# Surface Water Supply and Demand Projections for Selected Basins in Eastern Kansas

Kansas, Marais des Cygnes, and Neosho River Corridor Supply and Demand Projections

## Introduction

Two of the programs that the Kansas Water Office (KWO) oversees are water marketing and water assurance. The purpose of the water marketing program is to manage water supply storage in federal reservoirs as a wholesale raw water utility to meet present and anticipated (future) water needs. At the same time, the water assurance program's purpose is to assure adequate supply from that water supply storage during times of drought.

With the purpose of these two programs in mind, the KWO has initiated a review of supply and demand in three basins in eastern Kansas.

In order to identify future potential surface water supply vulnerabilities in select Eastern Kansas basins, the KWO has initiated a main stem river corridor surface water supply-demand projection project. Supply and demand projections were estimated under a severe drought scenario.

### *Surface Water Demand*

The task of projecting water demand employs two methods:

1) population growth projections for municipal demand estimation and
2) non-municipal water use for the agricultural, industrial and commercial demand estimation

Basin demands are projected for the years 2020, 2050, 2100 and 2200 and a linear trend line was fit to those projections to create the total demand for the basins of interest.

### *Surface Water Supply*

Supply projection also employed two methods:

1) Federal reservoirs yield estimation
2) Natural flow estimation

Reservoir yields for 2010, 2020, 2030 and 2040 were used to project a linear trend line. Natural flow estimates for each basin were added to the Federal reservoir yields to create the total basin supply.

## Surface Water Demand Estimation Method:

Demand was projected from an 80% seasonal precipitation exceedence value (1950-2005) as an approximation of the demand management that is anticipated to occur under a severe drought scenario.

## *Municipal Demand Projection*

State certified county level population projections were obtained from the Division of Budget. The Division of Budget population projections did not go beyond 2027, so for each county in Kansas, the KWO used the growth/decline trend contained within the certified projection totals in the years 2011 through 2027 to fit a simple linear regression which extended that linear trend from 2028 to 2050. Examples of the linear trend extension of the Division of Budget certified county population totals are shown in Figure 1 and 2 below.

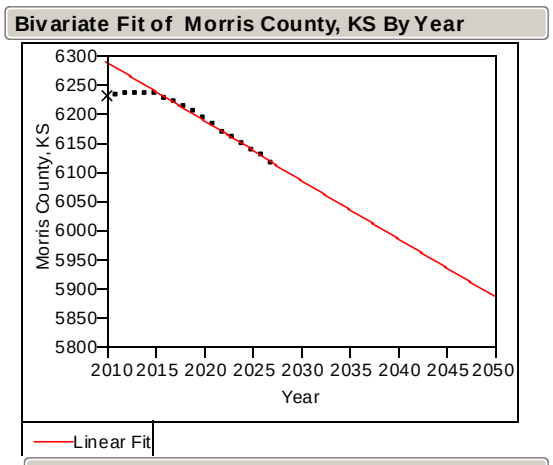



**Figure 1**

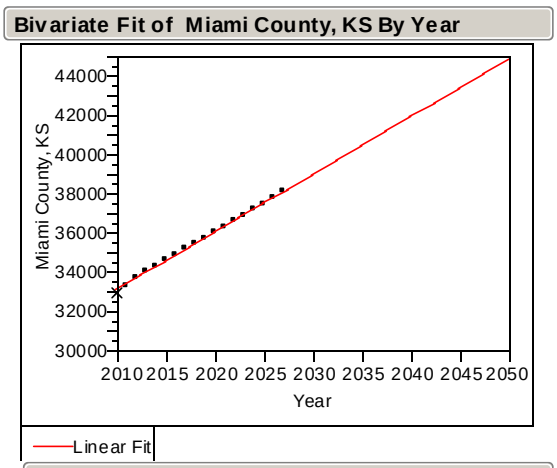
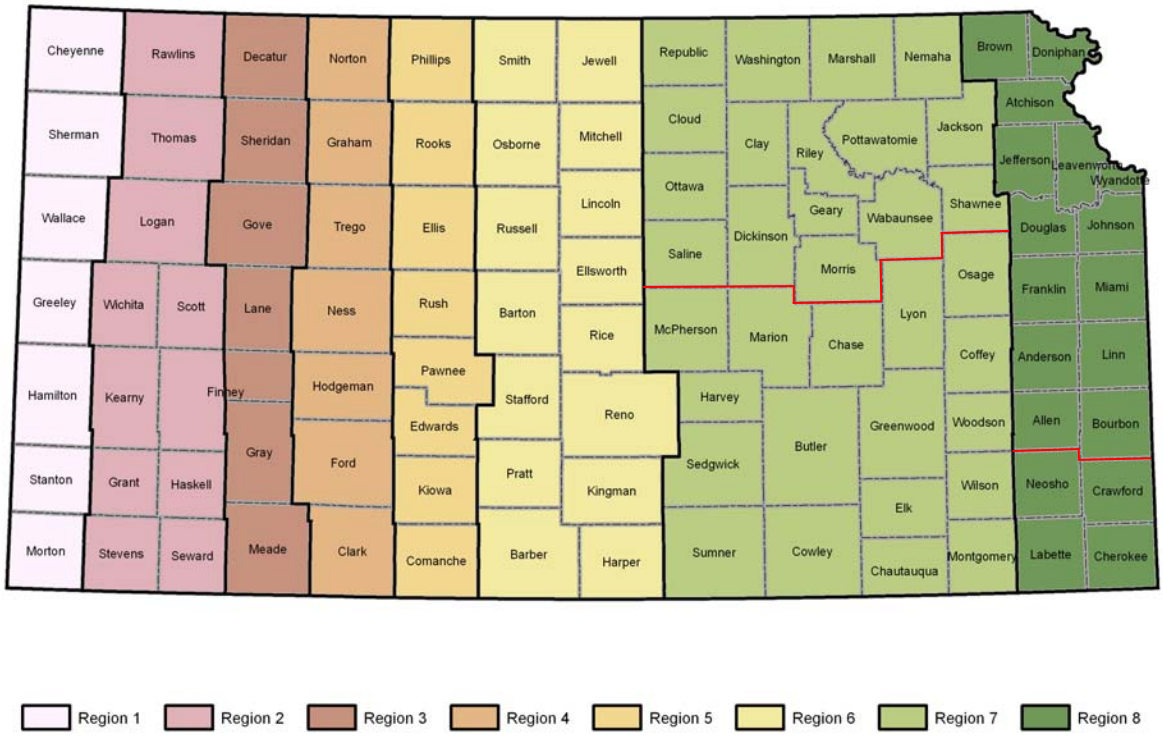



**Figure 2**

The resulting water demand associated with the population projections is based on municipal water use (as gallons per capita day usage) reported to the Kansas Department of Agriculture, Division of Water Resources for 2000 through 2004 by suppliers in the region of interest. These regions of interest in Eastern Kansas are 7 and 8 as shown in Figure 3.

Figure 3
Regions Used for Gallons Per Capita Per Day (GPCD) Analysis




In previous KWO municipal water demand projections, the method emphasized the use of the *average* gallon per capita day (GPCD) over a period of time for a region and the anticipated population in the future. The precipitation conditions that existed during that period, which typically drives a significant portion of the GPCD in certain months, were not considered in the context of whether the period was normal, wet or dry. Within this revised method, the projection has been revised to emphasize the GPCD usage that can be expected under drier than normal climatic conditions.

Each region was further subdivided into a north and south sub-region to optimize the relationship between GPCD and seasonal precipitation. A bivariate fit of GPCD water use by seasonal precipitation in each of the sub-regions for 2000 – 2004 was created. Seasonal precipitation was a county-wide average for monthly totals. Examples of these regressions are shown in Figures 4 and 5.

A seasonal precipitation exceedence was calculated for each county using data from 1950 to 2005. The 80% exceedence value was selected as the assessment/planning level for the 'dry' condition in this analysis. The 80% exceedence value for seasonal precipitation was used to solve the GPCD by seasonal precipitation regression equation developed for each region. The GPCD for this 'dry' condition was then applied to the estimated total population for a basin to estimate the expected municipal water usage for 2020, 2050, 2100 and 2200. A line was fit through these points to establish the municipal demand.

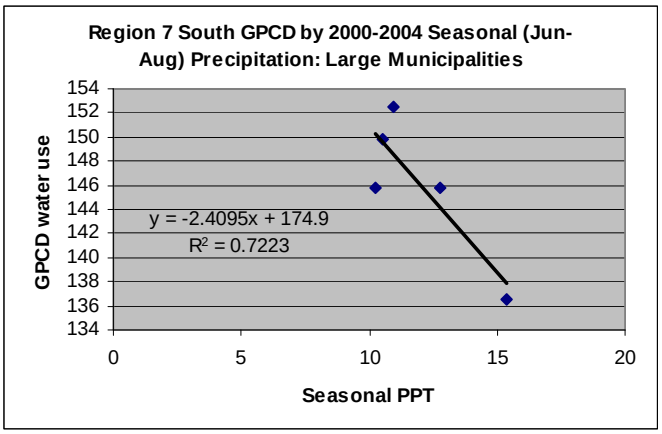



**Figure 4**

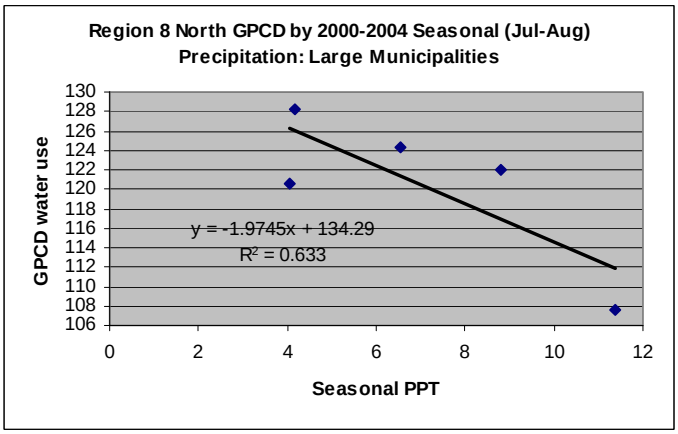



**Figure 5**

Since all population projections were developed from the county level, entire counties were assigned to the assessed Eastern Kansas basins. Counties were assigned to basins based upon predominance of area *and* existence of larger incorporated area within a particular basin. The Kansas River corridor from Junction City to the stateline included Geary, Riley, Pottawatomie, Wabaunsee, Shawnee, Jefferson, Leavenworth, Douglas, Johnson and Wyandotte counties (Figure 6). The Marais des Cygnes corridor included Osage, Franklin, Miami, Anderson and Linn counties (Figure 7). The Neosho included Marion, Morris, Chase, Lyon, Coffey, Woodson, Allen, Neosho, Crawford, Labette and Cherokee counties (Figure 8).

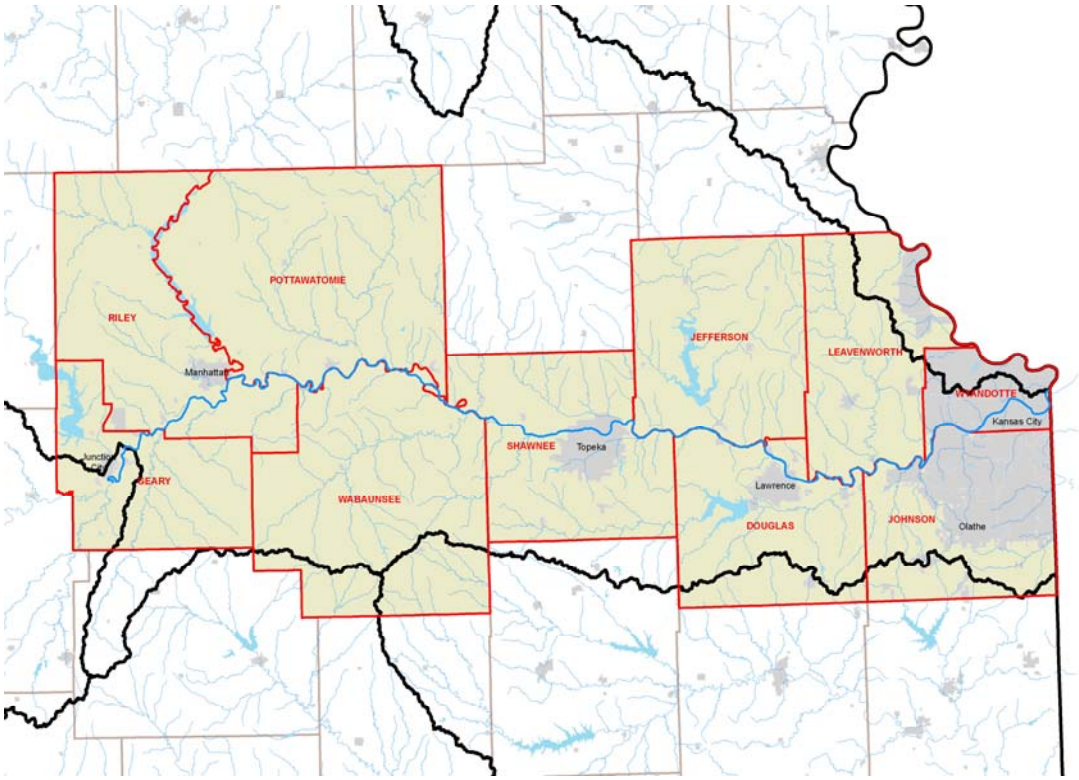



**Figure 6**

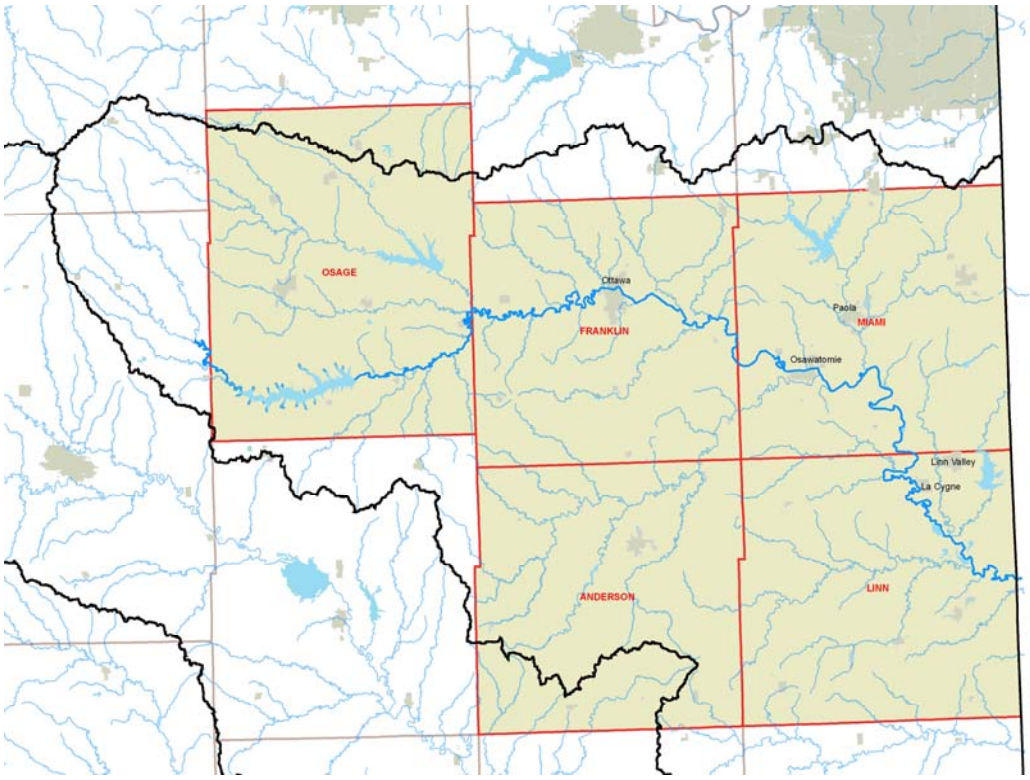



**Figure 7**

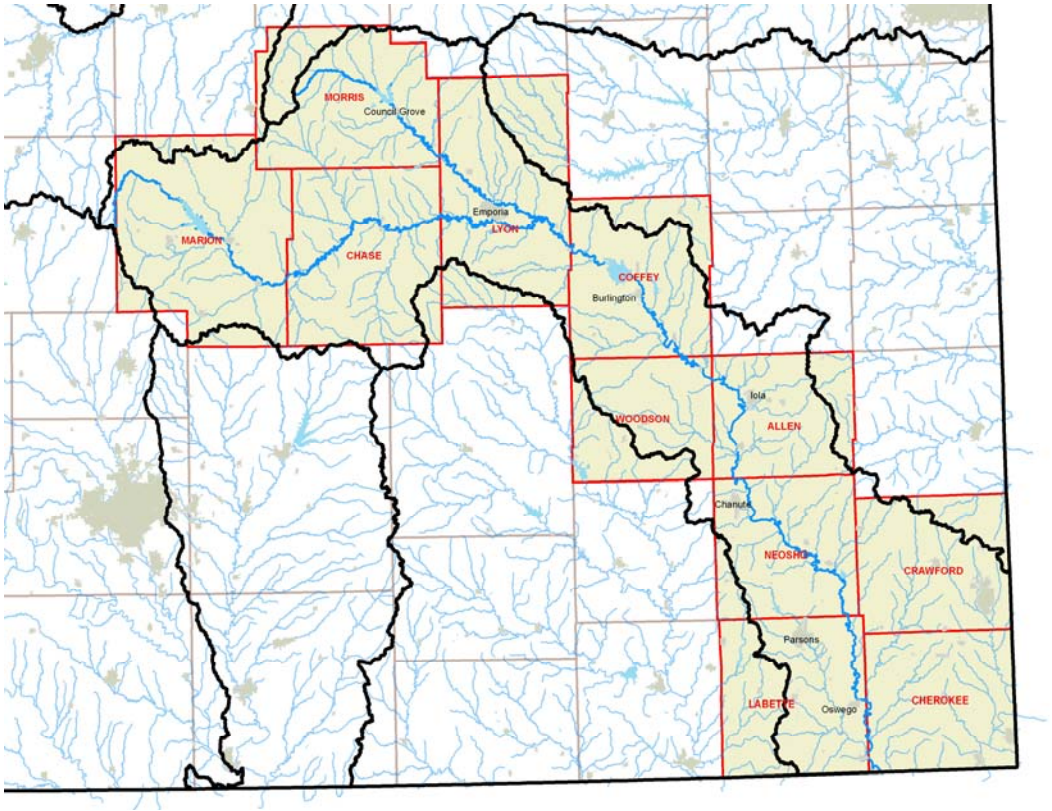



**Figure 8**

## Municipal-Related Industrial Demand Projection

In the process of reviewing the GPCD usage it was determined that the quantity of water that municipalities sold for non-domestic use was not contained in the GPCD calculation. Although removing this volume when calculating GPCD usage for municipalities is acceptable, that volume is important and should be accounted for when estimating and projecting *total* demand. The largest seven municipal-to-industry sellers account for 90% of the total industrial volume sold by municipal systems in 2002. These systems were located along the Kansas and Neosho main stem (none in Marais des Cygnes). The industrial water use sold by these 7 systems from 2000 – 2004 was reviewed for trend. None of the system's annual industrial sales correlated with seasonal precipitation. Two of these 7 systems showed no trend through time, one showed a significant increase through time and the remaining four showed a significant declining trend through time.

A number of conservative assumptions were used when projecting this industrial water volume sale from these systems. It was assumed that the industrial water sales were from surface water main stem sources. The single system that showed an increase in industrial water sales through time was projected to increase its sale into the future but the linear projection did not seem realistic; a curvilinear projection (transformed fit using the square of industrial water sales) was used instead. For the other six systems that showed no trend or a declining trend with time, the reported sales were used for 2004, but the median sale for the 2000-2004 period was used for the projection of future demand on each system. The resulting projections have been added to the Industry/Commerce/Agriculture/Recreation Demand Projections described below.

## *Other Industrial/Commercial/Agricultural/Recreational Demand Projection (Non-municipal Use)*

The demand projection for non-municipal use development was estimated by using 2002 reported water use within each basin of interest. 2002 seasonal precipitation was drier than the average seasonal precipitation for Regions 7 and 8, which follows the current method of demand projection for a planning condition that is drier than the average condition.

To develop the projected water use from industry, commerce, agriculture and recreation, all non-municipal surface water points of diversion within 5 miles of the main stem of each basin were selected. Reported water use was summed for the selected points of diversion whose priority dates were before 1991, then those before 1992 were selected, then 1993. This process was repeated through 2002. A bivariate fit of cumulative water use on the years 1990-2002 was created to estimate the annual rate of increase in water use from non-municipal sources in each basin. In an attempt to capture some of the uncertainty in this estimate, a 95% confidence interval was placed upon the fitted line. The upper confidence limit of the fitted curve was selected as the projected water use from non-municipal sources to stay conservative in water demand projections. Figures 9, 10 and 11 show the projected demand out to the year 2050 for the Neosho, Marais des Cygnes and Kansas River corridors, respectively. The upper and lower confidence limits for the 2050 non-municipal projection are also shown on the figures.

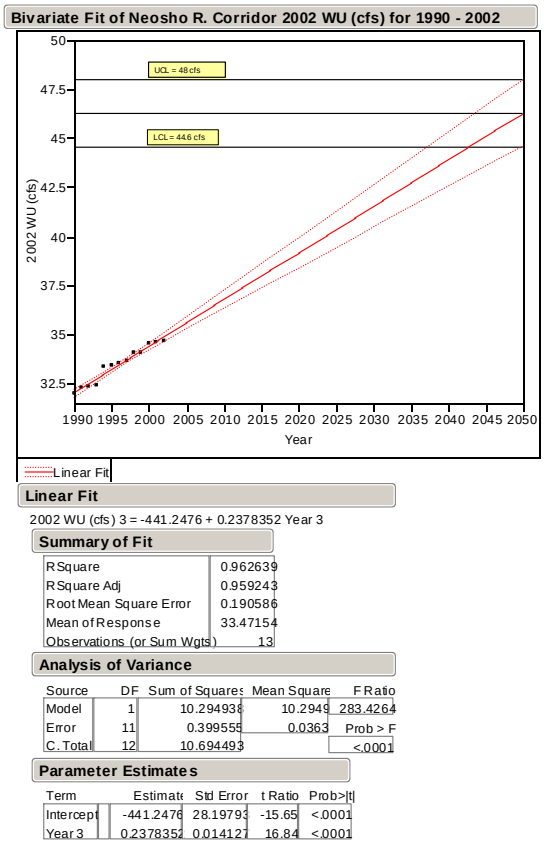



**Figure 9**

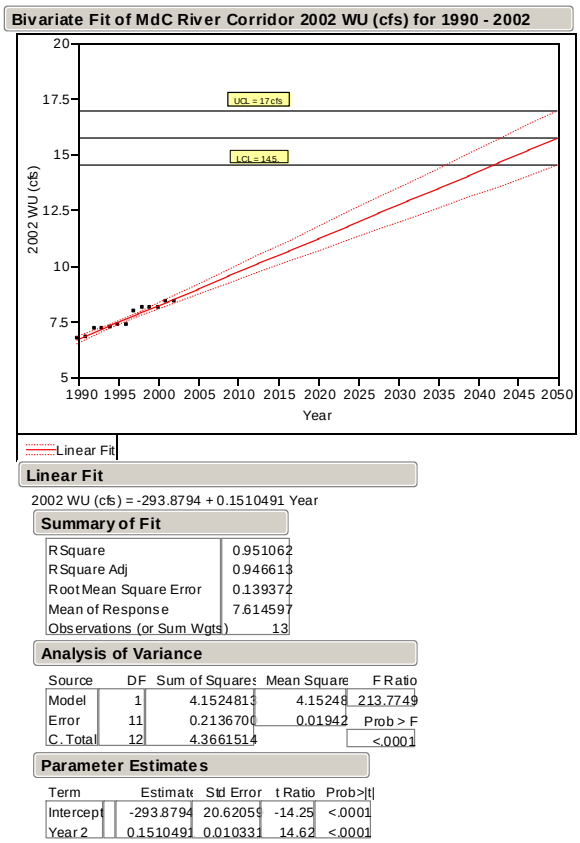



**Figure 10**

## Kansas River Corridor

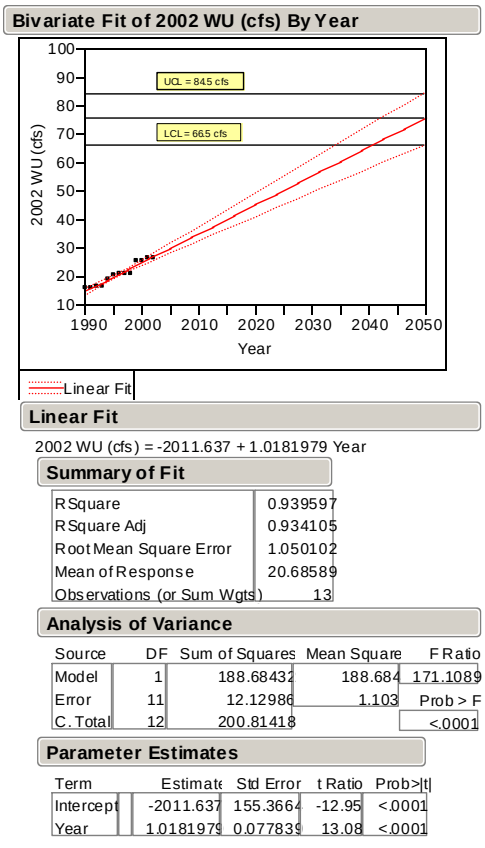



**Figure 11**

# Basin Demand Results

Figure 12, 13 and 14 display the resulting projected surface water demand for each of the basins of interest.

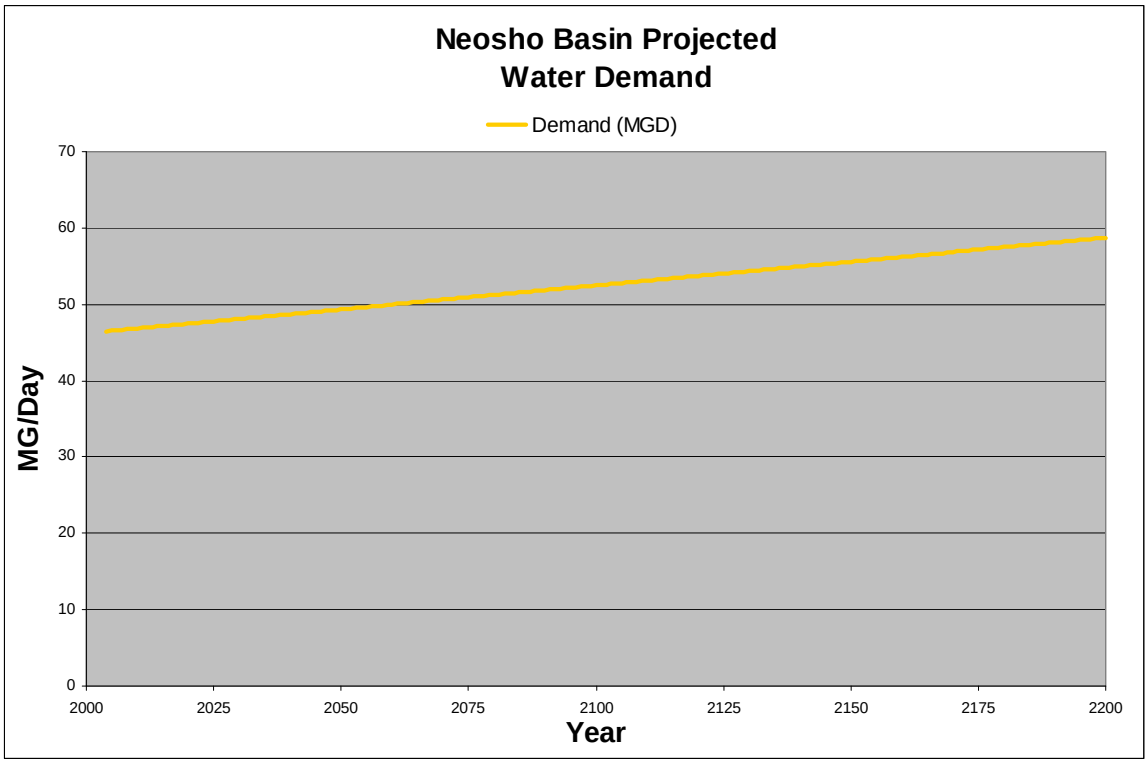



**Figure 12**

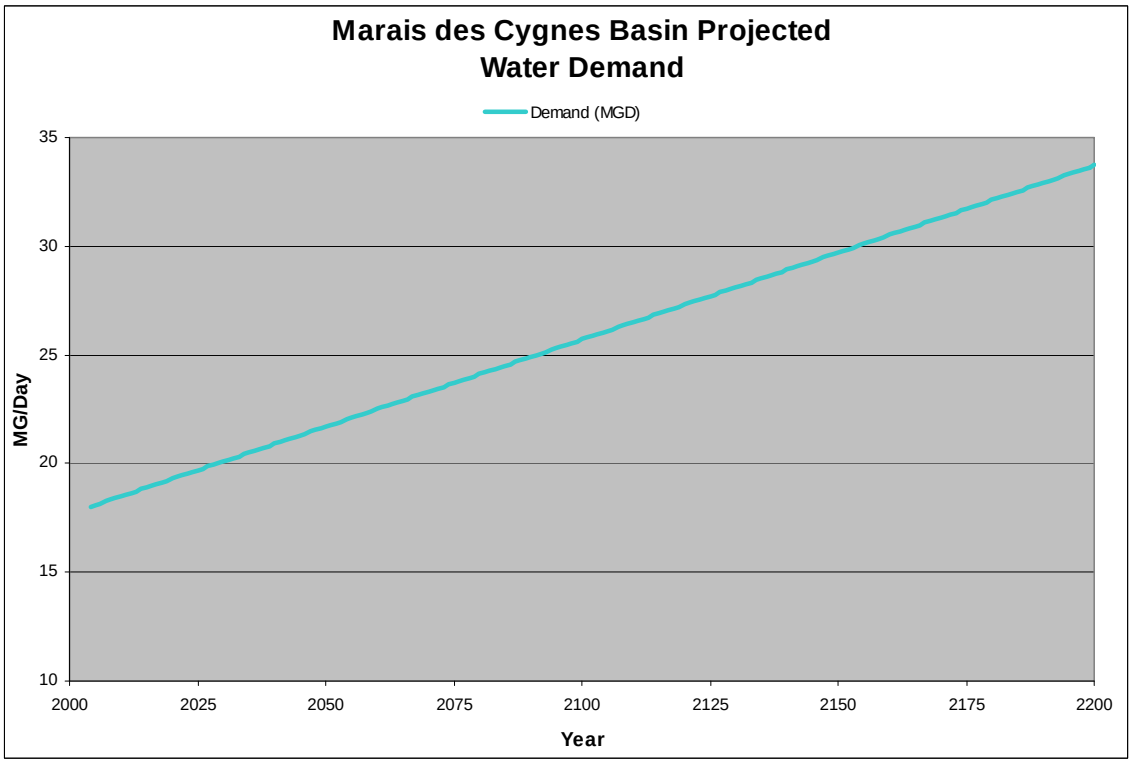



**Figure 13**

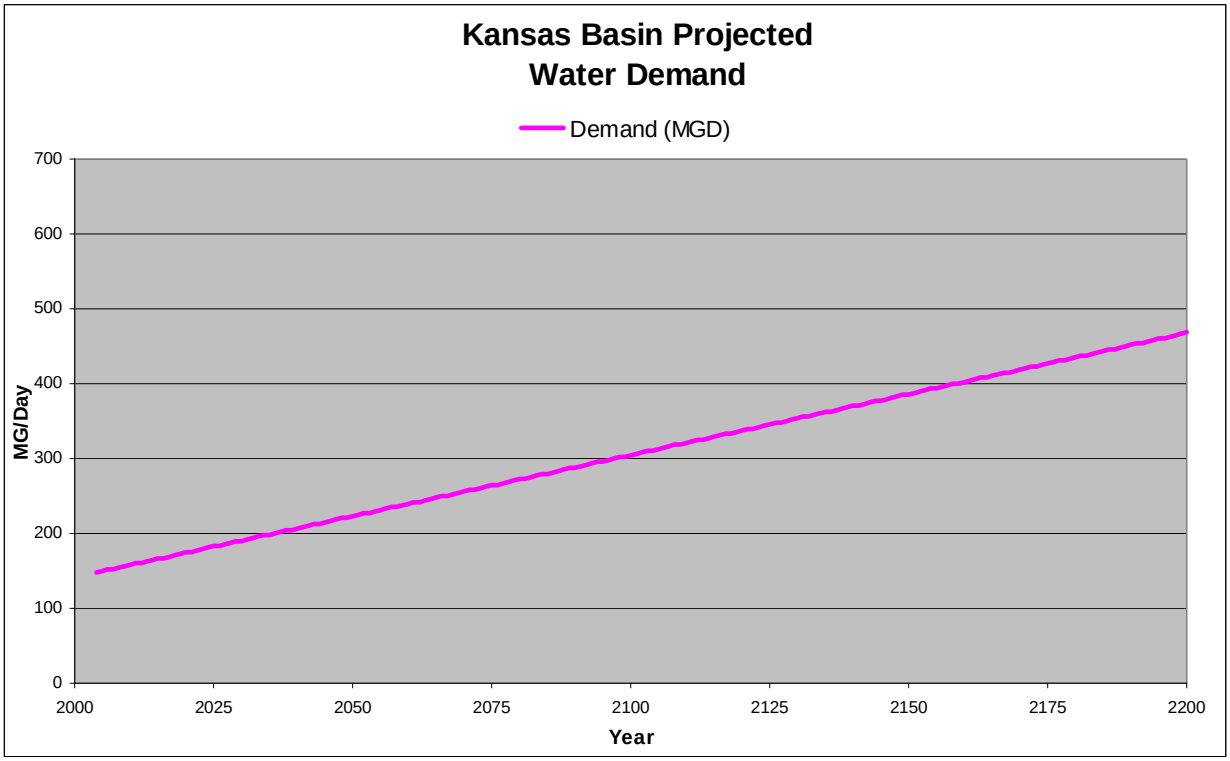



**Figure 14**

## *Main Stem River Corridor Demand Estimates by County*

The smallest component that the basin level main stem corridor surface water demand estimates can be broken into is the county level because the smallest unit available from the State-certified values for population projections is limited to the county level. The same methodology was used as described previously to estimate individual county demand.

### Neosho Basin Demand

Figure 15 shows the demand estimates by county for the Neosho main stem corridor. The surface water demand increase on the Neosho River is primarily associated with the anticipated demand increase of Lyon County; specifically the growth seen in the industrial sector in Emporia, Kansas, in the last 12-15 years. This growth was projected into the future.

Although a significant increase in demand was demonstrated in Neosho County, specifically in the recreational sector in the last 12 -15 years, that sector's growth was limited to current levels, since it is understood there is little to no desirable land remaining near the main stem in Neosho County that has not already been developed for recreational use.

Crawford and Cherokee county were excluded from surface water demand projections in this basin because of the ground sources available for their future supply and the Spring River surface water sources.

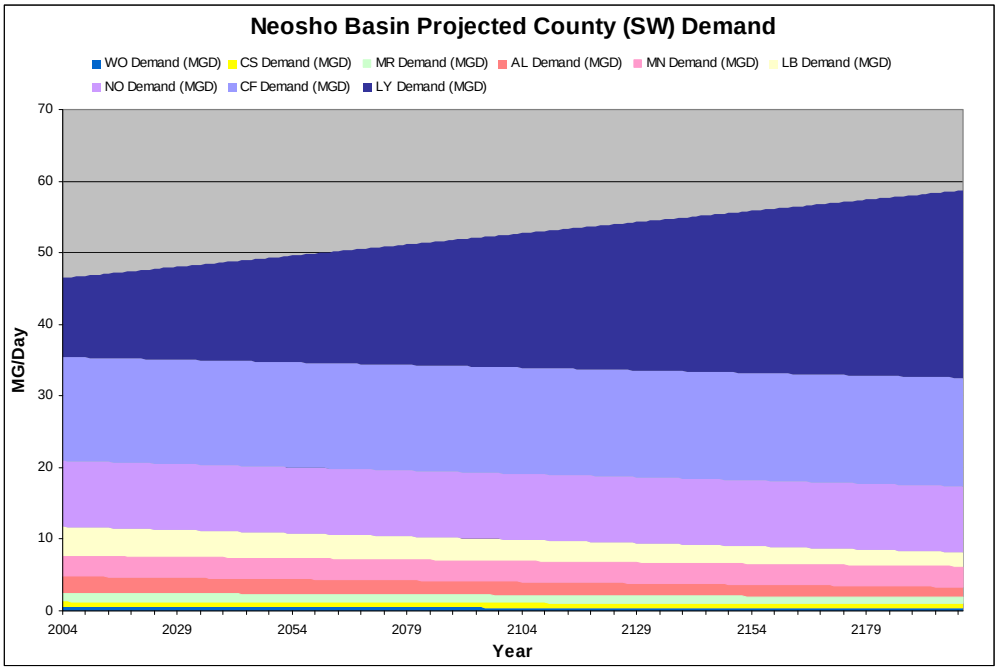



**Figure 15**

## Marais des Cygnes Basin Demand

Figure 16 presents demand estimates by county for the Marais des Cygnes main stem corridor. The surface water demand increase on the Marais des Cygnes River corridor is primarily associated with the anticipated demand increase of Miami County, specifically the future population growth projected to occur in that county. Although a significant increase in demand was demonstrated in Linn County, specifically in the recreational sector in the last 12 -15 years, that sector's growth was limited to current levels, since it is understood there is little to no desirable land remaining near the main stem in Linn County that has not already been developed for recreational use.

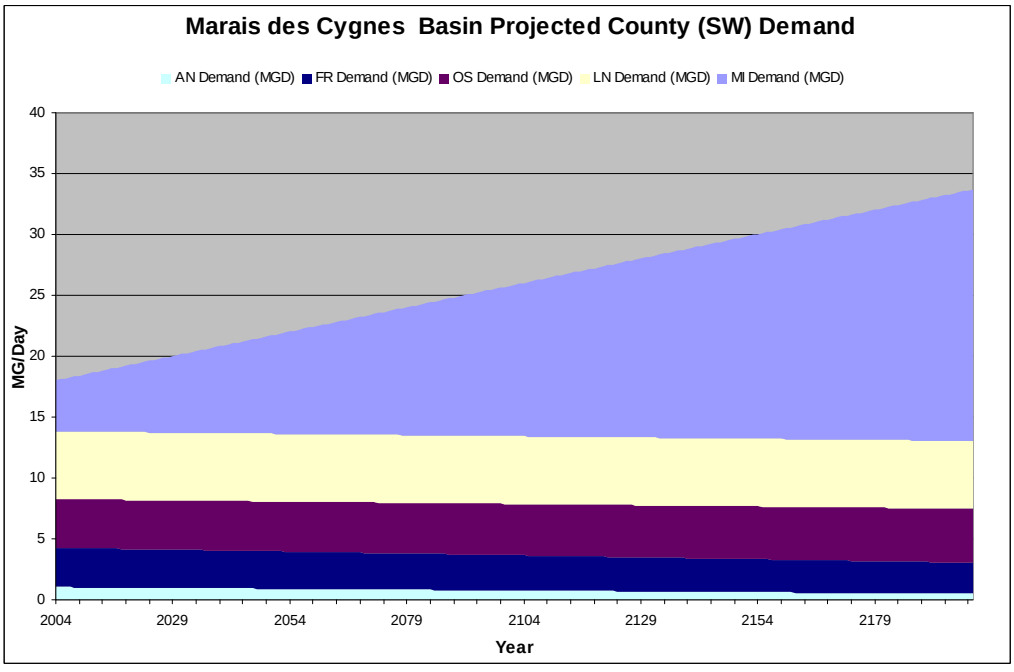



**Figure 16**

## Kansas River Basin Demand

Figure 17 presents the demand estimates by county for the Kansas River main stem corridor. The surface water demand increase on the Kansas River corridor is primarily associated with the demand increase of Johnson, Wyandotte, Shawnee, Douglas and Leavenworth Counties, specifically the future population growth projected to occur in those counties. Only 45% the population growth in Johnson County was assumed to be supplied by surface water sources in the Kansas River basin. This generally reflects the current percent of supply for the Kansas River basin for that county (Missouri River supplies the balance of the demand).

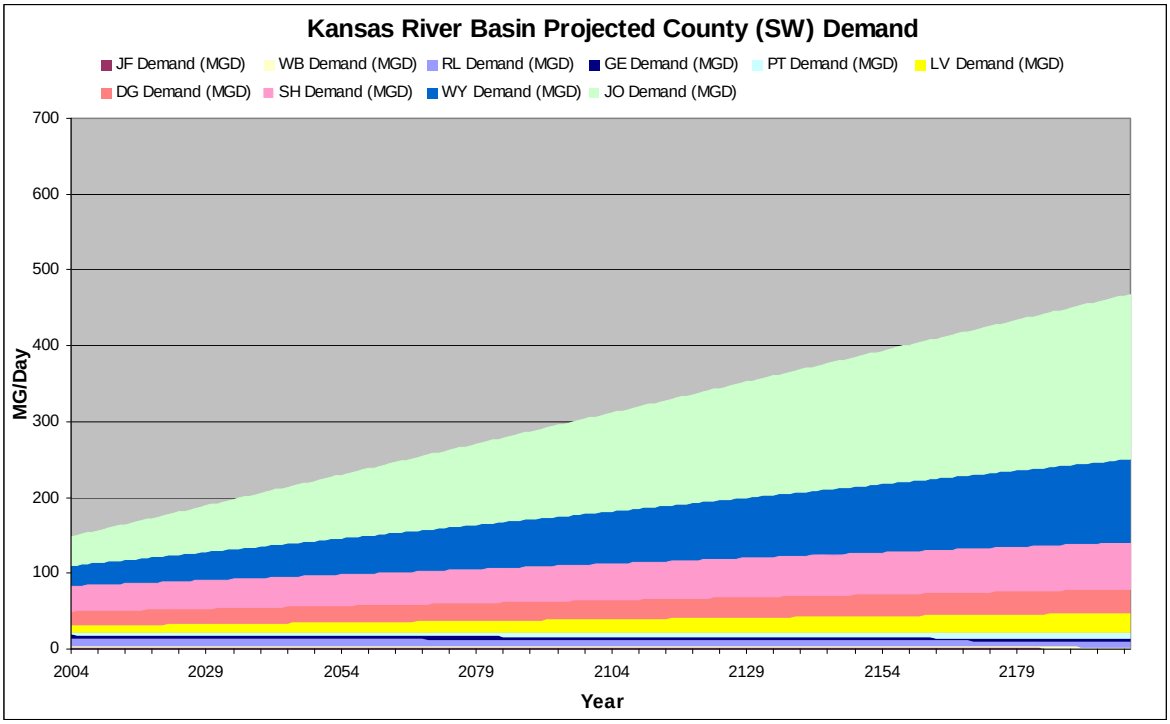



**Figure 17**

## Peak Usage Estimation

Estimated water demand is presently expressed as an average daily rate by year. From a planning perspective, estimating the peak demand over a shorter period than an average derived from an annual value (e.g. monthly, weekly or daily), - particularly during a very dry period – is significant. As the Eastern Kansas Basin supply/demand effort moves to more complex models, it is anticipated that peak demands will be explored more intensively. Although demand peaks are not applied in the current analysis, the daily water use for the City of Topeka (1985 – 2006), the City of Parsons and the City of Olathe were reviewed for their daily, weekly and monthly maximum usage in relation to that same year's daily, weekly and monthly averages. Between the three reviewed public water suppliers, the typical annual average to maximum peak ratio for daily use was 2.1, the weekly ratio was 2.0 and the monthly ratio was 1.7.

## Surface Water Supply Estimation Method:

Total basin supply was projected under a severe drought scenario.

### *Federal Reservoir Yield Projection*

The Kansas Water Office has previously estimated water supply yield under a severe drought scenario for all Federal reservoirs in the Kansas, Neosho and Marais des Cygnes.

A reservoir water supply yield analysis is, at its essence, an optimization problem. The setting for this optimization problem is created by artificially aging a reservoir through time by estimating reductions to area-capacity tables from projections of sedimentation rates. If conditions warrant, inflows are depleted and the reservoir is subjected to a drought scenario. Kansas statute defines this scenario as a 2% drought and regulations further define this scenario by establishing that the 2% drought occurred during 1952 – 1957. In the optimization problem, the artificially aged reservoir is subjected to the climatic conditions from the 1952-1957 with the optimization objective of maximizing water supply yield during this period. The primary constraint in the optimization problem is that the water supply pool volume is not allowed to equal zero (dry up).

Yields are typically projected 40 years into the future. A linear regression was established for each of the 40 year projections to extend those projections to the year 2200.

### *Natural Flow Estimation*

The Kansas Water Office has also previously estimated natural flows under the regulatory definition of the 2% drought scenario (1952-1957) for the Kansas, Neosho and Marais des Cygnes basins.

Initially, flows were estimated by the gaged flows at a location near the exit of each basin from observed flows during 1952-1957 (no federal reservoirs existed to regulate flow in the immediate area of the Kansas, Neosho and Marais des Cygnes main stem corridor during 1952-1957). The estimated consumptive use near the main stem of the basin that occurred during that same period was added to the gaged flow. The sum of those two creates the minimum monthly average flow (1952-1957) used to establish the natural flow expected under the 2% drought scenario. If necessary, adjustments are made for anticipated inflow depletions to a basin, as in the case of the Kansas River basin receiving inflows from Big Blue, Republican and Smoky Hill Rivers. For the Neosho and Marais des Cygnes basins these flow estimates represent the anticipated flow in the basin that would occur under the 2% drought scenario, absent the effects of federal reservoirs on flows. For the Kansas River basin, the estimated flow represents the anticipated flows under that same 2% drought scenario, except that a small portion of the flow is captured in Tuttle Creek's accounting to satisfy water quality concerns in the basin.

## Basin Supply Results

Figure 18, 19 and 20 display the resulting projected surface water supply for each of the basins of interest under a 2% drought scenario.

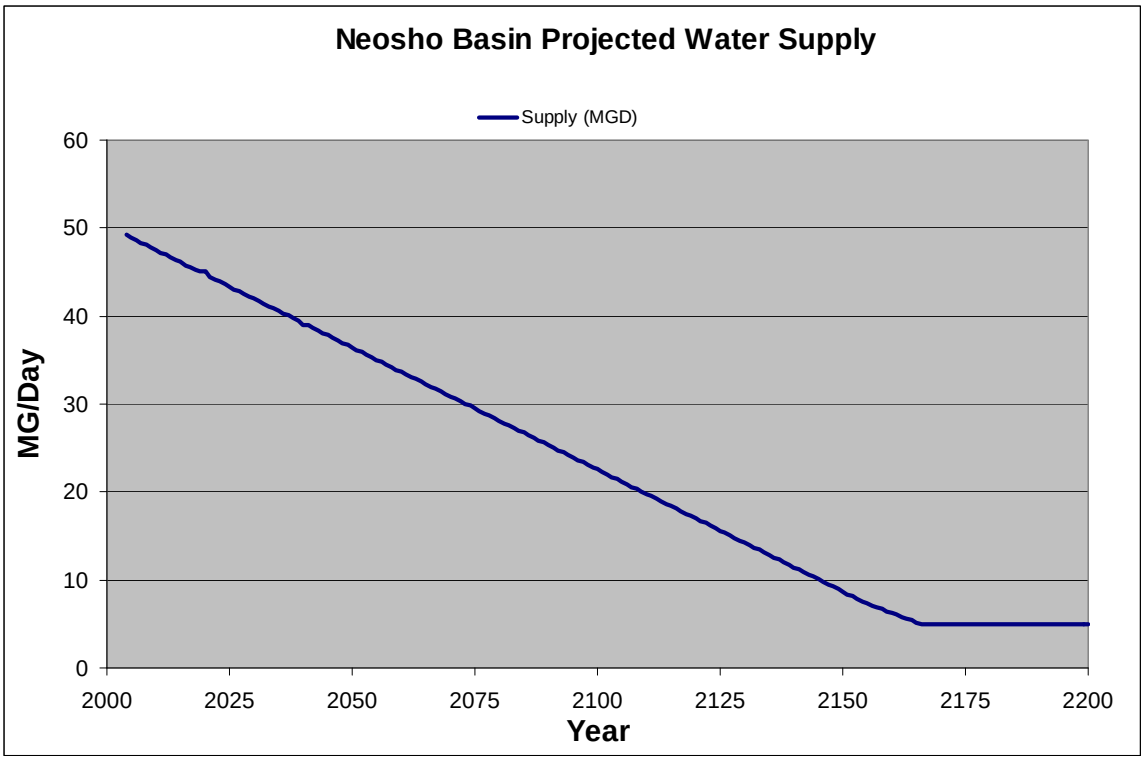



**Figure 18**

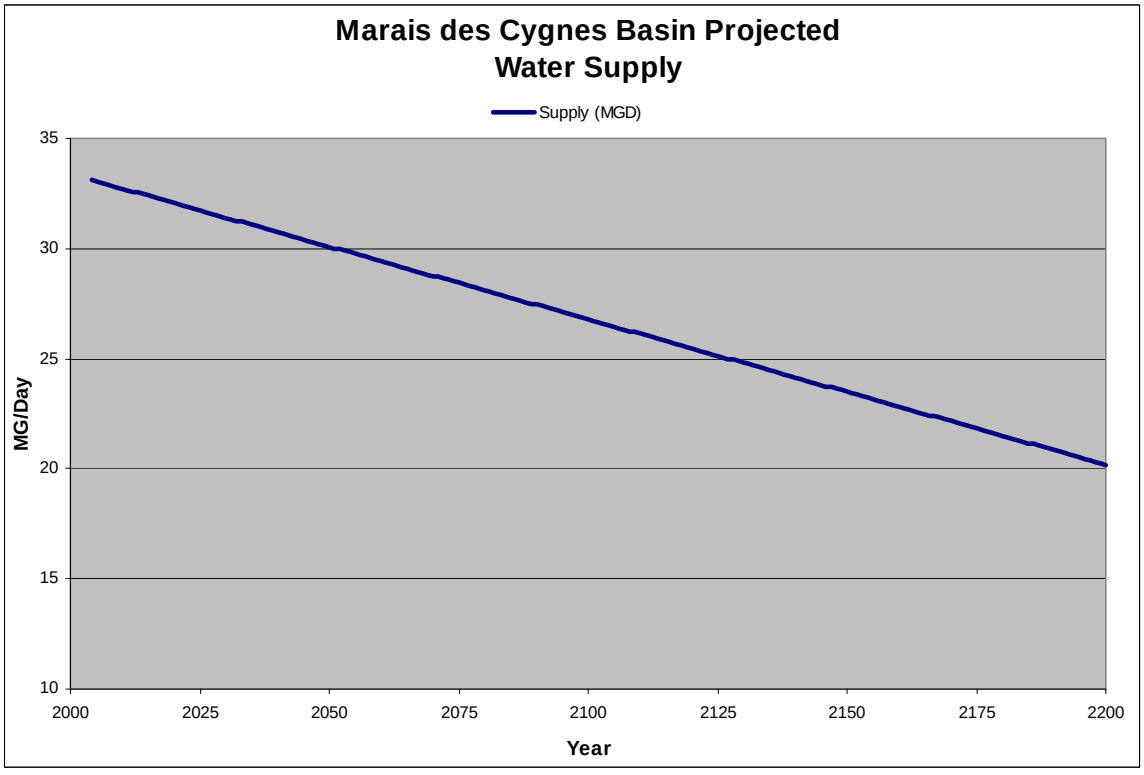



**Figure 19**

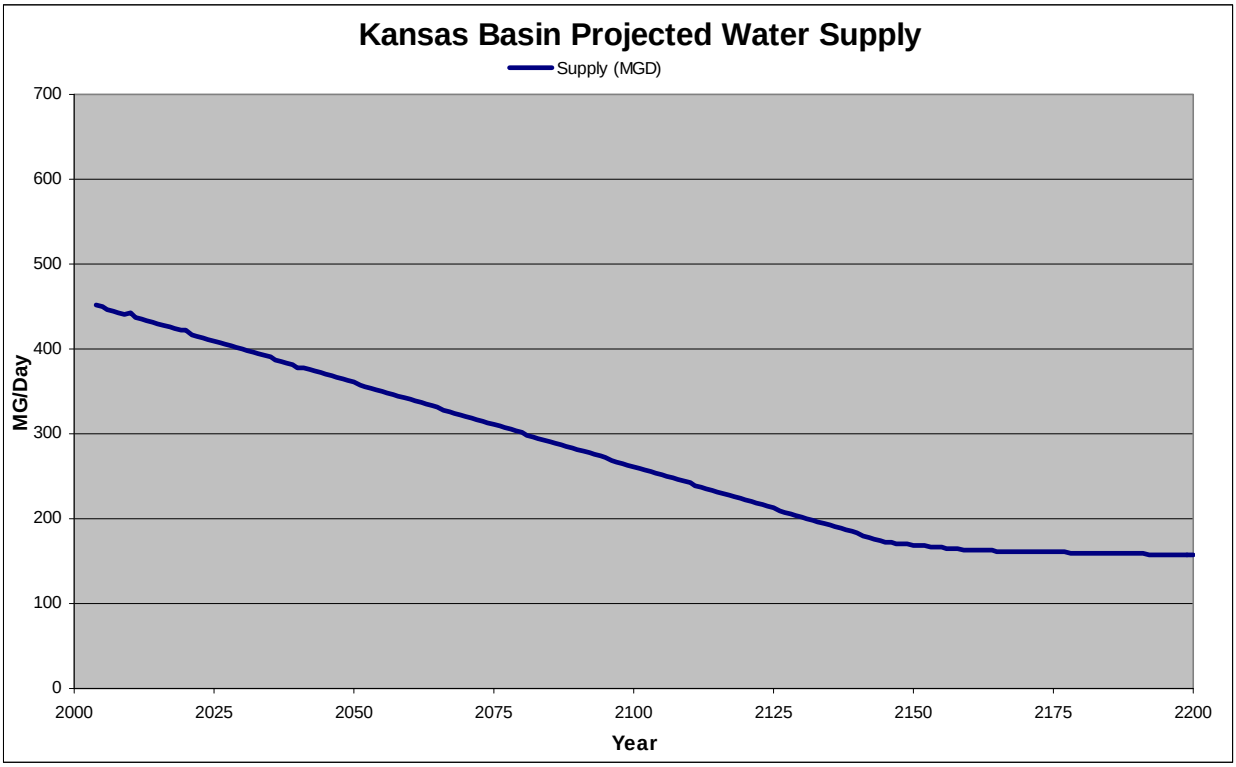



**Figure 20**

## *Basin Supply Estimates by Source*

Figures 21, 22 and 23 display the basin supply estimates broken into source components. The same methodology was used as previously described to estimate individual county demand. Supply sources for each basin are either Federal reservoirs or the 'other' source category which is the natural flows estimate for the basin's main stem.

### Neosho Basin Supply

Figure 21 shows the supply estimates in the Neosho Basin by source. Current sedimentation rates for Council Grove, Marion and John Redmond Reservoirs project all water supply will be lost to sediment deposition by the year 2200. Streamflow minimums for the 2% drought period were established from Parsons, Kansas, where zero flow was noted for 5 consecutive months from 1956 to 1957.

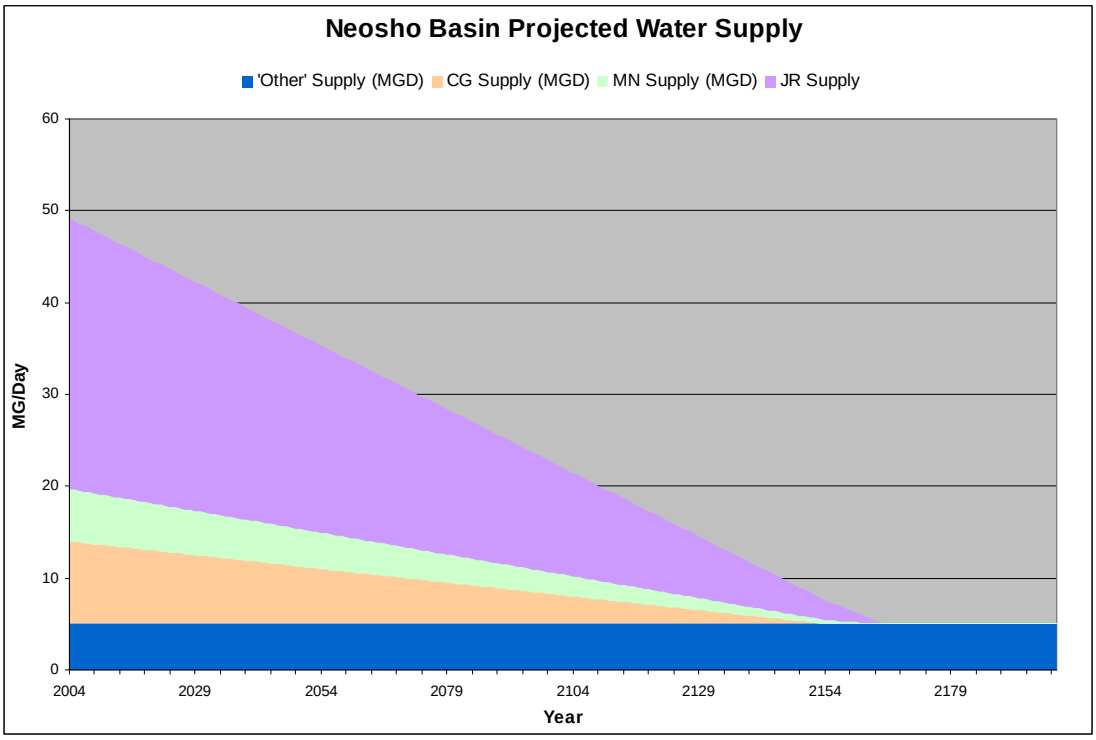



**Figure 21**

## Marais des Cygnes Basin Supply

Figure 22 shows the supply estimates in the Marais des Cygnes basin by source. Current sedimentation rates for Hillsdale, Melvern and Pomona Reservoirs, indicate available (although diminished) yields through the year 2200. Streamflow minimums were established for the 2% drought period from Trading Post, Kansas, where zero flow was noted for 3 consecutive months in 1956.

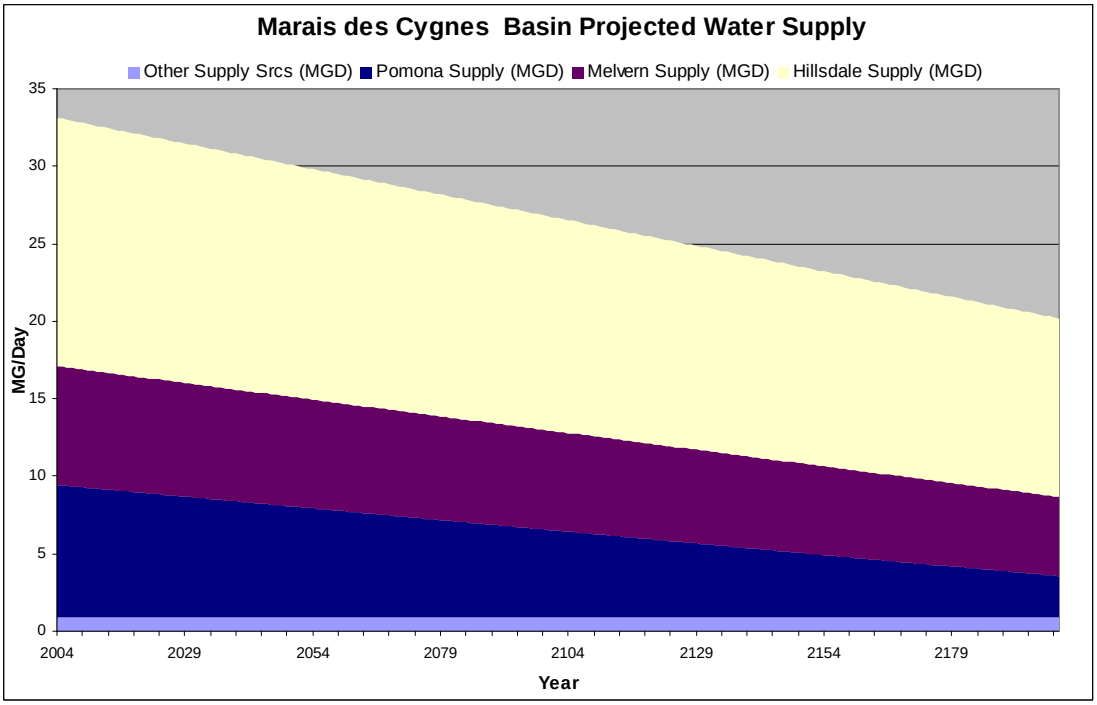



**Figure 22**

## Kansas Basin Supply

Figure 23 shows the supply estimates in the Kansas River basin by source. Current sedimentation rates for Milford and Clinton indicate available (although diminished) yields through the year 2200. The current sedimentation rates for Tuttle Creek and Perry project all water supply will be lost by the year 2200.

Streamflow minimums were established for the 2% drought period from Bonner Springs, Kansas, where a minimum average monthly low flow was noted in January 1957. Only the Smoky Hill, Republican, and Big Blue Rivers had gaged flows in them during that period. Due to inflow depletions on those rivers, it is anticipated that the Smoky Hill and Republican Rivers would have no flow in them under a 2% drought scenario today. The Big Blue should have flow under a 2% drought scenario today, but that flow would be used in the Tuttle Creek reservoir yield accounting procedure to meet in-stream flow demands in the main stem and, as a result, has been purposely excluded from this analysis. The estimated consumptive use from the main stem during January 1957 was estimated at 52 MGD. This consumptive use establishes the supply available from other sources on the Kansas River corridor to meet current/future water supply demand.

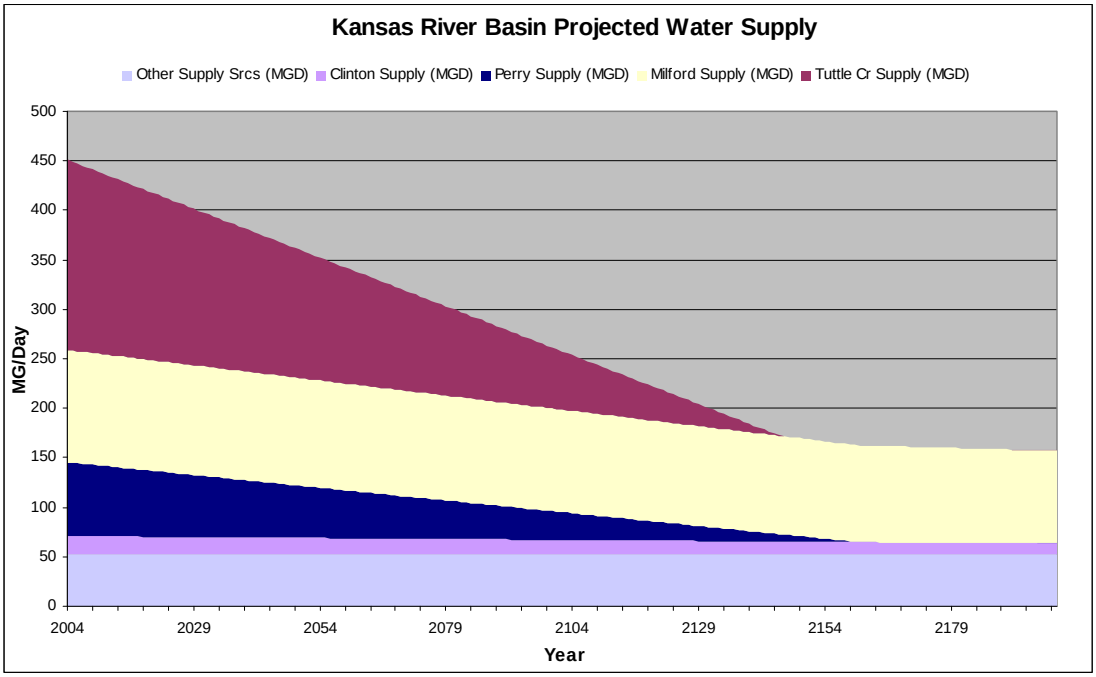



**Figure 23**

# Results

Main stem corridor supply and demand estimates are displayed in Figures 24, 25 and 26 for each of the basins of interest. The basin order of discussion is from expected greatest potential vulnerability to least.

## *Neosho Supply/Demand Estimates*

A 2% drought, such as that experienced during the 1950's, would stress the estimated supply for the Neosho River corridor in the very near future (Figure 24).

Two locations on the main stem are of particular interest.

The first area of concern is at Emporia. The estimated yields of Council Grove and Marion Reservoirs are relatively small in comparison to the yields of other reservoirs assessed in this report. They both have a relatively high sedimentation rate, so the present yields are also expected to decline through time relatively rapidly. At the same time, the projected demand of Emporia is anticipated to increase.

The second area of concern is the demand of Wolf Creek power plant and the rapidly declining water supply yield of John Redmond reservoir.

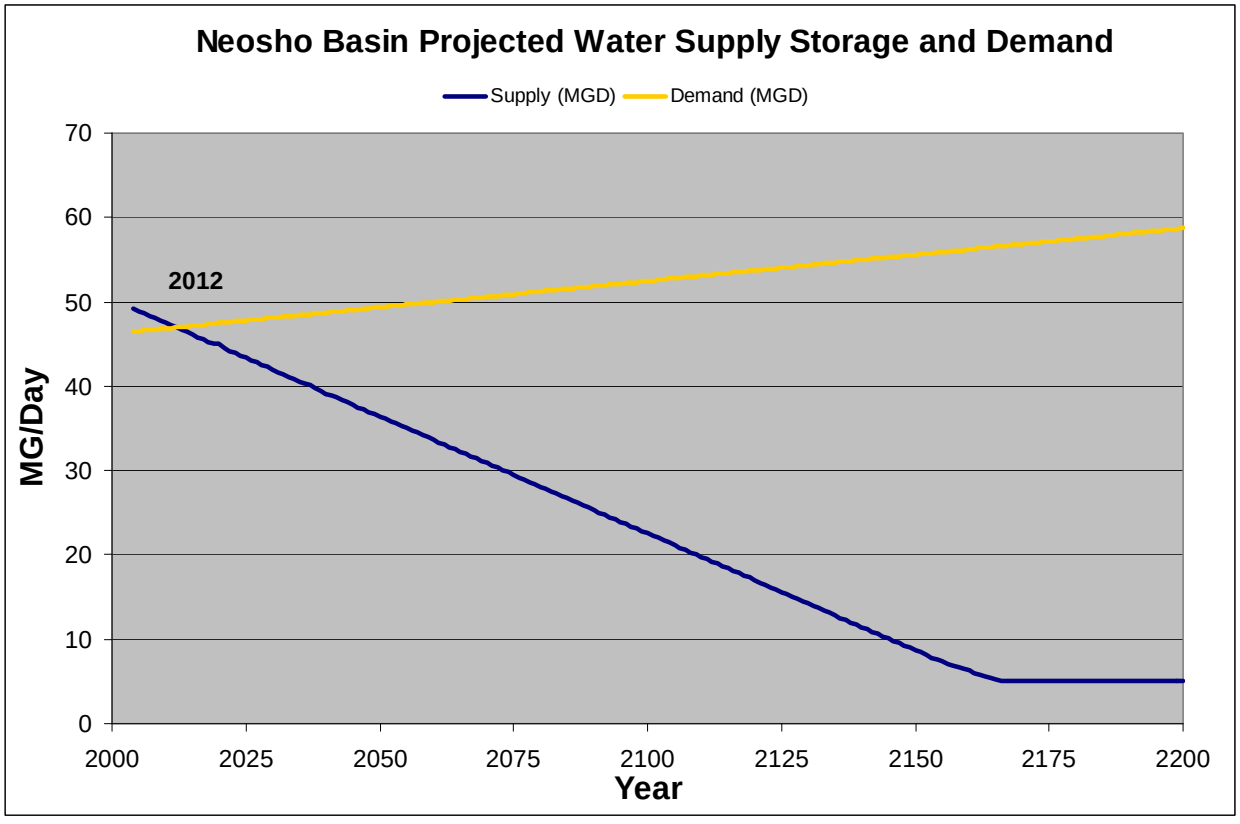



**Figure 24**

## *Marias des Cygnes Supply/Demand Estimates*

On initial review the projected demand on the Marais des Cygnes River corridor could be met by the estimated supply for the Marais des Cygnes River corridor into the next century. However, only 15% of the water supply available in Hillsdale reservoir has been called into service as of 2007. If the supply is adjusted to reflect the amount of supply the state currently has under contract in Hillsdale, a 2% drought would create a potential vulnerability on the supply side of Marais des Cygnes River corridor in the near future (Figure 25).

The area of concern in the basin is related to the anticipated increase in demand from Miami County and the present lack of supply under contract from Hillsdale reservoir. Purchase of the remaining water supply in Hillsdale should reduce the anticipated supply stress in the basin for many years.

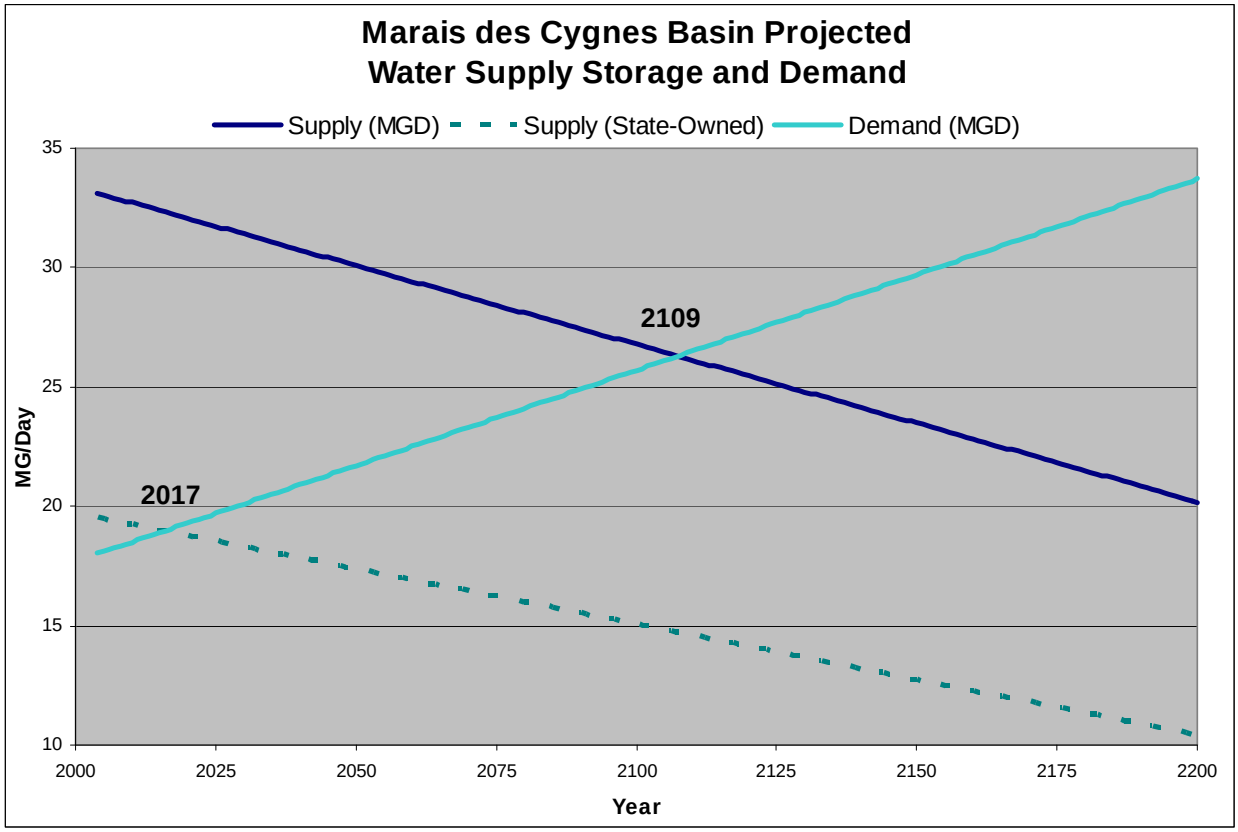



Figure 25

### *Kansas River Corridor Supply/Demand Estimates*

The Kansas River system supply side appears to be the most robust of all basins reviewed in this report. Even under a 2% drought condition, there appears to be adequate supply to meet future demand. Although only one-sixth of Perry Reservoir's and one-third of Milford Reservoir's water supply have been called into service, there still appears to be adequate supply to meet the estimated future demand to 2050 (Figure 26).

Unlike the Neosho and Marais des Cygnes basin, the Kansas basin received significant inflow from three major tributary systems during the historic 2% drought; the Big Blue, Republican and Smoky Hill Rivers. Although the use of natural flows in this analysis is intended to estimate the anticipated flows in the Kansas River if the conditions of the 2% drought would occur in the future, the Kansas Water Office believes that the inflows from those 3 major systems would be less today and in the future than what was observed in the past. This analysis assumes that the Smoky Hill and Republican River inflows have been depleted to the extent that their inflow to the Kansas River would be near zero under a 2% drought scenario. The inflow from the Big Blue River under the drought scenario would serve to meet the in-stream flow demands (not the water supply demands) and has been excluded from the water supply-demand projections for this basin. The effect of these assumptions should be explored in the future under a more sophisticated modeling effort.

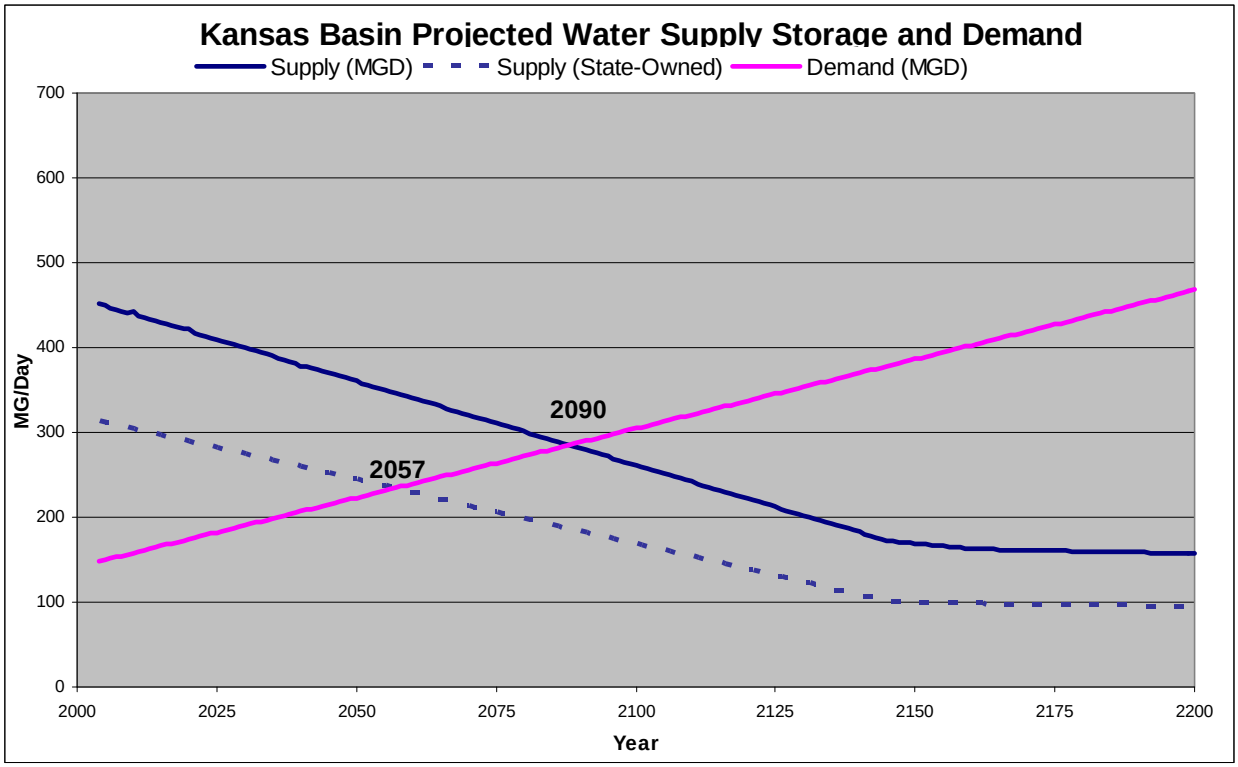



**Figure 26**

## Conclusions/recommendations

The current supply-demand model of the Kansas, Neosho and Marais des Cygnes basins has been created from the best available information at this time. However, peak demand and supply issues could not be reviewed for potential vulnerabilities including spatial supply-demand issues at multiple points along the main stem and primary tributaries. The interaction between and

effects upon water supply and water quality pools in federal reservoirs at meeting the water supply and in-stream flow demands on each of those pools was also not within the capability of the simplified assumptions in this current analysis.

A more complex model is needed to further refine projections and situations where anticipated demand may exceed supply on a more local scale.

### *Neosho River Basin*

Because of the potential lack of supply and the current demand projections, opportunities to enhance supply and manage demand should be explored immediately in this basin.

### *Marais des Cygnes River Basin*

Because of the current demand projections, opportunities to expand supply, specifically calling the remaining water supply yield of Hillsdale Reservoir into service, should also be explored within the next 5 years.

### *Kansas River Corridor*

The Kansas River corridor appears to have adequate surface water supply to meet the anticipated and significant demand increase through 2050.