4.0 Supply

The only significant improvement/change to Lincoln's water supply since the completion of the *2014 Master Plan* is the completion of Horizontal Collector Well 14-2, which increases pumping capacity for the collector well system by 17.5 mgd. Changes to the well field yield are discussed later in this chapter and in *Appendix B – 2019 Lincoln Well Field Groundwater Modeling*. Therefore, the primary points of focus under this master plan update include:

- An updated assessment of Lincoln's Water Rights.
- Updated Platte River flows as impacted by groundwater development and climate change.
- An update to the groundwater model to determine summer pumping rates for existing conditions and expansion of the wellfield to include two future horizontal collector wells.
- Recommended staging for future collector wells based upon projected demands.

4.1 Water Rights

4.1.1 Nebraska's Water Supply

Nebraska has over 24,000 miles of rivers and streams and nearly 2 billion acre-feet of useable groundwater in the High Plains aquifer beneath the state. Though water is abundant, problems arise due to water availability issues and/or difficult locations. Nebraskans have addressed this by developing nearly 3,000,000 acre-feet of storage in reservoirs (primarily used for irrigation) to retime the surface water supply, and have developed over 8 million irrigated acres for crop production. Most of these irrigated acres rely on groundwater pumping.

Nebraska Department of Natural Resources (NeDNR) developed the Integrated Network of Scientific Information and GeoHydrologic Tools, or INSIGHT, to help water managers across the state understand the dynamic nature of Nebraska's water supply. INSIGHT provides an annual snapshot of the state's water supply, water demands, nature and extent of use, and overall water balance. This information can be analyzed at a statewide level, a basin-wide level, or at a sub-basin level.

Figure 4-1 through Figure 4-3 provide examples of what INSIGHT shows.

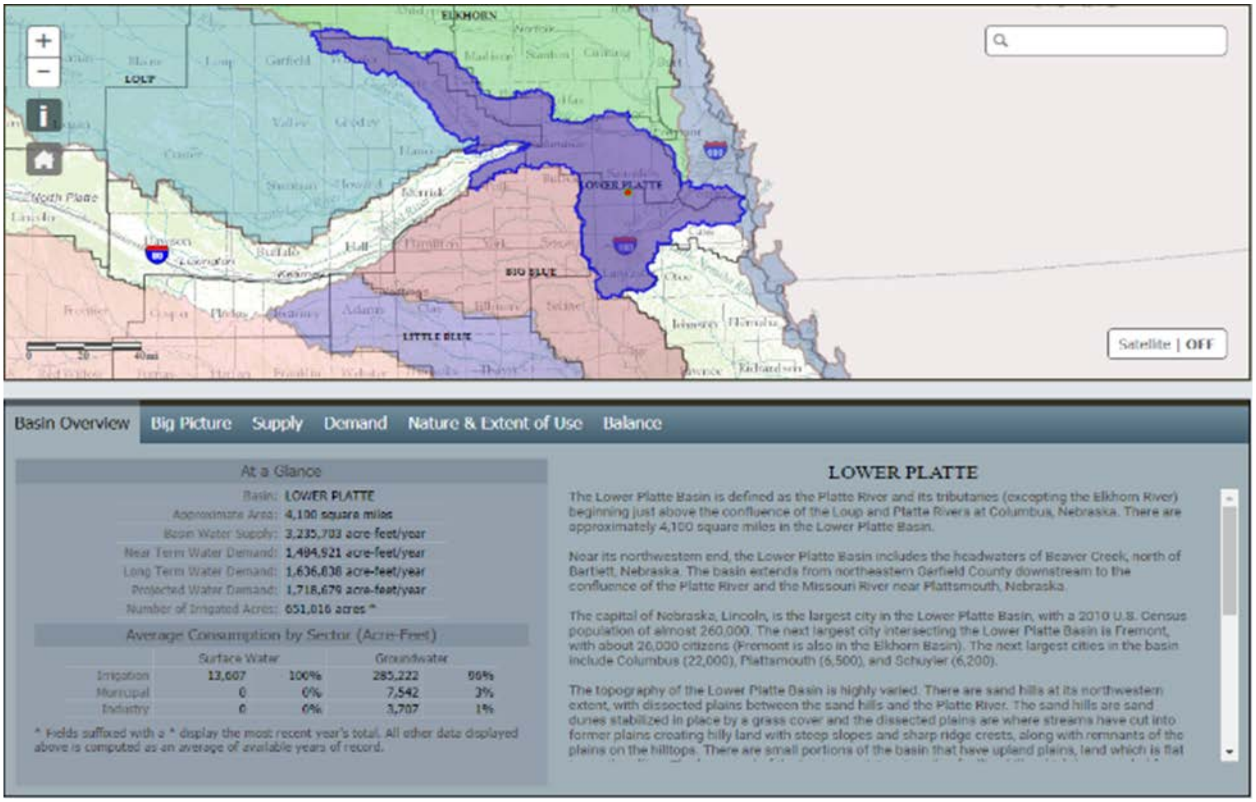

Figure 4-1 **The Lower Platte Basin Overview Screen in INSIGHT Gives A Summary Of The Basin's Characteristics and Projected Water Demands**

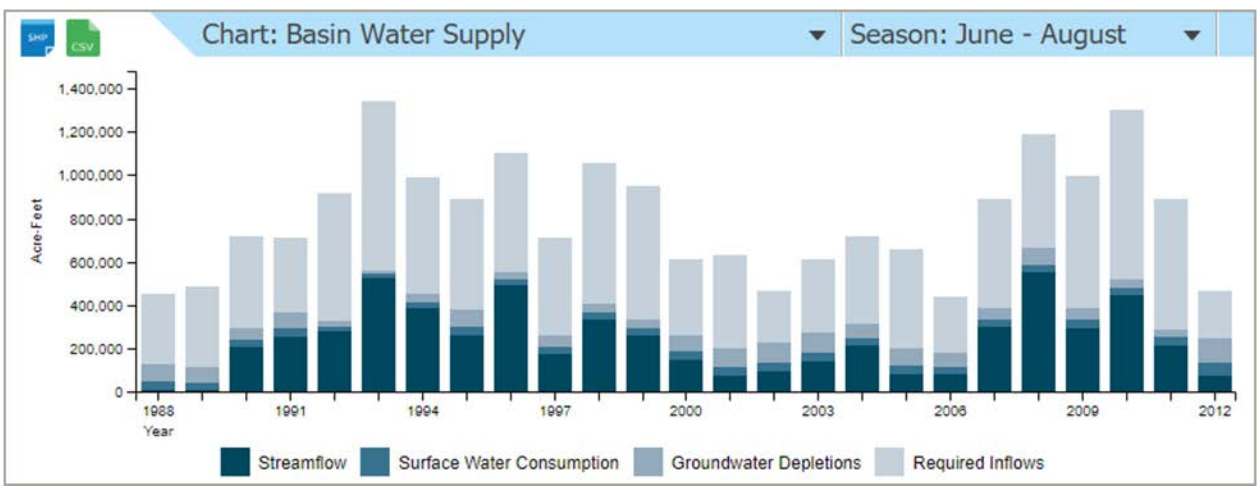

Figure 4-2 **The Lower Platte Basin Annual Water Supply for June-August in INSIGHT**

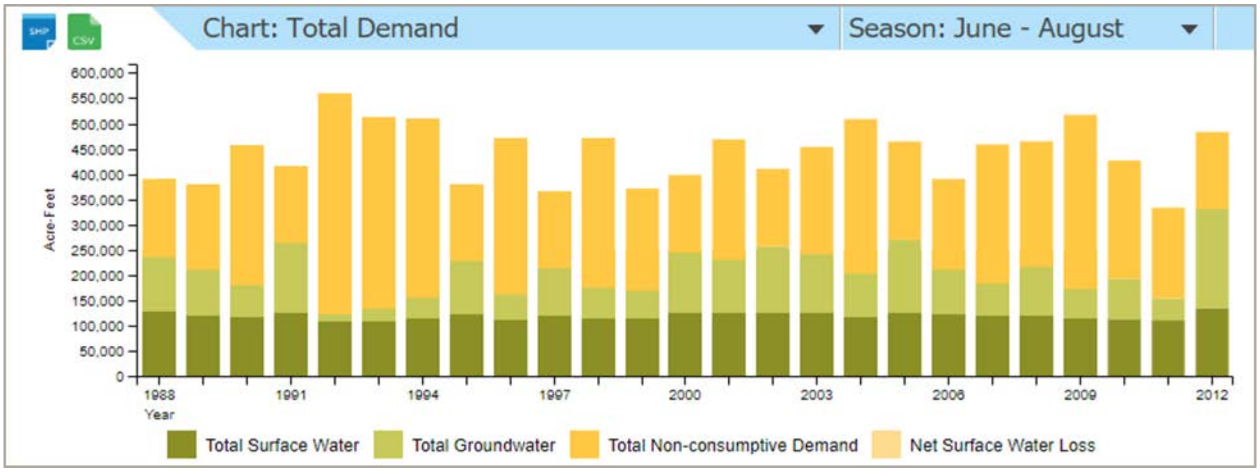

Figure 4-3 **Annual Total Demand Estimates for the Lower Platte Basin for the June- August Season in INSIGHT**

The information and data available from NeDNR and other agencies - including the U.S. Geological Survey, the U.S. Bureau of Reclamation, local natural resources districts, and other water users - can be combined with the state-wide regional groundwater models. This combined information can be used to evaluate the impacts of historic groundwater pumping and future projected groundwater pumping on aquifer levels and surface water flows. These future scenario model runs can also incorporate the effects of a changing climate on water supplies, which will be done as part of the Master Plan update.

4.1.2 Nebraska Water Law

The State of Nebraska has a bifurcated system of water laws that regulate the use of surface water and groundwater differently. The surface water system operates under the prior appropriation doctrine, often referred to as a system of “first in time, first in right.” Surface water appropriations are administered at the state level by the NeDNR. Every person that uses surface water must have a valid appropriation. Under this system, appropriators that have senior priority dates (older dates) are entitled to their quantity of water before more junior appropriators (newer dates) get their quantity of water.

Groundwater, however, operates under a modified correlative rights system. This means that in times of shortages, groundwater users will share the remaining groundwater supply. Groundwater in Nebraska is regulated by the 23 natural resources districts.

4.1.3 Existing Surface Water Rights Held by the City of Lincoln for the Ashland Wellfield

Nebraska law allows a public water supplier to make an application to appropriate waters for induced ground water recharge (Neb.Rev.Stat.46-233). The City of Lincoln holds 5 induced groundwater recharge appropriation permits (A-17312A, A-17312B, A-17312C, A-17312D, and A-17312E) for the Ashland wellfield. The amount of the appropriation is limited to 704 cubic feet per second (cfs) in the summer season and 200 cfs in all other seasons. The priority dates associated with streamflow are tied to a particular well series and range in dates from January 21, 1964, to January 1, 1993. The permits are administered by NeDNR in the same manner as other surface water appropriations. When streamflow in the Platte River is reduced to 704 cfs in the summer season or 200 cfs outside of the summer season, the City of Lincoln may request NeDNR to administer all junior surface water appropriations upstream of the Ashland wellfield until Platte

River flows again exceed either 704 cfs or 200 cfs. If requested by the city, NeDNR may also approve the transfer of priority dates among water wells within the wellfield under this permit - including replacement water wells - to improve the wellfield's efficiency of operation with respect to river flow, provided that certain conditions are met.

There are many water rights upstream of the city's wellfield that could be affected by a call for water administration. Figure 4-4 is a map of all storage permits upstream of the city's wellfield that are junior to the city's water right. The total amount of storage currently authorized under these water rights is just under 100,000 acre-feet. The owners of these facilities would not be required to release water stored prior to a call for water administration. However, if any of these facilities are otherwise filling up with water flowing in from upstream, they could be required to discharge those inflows downstream during a period of water administration for the City of Lincoln.

Figure 4-5 and Table 4-1 are a depiction of the permits related to active diversion or withdrawal of streamflow. Table 4-1 presents totals for all permits and for those permits that are senior to the Nebraska Game and Parks (NGPC) in-stream flow permit, as water users junior to the NGPCs in-stream flow permit would likely be shut off before the city could exercise their water right. The NGPC has an instream flow right for 1800 cfs (as measured at the North Bend stream gage) for the reach of the Platte River from the mouth of the Loup Power Canal Return to the mouth of the Elkhorn River, and an instream flow right for 3300 cfs (as measured at the Louisville stream gage) for the reach of the Platte River from the mouth of the Elkhorn River to the confluence with the Missouri River. The NGPC has historically requested administration of its water right on an annual basis.

Table 4-1 presents the diversion point, the number of permits by diversion point, and the total diversion amount for any appropriations that are junior to the city's water right. Pumps refers to multiple locations where water is directly pumped from a stream.

The vast majority of these are for irrigation, but a few are designated for manufacturing use. The Kent Canal is technically classified as an irrigation right, but it does not typically provide irrigation water directly to water users. Instead, it is used in spring and early summer to assist with filling Davis Creek Reservoir[1]. It typically diverts much less water than what is technically allowed under its water right. For the remaining canals, these water rights are not generally representative of typical withdrawals as this table is only documenting the water rights junior to the city's permit. These canals typically have other more senior and more substantial water rights that would not be affected by water administration for the city. However, the listed amounts are junior uses that could be curtailed, meaning these canals would have to cut back on the amount diverted. The diversion category of Pumps represents many water rights that are utilized by pumping water directly out of a stream. This category represents most of the water use that is likely to be occurring during any call for water administration during the summer months.

[1] Personal Communication, 7/17/2019, T. Klanecky, Nebraska Department of Natural Resources

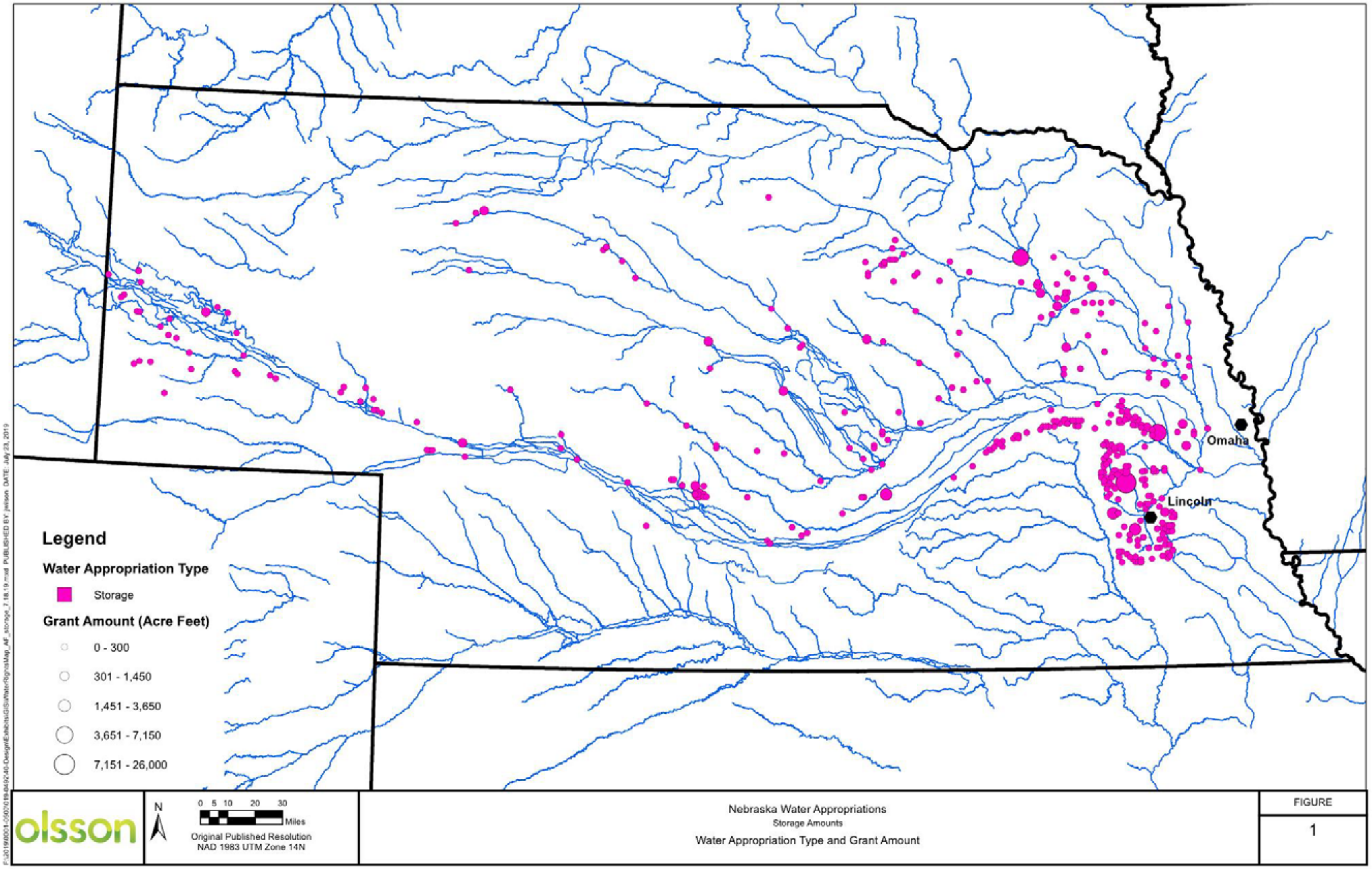

Figure 4-4 Storage Permits Upstream of the City's Wellfield that are Junior to the City's Water Right

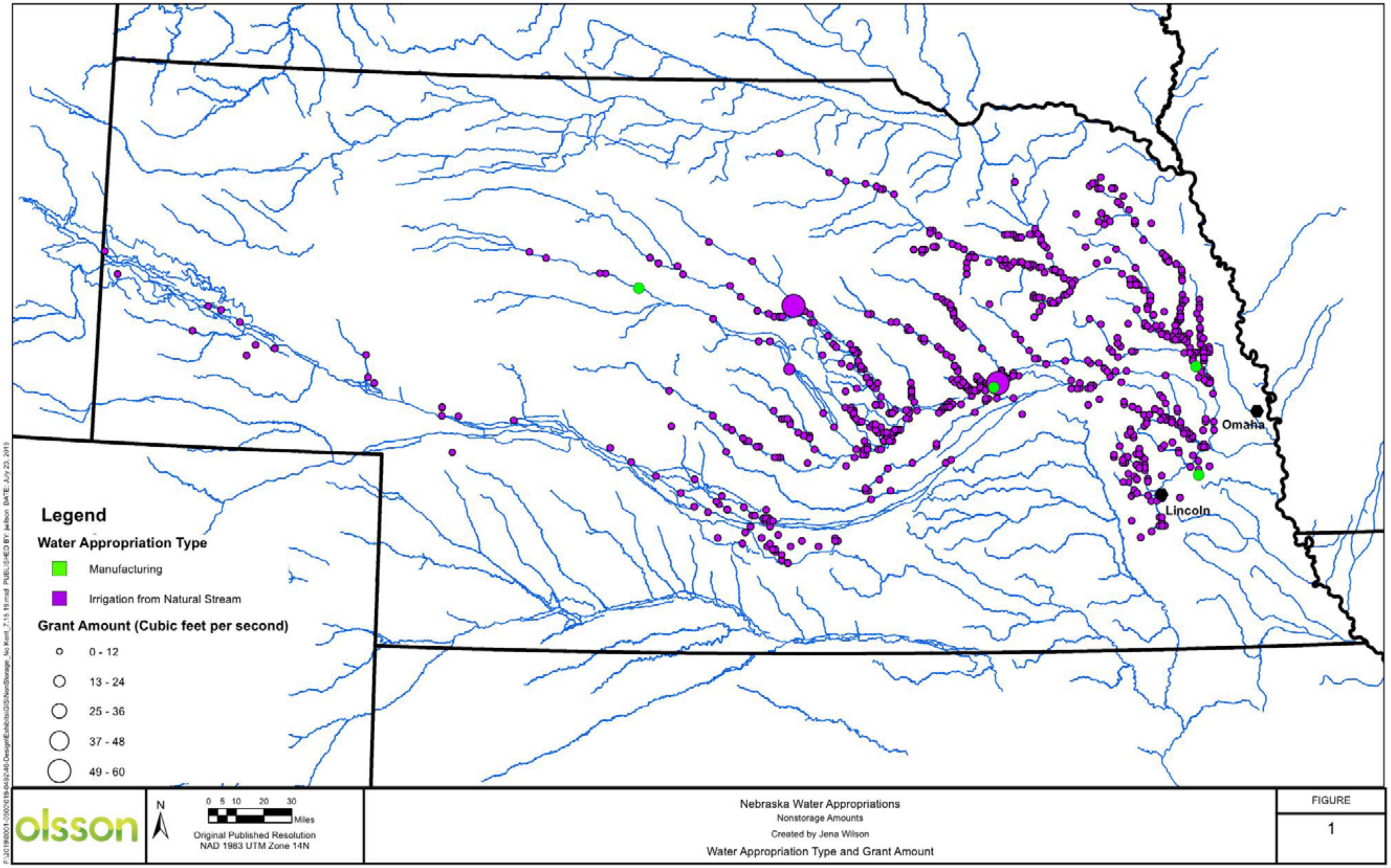

Figure 4-5 Permits to Divert Surface Water Upstream of the City's Wellfield that are Junior to the City's Water Right

Table 4-1 Junior Surface Water Diversion Rights Upstream of the City's Wellfield

Diversion	All Water Rights		Water Rights Senior to the NGPC In-stream Flow Right	
	Number of Permits	Total Diversion Rate (cfs)	Number of Permits	Total Diversion Rate (cfs)
Blue Creek Canal	2	0.24	2	0.24
Burwell-Sumter Canal	15	11.23	14	9.12
Canal No 1	1	0.73		
Canal No. 1 and 2	1	1.09	1	1.09
Canal No. 3	1	0.58		
Canal No. 3 and 4	6	5.29	6	5.29
Columbus-Genoa Canal	73	58.57	47	38.05
Cozad Canal	1	0.50	1	0.5
Dawson County Canal	1	0.91	1	0.91
Farwell Main Canal	5	20.69	4	11.02
Gothenburg Canal	3	3.78	3	3.78
Kearney Canal	1	4.86	1	4.86
Kelly Headgate	1	4.76	1	4.76
Kent Canal(1)	3	787.37	1	783.87
Mirdan Canal	5	50.10	2	45.21
O'Neal Canal	1	2.22	1	2.22
Ord-North Loup Canal	12	6.89	10	6.54
Pumps	937	1,152.42	774	906.53
Sargent Canal	6	10.83	4	4.29
Sutherland Canal	1	2.43	1	2.43
Taylor-Ord Canal	11	4.08	10	3.41
Total	**1,087**	**2,129.57**	**884**	**1,834.12**
Total without Kent Canal	**1,084**	**1,342.20**	**883**	**1,050.25**

(1)The Kent Canal is a feeder canal used to help fill Davis Creek Reservoir in the Spring and early summer. Therefore, it may not be in use during any requested water administration.

These water rights are classified as active by the NeDNR, and they continuously strive to maintain an accurate record of active water rights by investigating and canceling any water rights that have fallen into a state of nonuse. However, it is not possible to state directly from this data exactly how much actual water use would be curtailed during a call for water administration by the city. Periods of shortage of streamflows at the city's wellfield are likely to coincide with a high level of utilization of these junior water rights, and the total amount authorized for use exceeds the city's demand by a significant amount. Therefore, a proactive request for water administration would have a high degree of probability of maintaining the level of streamflow in the Platte that is required for stable operation of water withdrawals for use by the City of Lincoln.

The city should be aware that any non-domestic use of water that occurred in the city during a call for water administration would require compensation be provided to junior users. The Director of NeDNR is required to determine the amount of non-domestic use that does occur during a period of water administration.

A municipal groundwater transfer permit is a permit that a municipality may avail itself of under the Municipal and Rural Domestic Ground Water Transfers Permit Act (Neb.Rev.Stat.46-639), but it is not required. The City of Lincoln holds two municipal groundwater transfer permits for the Ashland Wellfield that total 110 million gallons/day (mgd). These transfer permits are A-10367 (with a priority date of June 15, 1931 for 60 mgd) and A-16917 (with a priority date of January 25, 1990 for 50 mgd). The city also holds a transfer permit for the Antelope Creek wellfield, but water has not been used under that permit for more than five years. The intent of the permit is to recognize continued withdrawals and to protect the source of the water supply for municipalities. If projected water demands for the city exceed 110 mgd, and there are planned expansions to treat and transport this additional demand, the city may apply for another municipal groundwater transfer permit. However, the total of 110 mgd should not be viewed as a limitation on use, it simply represents the amount of use that is protected under the existing permits.

Nebraska law (Neb.Rev.Stat.46-235.03) empowers natural resources districts with the authority to impose restrictions and controls on public water suppliers as specified in the Nebraska Groundwater Management and Protection Act. Such restrictions or controls may limit the withdrawal of groundwater to a greater degree or extent than is otherwise permitted or allowed by a permit issued by NeDNR. If the lower Platte River basin is ever declared fully appropriated under the Act, Nebraska law (Neb.Rev.Stat.46-740) would allow the integrated management plan developed pursuant to this designation to impose controls on the city's water use. Subsection 4 of this provision states in part that:

> *On and after January 1, 2026, the base amount for an annual allocation to a municipality shall be determined as the greater of either (a) the amount of water authorized by a permit issued pursuant to the Municipal and Rural Domestic Ground Water Transfers Permit Act or (b) the greatest annual use prior to January 1, 2026*

In order to avoid being subjected to an alternative annual allocation, the city should ensure that the total amount of water projected to be withdrawn, transported, and used is covered under a municipal groundwater transfer permit if the lower Platte River basin is determined to be fully appropriated in the future.

4.2 Future Streamflow Evaluation

The Lincoln wellfield is heavily dependent on Platte River streamflows that recharge the alluvial aquifer from which water is withdrawn. During periods of normal and high streamflows, the aquifer receives plenty of recharge and the wellfield is easily able to meet demands. However, during periods of lower streamflows, it is possible for withdrawals to begin to exceed the rate at which water is recharged from the stream to the aquifer. The single greatest threat to the wellfield's water supply are extended periods of low river flows, such as those that occurred in early Year 2000 and again in Year 2012.

The availability of streamflows during low-flow (or baseflow) conditions are affected by the amount of aquifer recharge and the resulting streamflows that occur upstream. These streamflows are coming from the High Plains aquifer, which contains an abundant supply of water. These streamflows are impacted over years, decades, or longer by changes in the system, like increased pumping and/or recharge. In other words, low flow conditions in the Lower Platte River during any given year will be affected by what has occurred over the past several decades or more. Therefore, it is not possible to base a prediction of the occurrence and magnitude of low flows on the current season weather conditions alone. To fully understand the impact of streamflows during low-flow conditions, it is necessary to conduct long-term groundwater flow modeling simulations using regional- scale models. These groundwater flow models (described below) represent the best available science to forecast future streamflow conditions.

There now exists regional-scale models that extend over the entire area of the High Plains aquifer in Nebraska. Three models are significant to this evaluation: the Cooperative Hydrology Study (COHYST) Model, the Central Nebraska Model (CENEB), and the Lower Platte – Missouri Tributaries (LPMT) Model. The areal extent of these models is shown in Figure 4-6.

These models have been calibrated to observations of groundwater levels and streamflows over a period that roughly extends from Years 1950-2010. To better understand the potential future streamflows in the Lower Platte River, these models were set up to provide simulations of future conditions based on antecedent conditions and an assumption that water use, and climate patterns would generally mimic those observed from the late 1980's to the early 2010's. By conducting simulations that predict streamflows under these baseline conditions and potential changes to those conditions, the model can be used to provide a likely range of future conditions relative to those experienced in the recent past.

Four future modeling scenarios were completed with each of the three groundwater models, with each groundwater model providing changes in streamflows for a discrete portion of the Platte River and its tributaries upstream of the Lincoln wellfield. With the exception of Scenario 1, which is intended to simulate a future that is very similar to the near past (specifically the climate from 1989-2013), the scenarios are intended to represent the results of an evaluation of potential changes in the future climate, which was conducted by Martha Shulski and is summarized in Appendix A. Two major changes are expected to occur in eastern Nebraska, based on the down-scaled results of a suite of global climate models. The climate is expected to get wetter overall, though these wetter conditions will primarily occur during the winter and spring months, and conditions will be dryer during the summer, with no change expected for the fall. Therefore, it is reasonable to expect that the aquifers that are simulated in these groundwater models may receive a greater amount of recharge during the winter and spring, and a lesser amount in the summer. The second change that is expected will be in temperatures, which are expected to be somewhat warmer during the summer months. The four scenarios are described in greater detail below.

Note: A modeling scenario is a set of conditions represented in the groundwater flow model.

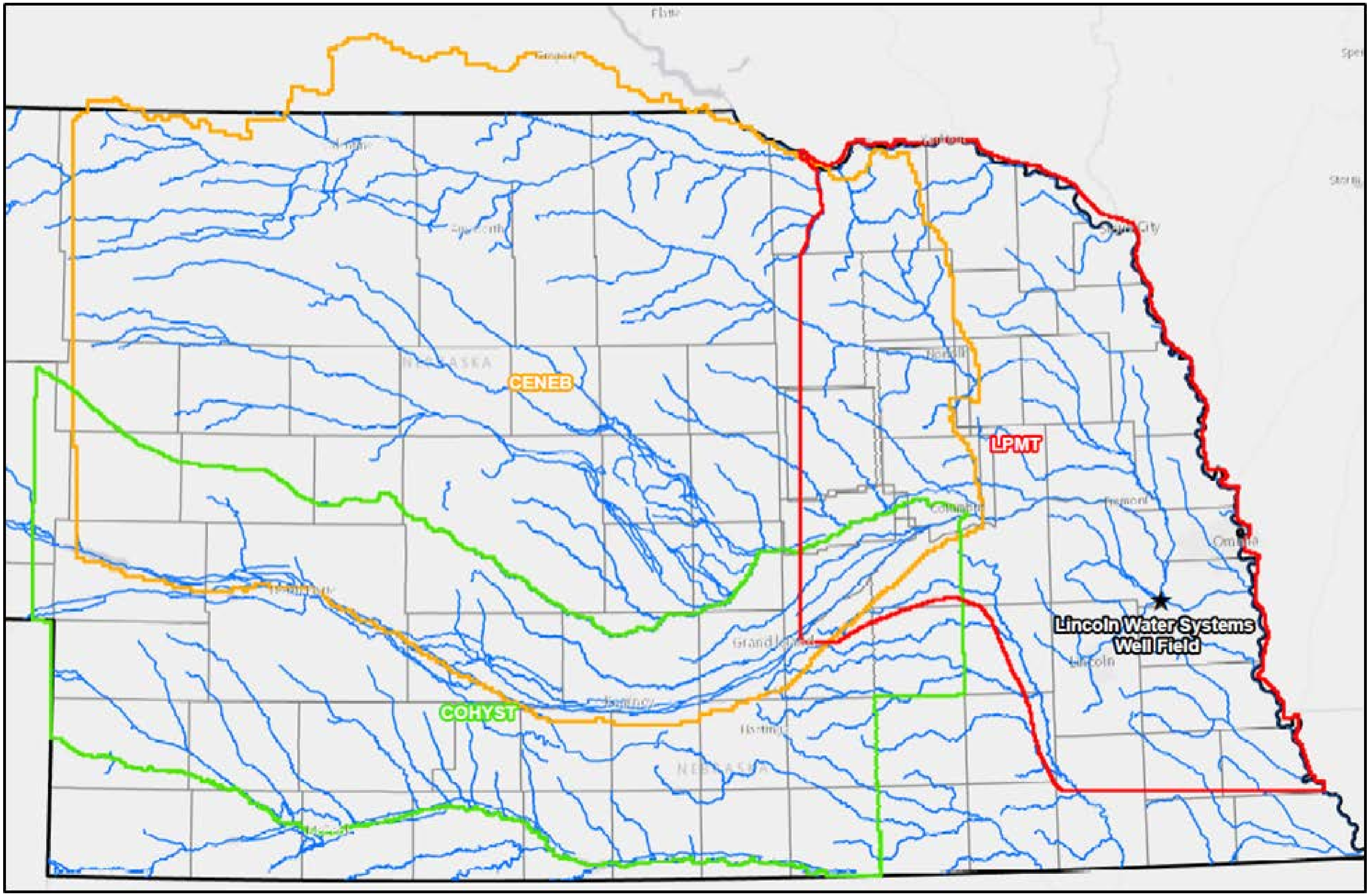

Figure 4-6 **Areal Extents of Regional Groundwater Models**

4.2.1 Modeling Scenarios

Scenario 1: Baseline conditions – this simulation simply repeated recent (late 1980's through early 2010's) climate conditions into the future. The purpose of this scenarios is to simulate how streamflows are predicted to change if climatic conditions do not change.

Scenario 2: Recharge changes – Climate models predict that in eastern Nebraska the precipitation will be somewhat greater in the future due to climate change. However, this increase will not be uniform throughout the year. The precipitation is expected to be greater during the months of December through May, and it is expected to be lower during the months of June through August. The purpose of this scenario is to simulate how streamflows are predicted to change if these changes in the precipitation occur and cause similar changes in the amount of groundwater recharge.

Scenario 3: Groundwater pumping increases – Climate models predict that in addition to being dryer during the summer months, it might also be warmer. This could lead to an increase in consumptive use demands for irrigated agriculture upstream of the Lincoln wellfield. Also, in some portions of the basin upstream of the Lincoln wellfield, groundwater irrigation is continuing to expand somewhat. For both reasons, groundwater pumping may increase in the future, causing a corresponding reduction in streamflow. The purpose of this scenario is to simulate how streamflows are expected to change if these increases in groundwater pumping occur.

Scenario 4: Recharge changes and groundwater pumping increases – The purpose of this scenario is to simulate how streamflows are predicted to change if both changes described in Scenario 2 and Scenario 3 occur.

4.2.2 Modeling Results

In order to evaluate the change in streamflow during future drought conditions, specifically at the Lincoln wellfield, the Years 2000-2006 were selected for evaluation. During these years, there were numerous occurrences of significantly low-flow conditions at the Lincoln wellfield. In the four modeling scenarios, these years recur in the future at roughly the Year 2040 and Year 2060 planning horizon being evaluated in this plan. To estimate the streamflows at these planning horizons under similar climate conditions, the actual modeled streamflows during the Years 2000-2006 were compared with the simulated streamflows at these planning horizons. The average monthly change in modeled streamflow under the Year 2040 planning horizon and the Year 2060 planning horizon are presented in Table 4-2 and Table 4-3, respectively.

These tables present the average monthly change in modeled streamflows during this 7-year period and are rounded to the nearest ten cfs. These results should be considered "order of magnitude" results, and not interpreted as a prediction of the exact quantitative results. Most of the reductions in streamflow are due to reductions that occur in the Central Platte River above the confluence with the Loup River. These reductions are masked to a great extent by increases in both the baseline run and during most months in the remaining scenarios from modeled streamflow increases in the Loup River, the Elkhorn River, and the Lower Platte River above Ashland.

Table 4-2 2040 Planning Horizon Difference in Modeled Streamflows (cfs)

SCENARIO	One	Two	Three	Four
January	-160	-70	-220	-140
February	-150	-70	-210	-130
March	-120	-30	-180	-90
April	-20	110	-80	50
May	130	320	70	260
June	60	180	0	120
July	-120	-40	-190	-110
August	-170	-100	-240	-180
September	-150	-80	-220	-150
October	-130	-60	-200	-120
November	-120	-50	-180	-110
December	-130	-60	-200	-120
Average	-90	0	-150	-60

Table 4-3 2060 Planning Horizon Difference in Modeled Streamflows (cfs)

Scenario	One	Two	Three	Four
January	-210	-90	-300	-170
February	-210	-90	-290	-170
March	-180	-50	-270	-140
April	-50	110	-140	30
May	120	350	40	260
June	40	200	-50	120
July	-170	-50	-270	-150
August	-190	-90	-290	-190
September	-160	-60	-260	-160
October	-120	-20	-220	-110
November	-120	-20	-220	-110
December	-150	-40	-240	-130
Average	-120	10	-210	-80

In order to put these results into the context of historical streamflows, the daily flow record for the stream gauge on the Platte River at Ashland was modified to reflect these potential changes in streamflows by month and scenario. Following this, the recurrence interval for various low flow event intervals were computed for the historical record and the four modified historical records. These low flows were determined using the U.S. Army Corps of Engineers Hydrologic Engineering Center Statistical Software Package Version 2.1.1.137 and the flow rates that were computed represent the maximum flow during a given time interval for a given return interval. For example, based on the historical flow record the 30-day low flow event that is expected to occur every other year on average (i.e., a 50% chance of the flow not being exceeded for 30 consecutive days in a given year) is approximately 2,600 cfs. The results of this evaluation for the 90-day low-flow at recurrence intervals between 5 years and 500 years for the 2040 results and the 2060 results are presented in Figure 4-7 and Figure 4-8, respectively. For additional context, these figures contain a label for 1500 cfs, 700 cfs, and 200 cfs. As can be seen, the worst case is Scenario 3, and a summary of the potential for these flows to not be met for a full 90-day period are summarized for the historical data and for the data adjusted according to the Scenario 3 results.

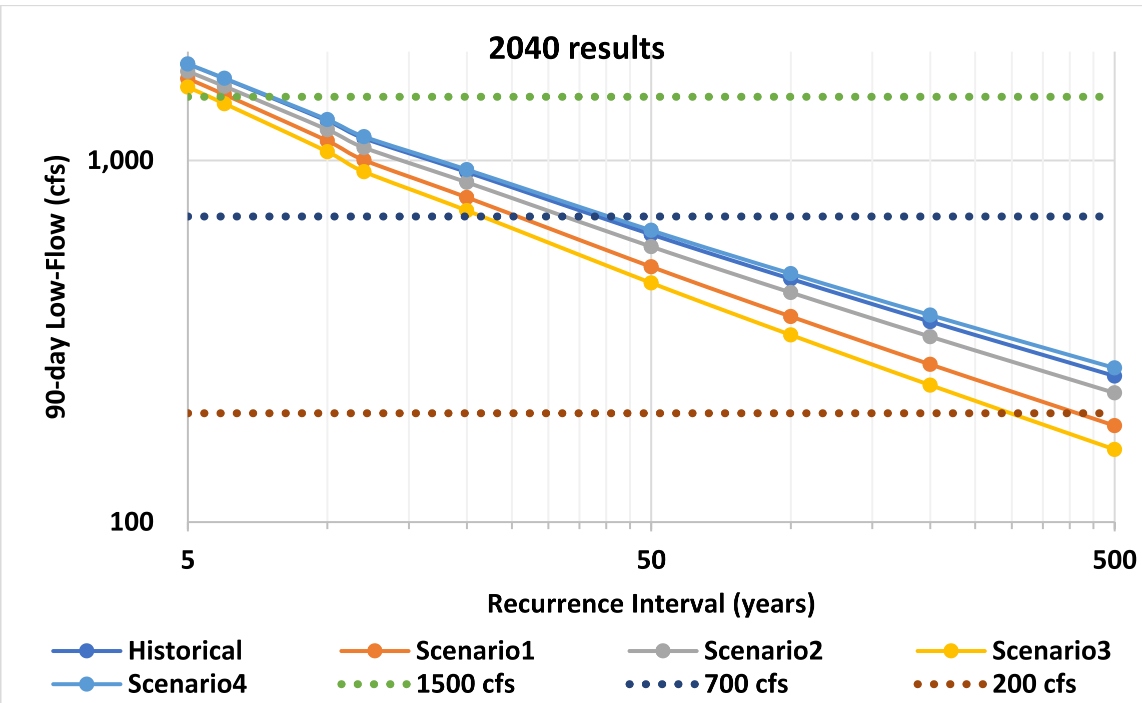

Figure 4-7 90-Day Low-Flow Conditions for the Historical Data and Each Scenario for the 2040 Model Results for Recurrence Intervals Between 5 Years and 500 Years

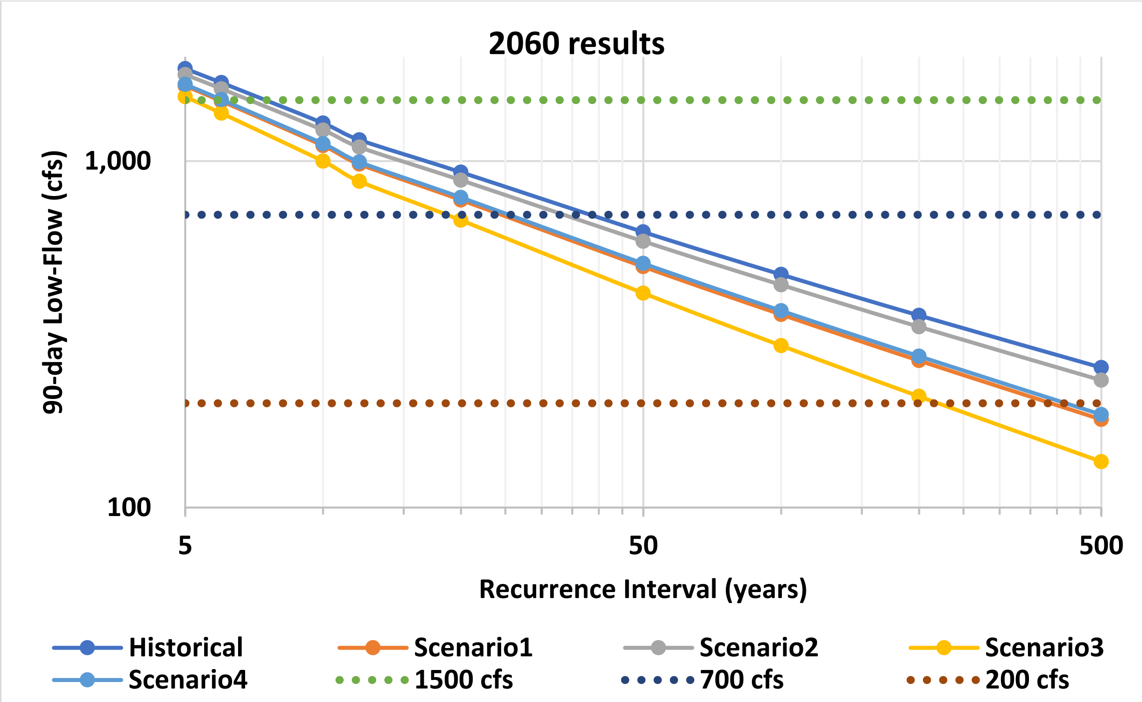

Figure 4-8 90-Day Low-Flow Conditions for the Historical Data and Each Scenario for the 2060 Model Results for Recurrence Intervals Between 5 Years and 500 Years

Table 4-4 2040/2060 Planning Horizon Chance of the Listed Low Flows Occurring At Least Once

	2040		2060	
Flow	Historically	Scenario 3	Historically	Scenario 3
1500	93%	97%	100%	100%
700	40%	64%	64%	87%
200	2%	6%	5%	18%

4.2.3 Climate Change Impact

The impact of climate change was a key consideration in the evaluation of water supply for the City of Lincoln. Results of the Climate Change Assessment (Appendix A) were used as direct inputs to the regional groundwater models, with the results of those modeling efforts summarized in Tables 4-2 and 4-3 for Year 2040 and 2060, respectively. The predicted impact to streamflow as a result of climate change can be derived by comparing Scenario 1 (Baseline Condition) and Scenario 3 (Groundwater Pumping Increases). In general, the anticipated decrease to streamflow in the critical late summer months of July, August, and September is around 70 cfs by Year 2040 and 100 cfs by Year 2060. This decrease is significant in comparison to the historical low flow benchmark for the river of 200 cfs. More specifically, climate change has the potential to reduce streamflow by 50 percent relative to the low flow benchmark by Year 2060.

4.3 Supply Improvements

The capacity of the wellfield is governed by two separate criteria. First, the aquifer must be capable of yielding the volume of water needed and second, the hydraulic capacity of the wells, pumps, and pipelines must be adequate to deliver maximum day demands. Relative to hydraulic capacity, the *2014 Master Plan* indicated that a majority of the flow from the fifth HCW could be conveyed through the existing 54-inch main to the East Plant. Therefore, no additional pipeline was recommended until the construction of the sixth HCW. It was also noted that the total raw water transmission capacity is approximately 145 mgd, which satisfies demands beyond the horizon of this study.

The primary focus of this update was to refine the 90-day seasonal yield, compare those yields to the project 90-day seasonal demand (as defined in Chapter 3), and update the Capital Improvement Program relative to timing of HCW-5 and HCW-6.

4.3.1 Aquifer Yield

The aquifer yield is evaluated using the USGS three-dimensional groundwater flow model, MODFLOW. The model for the LWS wellfield was first developed in the 1980's and has been updated periodically through the years to refine wellfield yield resulting from expansion of the raw water supply system.

Modeling scenarios have focused on river flows ranging from 200 cfs up to 3000 cfs. The low flow of 200 cfs represents a severe drought that may occur for a short duration, while 3000 cfs represents the condition at which point the river is flowing bank-to-bank and experiencing uniform recharge. The MODFLOW analyses were completed by Lamp Rynearson and the results of the analyses are summarized in a technical memorandum, included as Appendix B to this report.

4.3.2 MODFLOW Model Refinements

Two specific model refinements were made to the model used in previous studies. One of these changes was made based on climate modeling conducted by Martha Shulski, the Nebraska State Climatologist. Climate models indicate that on average in the future, fall through spring will tend to be 15 percent wetter, and summers will be 12.5 percent dryer. These results were incorporated into the model by adjusting the precipitation recharge. The 15 percent wetter fall through springs were included by increasing the recharge during the Antecedent period by 15 percent. The dryer summers were included by reducing recharge during the Dry Spring antecedent condition and during each drought scenario by 12.5 percent. The scenario descriptions provide more details on antecedent condition modeling.

The second refinement made was with regard to the location of the Platte River in low flow conditions. Observations made in support of previous modeling indicated that at flow rates less than 3000 cfs, the Platte River is no longer running bank-to-bank, and instead runs in smaller channels in the river bed. In previous studies, the river was modeled as running along the west bank north of Highway 6 and along the east bank south of Highway 6. For this study, an analysis was conducted comparing results where the river was run fully along the west bank.

4.3.3 Sensitivity Analyses

The two refinements described above were analyzed to evaluate to how the model results would be impacted by their incorporation into drought planning scenarios. The changes in precipitation recharge had little effect on well field production. This is attributable to the drought scenarios having a short duration and the prior model assumption that precipitation recharge is only

5 percent of the annual total precipitation during a drought. These combine to add very little water to simulation, and a reduction in that water supply had minimal impact on well field yields.

Placing the river to the west of Ashland Island had significant impact on yields compared to previous modeling. This is attributable to the increased distance between the horizontal wells and their water source. As the river moves further away from the horizontal wells, sustainable production from the wells drops considerably.

4.3.4 Wellfield Expansion

The benchmark for the most recent wellfield expansion is the capability to supply the summer seasonal demands over a 90-day period with the river level at 200 cfs. The MODFLOW modeling results determined that the existing system is capable of producing 90 mgd over the 90-day duration. As shown on Figure 4-9 on the following page, the existing facilities are capable of meeting this hypothetical design condition through Year 2035. Installation of an additional horizontal collector well (HCW-5) by Year 2035 would be considered a "just in time" improvement. It is therefore recommended that the City consider advancing this improvement a few years in the capital improvement plan to be ahead of the demand. MODFLOW modeling was also performed to determine the 90-day system capacity with the implementation of HCW-5 and HCW-6. These analyses indicate that with the two future wells, LWS's projected seasonal capacity would be 105 mgd.

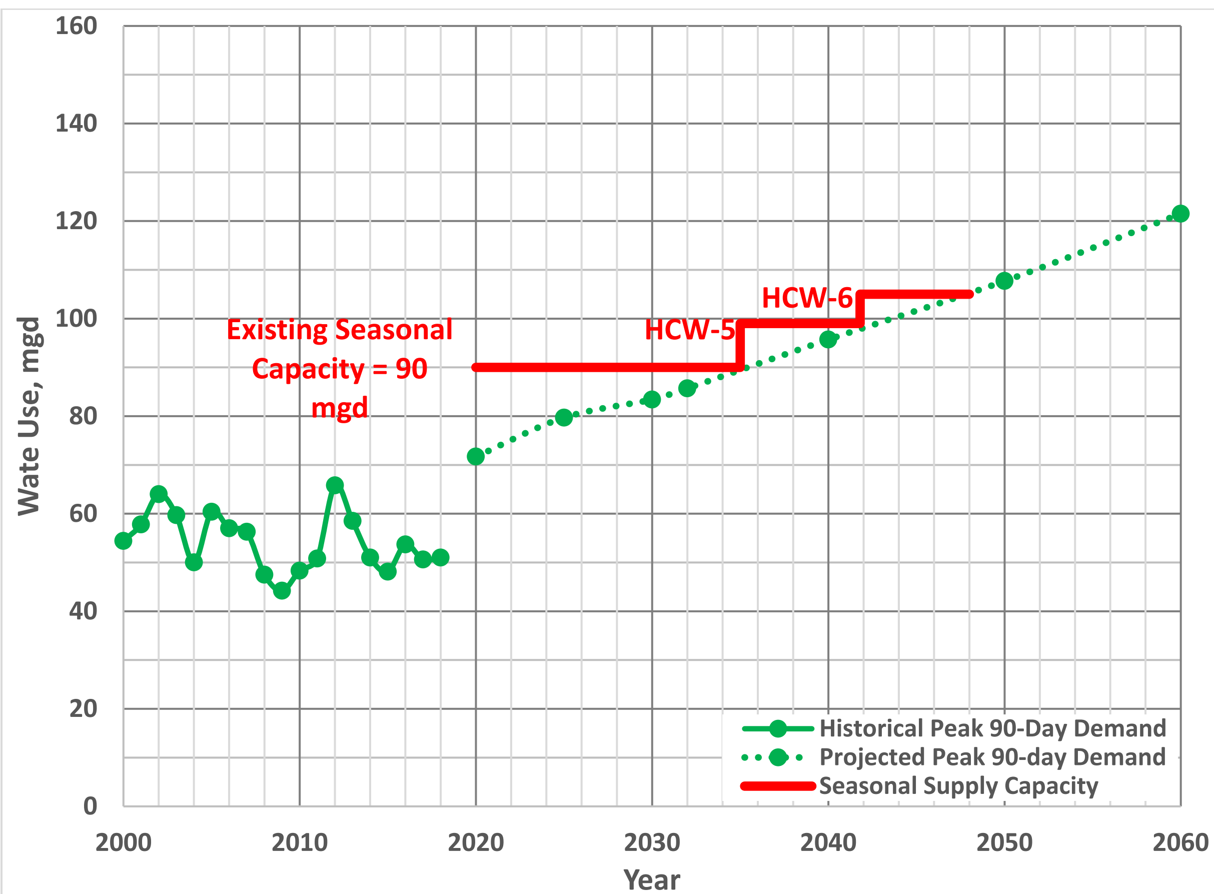

Figure 4-9 Future Supply Expansion