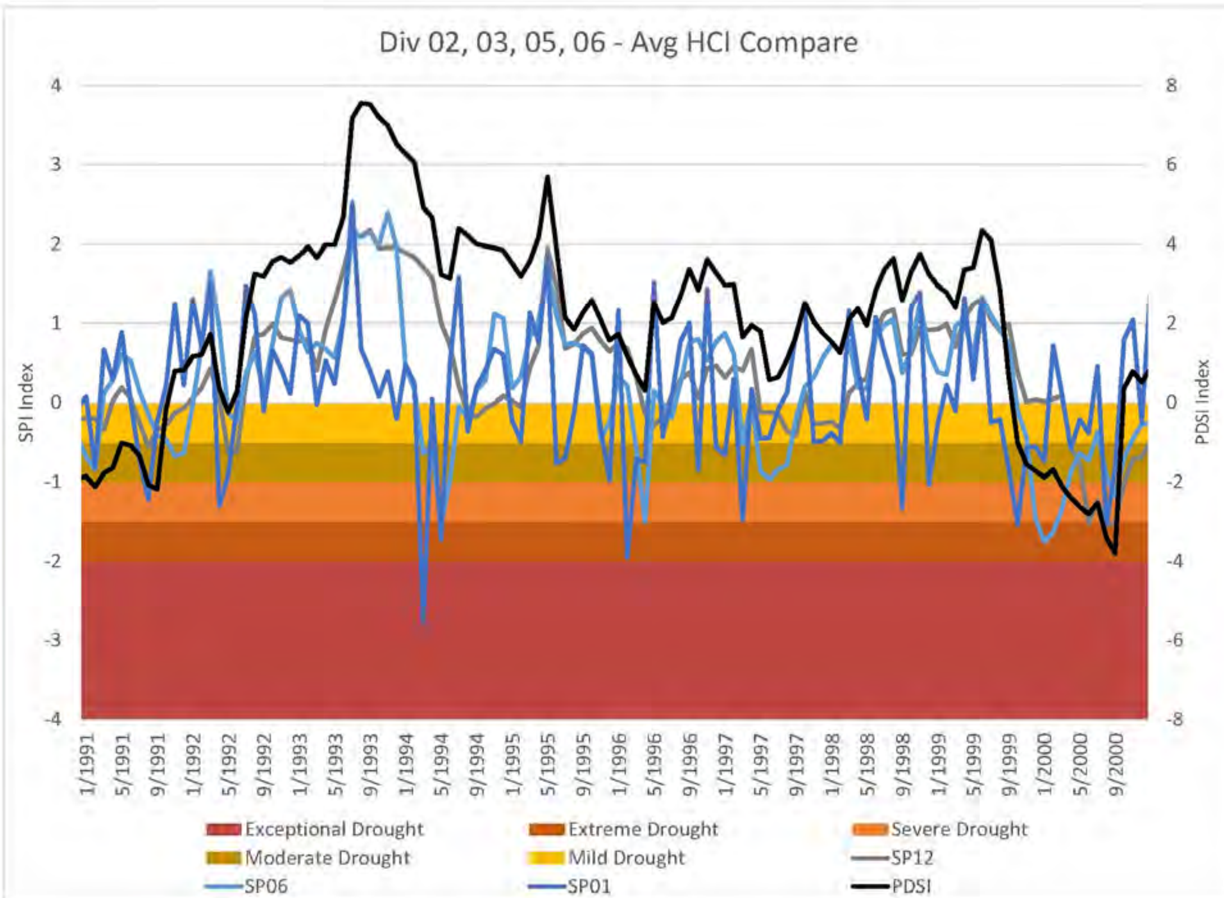
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-17: Composite SPI Index versus Composite PDSI Index – 1981 to 1990



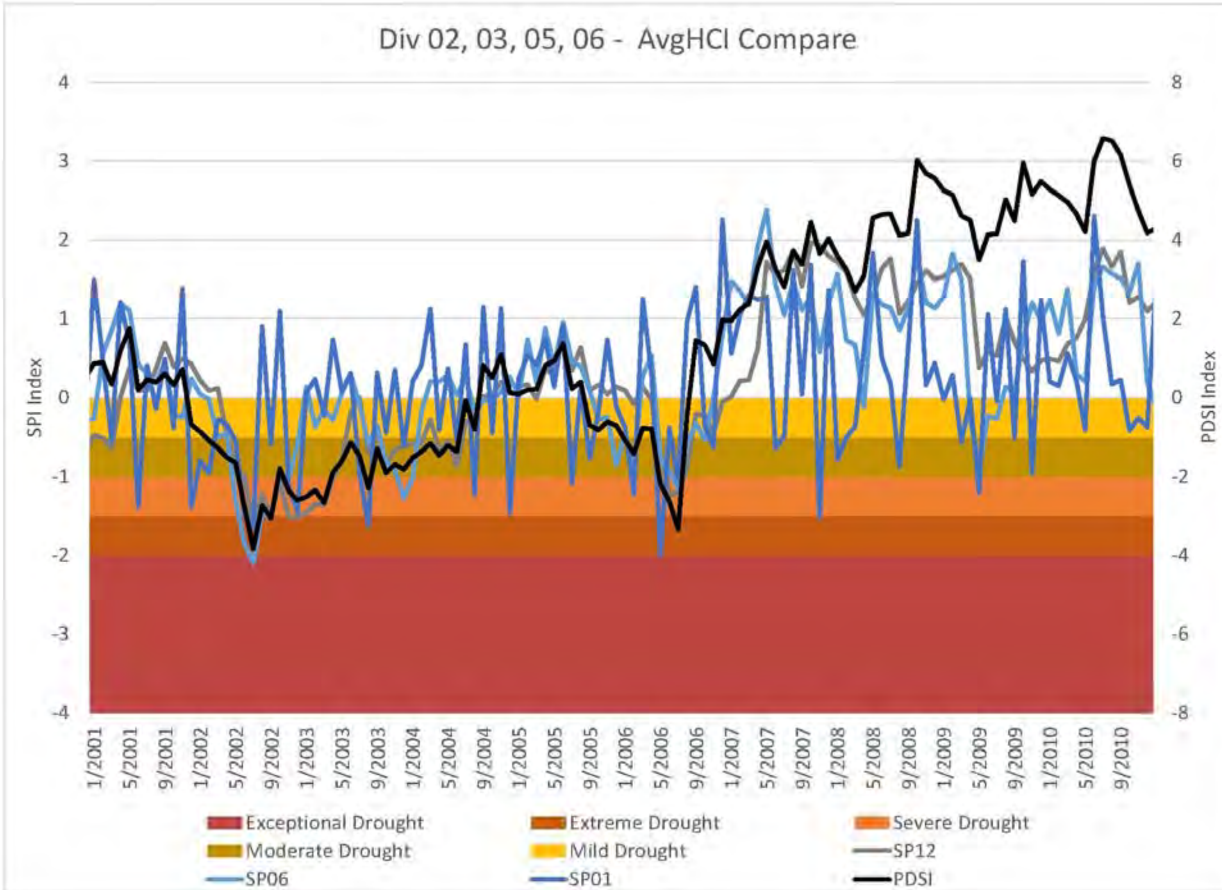
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-18: Composite SPI Index versus Composite PDSI Index – 1991 to 2000



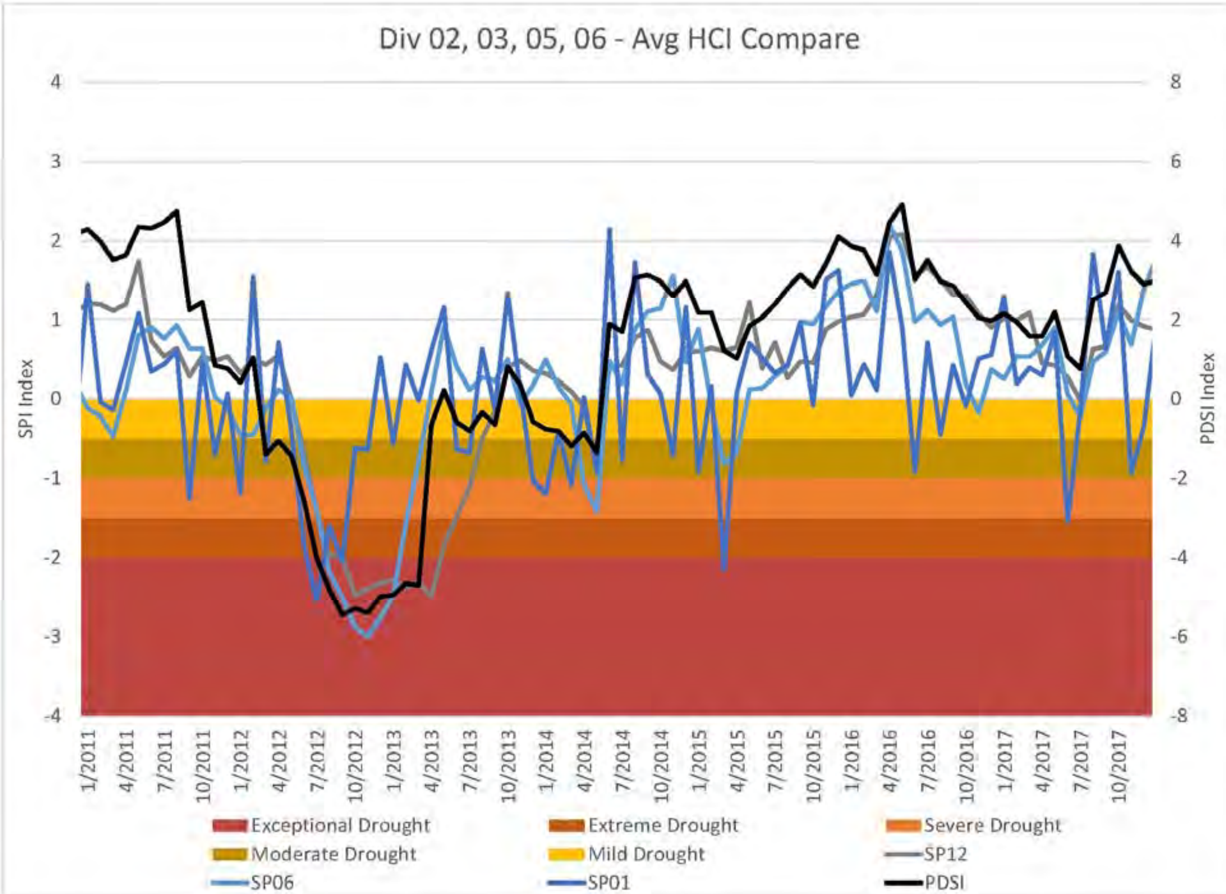
Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-19: Composite SPI Index versus Composite PDSI Index – 2001 to 2010



Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

Figure B-20: Composite SPI Index versus Composite PDSI Index – 2011 to 2017



Source: Supporting Data downloaded from National Climatic Data Center (obtained 2018)

The U.S. Drought Risk Atlas (a product of the National Drought Mitigation Center [NDMC]) summarizes the occurrence of drought by climate division, hydro climate indices, and severity as a percentage of the period-of-record. The historic occurrence of drought for the four climate divisions that encompass the Lower Platte River Basin are shown in Tables B-4 through B-7.

Table B-4: Climate Division 02: Percent of Time Spent in Drought – 1900 to 2016

Index Value	PDSI Percent of Time Spent in Drought	Drought Severity	Recurrence
-2 < PDSI ≤ -1	34%	Mild	1 out of 3 years
-3 < PDSI ≤ -2	21%	Moderate	1 out of 5 years
-4 < PDSI ≤ -3	12%	Severe	1 out 8 years
PDSI ≤ -4	6%	Extreme	1 out 0f 17 years

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)

Table B-5: Climate Division 03: Percent of Time Spent in Drought – 1900 to 2016

	PDSI		
Index Value	Percent of Time Spent in Drought	Severity	Recurrence
-2 < PDSI ≤ -1	26%	Mild	1 out of 4 years
-3 < PDSI ≤ -2	16%	Moderate	1 out of 6 years
-4 < PDSI ≤ -3	10%	Severe	1 out of 10 years
PDSI ≤ -4	7%	Extreme	1 out of 14 years

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)

Table B-6: Climate Division 05: Percent of Time Spent in Drought – 1900 to 2016

PDSI			
Index Value	Percent of Time Spent in Drought	Severity	Recurrence
-2 < PDSI ≤ -1	31%	Mild	1 out of 3 years
-3 < PDSI ≤ -2	18%	Moderate	1 out of 6 years
-4 < PDSI ≤ -3	11%	Severe	1 out of 9 years
PDSI ≤ -4	8%	Extreme	1 out of 13 years

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)

Table B-7: Climate Division 06: Percent of Time Spent in Drought – 1900 to 2016

	PDSI		
Index Value	Percent of Time Spent in Drought	Severity	Recurrence
-2 < PDSI ≤ -1	28%	Mild	1 out of 4 years
-3 < PDSI ≤ -2	17%	Moderate	1 out of 6 years
-4 < PDSI ≤ -3	10%	Severe	1 out of 10 years
PDSI ≤ -4	6%	Extreme	1 out of 17 years

Source: U.S. Drought Risk Atlas (frequency statistics obtained 2018)

In general, the PDSI and SPI compare reasonably well; however, the SPI does appear to predict fewer occurrences of severe and extreme droughts than the PDSI. This is likely due to the fact that the SPI and PDSI tell different stories. The PDSI considers the water balance and gives a more complete representation of conditions; however, the PDSI is a cumulative function where the PDSI from previous months can affect the PDSI of a current month making it harder to predict flash droughts). The SPI only considers precipitation anomaly compared to historic normal precipitation. Therefore, if precipitation returns to normal conditions, the SPI may indicate the drought is over whereas the PDSI may not.

For these reasons, both the SPI and PDSI should be considered together when evaluating drought conditions.

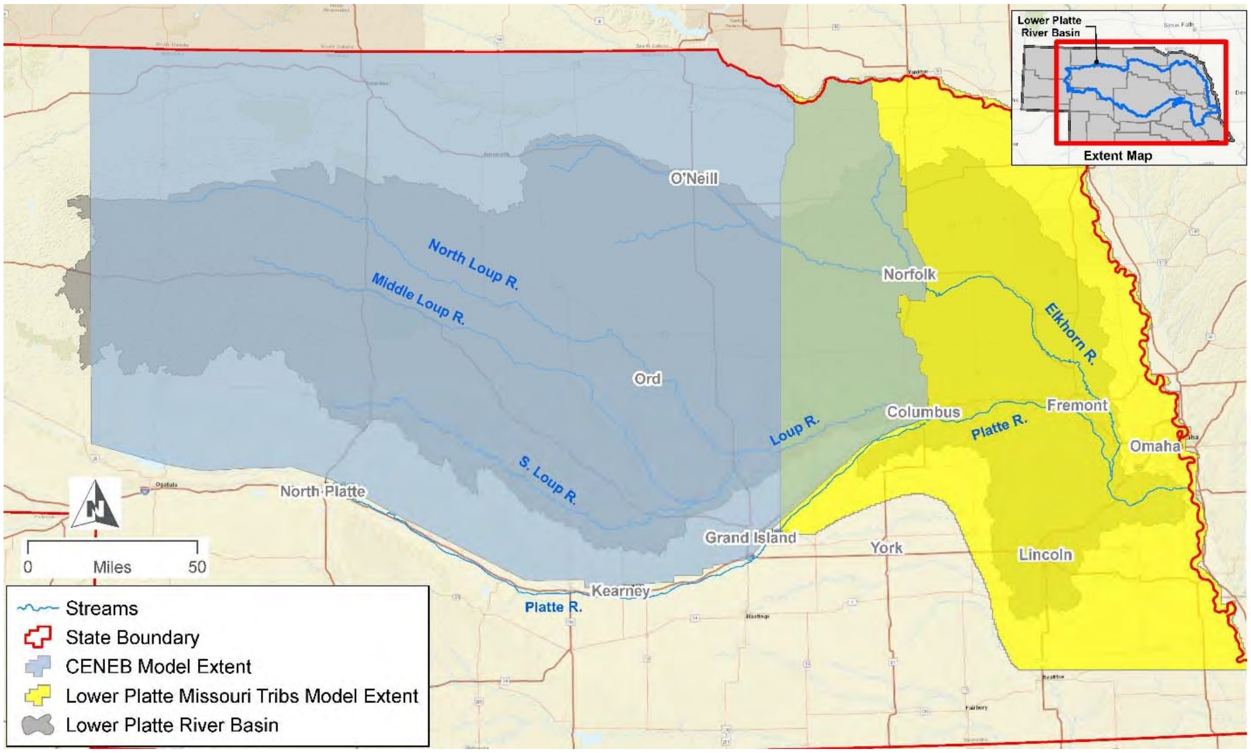
Analysis of historic PDSI values from the last 116 years reveal that mild, moderate, severe, and extreme droughts can be expected to occur in the Lower Platte River Basin once every three, six, nine, and fourteen years, respectively.

Appendix C: Cost-Estimate of Potential Mitigation Actions

Appendix D: Modeling Tools

There are three main groundwater water models that are encompassed by the Lower Platte River Basin. These include the Central Nebraska Model (CENEB) and Elkhorn-Loup Model (ELM) in the western and central portions of the basin and the Lower Platte Tributaries Model (currently under development) covering the eastern portion of the basin. These models analyze the surface and groundwater interaction in the basin.

Figure D-1: Groundwater Modeling Studies



Lower Platte Missouri Tributaries Model

The Lower Platte Missouri Tributaries (LPMT) Groundwater Model is being developed to assist the Nebraska Department of Natural Resources (NeDNR) in performing its annual evaluation of the expected long-term availability of surface water supplies and hydrologically connected groundwater supplies in both the Lower Platte River and Missouri River Tributaries basins.

This numerical groundwater model will be used as a tool to calculate the groundwater depletion component of the NeDNR's evaluation of the appropriation status in the Lower Platte River and Missouri River Tributaries basins by evaluating the effect of well pumping on stream baseflow.

The LPMT Model covers a large portion of eastern Nebraska, assessing the central and northern parts of the study areas. See Figure D1 for the geographical extent of the modeling area in relation to the Lower Platte River Basin.

Central Nebraska Model

The CENEB was developed as a modeling tool for simulating surface water-groundwater interactions by reproducing long-term trends under varying hydrologic and hydrogeologic conditions in the region, in support of the Department's annual evaluation of the availability of each basin's hydrologically connected water supplies.

The CENEB expands on the geographic area of a previous model, the ELM. The ELM encompassed the entire Loup River Basin and the lands draining to the Elkhorn River above Norfolk. The CENEB includes the same areas as the ELM, and adds portions of the Niobrara River Basin in north central Nebraska and the Lower Niobrara River and Ponca Creek drainages in South Dakota. See Figure D1 for the geographic extent of the modeling area with relation to the Lower Platte River Basin.

The CENEB was developed to characterize water supplies, uses, and demands in portions of the Niobrara, Loup, and Elkhorn Basins. The CENEB incorporates a groundwater model developed using MODFLOW-NWT and CROPSIM. A surface water operations model was not included as part of this model because there are few surface water demands in this region.

Elkhorn-Loup Model

The ELM, is a U.S. Geological Survey (USGS) Nebraska Water Science Center project is designed to assist the Natural Resources Districts (NRDs) and NeDNR by characterizing the groundwater system within the Elkhorn River and Loup River Basins and by providing a regional groundwater-flow model.

The ELM, a multi-phase project, is a study of surface-water and groundwater resources in the Elkhorn River basin upstream from Norfolk, Nebraska, and the Loup River basin upstream from Columbus, Nebraska. The study area is approximately the same as the CENEB (see Figure D1).

The first phase included construction of a groundwater-flow model using previously collected data. The calibrated groundwater-flow model was used to assess current and future impacts of groundwater pumping on surface water, and could be used to provide information to the NRDs for groundwater-management planning.

The second phase was part of a larger, ongoing effort to enhance the current knowledge of hydrogeology, improve the understanding of stream-aquifer interactions, and compile reliable data describing hydrogeologic properties such groundwater recharge, groundwater pumpage for irrigation, and groundwater discharge to evapotranspiration in the study area.

The third phase of the study continues to use new methods and data to refine the groundwater-flow model developed in phases one and two. Implementation of these new methods and data will increase the understanding of the availability of groundwater and the effect of anthropogenic stresses on the groundwater and surface-water resources in the Elkhorn and Loup River basins.

Finally, the results of the phase-three model will undergo calibration via parameter estimation similar to the calibration done for phase two, as well as the completion of additional analysis runs.

Lower Platte River Consortium Conveyance Tool

The Lower Platte River Consortium Conveyance Tool (CONSORV) was developed by The Flatwater Group as a resource to estimate stream losses along different portions of the Lower Platte Basin, and to evaluate potential management actions in terms of estimated river flow changes at certain critical locations. CONSORV is a surface water model, built using the Stella modeling platform developed by isee Systems, which operates on a daily timestep, and covers the Loup River basin downstream of St. Paul (along with a portion of the Middle Loup downstream of Dunning), the Elkhorn River downstream of Norfolk, and the Lower Platte River from Duncan to Louisville.

CONSORV primarily uses data from USGS and Nebraska DNR stream gages, focusing on the 2004 to 2015 time period, but can be used to project potential stream conditions and conveyance losses under various hydrologic and operational scenarios. The Stella framework used in CONSORV uses stocks, flows, and convertors to represent the storage, movement, and management decisions associated with water supplies in a river basin setting. Historic gains and losses within the model's river segments serve as the foundation for estimating changes to river flows under modified hydrologic conditions.

CONSORV takes advantage of the user-friendly, object-oriented nature of Stella to provide simple and intuitive interfaces, serving as dashboards for quickly constructing the conditions under a particular scenario, or set of scenarios, and then providing model output in an easily understood format. Simple buttons, dials, and sliders are included to allow the user to rapidly adjust the modeled conditions and run the model. Results are included in tabular, graphical, and map-based formats, allowing for quick and straightforward analysis of the output. Several of the key scenarios developed with input from the Coalition are "built-in" to the model, but can also be easily modified to test for sensitivity and to evaluate alternative management actions. Flow at the Ashland gage serves as one of the primary evaluation metrics, and the volume of any additional estimated flow at Ashland resulting from alternative management actions is displayed via bar graphs, line charts, and tabular entries.

Appendix E: Platte River at Ashland Recession Tool

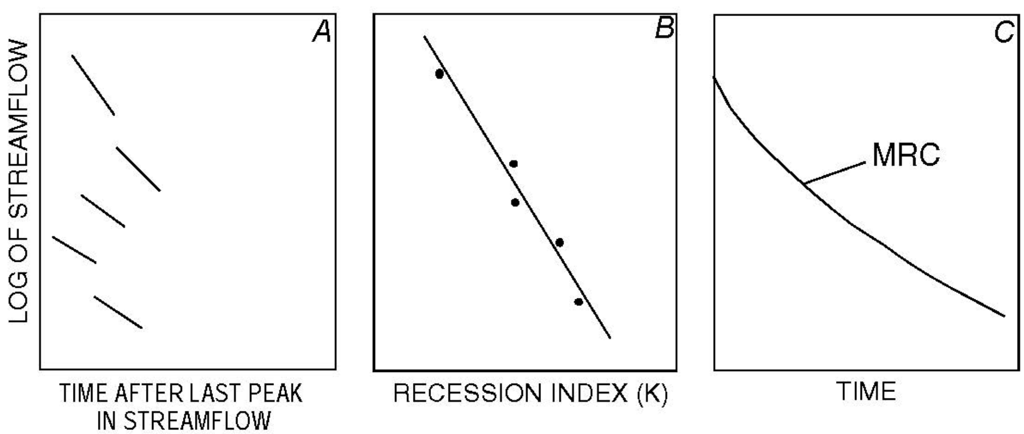
Flow Recession Analysis for the Platte River at Ashland

Understanding the behavior of the Platte River at Ashland as it recedes is important to the ability of the Consortium to properly time the implementation of response actions. Using the Platte River at Ashland Recession Tool allows the user to enter in a flow in the Platte River at Ashland and predict the decay behavior for 30 days assuming no further inputs to the system (precipitation or upstream storage releases). The tool plots the recession curve and the user can determine the estimated days until a critical threshold is reached. The following discussion explains the analysis behind the Platte River at Ashland Recession Tool.

The USGS program RECESS was used to generate the Master Recession Curve (MRC). The program RECESS (USGS 1998) is available free from USGS and determines the MRC of streamflow recession during times when all flow can be considered to be groundwater discharge and when the profile of the groundwater head distribution is nearly stable. The program uses a repetitive interactive procedure for selecting several periods of continuous recession, determines the best-fit equations for the rate of recession as a function of the logarithm of flow, then uses the coefficients of this equation to derive the MRC, which is an equation of time as a function of the logarithm of flow.

The basic steps for determining the MRC are illustrated in Figure E-1. First, the program locates periods of streamflow recession and allows the user to select nearly linear segments (Figure E-1[A]). Then, for each segment, the program determines the best linear equation for time as a function of LogQ (logarithm of flow), and extracts from this equation a coefficient that is the recession index (K) of the segment (data points, Figure E-1[B]). Coefficients of this equation are used to obtain the MRC (Figure E-1[C]), which is a second-order polynomial expression for time as a function of LogQ.

Figure E-1: Schematic representation of the method used to determine the master recession curve



Source: USGS 1998.
Notes: (A) selected regression segments; (B) recession index (K) (time per log cycle of streamflow recession) and best-fit line, and (C) the master recession curve, obtained from coefficients of function in B.

The analysis using RECESS utilized the mean average daily flow for the Platte River at Ashland from 1988 to 2015. The year was split into a summer period (April through September) and a winter period (October through March). The resultant MRC for both summer and winter are shown in Figure E-2 and Figure E-3, respectively.

Figure E-2: Summer Master Recession Curve for Platte River at Ashland

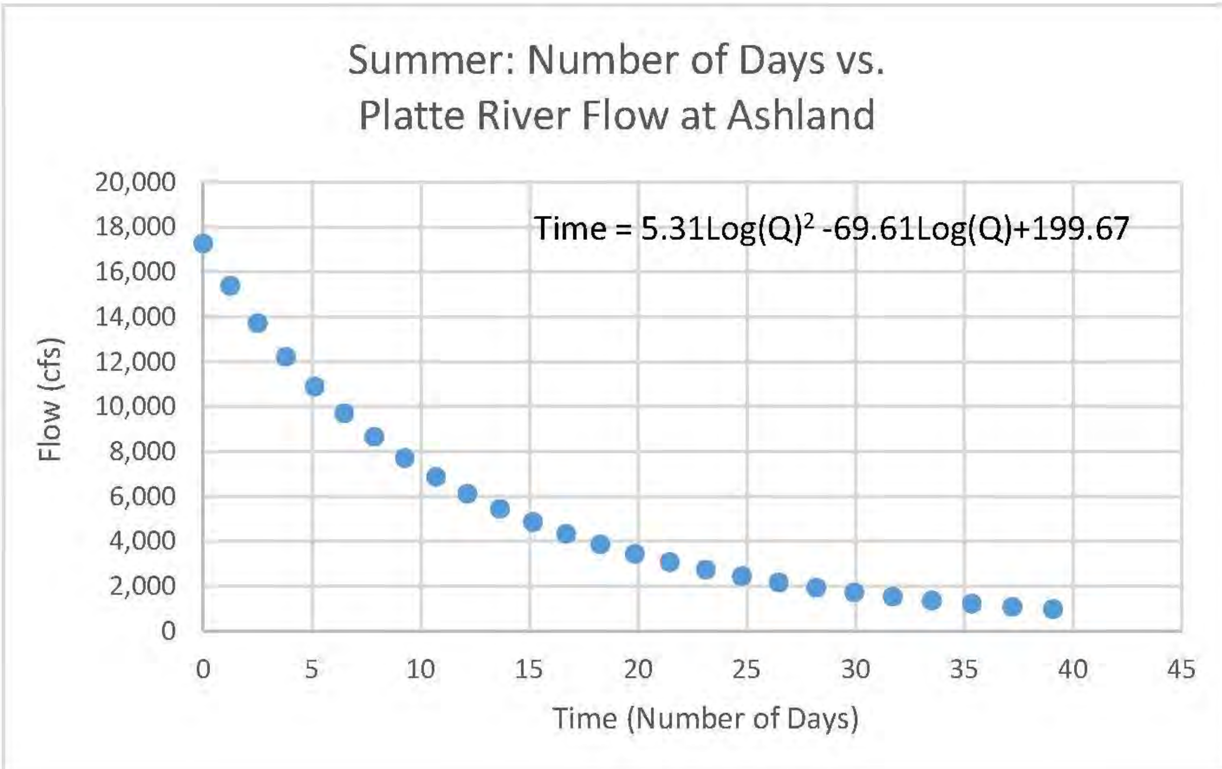
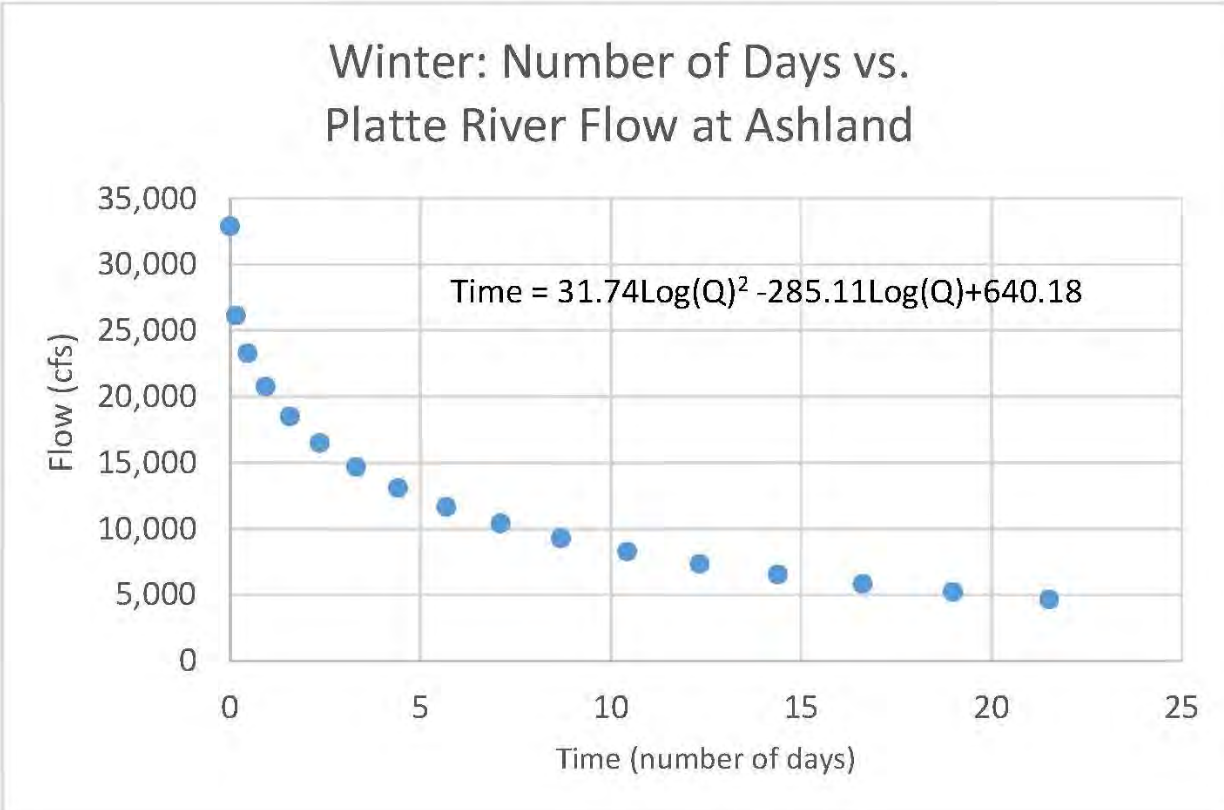
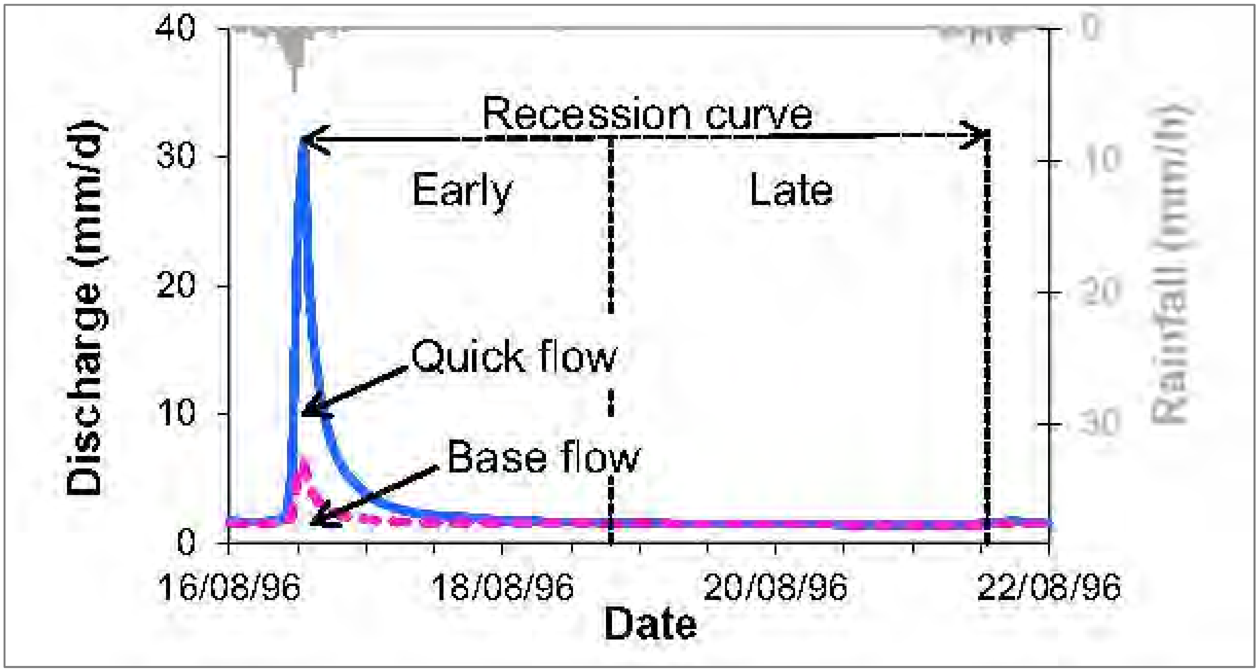


Figure E-3: Winter Master Recession Curve for Platte River at Ashland



As shown in Figure E-4, the total recession curve for a consists of both quick flow and baseflow. The USGS RECESS program results show the behavior of the MRC for the baseflow. Baseflow is the portion of streamflow that is not runoff and results from seepage of water from the ground into a channel slowly over time. For the analysis, it is necessary to understand the behavior of the early part of the recession known as quick flow. Quick flow occurs immediately after a rainfall/runoff event where the streamflow peaks. If no other system inputs occur (no additional rainfall), then the streamflow will recede until it reaches baseflow.

Figure E-4: Quickflow and baseflow components of streamflow



Source: Stewart, M.K. 2015. "Promising new baseflow separation and recession analysis methods applied to streamflow at Glendu Catchment, New Zealand." Hydrology and Earth System Sciences. *19:2587–2603. Doi: 10.5194/hess-19-2587-2015.*

For the Platte River at Ashland, the recession of the quick flow generally follows the behavior of Equation E-1 for the first 1-2 days. After which, the recession generally follows the behavior of Equation E-2.

$Q_n = Q_{(n-1)} 2^{(-0.55)} \ for \ 1 \le n \ \le 2$ Equation E-1

where *Q* is the flow in the Platte River at Ashland *n* corresponds to day *n* (the number of days after the start of the recession).

$Q_n = 10^{[LogQ_{(n-1)} - (\frac{k}{K})]} \ for \ n \ > 2$ Equation E-2

where $k = recession\ constant = 10^{\frac{-1}{K}}$ and $K = storage\ delay\ factor = 10.61 LogQ_{(n-1)} - 69.91$ for months April through September and $K = storage\ delay\ factor = \ 63.49 LogQ_{(n-1)} - 285.11$ for months October through March.

The storage delay factor, K, is defined as the time taken for discharge to recede by a factor of 10 (i.e. one log cycle). This factor is determined by RECESS and is provided in tabular output. The Platte River at Ashland Recession Tool uses the lookup function on these tables to obtain the K-value.

Figure E-5 through Figure D-9 show plots of randomly selected recession periods on the Platte River at Ashland and compares the historic streamflow versus the forecasted streamflow. In general, the forecasted streamflow reasonably matches the historic recession behavior.

Figure E-5: Forecasted versus Historic Flow for the Platte River at Ashland (June/July 2005)

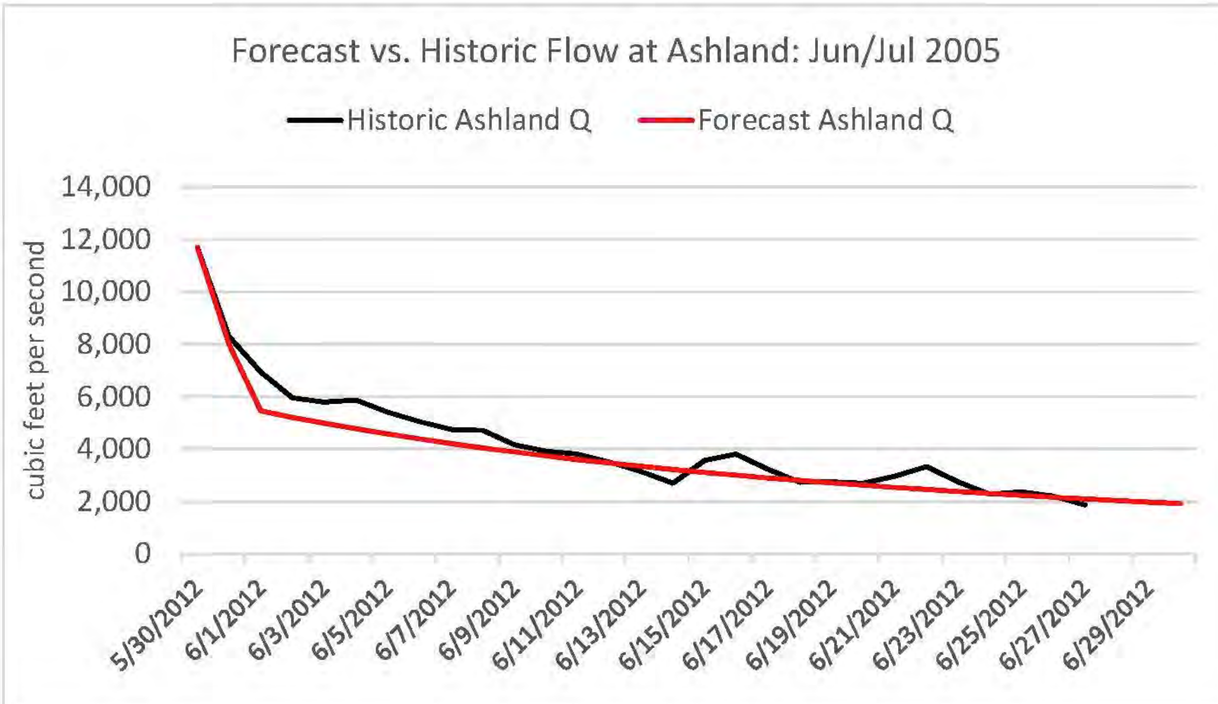


Figure E-6: Forecasted versus Historic Flow for the Platte River at Ashland (August/September 2007)

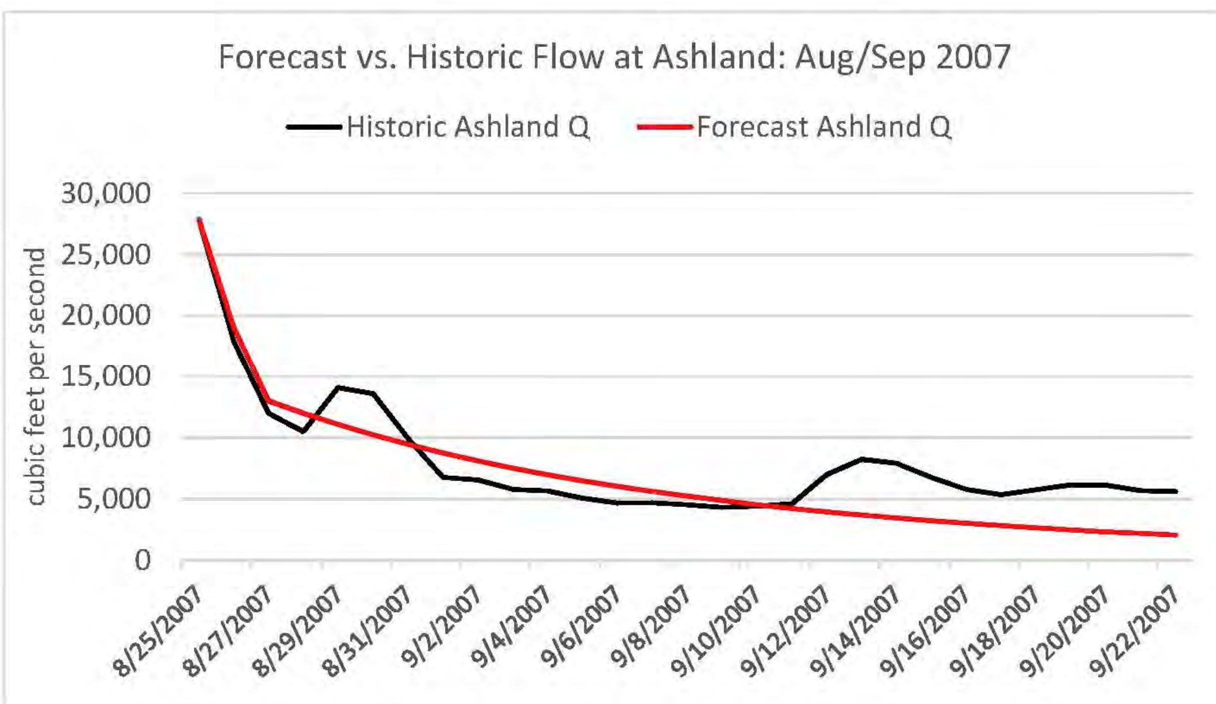


Figure E-7: Forecasted versus Historic Flow for the Platte River at Ashland (June/July 2008)

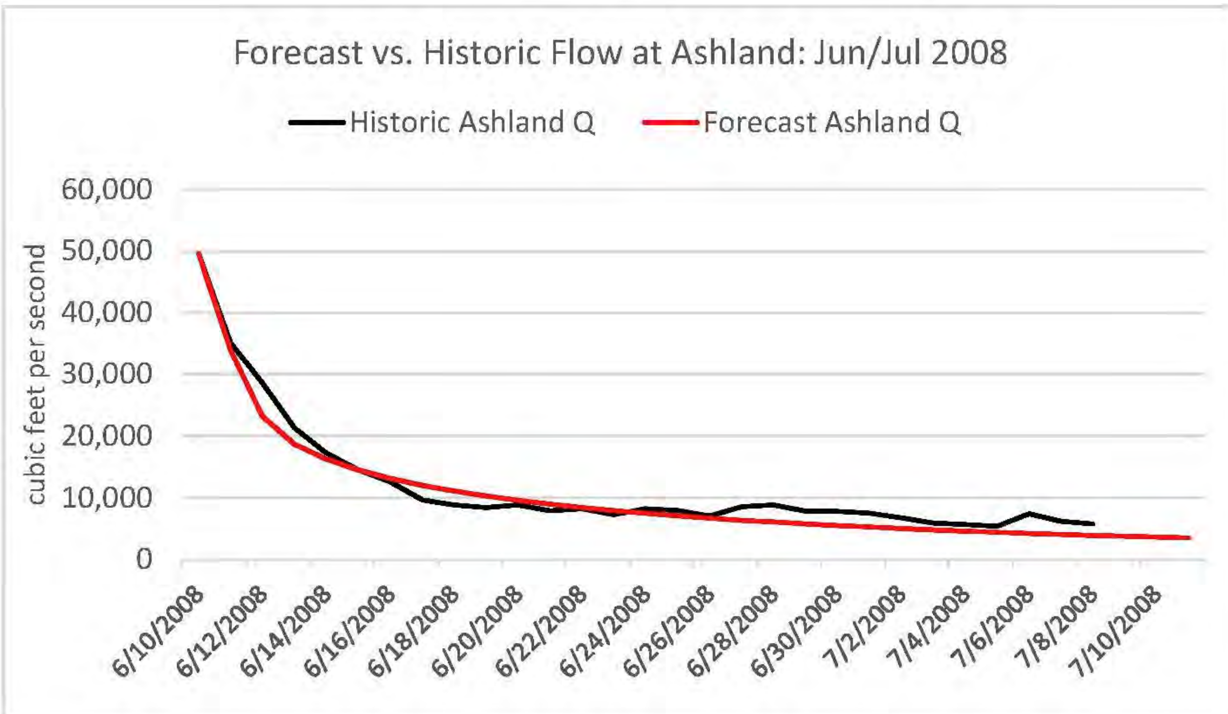


Figure E-8: Forecasted versus Historic Flow for the Platte River at Ashland (February/March 2009)

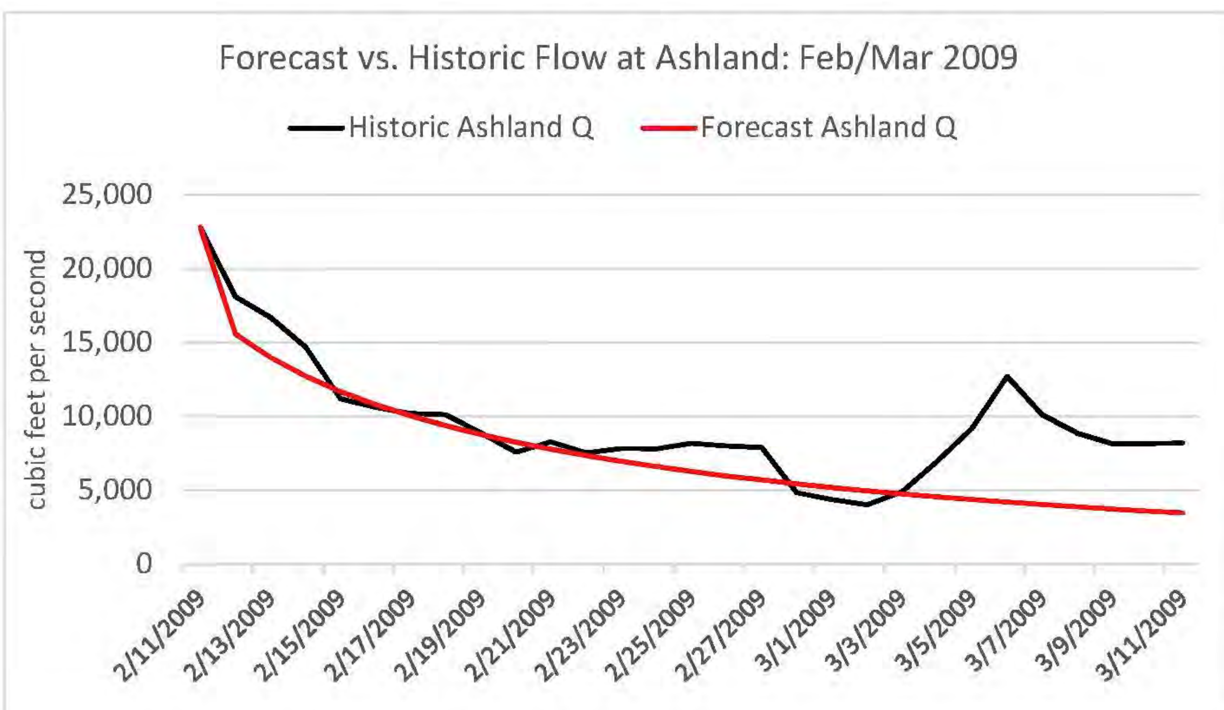


Figure E-9: Forecasted versus Historic Flow for the Platte River at Ashland (October/November 2013)