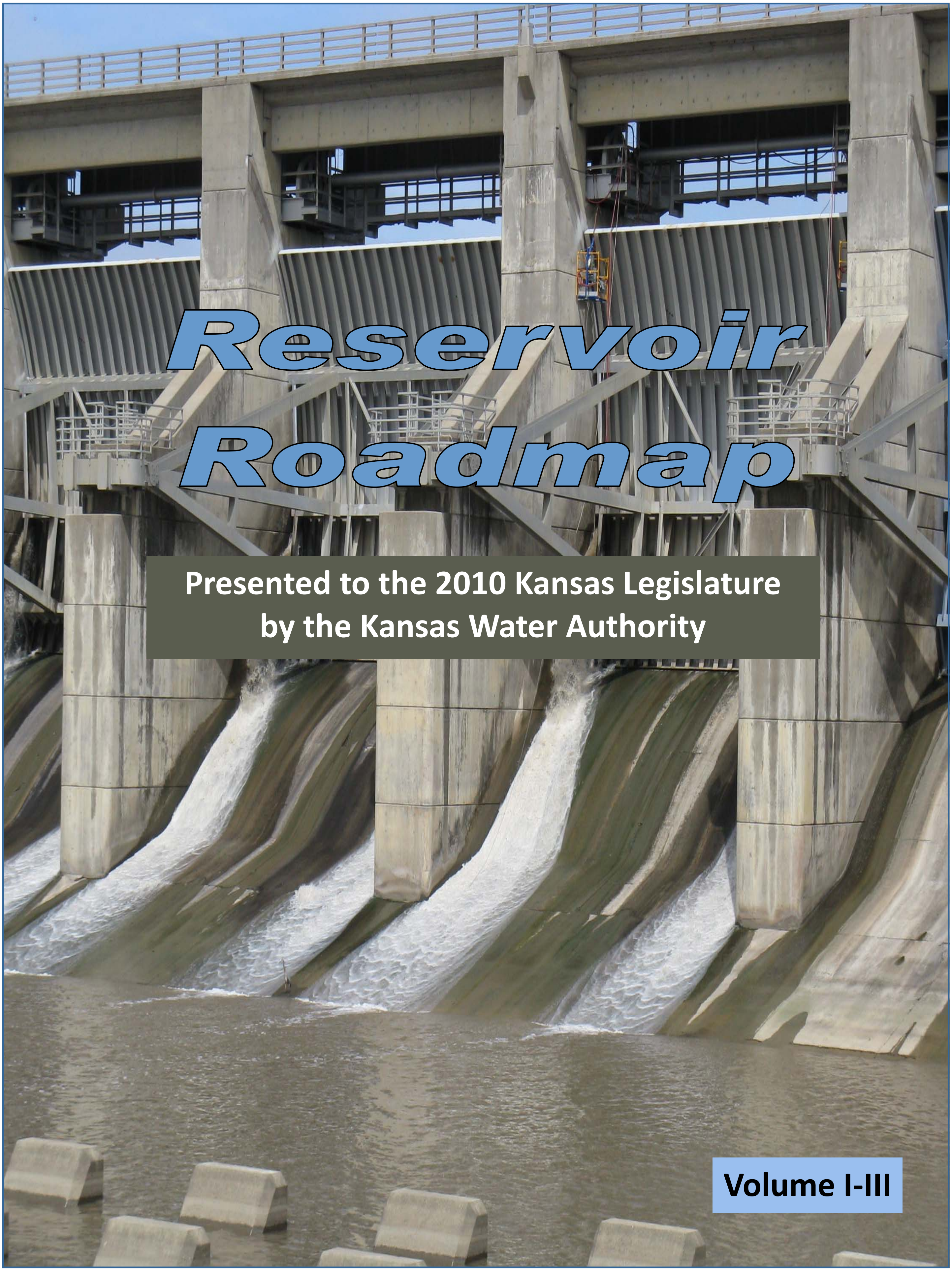

Reservoir Roadmap

Presented to the 2010 Kansas Legislature
by the Kansas Water Authority

Volume I-III

Front cover: Structural restoration of the gates at John Redmond Reservoir may help reduce water loss. ***Photo courtesy of KWO.***

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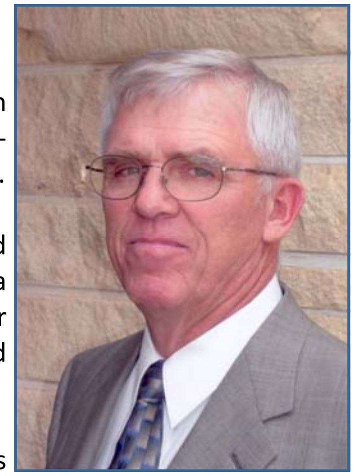


Dear Members of the 2010 Kansas Legislature, Vision 2020 Committee,

It is my pleasure to present to you the *Reservoir Roadmap* as directed by this committee in January 2009. This report outlines the actions necessary to insure an adequate future water supply for areas currently or potentially served by federal, state or municipal reservoirs.

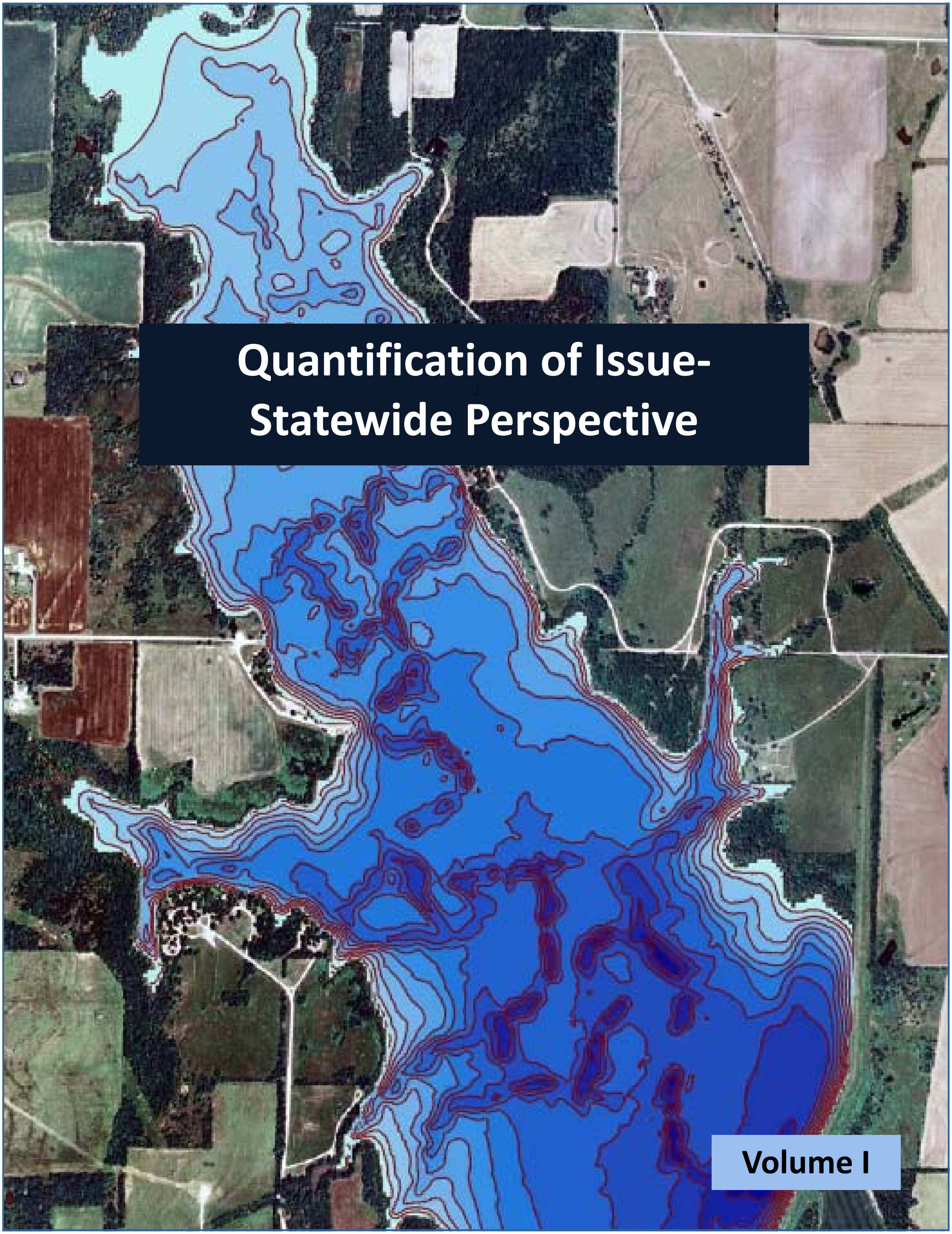
Preparation of this report was truly a collaborative effort with significant input, time and staff talent from many of the state and federal natural resource agencies. Developing a *Reservoir Roadmap* provided a unique opportunity to comprehensively address reservoir issues of securing storage to meet growing demands, protecting it from sedimentation and restoring the capacity that has been lost.

The Reservoir Roadmap describes the current condition of our water supply and outlines the recommended actions to secure, protect, and restore this supply in the Neosho basin. Implementation of these actions will require statutory changes and dedicated financial resources. In a year when the nation's economy and our state government's budget is limited and stressed, we must not lose focus on the long-term financial commitment needed to address water supply sustainability in Kansas. Healthy water resources are essential to providing for a stable and growing economy.

On behalf of the Kansas Water Authority and the state's natural resource agencies, we look forward to working with you on actions that will benefit the state's water storage and Kansas citizens.

Steve Irsik, Chairman
Kansas Water Authority

Quantification of Issue-Statewide Perspective



Volume I

EXECUTIVE SUMMARY

Following is the first of three volumes that comprise the Reservoir Roadmap. Volume I includes a statewide overview of the current conditions and future impacts to areas currently or potentially served by federal, state or municipal reservoirs in Kansas. Information in this volume is organized into five chapters, reflecting the major categories of conditions and impacts: data, supply and demand, water quality and recreation, flood protection, and irrigation.

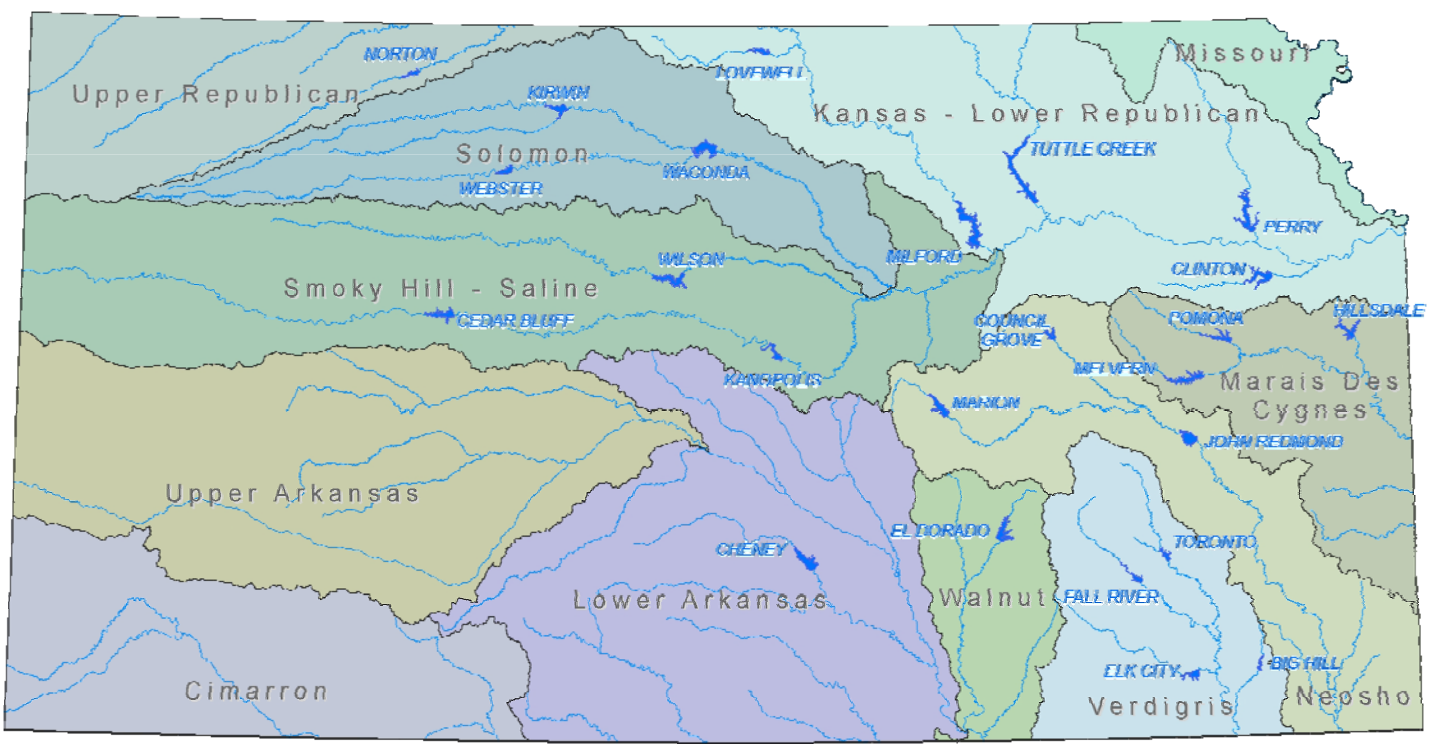
Data Collection, Storage, Analysis, and Dissemination. This chapter identifies and prioritizes the needs and opportunities to systematically integrate the data collection, storage, analysis, and dissemination activities of state and federal agencies and identifies data gaps regarding reservoirs.

Supply and Demand Projections. This chapter provides preliminary supply and demand projections for each of the state's major river basins that have significant municipal reservoir water supply and a prioritization for further action.

Water Quality and Recreational Impacts. This chapter identifies known water quality and recreation impacts caused by sedimentation in federal, state and municipal reservoirs.

Flood Protection Impacts. This chapter identifies potential impacts to flood protection caused by sedimentation.

Irrigation Impacts. This chapter identifies the impacts of sedimentation on irrigation supplies stored in federal and other reservoirs.



The research and background provided in Volume I lay the foundation for the budget and regulatory recommendations provided in Volume II. Many of the issues described broadly within this Volume will be explored in greater detail in Volume III: Basin Approach to Reservoir Sustainability.

INTRODUCTION

Multiple federal and state agencies in Kansas are responsible for collection of water quantity and quality data at or above water supply reservoirs and lakes. Following is a summary of data collected by each agency and a discussion of opportunities for improved collaboration and sharing. While the data related to reservoir sustainability are extensive in Kansas, some data gaps have been identified. These data gaps and a discussion of their impact on water resource decision making are included in this section.

OVERVIEW

Accurate and timely data is crucial to both planning and management of water resources in Kansas. Basic analysis and research is coordinated through the water planning process and the Kansas Water Authority (KWA). All state agencies with water resource responsibilities target data collection and analysis on high priority water resource issues in support of the *Kansas Water Plan* (KWP).

It is a policy of the state that all state agencies with responsibilities affecting water resources of the state shall carry on basic data collection, research and analyses concerning matters relating to the water resources of the state. It is a policy of the state that the Kansas Water Office (KWO) to review and coordinate financial assistance for research that may be provided by federal or state agencies to public corporations concerned with management, conservation and development of water resources to prevent duplication of effort (K.S.A. 82a-901 *et seq*). The KWO has a mandate to collect and compile information pertaining to a wide range of water issues and, in so doing, collect and compile information obtainable from other agencies, instrumentalities and political subdivisions of the state and the federal government (K.S.A. 74-2608 *et seq*).

DATA COLLECTION

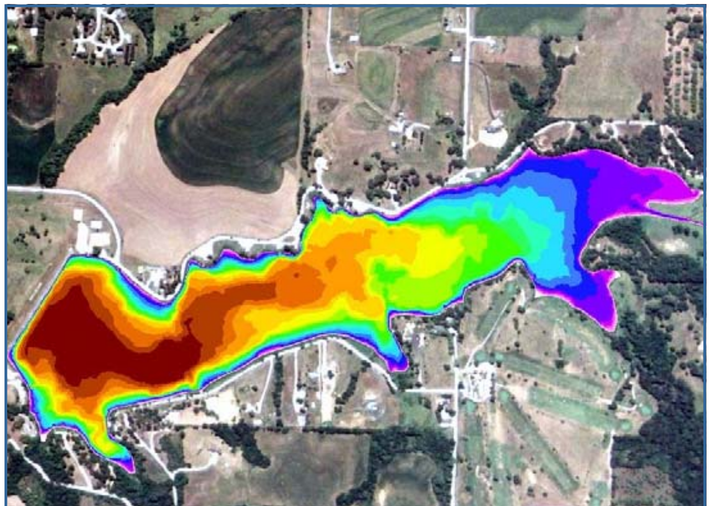
Following is a summary of reservoir and/or watershed related data collected by the federal and state natural resource agencies in Kansas.

Kansas Water Office (KWO)

The KWO collects a limited amount of water use information from holders of Water Marketing Program contracts. This information shows amount of water directly withdrawn from reservoirs each year. This information is used for contract compliance and is provided to the U.S. Army Corps of Engineers (Corps) to be combined with other reservoir information.

Kansas Biological Survey (KBS)

In 2006, the KBS initiated a Bathymetric Survey Program. This program is conducted in cooperation with the KWO and other local and state agencies. The survey program measures reservoir storage capacity and sediment accumulation. Data from this program are used to estimate the sediment rate in Kansas reservoirs and the chemical composition of the sediment that has been deposited.



Bathymetric survey of Mission Lake.

Kansas Geological Survey (KGS)

The KGS conducts geological studies and research to collect, correlate, preserve and disseminate information leading to a better understanding of the geology of Kansas, with special emphasis on water quality and quantity. While much of the KGS research is targeted towards ground water evaluation, often the research directly supports decision making on reservoir operations. For example, in 2008, KGS developed a numerical ground water model used by the KWO as a component of a larger, comprehensive review of the regional water supply in the Smoky Hill River basin, which includes Kanopolis Reservoir.

Kansas Department of Health & Environment (KDHE)

Water quality in flowing streams is measured primarily by the KDHE. KDHE collects grab samples at established sites on a rotational basis to determine water quality conditions and any changes that may be happening over time. This information is used to prepare biennial reports on the status of water quality, develop listings of impaired waters and the total maximum daily loads (TMDL) necessary to restore those waters, support limits and conditions of National Pollutant Discharge Elimination System (NPDES) permitting, inform Watershed Restoration and Protection Strategy (WRAPS) and other local groups on the condition of waters in their respective watersheds, support decisions on targeting non-point source abatement efforts and evaluate ongoing management program efforts in improving water quality.

Information on the quality of water in reservoirs is also collected by KDHE. This information is used in conjunction with stream information to determine reservoir loading and contaminant sources. Reservoir information of note include surface and near-bottom nutrient concentrations, chlorophyll-*a* concentrations, composition of algal communities, Secchi disk depths, measures of turbidity, total suspended solids and depth of photosynthetically available radiation, and temperature and dissolved oxygen profiles. These data also provide the foundation for the water quality management programs previously mentioned.

Kansas Department of Agriculture-Division of Water Resources (DWR)

The DWR collects information each year about water use in Kansas. Information for the previous calendar year is self-reported by each water right holder in Kansas by March 1. This information is used for water right compliance. When combined with water level measurements, these data can be used for multiple analyses related to aquifers and ground water movement in Kansas. This information also helps support demand & supply availability projections.

Kansas Department of Wildlife and Parks (KDWP)

Aquatic species monitoring is used to determine the relative water quality and changes that may be happening to the overall biological stream community. Monitoring is conducted by KDWP, KDHE and university researchers at Kansas State University (KSU), Kansas University's KBS and other regents' institutions.

U.S. Army Corps of Engineers (Corps) and U.S. Bureau of Reclamation (Bureau)

The Corps and the Bureau operate 24 federal reservoirs within the state of Kansas. For each of these reservoirs the respective federal agency collects daily information regarding lake surface elevation, water in storage, releases, evaporation and inflow. This information is used by state and federal agencies for reservoir operations as well as analyses of flood risk and reservoir yield. The Corps also maintains data on water quality and historic bathymetric surveys.

Weather Station.

U.S. Geological Survey (USGS)

Flow and stream surface elevation is automatically collected at 170 locations by gages maintained and operated by the USGS. A number of these gages (147) are operated in conjunction with state and local cooperators. This information is supplied in near real time to the Internet through satellite uplink. Stream gage data are used for flood forecasting, reservoir operations, water right administration, water quality monitoring and interstate compact compliance, in addition to other uses. Long-term stream gages provide the ability to complete analyses of changes in the hydrologic system in response to management or watershed changes. The USGS also has established a few continuous real time water quality monitoring stations in Kansas. This information is used to support TMDL development as well as measure impacts of management practices.

USGS collects bathymetric data to determine reservoir storage capacity and sediment accumulation. In addition, USGS conducts analyses to determine sources of sediment and trends in chemical occurrence in sediments. Real-time estimation of algal taste and odor and analysis of algal toxins is conducted by USGS.

Other

Information about precipitation, wind speed, temperature and other atmospheric conditions is measured at numerous weather stations throughout the state. These stations are operated by several government agencies for a variety of purposes. Agencies involved in this effort include the National Weather Service (NWS), the United States Department of Agriculture Natural Resources Conservation Service (NRCS), KSU, the Kansas Department of Transportation and local groundwater management districts.

In addition to automated airport stations, the NWS maintains a volunteer Cooperative Observer Program. Some of these stations, most of which are not automated, have been in operation for over 100 years. KSU operates a network of 14 automated weather stations located at KSU agricultural experiment stations. KSU also provides operation and maintenance for 16 additional automated stations that provide data primarily for irrigation scheduling.

Development of a multi-purpose Kansas Meso-scale Network (Mesonet) of automated stations was initiated in 2008. Mesonet stations eventually will be deployed in all Kansas counties. KSU will operate and maintain this network which is intended to identify weather conditions on a scale from several to a few dozen miles.

DATA STORAGE

Data Access and Support Center (DASC)

DASC was created by the State of Kansas, Geographic Information Systems (GIS) Policy Board. This board was established by the Governor in 1989 to develop Kansas GIS technology management policies and direct the Kansas GIS Initiative. The GIS Policy Board consists of directors of the major state, federal, and local agencies that are utilizing GIS technology.

One of the issues this board faced was an access policy for the growing core database being developed by the Kansas GIS Initiative. The Kansas GeoDatabase is a collection of various digital spatial information that is necessary to conduct spatial analysis. The GIS Policy Board realized that a central delivery and distribution center for core GIS databases was essential to ensure the effective and efficient development and implementation of GIS technology in state government. DASC was established in 1991 to administer access to the core database.

Cooperation between agencies in Kansas has led to the development of a sizable core database. The GIS Policy Board has a budgeted fund allocated in the KWP to help acquire the necessary layers of information. Currently data are being acquired and developed for Kansas from various federal, state and educational institutions. They are stored in several computers at DASC awaiting distribution.

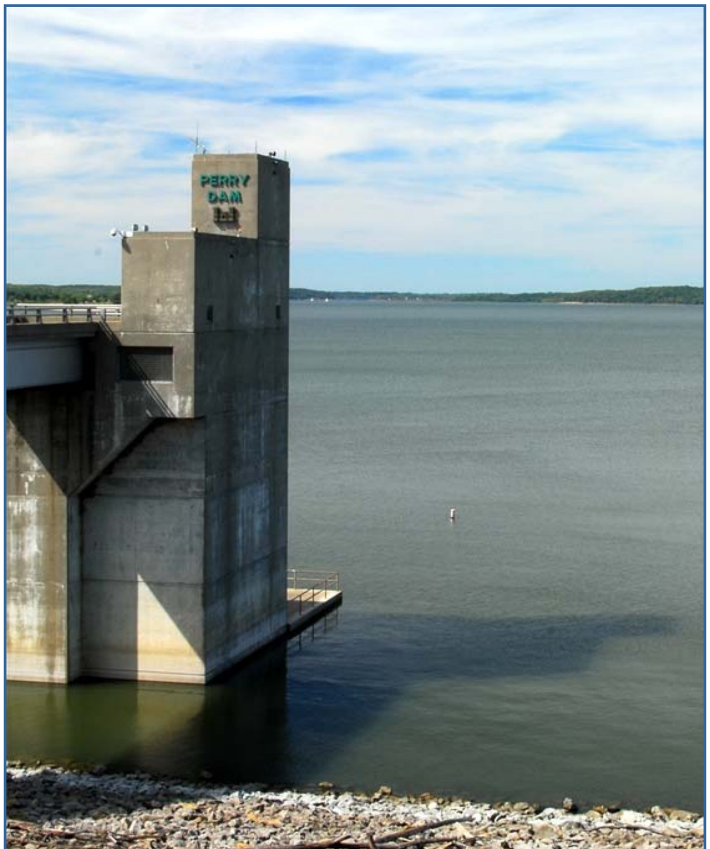
DASC is a cooperating member of the National Spatial Data Infrastructure (NSDI). DASC's node contains Federal Geographic Data Committee (FGDC) compliant metadata, File Transfer Protocol (FTP) access, search capabilities and metadata submission capabilities.

DASC has five basic functions associated with its task of maintaining the Kansas GeoDatabase. DASC services were intended primarily for the member agencies of the GIS Policy Board, but are provided to all other governmental and public organizations as a state service. Below are the basic services DASC offers:

- Receive, archive and catalog all core databases. Maintain associated documentation and information.
- Check and verify integrity of data to ensure they meet GIS Policy Board database standards.
- Convert and transform databases to varying software formats.
- Distribute databases as requested and handle inquiries for DASC services.
- Promote and assist the use of the core database and GIS technologies and produce the state GIS newsletter.

These are the services that are currently being offered. In years to come, DASC hopes to provide more services. If additional funding can be acquired, DASC would expand its services to provide more user support as GIS systems are very complex and require dedicated qualified personnel to support their operation. Ideally, DASC would provide training for various GIS systems, assist in map production and help trouble-shoot software deficiencies.

As a component of the *GIS Business Plan: Improved Elevation Data for Statewide Applications*, the GIS Policy Board recommended a phased approach for developing data products from base Light Detection and Ranging (LiDAR) data for Kansas. As described in the plan, the program would span a seven-year cycle to fully cover the state with improved elevation data and related product deliveries. The plan has not been implemented due to the current economy; however, several smaller projects have been developed through multi-agency partnerships. The Kansas River corridor project was completed in 2008 and included partial acquisition of LiDAR data for Geary, Riley, Pottawatomie, Wabaunsee and Leavenworth counties and full acquisition in Shawnee, Douglas, Jefferson, Wyandotte and Johnson (access restricted) counties. A LiDAR project for Sedgwick County has been completed. A third LiDAR project currently underway covers Republic, Clay, Washington and Cloud counties. Through a partnership with USGS, NRCS and DWR, the Corps Kansas City District plans to collect LiDAR in Marshall, Riley, Atchison, Leavenworth, Miami, Osage, Harvey and possibly Geary counties. Finally, with funding provided through the American Recovery and Reinvestment Act, the Corps will be collecting LiDAR at several of the federal reservoirs in Kansas.



Perry Reservoir. Photo courtesy Dennis Schwartz.

STOrage and RETrieval (STORET)

STORET is a U.S. Environmental Protection Agency (EPA) database of ambient environmental data relating to water quality. The original STORET was developed in the 1960s, and today the system continues to serve as EPA's principal repository for marine, freshwater and biological monitoring data. STORET is currently used by a variety of groups, including KDHE and the Corps. The Corps maintains water quality data collected prior to 1995 in STORET. Water quality data obtained by the Corps between 1995 and 2008 are stored on an internal server and shared with KDHE.

STORET provides a nationally consistent framework for water quality data. This common framework enables users to share data across multiple organizations. Once data are entered into STORET, agencies will always have access to their data in the event of internal data losses. STORET is maintained by EPA (http://www.epa.gov/storet/). The latest EPA water quality database, Water Quality Exchange (WQX), will supplant STORET and is expected to be populated with Kansas data from 2002 to present sometime in 2009.

Reservoir Sedimentation Survey Information System (RESIS) Database

The RESIS database, originally compiled by the Soil Conservation Service (now NRCS) in collaboration with the Texas Agricultural Experiment Station, is a comprehensive compilation of data from reservoir sedimentation surveys throughout the U.S. The database is a cumulative historical archive that includes data from as early as 1755 and as late as 1993. The 1,823 reservoirs included in the database range in size from farm ponds to the largest U.S. reservoirs (such as Lake Mead). Results from 6,617 bathymetric surveys are available in the database. The USGS will soon be maintaining this national reservoir sedimentation database.

National Water Information System (NWIS)

The USGS collects and maintains a national database of water information, the NWIS. This information ranges from streamflow measurement, to lake levels and ground water levels in certain cases. This information is readily accessible on the internet.

Data Resources Library

The Data Resources Library housed at the KGS is the state's repository for water well records. Documents are available to the public at the library or through the KGS website.

Weather Data Library

KSU maintains a Weather Data Library within its Department of Agronomy. The library serves as a repository for the weather data observed within the state. It is affiliated with the High Plains Climate Center and the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center. Information available from the Weather Data Library comes from a number of sources and is delivered to a wide variety of clients through either the internet or customer inquiry. The State Climatologist oversees the library.

DATA ANALYSIS

Research is primarily carried out at the Kansas Board of Regents universities and by federal agencies. Statutory guidance indicates that it is the responsibility of the KWO to coordinate and guide data collection and research toward issues of importance within the KWP.

The state develops and supports research, through the Kansas Water Resources Institute (KWRI), on high priority water resource issues and objectives of the state, as identified through the state water planning process. The KWRI fosters the dissemination and application of research results, and facilitates effective communication among water resource professionals in Kansas.

The KWRI was established in 1965 as part of the Water Resources Research Act. It is a component of a national network of water resources institutes in every state and trust territory of the U.S. The Institute supports research through a competitive grant program. KWRI distributes and applies research results through conferences, briefings, white papers and newsletters. The Institute also helps sponsor the annual Water and the Future of Kansas conference.

Each of the Governor's Natural Resource Subcabinet agencies conducts water resources research to support the agencies' missions. In addition, the KGS and KBS serve as research resources to the state. Both agencies are non-regulatory and non-degree granting research and service units of the University of Kansas (KU).

In 2006, the Applied Science and Technology Reservoir Assessment (ASTRA) initiative was created at the KBS in response to the need for information regarding the status and conditions of Kansas reservoirs. The Kansas Applied Remote Sensing (KARS) Program is a research program of the KBS that conducts research on environmental and agricultural applications of remote sensing technology.

Several federal agencies contribute water resources research to the state of Kansas including the USGS. Through the Kansas Water Science Center, the USGS conducts and produces publications about water resources.

Six state universities, 19 community colleges and a municipal university in Kansas conduct research that directly supports the goals and objectives of the water resource agencies in the state.

DATA SHARING

Water quantity and quality data are generally shared among natural resource agencies through the above mentioned data access sources or via direct requests to the collecting entity. For the general public, data are generally accessed through open records requests to minimize unmanaged access to data and improve data security and quality assurance/quality control. While respecting concerns for security and quality, Kansas should pursue one consolidated data clearinghouse for reservoir water supply. Providing streamlined access to these data will greatly enhance and improve decision making.

Central Plains Center for BioAssessment (CPCB)

CPCB is a non-regulatory and non-management aquatic research organization nested within the KBS at KU. It was created in 1998 to assist with the coordination of regional based nutrient criteria and biocriteria for water bodies in the EPA Region 7 (which covers Iowa, Kansas, Missouri and Nebraska). CPCB works to provide scientific expertise on aquatic resources of the Central Plains Region of the U.S.

Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)

CUAHSI is an organization representing more than one hundred U.S. universities which receives support from the National Science Foundation to develop infrastructure and services for the advancement of hydrologic science and education in the U.S. The CUASHI Hydrologic Information System (HIS) provides web services, tools, standards and procedures that enhance access to hydrologic data. Currently, Kansas does not participate as a CUASHI-HIS member.

KSU is a member of CUASHI and a Cooperating User of HIS, working with the HIS team to foster implementation of HIS in Kansas. Towards this end, K-State hosted the KS HIS workshop in March 2009 with participation of the Kansas DWR, KWO, KDHE, KGS and KBS. In this workshop, agency representatives learned how HIS works, and over the 1.5 day workshop actually uploaded Kansas data to the HIS and learned how to access and use this data through a variety of tools.

Following this meeting, KSU has established pilot web services for KWO reservoir data, the Kansas Weather Data Library and Groundwater Management District #4 (GMD4) observation wells. These services enable agencies and stakeholders to evaluate the potential of HIS to host, serve and provide access to information necessary for hydrologic studies using time series data related to federal reservoirs.

DATA GAPS

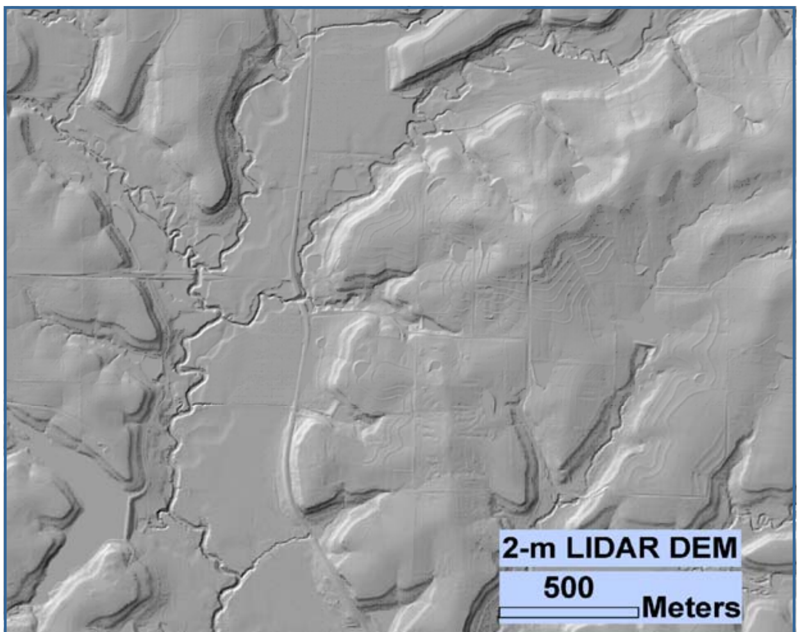
While the data currently collected in Kansas related to water supply are extensive, gaps in these data necessary to make informed decisions about the future of our infrastructure still exist. These data gaps include:

- Information about when sediment has been contributed to the reservoir historically (Sediment Aging). This information could be used to prioritize reservoirs in need of restoration and evaluate effectiveness of Best Management Practices (BMPs);

- Continuous, long-term updates of bathymetric surveys to identify sediment yields;
- Evaluation of additional constituents in sediment cores;
- Ground water/surface water interactions and transmission loss and their impact on reservoir inflows and release delivery downstream;
- Impact of climate change on reservoir operations, evaporation, flood capacity and future sedimentation rates;
- Historic changes in land use and adoption of BMPs should be characterized by watershed to identify how and when changes likely impacted sedimentation;
- Update statewide map of sediment yields. The map and corresponding study were originally created in 1965 by the predecessor to the KWO, the Kansas Water Resources Board. It is based on data provided by the Soil Conservation Service, USGS, Corps and Bureau. The map identifies sediment yield in Kansas using available information on areal geology, topography, soil characteristics, precipitation and runoff. The report also compares this surface information to reservoir sedimentation and measured suspended sediment loads in streams. The map and report should be updated with current soils and precipitation information and more current reservoir sedimentation and suspended sediment data;
- More extensive coverage of LiDAR to provide data on changes in stream corridors, gully formation and other factors that may impact a landscape contribution of sediment;
- Evaluate in-reservoir management practices effective in reducing sediment deposition. Identify portion of sediment load in water column attributable to resident deposition re-suspension and compared to recently delivered watershed sources;
- Determine the amount of sediment (legacy load) in a riparian/alluvial system and the amount of time expected before that sediment is flushed downstream; and
- Most local communities that treat and distribute public water supply have historic and current data on use, facility changes, water quality analysis, etc. The means by which these data have been stored and archived varies greatly. Collecting this information into a more accessible format could be useful for water resource agencies and researchers.

RECOMMENDATIONS

1. Conduct annual meetings with agencies identified in this section to collaborate on reservoir data sharing, collection and storage. These meetings should be coordinated through the KWO, consistent with its water resource planning and coordination authorities.
2. Establish protocols to provide access to reservoir-related reports, water quality and quantity data, bathymetric surveys, etc. for researchers and water resource agencies.
3. Complete bathymetric surveys of water supply reservoirs and develop a plan for continuous updates.
4. Implement the GIS Policy Board recurring 7-year cycle of LiDAR acquisition. As opportunities and funding are made available for additional LiDAR acquisition, target flyovers to high priority reservoirs and watersheds.
5. Update the statewide sediment yield map originally created in 1965.
6. Prepare a data development and research analysis plan to address the gaps identified above. The plan should include a schedule for completion and associated costs.
7. Continue to implement the research recommendations outlined in the 2006 Sediment Management Strategy.



LiDAR photo.

INTRODUCTION

The surface water demand and the supply, to meet that demand, have been reviewed for the main stem river corridors in five Eastern Kansas basins. For the severe drought scenario reviewed in this assessment, three of the five basins show some supply vulnerability within the next 15 years. In order of most vulnerable to least, the supply-demand findings were: Neosho, Marais des Cygnes, Walnut, Verdigris and Kansas River corridors.

A more complex model is needed to further refine projections and situations where projected demand may exceed supply on a more local scale within each watershed. The priority for enhanced model review was established by the analysis contained in this report. Opportunities for new supplies should be explored for the Neosho, Marais des Cygnes and Walnut River basins. Demand management should be a review component in these basins, especially for drier than normal climate conditions.

The Kansas Water Office (KWO) oversees the Water Marketing and Water Assurance programs. 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) municipal and industrial water supply needs. The purpose of the Water Assurance Program is to assure adequate supply from that water supply storage to meet downstream municipal and industrial needs during times of drought.

With the purpose of these two programs in mind, in 2006 the KWO initiated a review of surface water supply and demand in five basins in eastern Kansas. The intent of the analysis was to identify future potential surface water supply vulnerabilities along main stem river corridors in select eastern Kansas basins. The supply/demand projections derived in this report are for a severe drought condition 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.

Surface water demand estimates are a linear projection of the sum of those two types of demand for each basin of interest in eastern Kansas.

Municipal Demand Projection

State certified county level population projections were obtained from the Division of Budget (DOB). The DOB population projections did not go beyond 2027, so for each county in Kansas, 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 2027 into the future.

Surface water demand from the population projections is based on municipal water use (as gallons per capita per day usage (GPCD)) reported to the Kansas Department of Agriculture, Division of Water Resources (DWR) for 2000 through 2004 by suppliers in the region for each study basin.

In previous KWO municipal water demand projections, the method of estimating demand emphasized the use of the average 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 drive a significant portion of the GPCD in certain months, were not considered in the context of whether the period was normal, wet or dry. In 2006, KWO revised the method to emphasize the GPCD usage that can be expected under much drier than normal (drought) climatic conditions.

Milford Reservoir.

The revision to estimating GPCD usage was accomplished by first dividing the DWR regions into a north and south sub-region to enhance 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 of monthly totals.

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 a seasonal precipitation regression equation developed for each sub-region. The GPCD for this 'dry' condition was then applied to the estimated total population for a basin to estimate the expected future municipal water demand.

Due to the limitations imposed by the DOB population data, population projections could only be developed at the county level. Therefore, entire counties were assigned to eastern Kansas basins under study. Counties were assigned to basins based upon predominance of area *and* existence of larger incorporated areas within a particular basin. The Kansas River corridor from Junction City to the state line included Geary, Riley, Pottawatomie, Wabaunsee, Shawnee, Jefferson, Leavenworth, Douglas, Johnson and Wyandotte counties. The counties assigned to the Marais des Cygnes corridor were Osage, Franklin, Miami, Anderson and Linn. The Neosho included Marion, Morris, Chase, Lyon, Coffey, Woodson, Allen, Neosho, Crawford, Labette and Cherokee counties. The Verdigris counties were Chautauqua, Elk, Greenwood, Montgomery and Wilson. The Walnut basin was Butler and Cowley counties.

Based upon input and review from the Technical Advisory Committee assembled to review the demand projection method and discussions with interested parties, modifications were made to the initial list of county assignments. For the Neosho River surface water assessment, Crawford and Cherokee counties were excluded from the assessment due to the distance of the Neosho River from the population centers for those counties and the current availability of ground water as an alternative source of supply. The Kansas River surface water supply assessment assumed slightly less than half of the expected population growth in demand, for Johnson County, would be met from the Kansas main stem. This assumption follows the current surface water supply percentage in Johnson County where about 45% of the water supplied is from the Kansas River and the other half is from the Missouri River. In the Verdigris basin, Chautauqua was excluded from the county list due to its distance from any main stem source and lack of any relatively large population center. For the Walnut River main stem, only Butler County was assessed for surface water supply and demand. Cowley County was excluded because of the availability of ground water sources near population centers and the lack of water supply yield information about Winfield City Lake to include as a source of supply for the demand in that county.

Municipal-Related Industrial Demand Projection

Review of the GPCD usage established that the quantity of water 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 nine municipal-to-industry sellers account for more than 90% of the total industrial volume sold by municipal systems in 2002. These systems were located along the Kansas, Walnut and Neosho main stems (none in Marais des Cygnes or Verdigris). The industrial water use sold by these nine systems from 2000–2004 was reviewed for trend. None of the system's annual industrial sales correlated with seasonal precipitation. Three of these seven systems showed no trend through time, one showed a significant increase through time and the remaining five showed a significant declining trend through time.

A number of conservative assumptions were used when projecting 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 when considering future growth and supply limitations; a curvilinear projection (transformed fit using the square of industrial water sales) was used instead which created a future plateau of municipally supplied water for industrial demand. For the other eight systems that showed no trend or a declining trend with time, the reported sales were used for 2004, but the median sale value for the 2000-2004 period was used for the projection of future demand on each system. The resulting projections have been added to the 'non-municipal' demand projections described in the next section.

Other Industrial/Commercial/Agricultural/Recreational Demand Projections (Non-Municipal Use)

The demand projection for non-municipal use development was estimated with 2002 reported water use for each basin of interest. Seasonal precipitation for 2002 was drier than the average seasonal precipitation in eastern Kansas, 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. Using the drier than average 2002 as a base year, reported water use was summed for the selected points of diversion whose priority dates were before 1991 and recorded, then all those before 1992 were selected, summed and recorded, then 1993, then 1994, etc. This process was repeated through 2002 to create a cumulative water use by time data series. A bivariate fit of these summed water uses 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 regression line. The upper confidence limit of the fitted curve was selected as the projected water use from non-municipal sources to remain conservative in water demand projections.

Surface Water Demand Results by Basin

The municipal and non-municipal demand projections generated from the steps described above were combined to produce the basin surface water demand. The smallest unit that the basin level main stem corridor surface water demand estimates could be divided into is the county level, because the smallest unit available from the state-certified values for population projections is limited to the county level.

Neosho Basin Demand

The demand estimates for the Neosho main stem corridor indicate that surface water demand from the Neosho River is expected to gradually increase. This increase is primarily associated with the anticipated demand increase of Lyon County. Growth in the industrial sector in Emporia, Kansas has been driving the demand increase in Lyon County during the last 12-15 years. This increase was projected into the future based upon its current rate of growth (see orange line in Figure 1, next column (page 11)).

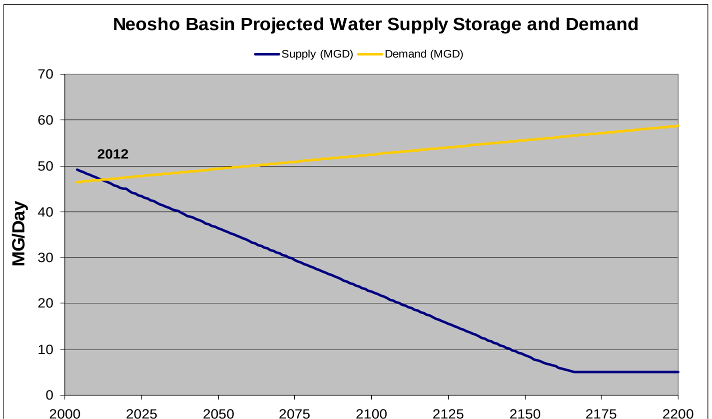


Figure 1.

Although a significant increase in recreational demand over the last 12–15 years was demonstrated in Neosho County, that sector's growth was ultimately limited to current levels due to input and discussion with the Kansas Department of Wildlife and Parks (KDWP) and KDA-DWR. There is little to no desirable land remaining near the main stem in Neosho County that has not already been developed for recreational use.

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

Marais des Cygnes Basin Demand

Main stem surface water demand in the basin is projected to increase. 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 (see light blue line in Figure 2 below (page 11)). Although a significant increase in demand was demonstrated in Linn County related to the recreational sector growth in the last 12-15 years, that sector's growth

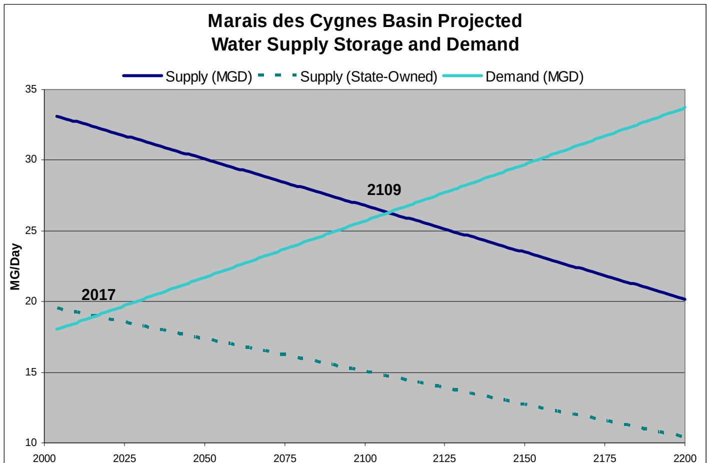


Figure 2.

was limited to current levels based upon input and discussion with KDWP and KDA-DWR. As was the case in the Neosho basin, there is little to no desirable land remaining near the main stem in Linn County that has not already been developed for recreational use.

Worthy of note in the Marais des Cygnes demand projection was the population projection for Franklin County which indicated a population decline. Certified *annual* population estimates from the DOB for Franklin County, assembled since their 2001 projections were originally made for that county, show significant population growth.

It is anticipated that the next census-based population projection cycle from the DOB will show a long-term population increase for Franklin County. Demand estimates for surface water should be reassessed once new information is available, since the effect of population growth for Franklin County would add to the rate of the demand increase in the basin.

Kansas River Basin Demand

Surface water demand on the main stem of the Kansas River is expected to increase significantly through time. Of the seven counties in Kansas that are currently projected to increase in population, five are along the Kansas River 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 (see light purple line in Figure 3 below (page 12)).

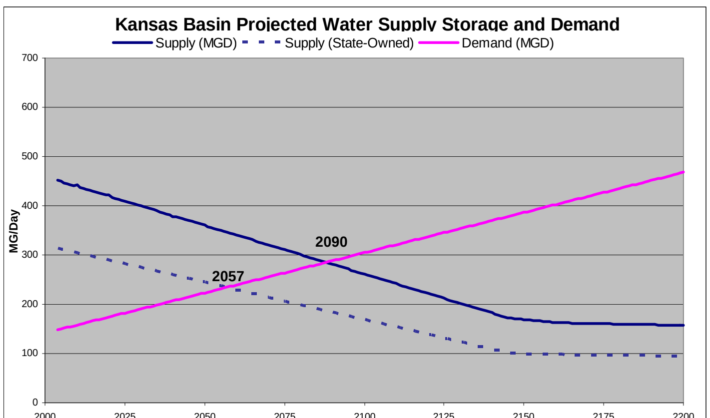


Figure 3.

As previously noted, only 45% of 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 (the Missouri River supplies the balance of the demand).

Verdigris River Basin Demand

Demand from the Verdigris River corridor is expected to slowly decline through time. The decline in demand is the result of the projected population declines for all the counties assigned to the basin.

For planning purposes, two sub-areas were created in the Verdigris basin on the supply side of the supply-demand estimation. One sub-area was Montgomery County (for the demand of that sub-basin see the orange line in Figure 4 below (page 12)) and the other was three counties of Elk, Greenwood and Wilson (see the orange line in Figure 5 below (page 12) for the projected demand of that sub-basin). Due to a lack of main stem corridor surface waters as a potential source of water supply, Chautauqua County was excluded from the demand analysis for the Verdigris River corridor.

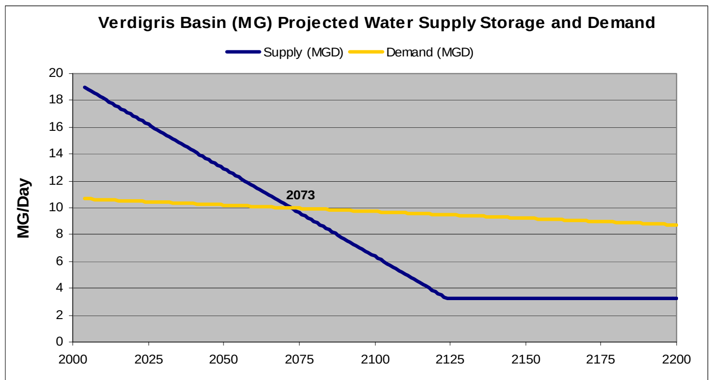


Figure 4.

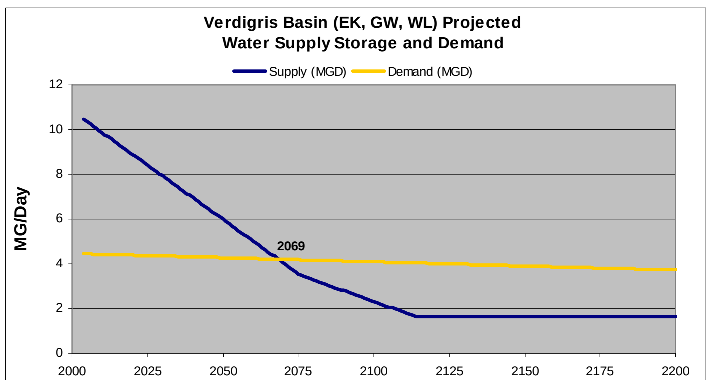


Figure 5.

Walnut River Basin Demand

Demand from the Walnut River corridor is expected to increase through time due to the anticipated population increase in Butler County (see the orange line in Figure 6 (page 13)).

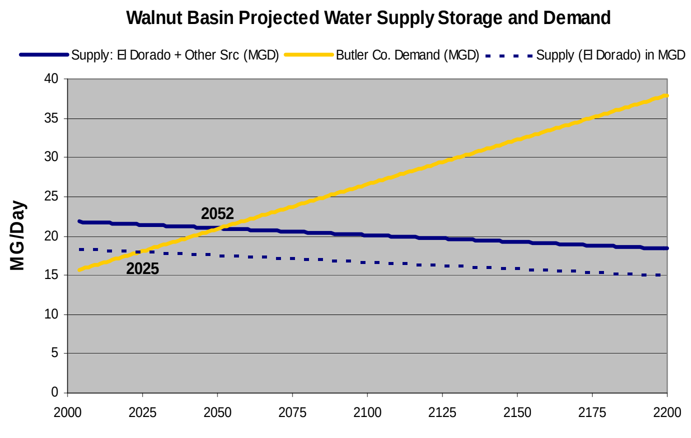


Figure 6.

As previously noted, only Butler County was assessed for surface water demand. Cowley County was excluded from the assessment because of the assumption that the population centers of that county had alternate sources of supply to meet their existing and future demand. Arkansas City had the availability of ground water sources and the City of Winfield has a large city lake. The lack of water supply yield information about Winfield City Lake also would have confounded the surface water supply side of the projections for Cowley County had it remained in the assessment for the Walnut River basin. This information is now available and will be included in the detailed model analysis to be conducted in this basin in the future.

SURFACE WATER SUPPLY

Supply projections also employed two methods:

1. Federal reservoirs yield estimation; and
2. Natural flow estimation

Reservoir yields were modified into a linear trend line projected into the future for each basin. Natural flow estimates for each basin were added to the federal reservoir yields to create total basin surface water supply estimates.

Federal Reservoir Yield Projection

The KWO has previously estimated water supply yields under a severe drought scenario for all federal reservoirs in the Kansas, Neosho, Marais des Cygnes and Verdigris basins.

The 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 then subjected to a drought scenario. Kansas statute defines this scenario as a 2 percent (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 of 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). The result is the water supply yield of a reservoir for the prescribed drought condition.

Water supply yields are typically projected in 10 year increments up to 40 or 50 years into the future. As sediment accumulates in a reservoir the volume available for water supply storage declines, which reduces the water supply yield of a reservoir over time. A linear regression was created to extend the declining trend in the water supply yield estimates for each federal reservoir in the eastern Kansas basins beyond the 50 year horizon.

Natural Flow Estimation

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

Initially, expected streamflows under a 2% drought scenario 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, Marais des Cygnes and Walnut main stem corridors 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 streamflow and consumptive use creates the minimum monthly average flow (1952-1957) used to establish the natural flow expected under the 2% drought scenario. If necessary, adjustments were 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, Marais des Cygnes and Verdigris 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.

Surface Water Supply Results by Basin

The water supply yield projections for the federal reservoirs in each basin were combined with the natural flow estimates for those basins as generated from the steps described, on the previous page, to produce the basin surface water supply under the severe drought scenario.

Neosho Basin Supply

The current sedimentation rates for Council Grove, Marion and John Redmond reservoirs project all water supply yield will be lost to sediment deposition by the year 2200. The estimated consumptive use was about five million gallons per day (MGD) in the Neosho basin. Streamflow minimums for the 2% drought period were established from Parsons, Kansas, where zero flow was recorded for six consecutive months from 1956 to 1957. The projected total supply for the Neosho basin is shown as the dark blue line in Figure 1 (page 11).

Marais des Cygnes Basin Supply

The current sedimentation rates for Hillsdale, Melvern and Pomona reservoirs indicate available (although diminished) yields through the year 2200. The estimated consumptive use was about one MGD in the Marais des Cygnes basin. Streamflow minimums were established for the 2% drought period from Trading Post, Kansas, where zero flow was recorded for three consecutive months in 1956. The projected supply of the basin, based upon existing state-owned storage, is shown as the dashed line in Figure 2 (page 11). If the state acquired all the water available for purchase from Hillsdale Reservoir in the basin, then the projected supply would be the solid dark blue line in Figure 2 (page 11).

Kansas Basin Supply

The current sedimentation rates for Milford and Clinton reservoirs indicate available (although diminished) yields through the year 2200. The current sedimentation rates for Tuttle Creek and Perry project all water supply function will be lost by the year 2200. The estimated consumptive use from the main stem during January 1957 was about 52 MGD. This consumptive use establishes the supply available from other sources on the Kansas River corridor to meet current/future water supply demand under the prescribed drought scenario.

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 (363 cubic feet per second (cfs)). Of the tributaries that feed into the Kansas River, only the Smoky Hill, Republican and Big Blue rivers had gaged flows in them during that period. Due to inflow depletions that have occurred on those rivers since that time, it is anticipated that the Smoky Hill and Republican Rivers would have no natural flow under a 2% drought scenario today. The Big Blue should continue to have flow under a 2% drought scenario today, but that flow would be captured in the Tuttle Creek Reservoir yield accounting procedure to meet instream flow demands in the main stem and, as a result, has been purposely excluded from this analysis because that source of supply would go to meet instream demands.

Additional water supply storage is available for purchase in Perry and Milford reservoirs. The existing state-owned storage supply projection is shown in Figure 3 (page 12) as the dashed line. The solid blue line depicts the supply projection if all available additional water supply storage was purchased in Perry and Milford reservoirs.

Verdigris Basin Supply

The current sedimentation rates for Toronto, Fall River and Elk City reservoirs project all water supply yield will be lost to sediment deposition by the year 2200. The current sedimentation rate for Big Hill Reservoir indicates some available (although diminished) yields through the year 2200. Some water supply storage is still available in Big Hill Reservoir. For the purposes of this supply/demand

Perry Reservoir.

projection the current and remaining available storage in Big Hill Reservoir, and its resulting water supply yield, is assumed to meet future demand in Labette and/or Cherokee County in the Neosho basin and has been excluded from the Verdigris surface water supply projections.

The estimated consumptive use was about 6.3 MGD for the basin. Streamflow minimums were established for the 2% drought period from Coffeyville, Kansas, where 2.8 cfs (1.8 MGD) was recorded in early 1957. However, Fall River Reservoir existed during the 1950's drought and its estimated releases for the same period was about 3.2 MGD. The net result of the basin's consumptive use, minimum recorded monthly flow and Fall River reservoir releases create a natural flow estimate of (1.8 MGD + 6.3 MGD – 3.2 MGD) 4.9 MGD for the 2% drought condition in the basin.

For supply projection purposes, the Verdigris basin was divided into two sub-basins; Montgomery County and Elk, Greenwood and Wilson counties. The supply projection (Elk City Reservoir) for the Montgomery County sub-basin is shown as the blue line in Figure 4 (page 12). The supply projection for the other sub-basin (Toronto and Fall River reservoirs) is shown as the blue line in Figure 5 (page 12). The natural flow estimate for the each sub-basin was created by portioning the current population estimates for the counties comprising each sub-basin.

Walnut Basin Supply

The current sedimentation rate for El Dorado Reservoir indicates available, although diminished, yields through the year 2200. The estimated consumptive use was about 5.2 MGD in the Walnut basin, however, a large portion of that use came from fairly large city lakes (El Dorado and Winfield) in the basin that existed during the 1950's drought. Without those lakes the consumptive use as estimated would probably be much lower. In fact, streamflow minimums were established for the 2% drought period from Winfield, Kansas, where zero flow was recorded for three consecutive months in late 1956.

Although the natural flow source has been included in the supply projection for the Walnut basin (the solid blue line in Figure 6 (page 16)), it is most likely that should the basin experience a 2% drought, there would be no natural flow to meet demand. The supply projection without the natural flows removed is shown as a dashed line in Figure 6 (page 13).

SURFACE WATER MAIN STEM CORRIDOR SUPPLY/DEMAND

Neosho River Corridor Supply/Demand

A 2% drought, such as that experienced during the 1950s, would stress the estimated supply for the Neosho River corridor in the very near future (Figure 1 (page 11)).

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, upstream of Emporia, are relatively small in comparison to the yields of other federal reservoirs assessed in this report. They also 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. However, even if demand were to decrease modestly through time, the high rate of water supply decline could cause demand to exceed supply within the next 15 years. The second area of concern is the demand of Wolf Creek Nuclear Power Plant and the rapidly declining water supply yield of John Redmond Reservoir.

Marais des Cygnes River Corridor Supply/Demand

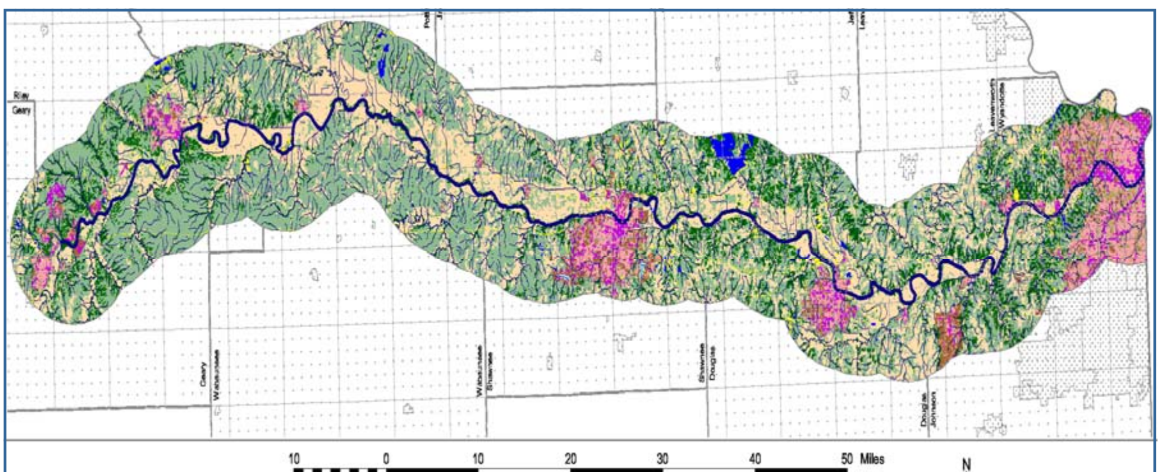
On initial review the projected demand on the Marais des Cygnes River corridor could be met by the estimated supply for the Marais des Cygnes River corridor into the next century. However, only 15% of the water supply available in Hillsdale reservoir has been called into service as of 2008. If the supply 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 2 (page 11)).

Marais des Cygnes Reservoir, courtesy of Kansas Geological Survey.

The areas of concern in the basin are three-fold: 1. the anticipated increase in demand from Miami County; 2. the likely change in the population projection for Franklin County (change to an increasing population instead of the current projection which is a declining population) and the rate of increase in demand associated with that change; and 3. the present lack of supply in service from Hillsdale Reservoir. Purchase of the remaining water supply in Hillsdale should reduce the projected supply stress in the basin for many years.

Kansas River Corridor Supply/Demand

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 3 (page 12)).



Kansas River Corridor map courtesy of KGS.

Unlike the other eastern Kansas basins reviewed in this report, 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 KWO believes that the inflows from those three major systems would be much less today 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 natural flow 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 instream 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 will be explored in the future under a more sophisticated modeling effort.

Verdigris River Corridor (Montgomery County Only) Supply/Demand

The Montgomery County sub-basin in the Verdigris basin analysis indicates that, for the 2% drought scenario, demand will not exceed supply in the near future (Figure 4 (page 12)). However, demand and supply trends should continue to be monitored and projection adjustments made as needed.

Verdigris River Corridor (Elk, Greenwood and Wilson County) Supply/Demand

The Elk, Greenwood and Wilson county sub-basin in the Verdigris basin analysis also indicates that, for the 2% drought scenario, demand will not exceed supply in the near future (Figure 5 (page 12)). As with the other sub-basin unit in the Verdigris basin, supply/demand trends should continue to be monitored and projection adjustments made as needed.

Walnut River Corridor (Butler County Only) Supply/Demand

Due to the likelihood that the source of natural flows in the basin will not be available during an extended drought, the more conservative supply projection for this basin, the dashed line in Figure 6 (page 13), will be used in this supply/demand discussion. This leaves the Butler County demand vulnerable to a 2% drought scenario fairly soon.

The primary area of concern for this basin is the rate of demand increase associated with the population growth in Butler County. The population growth in Butler County should continue to be monitored and demand adjustments need to be made with any increases in that growth rate. A new source of supply will soon be needed in the basin to satisfy growth in demand.

Lower Smoky Hill Basin

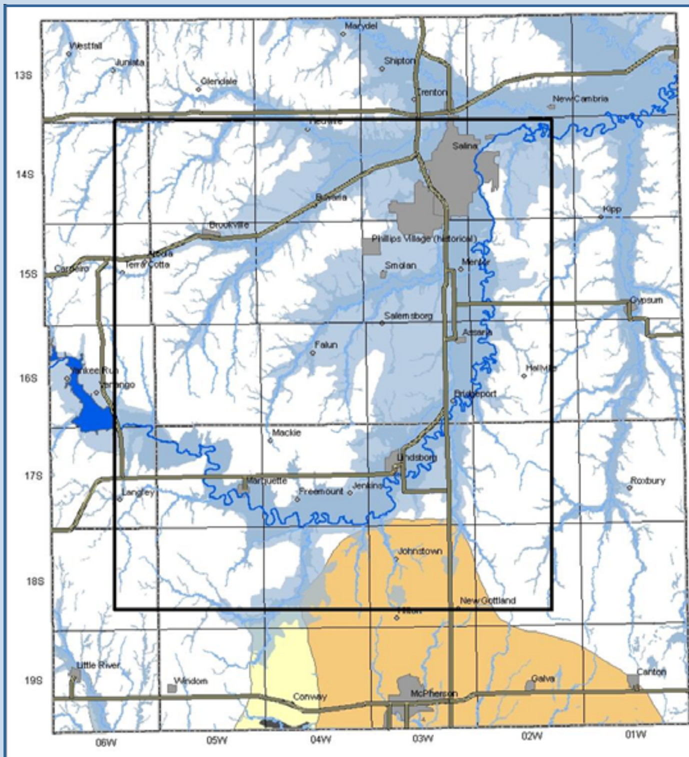
In 2007 the Kansas Water Office (KWO) contracted with the Kansas Geological Survey (KGS) to develop a numerical ground water model to aid in the evaluation of the regional water supply issues down stream of Kanopolis Reservoir in the Smoky Hill River valley. In December 2008, KGS produced Open File Report 2008-20, the results from that modeling effort. That Open File Report includes the results of a model scenario that KWO asked KGS to perform and those results formed the down stream demand basis for the KWO Kanopolis Reservoir Model.

The KGS model scenario of interest to the KWO was to repeat the climatic conditions of 1948-2006, but use the hydrologic starting condition in the simulation of 2006 ground water and surface water levels and current water demand. Water demand changes during this simulation were based upon the climate conditions from 1948-2006, but the number of water rights in the system was for the rights that existed in 2006. Also in this scenario, a target flow rate of 20 cubic feet per second (cfs) was established on the Smoky Hill River just down stream of Salina. For each time-step in the simulation the inflow to the KGS model was initially set to zero and, if necessary because of climate and/or hydrologic conditions in the model during that time step, the inflow to the model was iteratively increased until the flow target was met. This process was repeated for all time steps in the simulation.

The result of the scenario provides an estimate of the amount of water necessary to be released from Kanopolis Reservoir to meet the flow target down stream of Salina while satisfying the anticipated demand of existing water right holders below Kanopolis Reservoir under the varying climate conditions experience over the last 59 years.

The KWO Kanopolis Water Supply Yield Model, finalized in the May 2008, was expanded temporally to cover the same climatic time period as the KGS model scenario (1948–2006) and the releases from Kanopolis were modified to the same values as the inflows determined from the KGS scenario explained above. Using that as a starting point, three Kanopolis scenarios were run by the KWO. The KWO scenario results show simulated Kanopolis Reservoir volumes/elevations when:

1) The current water quality monthly release schedule is applied;
2) A best/improved monthly water quality release schedule is applied; and



Smoky Hill Saline Model Aquifer.

3) Releases are optimized to only meet the Smoky Hill Model demands (no predetermined monthly release schedule established).

Significant improvements to the simulated Kanopolis Reservoir volumes/elevations can be made over the current monthly water quality release schedule with some adjustments to them. The average number of months where the reservoir elevation was less than 1,460 feet above mean sea level was reduced by about 20% and the typical minimum water supply pool volume during the simulation was 48% larger using the adjusted water quality release schedule.

Even greater improvements to the simulated Kanopolis volumes/elevation can be made by optimizing reservoir releases to only meet the Smoky Hill Model demands. The average number of months where the reservoir elevation was less than 1,460 feet above mean sea level was reduced by about 51% over the current monthly water quality release schedule simulation and the typical minimum water supply pool volume during the simulation was almost 63% larger.

Fewer months where water levels are below 1,460 feet signify an improvement to recreational opportunities at Kanopolis. Volume increases in the minimum size of the water supply pool during the simulation signify improvements in the current water supply yield of the reservoir.

CONCLUSION/RECOMMENDATIONS

The surface water supply/demand models of the eastern Kansas basins were created from the best information available at the time of review. 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 instream 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 projected demand may exceed supply on a more local scale.

Basin Priority

The results of this analysis indicate a priority for enhanced modeling and study of the eastern Kansas basins reviewed for supply and demand.

Neosho River Corridor

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

Marais des Cygnes River Corridor

The demand increases projected in this basin, coupled with the anticipated increase in the existing rate of population growth, as related to the anticipated change to Franklin County's population projection, should necessitate supply expansion. The most obvious method of expanding supply in this basin is to call a portion of the remaining storage of Hillsdale Reservoir into service. The amount of storage to call into service should be explored within five years and implemented immediately thereafter.

Walnut River Corridor

The demand increases projected in Butler County should continue to be monitored. An additional supply source to meet that demand is likely to be needed. Supply source enhancements and options should be reviewed for the basin.

Verdigris River Corridor

The Verdigris River corridor appears to have adequate surface water supply to meet the basin's demand through 2050. Bathymetric surveys of the storage space available in the federal reservoirs in this basin are needed to improve the supply projection estimate in this basin.

Kansas River Corridor

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

INTRODUCTION

Public water supply reservoirs in Kansas have an average age of 44 years. Loss of storage capacity in these reservoirs due to sedimentation is influenced by the frequency of high flow events, the age of the reservoir and by watershed characteristics. As sediment accumulation reduces capacity, water quality problems intensify. Reservoirs act as settling basins in which the sedimentation process deposits silts, clay and smaller rock particles. When sediment accumulates in the upper ends of reservoirs, as is the case in many Kansas reservoirs, the situation is exacerbated because flat shallow areas provide ideal conditions for blooms of cyanobacteria and other phytoplanktonic species.

Numerous reservoirs around Kansas are experiencing sediment related problems: Cheney Reservoir, Clinton Lake, Marion Lake: massive algae blooms resulting in both taste and odor (T&O) problems and presence of toxins, and recreational use impairment at Perry and Tuttle Creek reservoirs:

- Log jams at John Redmond and Melvern Reservoirs, partially due to sedimentation;
- Abandonment of recreation areas, boat ramps, loss of fish habitat;
- Shutdowns or clogging of drinking water intakes;
- Taste and odor problems are expensive to treat at the plant.

Reservoir/Lake	Surface Area (acres)	Age (Years)	MP % Filled
Tuttle Creek	15,380	42	38
John Redmond	8,300	40	41
Cheney	9,500	39	5
Perry	12,200	35	23
Cedar Lake	54	71	50
Mission Lake	123	85	50

Table 1 summarizes the degree of sediment deposition in several Kansas reservoirs. Source: KWO

The upper regions of reservoirs, where streams enter, fill with sediment three to five times more rapidly than deeper areas. Expanding shallow zones reduce water quality and wildlife habitat as well as operational storage capacity for public water supply and recreation. Impacts of sediment and nutrients in receiving waters including streams, lakes and reservoirs are strongly linked and are best evaluated in relation to each other. It is important to understand the relationship between sediment and nutrients because problems in reservoirs include impacts from sediment bound nutrients. These can also cause a water body to not attain water quality standards and designated uses.

Erosion of crop land soils produces elevated concentrations of silt in many streams and lakes, often to the detriment of native aquatic life. The presence of nitrogen and phosphorus-containing fertilizers in stormwater runoff promotes nuisance growth of cyanobacteria and algae and often detracts from the recreational and drinking water uses of surface water. Stream channelization and land use practices that increase runoff in stream destabilization often leads to streambank erosion, adding excess sediment to the system.

Responding to an increasing frequency of water quality problems affecting use of Kansas reservoirs is an enormous challenge. The most pressing issue is ensuring the quality of water available to public water suppliers. These suppliers provide treated water to more than 60% of Kansas residents. Flood control, recreation and irrigation utilize reservoirs as a raw water source, and other authorized uses also must be protected. Sediment accumulation and other factors continue to create immediate problems for water and habitat quality.

WATER QUALITY IMPACTS OF SEDIMENTAITON

Nutrient Enrichment

Although the primary focus of Vision 2020 is the effect of sedimentation on public water supply storage capacity, a related and more imminent concern is the effect of sedimentation on water quality. The main water quality issue is eutrophication, the process that both natural lakes and constructed reservoirs undergo as they age. Eutrophic conditions occur as sediment and nutrients attached to sediment or suspended in water gradually accumulate, leading to excessive aquatic plant growth, especially algae and cyanobacteria. Most federal reservoirs in Kansas are in some stage of eutrophication, and some are in advanced stages.

Trophic state, a measure of the degree of eutrophication, is used as an indicator of nutrient enrichment. Trophic state describes the productivity of a reservoir/lake ecosystem classifying it as one of four increasingly eutrophic categories based on algal and other plant biomass: oligotrophic (low productivity), mesotrophic (moderate productivity) or eutrophic (high productivity) and hypereutrophic (excessive productivity). Additional trophic states are identified within these main categories. Trophic state indicators are calculated on the basis of total phosphorus, chlorophyll-*a* and water transparency measurements by a Secchi disk.

When reservoirs in Kansas were designed and constructed, most sediment was expected to accumulate at the bottom of reservoirs, near dams. However, large quantities of sediment are settling out in the upper arms of reservoirs, creating shallow flats and deltas. Because inflow waters typically are nutrient rich, these shallow areas of water provide ideal conditions for algal/cyanobacterial growth and dense growth of rooted aquatic plants.

Trophic Status	Number of Lakes		Acreage of Lakes	
	Count	% Total	Acres	% Total
Argillotrophic	13	4	41,814	22
Oligomesotrophic	13	4	450	<1
Mesotrophic	36	11	12,071	6
Slightly Eutrophic	47	14	43,793	23
Eutrophic	65	20	73,560	39
Very Eutrophic	39	12	13,568	7
Low Hypereutrophic	17	5	283	<1
High Hypereutrophic	66	21	3,096	2
Unknown	26	8	2,347	1
Totals	322	100	190,982	100

Table 2. Summary of the trophic status of Kansas lakes and reservoirs in 2008. Source: KDHE 2008 305(b) report.

Nitrogen (N) and phosphorus (P) are the most important nutrients observed during cyanobacterial blooms. Of the mineral nutrients required for algal growth, N and P are the least abundant and are in highest demand. These two key nutrients, relative to all of the other resources that are necessary for normal algal/cyanobacterial growth, are said to be growth-limiting. When N/P ratios are favorable, much of the algal biomass is composed of cyanobacteria that are capable of producing geosmin and 2-Methylisoborneol (MIB). These compounds cause taste and odor problems in drinking water, issues that can be difficult and expensive to treat. Additionally, aquatic plant growth produces living and decaying biomass that restricts boat access and adds to taste and odor problems.

The main sources of excess nutrients in aquatic ecosystems in the mid-west are municipal wastewater disposal, confined animal feeding operations (CAFOs) and row crop production agriculture. Wastewater and CAFOs can be dealt with at the source through discharge limits associated with National Pollutant Discharge Elimination (NPDES) permits, so they are relatively easy to control. In the case of row crop agriculture, rainfall events wash nutrients and soil into the rivers and streams that feed drinking-water reservoirs. This can cause nutrient concentrations in the reservoir itself to increase thereby creating conditions that can lead to algae/cyanobacteria blooms.

During the summer months, the upper layer (epilimnion) of a reservoir heats up relative to the lower layer (hypolimnion) and the lake becomes thermally stratified. Except in cases of severe weather, the warm upper layer and cold lower layer will not mix until late fall when the upper layer cools. When thermal stratification occurs, decomposition of decaying organic matter that settles to the bottom of the reservoir can use up dissolved oxygen in the lower layer. This layer sometimes can become completely devoid of oxygen (anoxic) and incapable of supporting most aquatic life, especially fish. Under these anoxic conditions, lake sediments have been found to release biologically available phosphorus into the water column. This newly released phosphorus will normally remain in the hypolimnion until the fall when the layers mix. Upon mixing, the excess phosphorus is immediately available to support the growth of algae and may contribute to the occurrence of undesirable fall/winter blooms.

Taste, Odor and Toxicity Problems

Growth of many species of cyanobacteria seem to be favored by high concentrations of total phosphorus (TP) and by low ratios of total nitrogen to total phosphorus (TN:TP) because they are capable of fixing nitrogen from the atmosphere into an organically available form.

Cyanobacteria produce a diverse group of toxins that target fundamental cellular processes and affect a wide range of organisms. Several animal poisonings involving cyanotoxins have recently drawn attention, prompting many states to include cyanotoxins in their routine monitoring programs. During the summer of 2007, two dogs that had contact with water in Marion Reservoir died shortly after exposure. Cyanobacteria toxins were implicated as the cause of death. Although cyanotoxins are the focus of recent attention, toxic cyanobacterial blooms are not a new phenomenon. Cyanobacteria toxicity incidents have been reported in the mid-western United States for over a century. Some of the earliest records of poisonings are from Minnesota in the late 1800s. Microcystin, produced by at least 13 cyanobacterial genera including *Anabaena, Microcystis* and *Oscillatoria,* is one of the most common cyanotoxins.

Toxic incidents involving Microcystin have been reported in a variety of freshwater environments ranging from oligotrophic (naturally pollutant free) alpine lakes to hypereutrophic (very productive due to nutrient inputs) tropical reservoirs. Microcystin targets the liver (heptatoxic) and has been implicated in human and animal illness and death in over 20 countries worldwide, including the United States. The major routes of human exposure to Microcystin are through recreation and drinking water. The adverse health effects caused by ingestion or inhalation of high concentrations of Microcystin (acute exposure) include rash, inflammation of membrane tissues, vomiting and diarrhea. The effects of exposure to low levels of Microcystin over an extended period of time (chronic exposure) are currently unknown, but Microcystin is thought to promote the growth of tumors.

Harmful blooms can occur anytime water quality is impaired due to excessive accumulations of algae and cyanobacteria. Taste and odor compounds and toxins are of particular concern in lakes, reservoirs and rivers that are used for either drinking water supplies or full body contact recreation. Taste and odor compounds cause malodorous or unpalatable drinking water, resulting in increased treatment costs and loss of aqua-cultural and recreational revenue. Cyanobacterial toxins have been implicated in human and animal illness and death in over fifty countries worldwide, including at least 35 states in the U.S. Human toxicoses associated with cyanotoxins have most commonly occurred after exposure through drinking water or recreational activities.

The occurrence of harmful blooms is affected by a complex set of physical, chemical, biological, hydrological and meteorological conditions making it difficult to isolate specific causative environmental factors. Although anecdotal reports are common, few studies have documented the distribution, occurrence and concentration of taste and odor compounds and toxins in cyanobacterial blooms throughout the U.S. In addition, while the general factors influencing cyanobacterial bloom formation are well known the specific factors driving particular occurrences of taste and odor compounds and toxins remain unclear. No strong correlations have been identified between species present in the bloom, the occurrence of taste and odor incidents, and the presence of toxins.

Knowledge of reservoir characteristics develops through disciplined inquiry. Documentation of the characteristics and water quality parameters of reservoirs is essential for consistent and effective management. For example, a documented history of the chemical and physical parameters of a given reservoir (such as temperature, pH and oxygen profiles, prevailing flow patterns, and surrounding watershed land use) can greatly assist scientists and managers to understand what “normal” conditions are. It can also help to begin an understanding of the conditions that surround taste and odor events.

Algae Bloom.

Unfortunately, continuous processing of geosmin and MIB samples is unrealistic for most water utilities in Kansas on both a time and cost basis. Taste and odor events tend to occur rapidly and rather infrequently in space and time. For example, in a study of 18 Kansas lakes and reservoirs, human-detectable levels of geosmin (≥ 5 parts per trillion) were found in only 12% (four in 51) samples. Similarly, in a study of eight Kansas reservoirs specifically chosen because of documentation of recurring taste and odor issues, human-detectable levels of geosmin were found in 59% (19 of 32) samples. Human-detectable taste and odor events were observed in just over half of the samples even when sampling was specifically targeted at lakes in which the compounds are known to occur repeatedly. In addition to being limited in time, taste and odor events are typically limited in their spatial extent. Therefore, a wide array of sampling sites would need to be continuously maintained in order to directly measure geosmin and MIB. Moreover, geosmin and MIB samples would need to be processed relatively quickly (on the order of one day) to recognize the rapid increase (days to a week) of these compounds that characterize taste and odor events.

Prediction and Response to Taste and Odor Events

Taste and odor compounds and cyantoxins represent both economic and public-health concerns and resource managers, drinking water treatment plant operators, lake associations and local officials are increasingly faced with decisions about cyanobacteria that affect public awareness, exposure and health. Understanding the environmental factors associated with the occurrence and concentration of taste and odor compounds and cyanotoxins is key to reservoir and lake management, drinking water treatment decisions and minimization of human health risks.

A taste and odor workgroup was established in 2006 by the Kansas Biological Survey (KBS) to determine if models could be developed to predict when cyanobacterial blooms and resultant taste and odor and toxicity occurrences could be developed. Seventy-seven Kansas water treatment personnel and over 400 regional limnologist were contacted for relevant data. Additional data requests were made through a Kansas Rural Water Association publication and two newsletters distributed to Kansas water utilities. From these existing data sources and additional research, KBS developed a database of physical, chemical and watershed characteristics of Kansas lakes and reservoirs. These data are available from KBS online. Further consistent documentation of Kansas water bodies will contribute to the growing knowledge base that is the foundation of understanding how, when and where taste and odor events occur in Kansas.

Preliminary models for geosmin levels were developed for five Kansas reservoirs: Marion, Cheney, Clinton, Big Hill and Garnet City Lake. The models represent initial findings and need further research for validation and calibration. However, they represent the current scientific understanding of the relationship of taste and odor events with other water quality parameters in these Kansas lakes. An interactive tool for preliminary geosmin level prediction in Kansas lakes and reservoirs using these models is available from KBS. The results of research in Kansas are similar to those of concurrent research in the Great Lakes and in water supply systems of California; measuring taste and odor compounds directly is still recommended for management of taste and odor events.

More information is needed. Measurement and recording of specific data on a consistent basis has not occurred during routine operations of water treatment plants. Efforts are underway to incorporate more data gathering by water treatment personnel. Scientists from both the University of Kansas (KU) and the United States Geological Survey (USGS) have shown that there are strong relationships between the taste and odor compound geosmin and chlorophyll-*a* (an indicator of algal/cyanobacterial biomass) in Kansas reservoirs. Therefore, it may be possible to use chlorophyll-*a* as an early indicator or predictor of taste and odor events. By routinely monitoring chlorophyll-*a* levels with relatively simple laboratory techniques, water treatment personnel may be able to determine in advance when water should be treated in order to reduce the likelihood of a taste and odor event.

Treating the cause, not the symptom, is the long-term solution to taste and odor problems. In Kansas, a better understanding of the factors leading to taste and odor events must be developed for the cause to be identified. Current treatment strategies in Kansas are primarily focused on the symptoms (i.e. the amount of geosmin or MIB present in the source water).

Trends in Reservoir/Lake Water Quality

Trends in water quality are difficult to determine for individual lakes in Kansas, due largely to a traditional emphasis on the performance of statewide assessments rather than intensive, site specific studies. Lake trophic status appears to provide the best long-term indicator of water quality and has been used by the KDHE for 305(b) assessment purposes for many years. KDHE tracks trends in water quality in water bodies that are sampled within the state water quality monitoring network.

Trend analyses for individual lakes are performed only if the water bodies had undergone three or more trophic state assessments since the inception of the Lake and Wetland Monitoring Program or their addition to the sampling network. These analyses assigned lakes to one of four categories as follows:

1. Improving: Evident decrease in trophic state over time.
2. Degrading: Evident increase in trophic state over time.

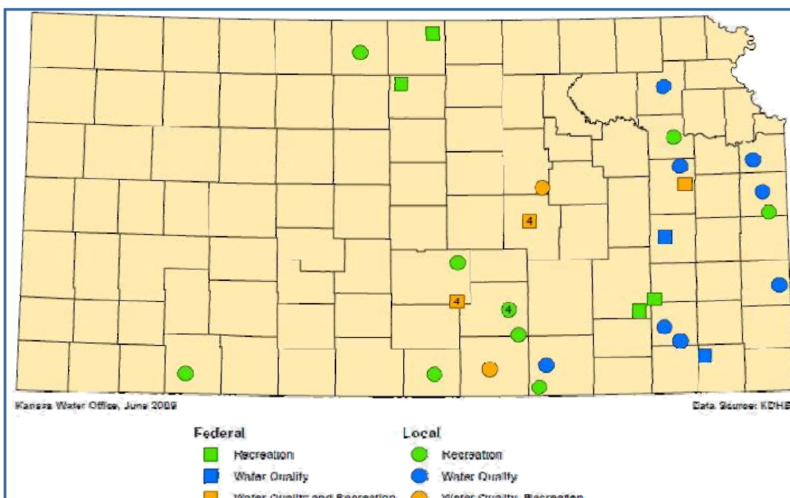


Figure 1. Spatial distribution of these reservoirs, the type of reservoir, and the impacts reported. For specific information on the lakes and impairments, see Appendix A.

3. Stable: Assessments changed little over time, or if they fluctuated widely, preventing the detection or confirmation of any trend.
4. Unknown: Little or no historical data or fewer than three trophic state assessments had been performed during the monitoring period of record.

Category	Number of Lakes		Acreage of Lakes	
	Count	% Total	Acres	% Total
Total Assessed for Trends	322	100	190,982	100
Improving	17	5	7,423	4
Stable	148	46	128,005	67
Degrading	39	12	49,903	26
Unknown	119	37	5,651	3

Table 3 summarizes trophic status trends in Kansas reservoirs and lakes. Source: KDHE 2008 305(b) report.

Documented Taste and Odor Events in Kansas

KDHE established a Taste and Odor Assistance Program in 1989. Water treatment plant operators and the public can report and have investigated water quality disturbances related to water supply, fish kills or general water quality related complaints. Between 1989 and 2007, at least 31 incidents related to taste and odor problems were reported and investigated. Problems have occurred in water bodies as small as residential subdivision lakes and as large as federal reservoirs. The first occurrence of a massive bloom in Cheney Reservoir occurred in 1993. However, it is likely that many more incidents have occurred and gone unreported to the program. For each of these 31 documented events, there may well be a 100 that are not reported.

SEDIMENTATION IMPACTS ON RECREATION USE OF KANSAS RESERVOIRS

Establishing a cause/effect relationship between sedimentation and recreational use impairment is not straightforward. Public perception of the suitability of the water for contact or other recreation is difficult to assess and document. Some impairments are aesthetic or physical. While many reservoirs are impaired by eutrophication, often resulting at least partially from sedimentation, the way in which eutrophication manifests varies in space and time. Facilities to support recreational boating have been impacted by sedimentation as reservoirs age. KDHE conducts a Use Attainability Analysis (UAA) to determine the ability of a water body to support designated uses assigned to it including both contact and non-contact recreation. However, designated recreational use attainability does not necessarily reflect willingness of the public to actually recreate in or on the water. Public perception is a better indicator of uses than water quality criteria.

An obvious indication of recreational impairment due to sedimentation is loss of access to the water from boat ramps and docks that are silted in. Entire recreation areas in the upper reaches of Perry and Tuttle Creek reservoirs have been converted to wildlife areas as the shoreline silted in and boat ramps became unusable. Fancy Creek boat ramp on Tuttle Creek Reservoir lost all water access, destroyed a thriving boat ramp and marina and essentially lost 95% of its visitation; at one time it was one of the best facilities on Tuttle Creek Reservoir. Boat ramps at the upper end of John Redmond and Melvern reservoirs no longer allow access to the main water body due to log jams, attributed at least partially to sedimentation. Some lakes exhibit large mud flats that may be perceived as undesirable areas for recreation. The water may be too shallow for boat operation in these areas. Even the appearance of the water, if it has obvious brown or green coloring, can be a deterrent to recreational use.

At Pomona, Fall River and Toronto reservoirs, high flow flood events result in sediment accumulation around boat ramps that has to be periodically removed before the ramps can be used. At Fall River and Toronto reservoirs, riparian erosion is a major problem and contributes to reservoir sedimentation. At conservation pool, most boats can no longer travel between the river and reservoir due to the extensive alluvial silt plumes present at both reservoirs. At Lovewell Reservoir, periodic dredging in front of the dam's outlet gates is necessary to ensure adequate outflow capacity for irrigation and flood control. The Kansas Department of Wildlife and Parks (KDWP) provides the following estimates of repair costs for damage due to sedimentation at Glen Elder Reservoir.

Reservoir Recreation Economics in Kansas

While generally smaller in size, state-owned fishing lakes, along with city and county operated lakes, offer varied and widely distributed water recreation opportunities. Ranging from small fishing ponds to impoundments, such as the 1,250 acre Winfield City Lake, these waters offer recreational opportunities close to the majority of Kansas

Type of Repair	Estimated Cost
Bank Erosion – Debris Removal/Smoothing	$40,000
Boat Ramps/Docks – Dredge Ramps/Install Docks	$160,000
Fishing Pond Silt – Dredge/Remove Silt	$30,000
Marina Water Depth – Silt Removal	$250,000

Table 4. Summary of cost of repairs due to sedimentation at Glen Elder Reservoir. Source: KDWP

Reservoir	Visitors	Visitor Hours	Visitor Expenditures (millions of dollars)
John Redmond	127,486	1,193,936	1.1
Kanopolis	250,535	1,777,746	2.6
Milford	746,666	7,024,587	7.6
Toronto	141,109	3,036,266	1.9
Clinton	2,008,108	10,659,086	19.3
Elk City	120,493	1,482,006	1.1
Tuttle	454,966	1,781,549	3.7

Table 5. Summary of the economic benefits of selected federal reservoirs on surrounding communities. Source: K-State Agricultural Economics Program

residents. Many of these smaller lakes, including Mission, Sabetha and Lone Star, are also experiencing recreational impacts due to sedimentation. Decreased recreational use of these lakes also impacts local economies.

The 1999 report from the National Recreation Lakes Study Commission titled "Reservoirs of Opportunity" estimated that the economic impact of federal reservoirs over 1,000 surface acres in Kansas was $713 million/year.

In 2000, there were 103,170 registered boats in Kansas contributing an estimated $388,870,600 to the Kansas economy with $105,343 of this coming from registration of personal watercraft owners. Recreational boating accounted for 3,627,524 user days of activity in 2000. Kansans spent $43,864,000 on boat purchases, $13,906,000 on outboard motors, $1,318,000 on boat trailers and $11,114,000 on boating related accessories in 1999. In 2002, boating registrations generated a total of $823,250 in KDWP revenue.

KDHE Visual Assessment for Recreational Use

Trophic state, a measure of the degree of eutrophication, can be used as an indicator of recreational suitability. A number of recent studies have indicated a strong connection between increasing lake trophic state and loss of economic revenues from lakes. Kansas has had a narrative eutrophication criterion in its water quality standards for many years. The validity and value of using non-regulatory numeric criterion to implement a regulatory narrative criterion has been recognized by experts in the area of eutrophication management and is encouraged by the Environmental Protection Agency (EPA) in many of their guidance documents.

The KDHE, Bureau of Environmental Field Services (BEFS), developed and tested a method to assess public perception of the appearance of water in relation to their desire or willingness to enter the water for recreational purposes. Scores derived from this method were compared to measured water quality data taken at the same time. A strong relationship between elevated trophic state and low public perception of the water for suitability for recreation was found.

Data for this project were collected from 1998 to 2002. The objective was to provide refined threshold levels for determining lake use impairments based on trophic status and water clarity. This project was an attempt to verify the suitability of numeric guidelines (Table 6 below (page 27)) for assessing lake use impairment by eutrophication. The basic method involves 1. *a-priori* assessments of lake use support, based on visual inspection; 2. correlating visual assessment data with analytical data for trophic state parameters (nutrients, chlorophyll-a, Secchi depth, and non-algal turbidity; 3. conducting a frequency analysis of the data; and 4. using that frequency analysis to develop criteria based on perceived risk levels (<1%, 10%, 25%, etc.).

Three lake uses were assessed for the study: contact recreation, non-contact recreation and aesthetic use. Kansas Water Quality Standards do not utilize an "aesthetic" use for surface waters, unlike some neighboring states such

Designated Use	A	M	SE	E	VE	H-no BG TSI 70+	H-no BG TSI 70+	H-with BG TSI 64+
Aquatic Life Support	X	Full	Full	Full	Partial	Partial	Non	Non
Drinking Water Supply	X	Full	Full	Partial	Partial	Non	Non	Non
Primary Contact Recreation	X	Full	Full	Partial	Partial	Non	Non	Non
Secondary Contact Recreation	X	Full	Full	Full	Partial	Partial	Non	Non
Livestock Water Supply	X	Full	Full	Full	Partial	Partial	Non	Non
Irrigation	X	Full	Full	Full	Partial	Partial	Non	Non
Groundwater Recharge	Trophic state is not generally applicable to this use.							
Food Procurement	Trophic state is applicable to this use, but not directly.							

KEY: **BG** = cyanophytes dominate the community (50% as cell count and/or 33%+ as biovolume); **X** = use support assessment based on nutrient load and water clarity, not algal biomass; **A** = argillotrophic (high turbidity lake); **M** = mesotrophic (TSI = 0 to 49.9); **SE** = slightly eutrophic (TSI = 50 to 54.9); **E** = eutrophic (TSI = 55 to 59.9); **VE** = very eutrophic (TSI = 60 to 63.9); **H** = hypereutrophic (TSI > or equal to 64).

Table 6. Summary of lake use support determination based on lake trophic state.

Score	Aesthetic Appearance	Contact Recreation	Non-Contact Recreation
1	Beautiful, no problems	Beautiful, no problems	Beautiful, no problems
2			
3	Not clear. Some algae/ turbidity and color visible	Slight hesitation about swimming in or contacting water	Slight hesitation about wading in or boating on the water
4			
5	Definite or strong green/ turbidity/brown color	Definite hesitation about swimming in or contacting water	Definite hesitation about wading. Some reduced boating quality
6			
7	Very strong green algae/ turbidity/brown color	Strong hesitation about swimming in or contacting water	Strong hesitation about wading. Quality of boating experience definitely impaired
8			
9	Extreme green algae/ brown/turbidity color. Scum and/or odors evident	Contact recreational use enjoyment impossible due to algae/turbidity levels	Wading and boating enjoyment almost impossible due to algae/turbidity
10			

Table 7.

as Nebraska. Nonetheless, the aesthetic quality of lakes does exert an impact on other types of use support and even property values. In Kansas, many housing projects have used locations near a lake to attract buyers. Lowered water quality in these lakes does have an effect on property values and buyers. Aesthetic assessment of the water looked for a presence or absence of an overtly visible algal community and inorganic turbidity. Visible presence of an algal community should reflect support for water supply uses also because water supply impairments can occur at very low algal biomass.

The study involved two separate visual color assessments: green and brown. These visual assessments relate to impairments resulting from elevated lake trophic state (algal biomass) and reduced levels of water clarity, respectively. Because recreational impacts may occur due to both sediment and nutrients, visual assessment of each was included. Assigned scores between field staff rarely differed by more than one unit, demonstrating a general uniformity of perception among informed observers. Table 7 above (page 25) shows the scoring criteria, combined for both greenness and brownness.

A score of three represents the onset of minor use impairment while a score of five is meant to represent the onset of significant use impairment (non-support). Only the green or brown quality of the water column was taken into account in assigning scores. Factors such as water depth impact on contact recreation, shoreline condition on aesthetic appeal of the lake or lack of a boat ramp on non-contact recreation were not considered. KDHE BEFS staff conducted visual assessments at each waterbody surveyed during the summers of 1998 through 2002, resulting in 3,012 total observational scores being included to evaluate the method.

The best relationship, based on scatter plots and regression analyses, were between green scores and chlorophyll-*a* for the three lake uses (0.74< R^2 >0.83). Relationships were statistically significant (P<0.01) for green scores and chlorophyll-*a*, total phosphorus and Secchi depth. Brown scores were most strongly correlated with Secchi depth (R^2 between 0.52 and 0.63) for the three lake uses. Relationships were statistically significant (P< 0.01) between brown scores and Secchi depth, total phosphorus and non-algal turbidity.

Based on the array of analyses conducted, chlorophyll-*a* was confirmed to be a good parameter for assessing lake trophic state impacts on recreation use and user perception. Secchi depth and calculated non-algal turbidity values are about equally good parameters for assessing water clarity impacts on recreational uses and user perceptions. The visual assessment score data appeared to validate KDHE's numeric data used to assign impairment, or lake use support, for both greenness and brownness. Vis-

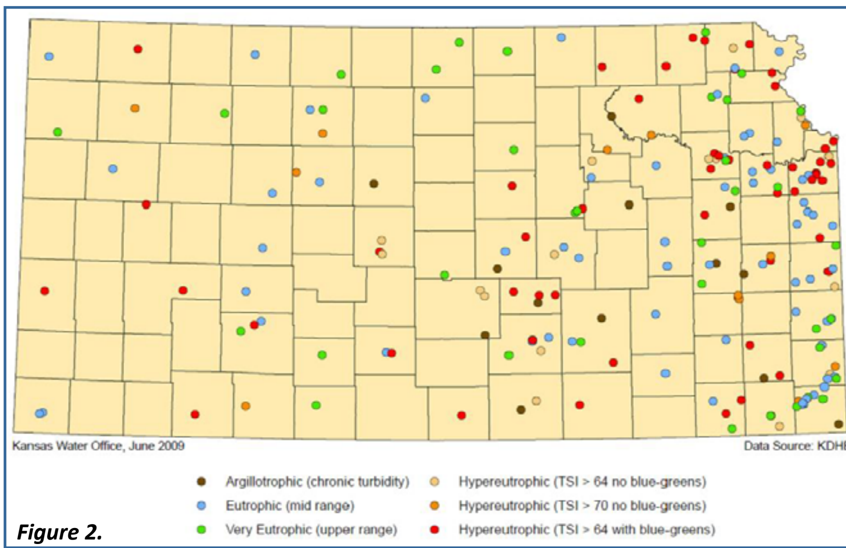


Figure 2.

ual scoring data validate current techniques for assessing lake use support for eutrophication impacts.

Figure 2 (page 25) shows the lakes that are impaired for recreational use due to their trophic condition, according to the KDHE 2008 305(b) report. The 305(b) report is submitted to EPA every two years and reports on the quality of the states waters and their ability to meet water quality standards according to designated uses.

RECOMMENDATIONS

1. Continue working with water treatment personnel to capture reservoir specific data on taste and odor events.
2. Use this information to develop reliable means of predicting and responding to cyanobacterial blooms.
3. Continue watershed based efforts to reduce sediment entering into reservoirs.

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Appendix A. Selected examples of water quality problems reported to KDHE Taste and Odor Assistance Program.

Date	Location	Description
September 1989	Miola Lake, Miami County	Cyanobacteria bloom causing taste and odor problems in drinking water.
October 1989	Verdigris River, Wilson County	Raw water from Verdigris River had musty odor at both Fredonia and Neodesha. Cyanobacteria bloom confirmed.
January 1990	Marmaton River, Ft. Scott, Bourbon County	Golden algae bloom, septic taste in drinking water.
September 1990	Cheney Reservoir, Reno County	Cyanobacteria bloom resulting in severe taste and odor in Wichita drinking water. The responsible species also produces toxins linked to both fish kills and livestock poisonings.
August 1991	Wellington City Lake, Sumner County	Extreme taste and odor problem in drinking water. Cyanobacteria bloom; species a producer of taste and odor and toxic compounds.
July 1992	Teal Brook Estates, Mulvane, Sedgwick County	Large cyanobacteria bloom. Odorous. Potentially toxic compounds; children and pets advised to stay out. Flu like symptoms of some residents potentially attributed to aerosols from the pond surface.
September 1992	Cheney Reservoir, Reno County	Large taste and odor incident attributed to cyanobacteria bloom. Species known to also produce toxins.
September 1993	Cheney Reservoir, Reno County	Large taste and odor incident attributed to cyanobacteria bloom. Species known to also produce toxins.
July 1996	Pomona Reservoir, Osage County	Taste and odor in drinking water. Cyanobacteria implicated as cause.
July 2000	Small residential lake in Wichita, Sedgwick County	Fishkill. Cyanobacteria bloom with species known to produce toxins. Advice to prevent children and pets from contact with water until bloom disappeared.
August 2000	Breezy Point Lake, Western Wichita, Sedgwick County	Cyanobacteria bloom with species known to produce toxins. Advise to prevent children and pets from contact with water until bloom disappeared.
November 2001	Lakeside Acres Lake, East of Hutchinson, Reno County	Cyanobacteria bloom; species a producer of taste and odor and toxic compounds.
April 24, 2002	Subdivision pond in Wichita, Sedgwick County	Fishkill. Low DO attributed to high algal biomass and nutrient enrichment.
July 2002	Garden Plains subdivision lake, Sedgwick County	Fishkill. Massive cyanobacteria bloom. Algal toxicity and low DO were cause. Residents advised to avoid contact until bloom and fishkill gone.
February 2003	Winfield City Lake, Cowley County	Taste and odor complaints in finished drinking water from Winfield. Cyanobacteria capable of producing geosmin found.
June 2003	Marion Reservoir, Marion County	Severe algal bloom with resultant taste and odor problems for Hillsboro and Marion drinking water. Very large cyanophyte community capable of producing both geosmin and toxins. Posted for recreational use advisories most of June. Attributed to excessive nutrient inputs.
June 2003	Cheney Reservoir, Reno County	Massive cyanobacteria bloom capable of producing both geosmin and toxins. Threat to recreation and aquatic and terrestrial wildlife from toxins, in addition to severe taste and odor problems. Excessive nutrients identified as cause. This bloom was one of the most severe ever documented by KDHE.
July 2003	Small lake, Smith County	Fishkill. Cyanobacteria bloom identified. Low DO caused by agricultural runoff primary source of nutrients.
January 2004	Small urban lake in Arkansas City, Cowley County	Massive cyanobacteria bloom. City staff closed the lake to recreation until after the bloom passed.
April 2004	Lake Anthony, Harper County	Fishkill. Algae boom due to excessive nutrients identified as cause.
June 2004	Marion Reservoir, Marion County	More cyanobacteria blooms. Continued into late summer. Recreation advisories posted.
August 2004	Lake Meade State Park, Meade County	Massive cyanobacteria bloom. Species known to have potential for producing toxins. Beach closed to contact recreation.

February 2005	Gardner City Lake, Johnson County	Taste and odor in drinking water attributed to algae bloom.
Summer 2005	Marion Reservoir, Marion County	More blooms in Marion Reservoir. Continued into late summer. Cyanobacteria. Recreation advisories posted; taste and odor in drinking water.
June 2005	Big Hill Lake, Labette County	Taste and odor attributed to cyanobacteria.
July 2005	John Redmond Reservoir and Neosho River downstream, Coffey County	Taste and odor attributed to cyanobacteria.
August 2006	Miami County State Fishing Lake, Miami County	Recreational advisory due to very large cyanobacteria bloom
September 2006	Strowbridge Reservoir, Osage County	Cyanobacteria bloom caused taste and odor in finished drinking water.
June 2007	Banner Creek Reservoir near Holton, Jackson County	Taste and odor attributed to cyanobacteria.
July 2007	Marion Reservoir, Marion County	Cyanobacteria bloom resulted in death/illness of two dogs who drank and swam in the water. Algal toxicosis.
July 2007	Herington City Lake, Dickenson County	Cyanobacteria bloom. Health advisory issued.
September 2007	Trianon apartment complex in Topeka, Shawnee County	Cyanobacteria bloom with toxic compounds in water.
June 2008	Small lake, Barton County near Great Bend	Fish kill attributed to large algae bloom.

Source: KDHE Lake and Wetland Annual Reports, Taste and Odor Assistance Program.

INTRODUCTION

Structural flood control projects seek to control the flow of water and are intended to prevent flood waters from reaching land, structures, or other property at risk of damage. There are three general types of structures: levees and floodwalls, dams and diversions, and channel and drainage modifications. Over time sediment will accumulate behind dams and in channels. This accumulation will reduce the carrying capacity of channels, as well as reduce the storage capacity and function of reservoirs for important uses including water supply, flood control, and recreation. Most reservoirs are designed so that the sediment pool will be available for the design life of the reservoir, which is approximately 50 -100 years. Once the sediment pool is filled, the incoming sediment begins to accumulate in the remainder of the reservoir, reducing storage for water supply and possibly recreation. The flood pool function is designed not to be diminished by sediment through the design life of the dam.

Aging infrastructure is another significant problem. Dams and levees need to be maintained and repaired not only because they are aging, but also because development has occurred in more recent years below dams and behind levees subjecting structures and people to increased flooding risk and increasing hazard classifications.

SEDIMENTATION

Federal reservoirs are an important source of water supply and flood protection in Kansas, providing water in some manner to roughly two-thirds of the citizens of the state and reducing costly flood losses. The state of Kansas owns water supply storage in 13 federal reservoirs operated by the U.S. Army Corps of Engineers (Corps), but flood control is a part of every federal reservoir. Storage is being diminished over time due to sediment deposition, reducing reservoir capacity.

Reservoir sedimentation is a result of soil erosion from the land surface and from stream channels and banks. In most Kansas watersheds, this natural process has been accelerated due to changes in land cover and the modification of stream channels to accommodate agricultural, urban, and other land uses. Naturally occurring wetlands and healthy riparian areas are integral components of managing sediment in a watershed and maintaining stable streams. State and federal agencies work to promote voluntary participation in government cost share programs that restore, enhance, and create wetlands and riparian vegetative buffers to reduce sediment from entering into the reservoirs.

Historically, most erosion control programs have focused on reducing the amount of soil erosion coming from the land surface through the implementation of best management practices (BMPs) on cropland, pasture and rangeland, and construction sites. Watershed structures, which can reduce floodplain scour and trap sediment, have also been constructed in many watersheds to address localized rural and agricultural flooding concerns.

While sedimentation affects all reservoirs, those in the Neosho River basin experience the highest rate of sedimentation. Sedimentation is a large factor in the decreasing quantity of storage capacity in all of the reservoirs in the Neosho basin as indicated in table below. Reservoirs are planned for a design life which is the period of time during which a reservoir can provide 100% of all authorized purposes. During design, the dam is sized to accommodate the amount of sediment expected to be delivered to the lake from the watershed over that design life (typically 50 to 100 years), as well as enough storage to meet the authorized purposes. The sediment storage is apportioned among the conservation and flood pools. Theoretically, until the end of the design life, the quantity of storage for the authorized purposes is not affected by the sediment depositions, with the flood pool designed to continuously function as flood protection. Periodic bathymetric surveys are conducted to determine the amount of sediment actually accumulating in the reservoir. This is compared to the original survey to determine the loss of storage capacity that has occurred.

Reservoir	Top of Conservation Pool (Feet)	Original Storage Capacity (Acre-feet)	Capacity at most recent survey (Acre-feet)	Estimated Current Capacity (Acre-feet)	Design Sedimentation Rate (Acre-feet/Year)	Actual Sedimentation Rate (Acre-feet/Year)	Loss of Capacity to Date
Council Grove	1,274.0	52,375 (1963)	43,781 (2008)	43,581	206	200	17%
John Redmond	1,039.0.	82,231 (1963)	50,227 (2007)	48,739	404	745	41%
Marion	1,350.5	84,948 (1967)	80,926 (2008)	80,825	94	100	5%

Table 1. Sedimentation estimates for reservoirs in the Neosho basin.

Of the three federal reservoirs in the Neosho basin, John Redmond has the highest sedimentation rate and greatest loss of capacity. With a conservation pool elevation of 1,039 feet, John Redmond has a current estimated capacity of 52,687 acre-feet. The reservoir's original capacity was 82,231 acre-feet in 1963. In the bathymetric survey conducted in 2007, the capacity was determined to be 53,927 acre-feet. In comparing the 2007 survey and the 2000 survey, the sedimentation rate for John Redmond is calculated to be 643 acre-feet/year. The reservoir was designed for a sedimentation rate of 404 acre-feet/year. The loss of capacity in the conservation pool is 36%. The loss of capacity in the flood pool, if any, is unknown.

FLOODING

A Historical Look

In the 20th century, notable flooding occurred on the Kansas River in 1903, 1951, and 1993. Flooding of the Arkansas River (1965), the Marmaton River (1986, 1998) and the Walnut River (1998) are additional examples. Disastrous flash flooding occurred in the Kansas City metropolitan area in 1977 and 1998.

A Recent Look

According to the National Climatic Data Center, between January 1, 2008, and October 31, 2008, there were 215 flooding events documented in Kansas. These flooding events resulted in property damage totaling a little more than $6 million and crop losses valued at $293,000. The greatest loss due to the recent flooding was one death in Valley Center on September 12, 2008, and another death in Argonia on September 13, 2008.

Flood prevention and mitigation in the mid-20th century concentrated on structural controls. A total of 24 large federal reservoirs have been constructed in Kansas by the Corps and the U.S. Bureau of Reclamation (Bureau). Additional federal funding for watershed dams has been provided by the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). The primary purpose of these reservoirs is flood control. Federally funded levees also provide a measure of structural flood protection.

CONSTRUCTION OF FLOOD CONTROL STRUCTURES

Federal Role

Reservoirs and Dams

The *Flood Control Act of 1944*, which included the *Pick-Sloan Missouri Basin Plan*, significantly expanded Corps involvement in large multi-purpose projects. This Act authorized massive flood control and irrigation development within the Missouri River basin, including that portion within Kansas. Other federal legislation authorized construction of reservoirs within the Arkansas and Missouri river basins. Eighteen Kansas reservoirs were built between 1944 and 1960. During the peak of the reservoir construction period in the 1960s, 13 reservoirs were constructed. By the late 1960s, construction of major water projects had declined. Changing national priorities, increasing construction costs, and completed projects at most prime locations were contributing factors. Between 1970 and 1985, no major water projects were approved and Congress deauthorized several previously approved projects. In Kansas, a total of 55 major federal reservoirs were authorized, but only 24 were built as illustrated by the Figure 1 below (page 30).

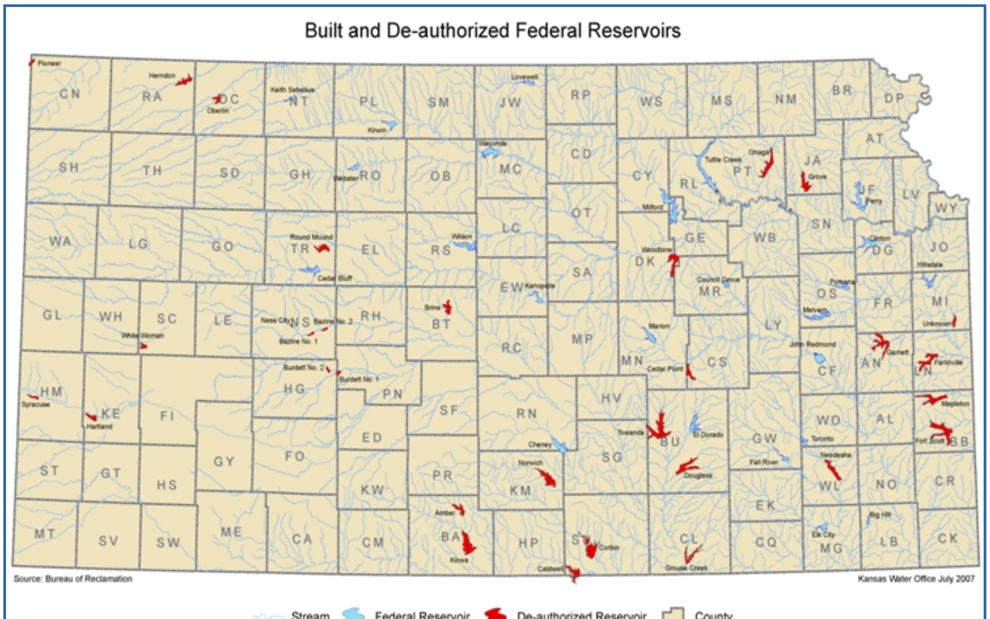


Figure 1. Constructed and De-Authorized Federal Reservoirs.

The 24 federal reservoirs in Kansas have a combined contributing drainage area of over 40,000 square miles and a flood control storage capacity of nearly 10 million acre-feet. Table 2 (page 30) provides a summary of information about these reservoirs.

The Corps' water project planning and funding process was fundamentally changed by the *Water Resource Devel-*

opment Act (WRDA) of 1986. WRDA established new cost-share formulas, resulting in financial and decision-making roles for non-federal project sponsors. WRDA provided the Corps with authority to determine if changes can be made in existing structures or operations to improve environmental quality.

Major Federal Reservoirs in Kansas					
				Storage Capacity (acre-feet)[3]	
	Operating Agency[1]	Year Storage Began	Drainage Area (sq. miles)[2]	Conservation/ Multi-purpose	Exclusive Flood Control
Big Hill	Corps	1981	37	26,650	12,571
Clinton	Corps	1977	367	120,643	394,000
Council Grove	Corps	1964	246	43,176	64,217
El Dorado	Corps	1981	234	157,973	79,259
Elk City	Corps	1966	634	38,385	248,667
Fall River	Corps	1949	585	19,433	232,249
Hillsdale	Corps	1981	144	71,950	160,000
John Redmond	Corps	1964	3,015	44,385	524,417
Kanopolis	Corps	1948	2,327	43,121	419,000
Marion	Corps	1968	200	75,133	61,213
Melvern	Corps	1970	349	147,973	360,000
Milford	Corps	1964	3,796	351,577	1,146,000
Perry	Corps	1966	1,117	199,824	723,000
Pomona	Corps	1962	322	59,642	240,000
Toronto	Corps	1960	730	15,734	179,808
Tuttle Creek	Corps	1963	9,628	253,265	2,151,000
Wilson	Corps	1965	1,917	243,000	773,000
Cedar Bluff	Bureau	1950	5,530	170,658	364,000
Cheney	Bureau	1964	933	143,427	80,857
Kirwin	Bureau	1955	1,373	99,435	313,000
Lovewell	Bureau	1957	364	41,690	86,000
Keith Sebelius	Bureau	1964	712	34,330	134,000
Waconda	Bureau	1967	5,076	217,426	942,000
Webster	Bureau	1956	1,125	77,370	260,000
Total			40,761	2,696,200	9,948,258

Table 2. [1]Corps – U.S. Army Corps of Engineers; Bureau – U.S. Bureau of Reclamation
[2]Contributing drainage area Conservation/Multi-purpose pool 2004 estimate by KWO; Exclusive flood control from BOR or COE

The National Dam Safety Program (NDSP), established by WRDA in 1996 and administered by The Federal Emergency Management Agency (FEMA), was designed to provide incentive grants to states and training to encourage research. While there have been successes and improvements and implementation of stronger state programs as a result of the NDSP, the safety and condition of the nation's dams have not improved overall. Successes have included modest increases in staffing, budgets and dam safety inspections in some state programs. The number of Emergency Action Plans (EAPs), the essential plans used in the event of a failure to identify and notify people residing below a dam and to coordinate their evacuation, have increased. However, the number of high hazard potential dams nationwide that have EAPs remains at only 50%. More significantly, many high hazard potential dams are unregulated and uninspected. Approximately 30% of the high hazard potential dams have not been inspected within the last five years.

Federal agencies own or regulate a very small percentage of the 85,000 dams in the U.S. but they face significant oversight challenges. As the country's dams age and downstream development increases, more significant rehabilitation will be needed. Examples include the major improvements to Folsom Dam in Northern California, which were jointly undertaken by the Corps and the Bureau at an estimated cost of $1.5 billion through 2019.

Despite some successes, the overall condition of the nation's dams has not improved in recent years. This is evidenced by the rising numbers of dams, especially high hazard dams, that are deficient and in need of repair as well as by the limited number of dams that are actually repaired each year. To make significant improvements in the nation's dams, a matter of critical importance to public health, safety and welfare, Congress, the administration, state dam safety programs, and dam owners will have to develop an effective inspection, enforcement, and funding strategy to reverse the trend of increasingly deteriorating dam infrastructure.

Watershed Projects

The *Watershed Protection and Flood Prevention Act* of 1954, PL 83-566, authorized a permanent, nationwide program to provide technical and financial assistance to local watershed groups willing to assume responsibility

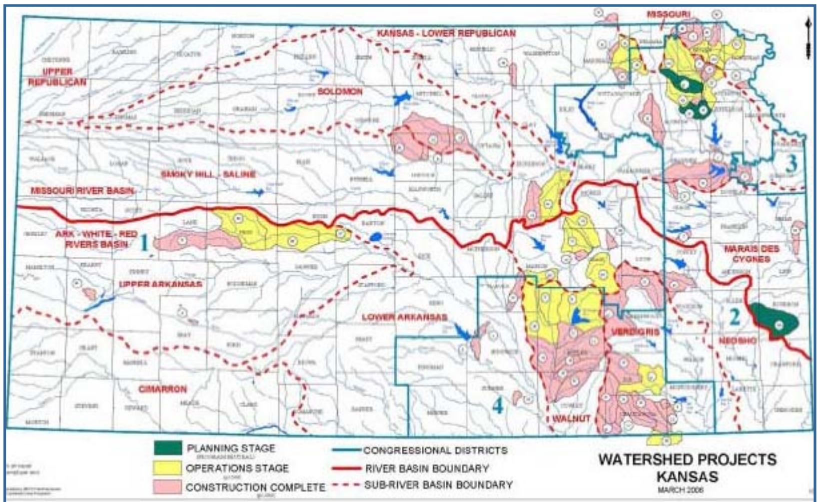


Figure 2. Status of PL-566 Dams in Kansas

for initiating, constructing, and sharing in costs of upstream watershed conservation and flood control. A Pilot Watershed Program within the former USDA Soil Conservation Service was funded in the *Agricultural Appropriations Act of 1953*. Fifty-four pilot watershed projects were authorized, of which five were in Kansas under this program. The 2000 amendments authorized the NRCS to work with local communities and watershed project sponsors to address concerns related to aging dams.

The NRCS implements the provisions of PL 83-566 through three programs:

- Watershed Surveys and Planning
- Watershed Protection and Flood Prevention Operations
- Watershed Rehabilitation

Kansas ranks third among the states in the federal watershed dam construction program with 63 active PL 83-566 projects. Only Texas and Oklahoma have more. Figure 2 above (page 32) shows the location of these projects and their status as of March 2006.

The 1960s and 1970s were the prime decades for watershed dam construction in Kansas. More than 70 dams were constructed in 1965 alone. In recent years fewer than 10 dams have been constructed annually under federal programs. The graph (Figure 3 to the right (page 32) shows this trend in the number of dams constructed.

As of 2006, 778 dams had been completed in Kansas, five were under construction, and 190 remained to be built. The unfunded federal commitment resulting from this backlog in PL 83-566 construction in Kansas was $68.4 million. More than 1,400 small dams in Kansas have been constructed by watershed districts for flood control purposes, including the 778 constructed with federal assistance. Technical assistance was provided for some dams by the NRCS as authorized by the PL 83-566 and other authorizations. Cost-share assistance has been provided by NRCS and, since 1977, by the State Conservation Commission (SCC).

State Role

KDA - DWR: Dam Safety Program

This program is part of the *Stream Obstructions Program* within the Water Structures Program of the DWR. The *Kansas Stream Obstructions Act* gives the Chief Engineer-DWR the exclusive authority to regulate the construction, operation, and maintenance of dams in Kansas. Written consent or a permit from the Chief Engineer is required to construct a dam or make changes in any dam as required by the Act. The Chief Engineer has the power and duty to inspect any dam and may issue orders requiring correction of deficiencies or removal of the dam if deemed necessary. An annual inspection of all dams found to be unsafe is required until the deficiency is corrected or the dam is removed.

Following amendments to the *Stream Obstruction Act* in 2002, a structure requires a permit as a dam if it meets either of the following three criteria:

1. It is an artificial barrier which can impound water or other liquids that has a height of 25 feet or

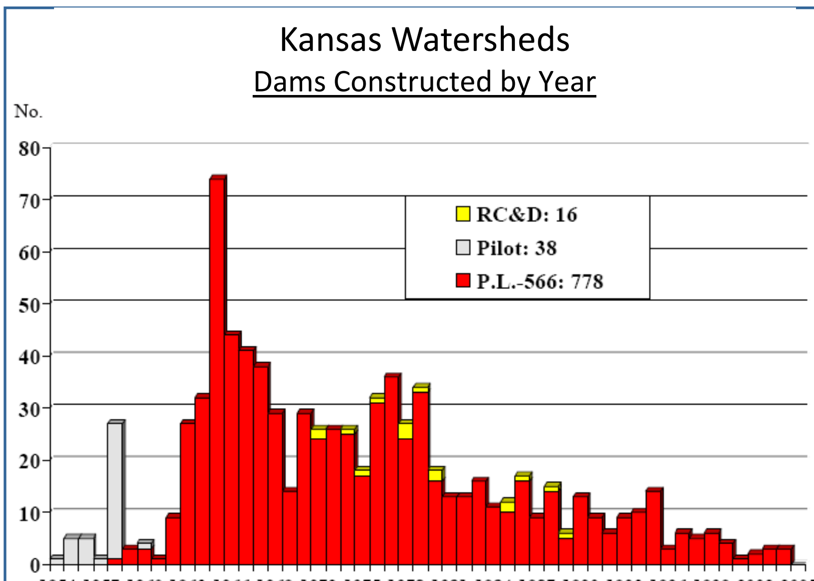


Figure 3. Trend in the number of dams constructed.

more measured from the lowest point on the downstream toe to the top of the barrier; or

2. It is an artificial barrier which can impound water or other liquids that has a height of six feet or more, measured as in number 1, and is capable of impounding 50 acre-feet or more.
3. Between 1978 and 2002, the statute exempted from the permitting requirement all dams which impounded 30 acre-feet of water or less.

The Chief Engineer has the power and duty to inspect any dam and to issue orders requiring correction of deficiencies or removal of the dam. Where a dam's condition is so dangerous as to pose an immediate safety threat, the Chief Engineer shall immediately employ any remedial means considered necessary. The Chief Engineer continues in control of any such dam until it is considered safe or the emergency prompting the remedial action has ceased. The *Stream Obstructions Act* requires that the Chief Engineer adopt rules and regulations to establish standards for the administration and enforcement of the Act. Three dam hazard classifications (A, B, and C) have been established and updated as of May, 2007. Full descriptions of these three dam hazard classifications can be found in K.A.R. 5-40-20.

K.A.R. 5-40-73 requires the owner of each significant hazard dam to create an EAP. Owners of high hazard dams are required to create and maintain an EAP that meets FEMA guidelines presented in Handbook 64 – Federal Guidelines for Dam Safety. Plans are submitted to the Chief Engineer.

The DWR has received federal financial assistance for enhancement of the *Dam Safety Program.* Current Congressional authorization for these grants runs through September 30, 2011. Grants are renewed each year.

The State Conservation Commission: Watershed Dam Construction Program (WDCP)

The *Kansas Watershed District Act* (WDA) was enacted in 1953 to provide a subdivision of state government with adequate powers and duties to sponsor watershed projects developed with federal assistance under PL 83-566. Watershed districts have authority to levy taxes and special assessments, issue bonds, and to acquire interests in land by gift, purchase, exchange, or eminent domain. Figure 4 in the next column (page 33) shows watershed district boundaries.

The WDA requires that a general plan identifying planned works of improvement such as dams and their associated

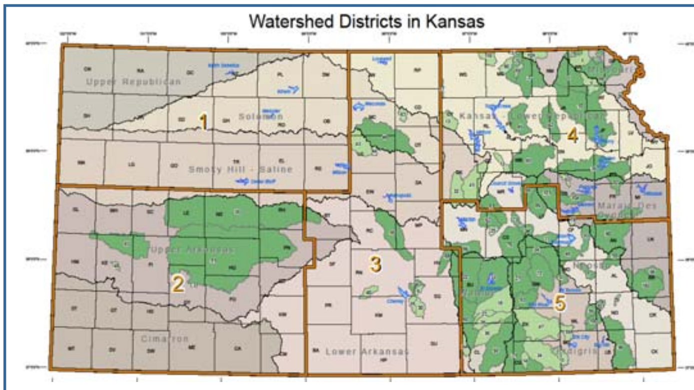


Figure 4.

costs and benefits be prepared. The general plan is reviewed and approved by the Chief Engineer, DWR. There are presently 86 organized watershed districts in Kansas that cover about 22% of the state's area. Approximately 60 districts have active general plans. Improvements may be financed by general tax levy or special assessment against the area benefited. Bonds may be issued by the district following a vote. A majority of affected landowners must approve special assessments. General tax levies may be used to finance operating costs and works of improvement without a special election. Most districts have found it necessary to finance their projects within their taxing authority with only a few utilizing the special assessment option.

Watershed district general plans sometimes include works of improvement beyond those eligible for federal financial assistance. The most common funding source other than federal PL 83-566 assistance has been the *Watershed Dam Construction Program* (WDCP) managed by the SCC. The WDCP provides state financial assistance to organized watershed, drainage, or other special purpose districts to implement flood control structural and non-structural practices. These practices provide protection for roads, bridges, utilities, agricultural lands, rural areas, and occasionally urban areas. In addition, structures may provide water for livestock and in some instances for rural fire departments. The structures also provide wildlife habitat and trap sediment and pollutants. Construction and rehabilitation, including inundation mapping, of flood control and/or grade stabilization dams are the main practices and components of the program. The chart, Figure 5 (page 34), shows the amount of money spent per fiscal year for cost-share assistance for new dam construction sites projects.

State Watershed Rehabilitation Program

Since 2006 Kansas legislators have recognized that the key to the success of the WDCP is a sustained rehabilita-

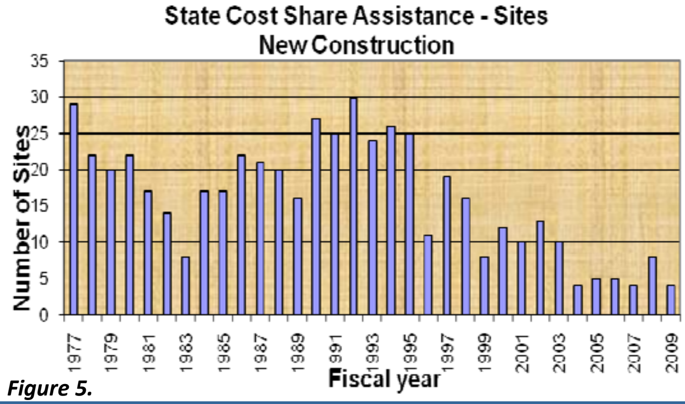


Figure 5.

tion program. Rehabilitation was defined as any work, except work required due to inadequate operation and maintenance, to extend the service life of a dam and to meet the applicable safety and performance standards. Inundation mapping was identified as a rehabilitation component.

	Rehabilitation		Inundation Mapping	
	Sites	Funding	Sites	Funding
FY 2007	11	$419,965	$160	$494,505
FY 2008	10	$176,954	$46	$167,093
FY 2009	14	$270,517	$23	$86,282
Total	**35**	**$867,436**	**$229**	**$747,880**

Table 3.

<u>Breach Inundation Zone Mapping</u> – The SCC provides 70% cost-share assistance for dam breach inundation zone mapping. Maps produced are approved by the Chief Engineer-DWR. The maps are developed using engineering principles and represent the best estimate of where the water would flow in the event of a dam failure. These maps should be used in advance to develop warning and evacuation plans as well as to manage development in the inundation zones and identify downstream hazards.

On November 18, 2005 the Kansas Water Authority approved a Policy Section for the *Kansas Water Plan* concerning Small Dam Safety and Rehabilitation. The Policy Section made recommendations for expenditure of the FY 2006 SCC appropriation. Included in the recommendations were stipulations that part of the appropriation be used for breach inundation area mapping and cost-share assistance for such mapping, provided that appropriate measures to control future development within the inundation area have been taken. Establishment of a state cost-share program for small dam rehabilitation and upgrades were also recommended, along with notification to owners of property within dam breach inundation areas and limitation of dam owner liability.

As noted in the previous column, the SCC currently provides cost-share assistance to watershed districts to accomplish dam rehabilitation and inundation area mapping. However, the SCC does not currently, due to regulation, provide assistance to private dam and levee owners. Part of the Small Dam Safety and Rehabilitation Policy Section approved in 2005 addresses the need for this.

Multipurpose Small Lakes Program

Administered by the SCC, the Multipurpose Small Lakes (MPSLP) Program is another means for the state to assist with the provision of a public water supply and flood protection, at an affordable price, especially for smaller towns and rural water districts. The map, Figure 6 below (page 34), shows the status and location of multipurpose small lakes in Kansas.

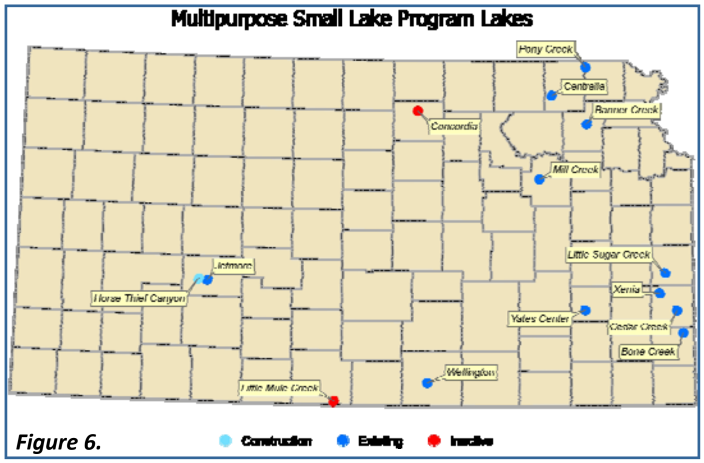


Figure 6.

Projects funded by the legislature will receive assistance in the form of a grant for flood control and, if included, recreation. Funds appropriated for the water supply component shall be on a loan to be paid back to the state. The state initially funds the construction of the dam, typically a watershed structure, but is paid back by the participating community or communities. Upon repayment of the costs, the developed water right is transferred to the

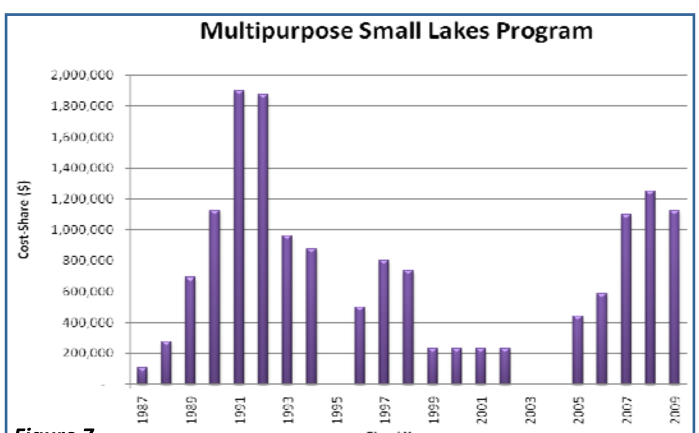


Figure 7.

community once use of water starts. Figure 5 (page 34), shows the amount of money spent per fiscal year for cost-share assistance for the MPSLP.

Maintenance and Rehabilitation of Existing Flood Control Structures

Small Dam Safety

Dam failure occurs infrequently but the consequences can be catastrophic, depending upon the degree of development downstream from the dam. The breach inundation zone may extend as much as 5 to 10 miles below a small dam depending upon factors such as the height of the dam, the water storage capacity of the reservoir and local topography. As is the case with other physical infrastructure, dams need regular maintenance and upkeep. Many dams were constructed in the 1950s and 1960s and are now showing the effects of aging. These effects include physical deterioration of structural components and increased runoff due to upstream development, with increased sediment deposition into the reservoirs. Since the reservoirs are designed to store the sediment anticipated to accumulate during the design life of the dam, all such reservoir storage pools will be filled with sediment at some time in the future. If modifications are not performed, continued delivery of sediment to the reservoir will eventually encroach on the flood detention storage resulting in more frequent flows through the auxiliary spillway, increased maintenance needs, and the increased threat of dam failure. If the dam fails, the stored sediment will be released into downstream riparian areas that could be damaged by pollutants attached to the sediment particles.

Demographic and land use changes have greatly altered the physical setting of some projects. Dam construction standards have been revised since many dams were built. The hazard class of some dams, as defined in the K.A.R. 5-40-20, has been increased due to breach zone map development. Dams elevated to a higher hazard class may be required to be upgraded to meet the design standards for that class as per decision of the chief of engineer. Dam owners may be challenged by the costs of routine maintenance and upkeep. The *Kansas Stream Obstructions Act* gives the Chief Engineer exclusive authority to regulate the construction, operation, and maintenance of dams in Kansas. As of 2005, nearly 6,000 small dams falling under this authority had been constructed in Kansas.

These dams provide flood control, public water supply, recreation, and other benefits. Many dams were built by local watershed districts using federal or state cost-share assistance. Others have been constructed by municipalities and by the state, but mostly by private entities.

NRCS Watershed Rehabilitation Program

There is growing national concern that many small flood control dams built by local watershed districts with USDA technical and financial assistance are at or near the end of their 50-year planned design life. Watershed rehabilitation amendments to the *Watershed Protection and Flood Prevention Act of 1954* (PL 83-566) were enacted in 2000, establishing the *Watershed Rehabilitation Program*.

These amendments authorize the NRCS to work with local communities and watershed project sponsors to address public health and safety concerns and potential adverse environmental impacts of aging dams. Only dams constructed through USDA assisted water resource programs or authorizations qualify for rehabilitation assistance. Rehabilitation projects must be cost-shared between the federal government and local project sponsors. The NRCS may provide up to 65% of the total cost of the rehabilitation project.

There are 829 watershed dams in Kansas that qualify for this rehabilitation assistance. Most of these dams have a 50-year design life and their average age is 33 years. Thirty-four of these dams have exceeded their design life; an additional 462 dams will do so by 2018. One hundred twenty-six of these dams have had a hazard class change due to development below the dam or because of a change in definitions, methods, criteria, and/or policy. Fifty-seven other dams have had a hazard class change due to removal of potential hazards. Between 1958 and 1979, 105 dams were built with corrugated metal pipe as the principal spillway. A study of one of the first watershed projects showed that 40% of such spillway pipes needed replacement which would also include upgrading the dam to today's design standards. Presently, the NRCS has completed assessment of 47 dams in Kansas. Of these, structural deficiencies were discovered in 5 dams and 18 dams have had a hazard class increase since construction.

To date, the NRCS has received five applications for rehabilitation planning in Kansas from the following sponsors:

- Rock Creek in Butler County
- Sand Creek in Harvey County
- Switzler Creek in Osage County (funded with American Recovery and Reinvestment Act funds)

- Spring Creek in Sedgwick County
- Wakarusa River Watershed Joint District

SCC is providing cost-share assistance through the WDCP to four of the above five listed watershed sites.

Levees

A National Look

Of the nation's estimated 100,000 miles of levees, more than 85% are locally owned and maintained. The reliability of many of these levees is unknown and many are over 50 years old and were originally built to protect crops from flooding. With an increase in development behind these levees, the risk to public health and safety from failure has increased. Rough estimates put the cost at more than $100 billion to repair and rehabilitate the nation's levees.

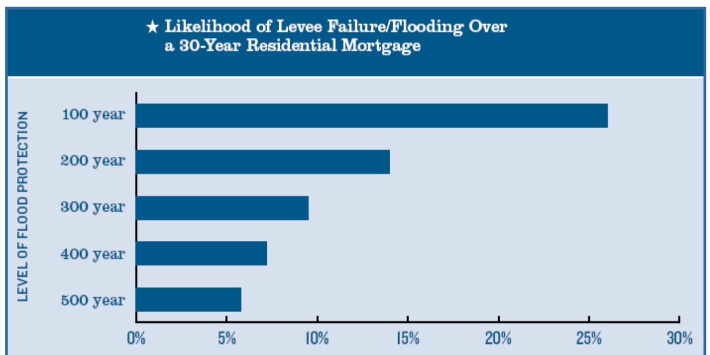
There is no definitive record of how many levees there are in the U.S., nor is there an assessment of the current condition and performance of those levees. Recent surveys by the Association of State Dam Safety Officials and the Association of State Floodplain Managers found that only 10 states keep any listing of levees within their borders and only 23 states have an agency with some responsibility for levee safety. FEMA estimates that levees are found in approximately 22% of the nation's 3,147 counties. Forty-three percent of the U.S. population lives in counties with levees. Many of those levees were designed decades ago to protect agricultural and rural areas, not the homes and businesses that are now located behind them.

In the aftermath of hurricanes Katrina and Rita in 2005, Congress passed the Water Resources Development Act (WRDA) of 2007. The Act required the establishment and maintenance of an inventory of all federal levees, as well as those non-federal levees for which information is voluntarily provided by state and local government agencies. The inventory is intended to be a comprehensive, geospatial database that is shared between the Corps, FEMA, the Department of Homeland Security (DHS), and the states.

While the Corps has begun the inventory of all federal levees, to date, few states or local agencies have provided any formal information, leaving the inventory far from complete. In addition, there is still much to be determined about the condition and performance of the nation's levees, both federal and nonfederal. As of February 2009, initial results from Corps' inventory show that while more than half of all federally inspected levees do not have any deficiencies, 177, or about 9%, are expected to fail in a flood event equal to or smaller than the flood event for which they are designed for. The inventory data collection process is ongoing and these preliminary findings are expected to change as the process continues.

WRDA 2007 also created a committee to develop for the first time recommendations for a national levee safety program. The National Committee on Levee Safety completed its work in January 2009 and the panel recommended that improvements in levee safety be addressed through comprehensive and consistent national leadership, new and sustained state levee safety programs, and an alignment of existing federal programs.

Often, the risk of living behind levees is not well-known, and the likelihood of flooding is misunderstood. For this reason, little focus is placed on measures that the public can take to mitigate their risks. Though the 1% annual chance flood event ("100-year flood") is believed by many to be an infrequent event, in reality there is at least a 26% chance that it will occur during the life of a 30-year mortgage. The likely impacts of climate change are expected to increase the intensity and frequency of coastal storms thereby increasing the chance of flooding (Figure 8 below (page 36)).



SOURCE National Committee on Levee Safety ***Figure 8.***

In 1968, Congress enacted the National Flood Insurance Program (NFIP). One of the primary purposes of the NFIP was to address the inability of the public to secure privately backed insurance for economic losses from flooding. The NFIP designated the 1% annual chance event ("100-year flood") as a special flood hazard area in which those holding federally backed mortgages would be required to purchase flood insurance. Never intended to be a safety standard, the 1% annual chance event became the target design level for many levees because it allowed development to continue while providing relief from mandatory flood insurance purchase for homeowners living behind accredited levees. Allowing levees to simply meet the minimum requirements of the NFIP has created an unintentional—and potentially dangerous—flood insurance standard that is now used as a safety standard.

During the past 50 years there has been substantial development on lands deemed to be protected by levees. Coupled with the fact that many levees have not been well maintained, this sizeable growth has put people and infrastructure at risk—the perceived safety provided by levees has inadvertently increased flood risks by attracting development to the floodplain. Continued population growth and economic development behind levees is considered by many to be the dominant factor in the national flood risk equation, outpacing the effects of increased chance of flood occurrence and the degradation of levee condition. Unfortunately, lands protected by levees have not always been developed in a manner that recognizes the benefits of the rivers and manages the risk of flooding.

Additionally, in the absence of a comprehensive levee inventory, there are many uncertainties regarding location, performance, and condition of levees. The lack of formal government oversight, sufficient technical standards, and effective communication of the risks of living behind a levee, has further placed people and property in danger of floods.

Finally, FEMA's Flood Map Modernization Program, which remaps floodplains using modern technologies, is resulting in a reexamination of levees throughout the United States to determine if they can still be accredited. Before accrediting a levee, FEMA is requiring many communities to certify that their levees meet the 1% criteria and are in sound condition. Flood insurance is one of the most effective ways to limit financial damages in the case of flooding and speed recovery of flood damaged communities. Currently, many people who live behind levees do not believe that they need flood insurance, believing that they are protected by a levee structure. Requiring the purchase of mandatory flood insurance is intended to increase the understanding that living behind even well-engineered levees has some risk. This may encourage communities to build levees to exceed the 1% annual-chance protection standard or limit further development behind levees.

To address the current lack of resilience in the nation's levee system, DHS has included levees within the critical infrastructure protection program in an attempt to identify those levees that present the greatest risk to the nation. DHS has also funded research to increase the robustness of levees—for example, armoring the slopes to resist erosion should floodwaters exceed the design elevation—and technologies are currently under study to rapidly repair breaches that may occur in a levee. To ensure system integrity, future investments must also focus on life-cycle maintenance, research, development of EAPs for levee-protected areas, and security. Much is still unknown about the condition of the nation's tens of thousands of miles of levees. The residual risk to life and property behind such structures cannot be ignored. Due to their impact on life and safety issues, and the significant consequences of failure, as well as the financial burden of falling property values behind levees that are not safe and are being decertified, the nation must not delay addressing levee issues.

Kaw Levee– Wyandotte.

A Statewide Look

DWR has established levee hazard classes per K.A.R. 5-45-8 and has also established levee design criteria per K.A.R. 5-45-10. Levees in Kansas, as found nationally, were built solely for flood protection and were largely constructed to protect agricultural land. In many areas of Kansas, communities rely on levees for protection from flood waters even though many were not built to design standards established to protect people and property. The design level of many of these levees is listed as 1% annual-chance of occurrence, however the actual design level is often unknown and their presence can generate a false sense of security. In 1993 crop acres suffered losses due to overtopping of nine of 15 units in the federally constructed Missouri River Levee System and virtually all nonfederal farm levees in the district. Due to increasing risk to safety incurred from increased development behind the levees, coupled with the unknown design level of many levees and their status as aging infrastructure, a more comprehensive compilation of information about levees in Kansas should be available in 2010 according to the Kansas Hazard Mitigation Plan.

In Kansas there are countless privately owned levees and approximately 80 levees that protect communities in Kansas, including at least 19 federal levees. The Corps recently published a list of levees of concern and Kansas has one levee that was included on the list. That levee is at Ft. Leavenworth in Leavenworth County and was breached by the large flooding events in 1951 and 1993. Another levee of concern in Kansas is the Hartford Levee, near Hartford, Kansas, upstream of John Redmond Reservoir. The Corps has transitioned the Dam Safety Program to a risk informed program. This program applies to levees, dikes, and other structures associated with Corps projects. The initial step to this program is a Screening Portfolio Risk Assessment (SPRA). This screening level assessment, completed by a Corps risk cadre, is a screening level evaluation of the possible failure modes and the consequences of that failure. The SPRA for the Hartford Levee identified two areas of concern that led to the levee being considered high risk. Although the levee height is sufficient to contain the Probable Maximum Flood (PMF), the levee has inadequate freeboard for wind/wave run-up during unusual and extreme events. Seepage beneath the levee has been a concern for years. Construction of a foundation cut-off wall, seepage berm, relief wells, and an inverted filter have addressed much of the seepage area. Seepage and piping of foundation material is considered to be a risk at higher pool levels.

As part of the Corps feasibility study that included the reallocation of John Redmond Reservoir, a two foot pool raise was suggested to compensate for lost storage in John Redmond due to its high sedimentation rate. However, as part of the Corps risk informed program, reallocations that include pool raises on structures considered to be a high risk will not be approved until the concerns leading to higher risk are adequately addressed.

Pilot Projects

NRCS Rehabilitation Needs and Costs in Kansas

In a 1999 report, the NRCS estimated that it would cost approximately $20 million to repair or upgrade 97 PL 83-566 watershed dams in Kansas needing rehabilitation. An inspection of dams in the Little Delaware-Mission Watershed in northeast Kansas identified 11 grade stabilization structures in need of major rehabilitation. The cost of rehabilitating one of these dams, constructed in 1958, to current dam safety standards, was estimated to be $155,000. Another cost example is provided by a Pilot Rehabilitation Project conducted by the NRCS in the Sergeant Major Creek Watershed in Oklahoma. Two dams in this watershed were determined to be unsafe. Both had deteriorated metal and concrete components in the principal spillways and both structures had collected a considerable amount of sediment, resulting in lost flood protection. Rehabilitation work included:

- The old principal spillway pipes were plugged for abandonment and new pipes and concrete towers were installed.
- Foundation drains were installed in the back of the dams to stabilize the embankment.
- The earthen spillways were enlarged.
- The height of Dam No. 2 was increased to provide additional downstream protection, to protect a state highway, and to regain storage for flood protection.

Rehabilitation extended the life expectance of the dams for another 100 years. Rehabilitation costs were $325,998 for Dam No. 1 and $431,822 for Dam No. 2, giving an average cost per dam of $378,910. If this project had been completed under the dam rehabilitation provisions of the 2000 amendments to PL 83-566, the local sponsor would have been responsible for 35% of the total cost or $265,237 ($132,619 per dam).

SCC – Water Supply Restoration Program
Dredging of Mission Lake - Horton, Kansas

Mission Lake was constructed in 1924 by damming Mission Creek. The reservoir was constructed primarily as a raw water source for potable public water supply and for recreation. Sediment accumulation within the lake since the dam was constructed has significantly reduced the reservoir's water storage capacity. The City of Horton is now relying on water from ground water wells to serve the residents of the City and the town of Willis. The reservoir continues to be an attraction for boaters, skiers, and fisherman.

The City of Horton is participating as a pilot project under the Water Supply Restoration Program administered by the SCC. As a participant of this program, the City will receive cost share assistance for the restoration of Mission Lake. Restoration will include removal of up to 1,000,000 cubic yards of sediment and construction of a Confined Disposal Facility (CDF) within an unnamed tributary to Mission Creek for the purpose of depositing the dredged material upstream of the CDF.

Scope of Work-Design-Dredge Project for Mission Lake consists of the Design-Dredge removal of up to 1,000,000 cubic yards of sediment from Mission Lake. The Scope of Work for this Design-Dredge project is:

1. Design plans and specification for sediment removal and CDF;
2. Acquisition of permits;
3. Construction of CDF;
4. Mobilization of dredge equipment;
5. Dredging of up to 1,000,000 cubic yards of sediment;
6. Land Reclamation and Environmental Remediation;
7. Demobilization of dredge equipment.

The City of Horton expects the work to be completed by January 10, 2010.

Mission Lake Construction.

Although Mission Lake is used primarily for water supply and not flood control, the impacts of sedimentation are evident. The Pilot Project will be a good indicator of all the problems and concerns encompassed by the dredging of a federal reservoir or even a smaller watershed lake or MPSLP.

CHANGING CLIMATE

Kansas is a state with many dams, impoundments, and levees, and failure of these structures could result in loss of life and property and incurred environmental and economic damages. Severe flooding and other storms can increase the potential that dams and levees will be damaged and fail as a result of the physical force of the flood waters or overtopping. Dams and levees are usually designed to withstand a flood with a computed risk of occurrence. If a larger flood occurs, then that structure will likely be overtopped. If during overtopping the dam or levee fails or is washed out, the water behind it is released as a flash flood.

Recurrence intervals and probabilities of occurrences

Recurrence interval, in years	Probability of occurrence in any given year	Percent chance of occurrence in any given year
100	1 in 100	1
50	1 in 50	2
25	1 in 25	4
10	1 in 10	10
5	1 in 5	20
2	1 in 2	50

Table 4.

The term "100-year flood" is used in an attempt to simplify the definition of a flood that statistically has a 1% chance of occurring in any given year. Likewise, the term "100-year storm" is used to define a rainfall event that statistically has this same 1% chance of occurring. Over the course of one million years, these events would be expected to occur 10,000 times. However, just because it rained 10 inches in one day last year doesn't mean it can't rain 10 inches in one day again this year. The recurrence intervals and probabilities of occurrences are shown in Table 4 above (page 42).

Recent literature and global climate models suggest that changes in climate will make extreme precipitation events more common. The U.S. Geological Survey (USGS) and collaborating scientists are seeking to understand how the causes and timing of climate changes will affect events such as flooding and sediment discharge in alluvial environments. Prudent emergency preparedness and flood mitigation measures should be based on understanding historic flood records while searching the data for trends related to climate-forced events.

CONCLUSIONS AND RECOMMENDATIONS

Flooding is a reoccurring challenge in Kansas that can be costly, both in property lost and more significantly in loss of lives. Due to the high cost of flood damage and the even more significant potential loss of life, flood control measures such as reservoirs, dams, and levees are necessary. Although these structures do provide flood protection they are subject to deterioration due to aging and reservoirs are continuously affected by sediment.

Aging infrastructure is a national problem and increases the risk that dams and levees could fail during a flooding event. Failures could be disastrous due to development below dams and behind levees. Although national efforts are being initiated, additional state and local action is needed to ensure the safety of communities thought to be protected from flooding by dams and levees.

Reservoirs are designed to accumulate sediment, but that sediment can have impacts on all of the beneficial purposes of the reservoir, including water supply, recreational opportunities, and flood protection. A large contributor of sediment into the reservoirs is land surface and stream bank erosion. Because the rate of sedimentation is so high in many river basins in Kansas, it is important that actions are taken to reduce or remove sediment in reservoirs.

Due to the impacts on reservoirs and their beneficial purposes, and dams and levees protecting people and property, the following recommendations are proposed:

1. Design, populate, update, and maintain a statewide database on dams and levees including correct locations, hazard class, status, age, and condition that is available to all state agencies with limited public access.
2. Develop and maintain a funding source to assist dam and levee owners in permitting, maintaining, and rehabilitating dams and levees that is not limited to Watershed Districts.
3. Develop and maintain a funding source to assist dam owners in completing inundation maps that is not limited to Watershed Districts.
4. Develop and maintain a funding source to assist dam owners in removing residential structures from the inundation area of the dam. An easement prohibiting future development of the inundation area would need to be acquired that is not limited to Watershed Districts.
5. Develop and maintain voluntary incentives for proactive dam and levee maintenance for private owners.
6. Map flood pools to evaluate impacts from sediment.
7. Use LiDAR to conduct flood mapping for areas at risk.
   a. Show areas that are more prone to flooding, which will be a benefit to inundation mapping.
   b. Evaluate dams and levees more closely to improve effectiveness and reduce possible damage to the structures.
   c. Prevent or minimize construction in flood prone areas to minimize loss of life and property damage.
   d. Allow for removal of levees so areas could flood naturally so more critical areas, including inhabited rural areas and urban areas, would not flood.
8. Continue work on reduction of sediment entering the reservoirs to protect water supply storage, flood protection, and recreation. This work should include continued efforts with Best Management Practices (BMPs), stream bank stabilization and wetland creation and restoration, and continued efforts through the Watershed Restoration and Protection Strategy (WRAPS) groups.
9. Begin initial scoping process for additional pilot projects for reservoir dredging to determine feasibility and to locate possible dredging sites.

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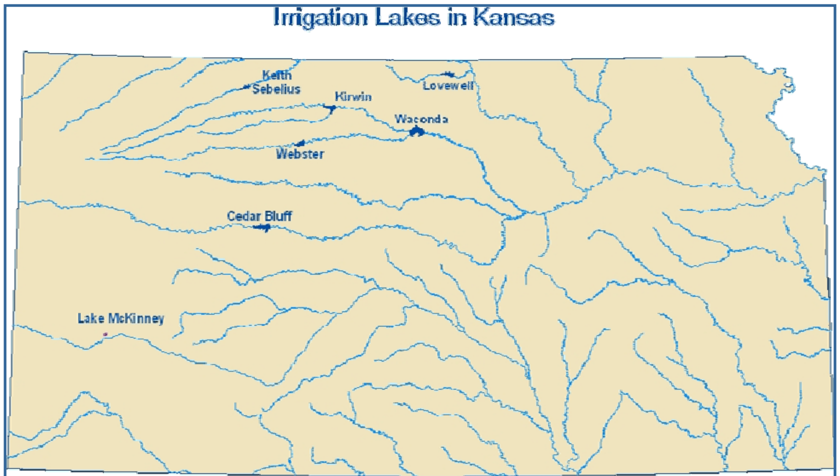

Figure 1.

INTRODUCTION

Irrigation is the dominant use of water in Kansas, accounting for approximately 84% of all water diversions (2007 data). The source for most of the irrigation water is ground water; however, many irrigators and irrigation associations rely on surface water impoundments (27% of all surface water use). This report covers the federal reservoirs and in more general terms the state, city and private impoundments. Irrigation was an authorized use for six federal reservoirs in Kansas (Figure 1 above (page 42)). Irrigation below reservoirs without formal (ownership of) storage rights in the reservoir or membership in irrigation districts also occurs in Kansas. These water right allocations may depend on the ability of the hydrologic system to supply surface water from "natural flow", water quality reservoir releases or ground water recharge from the surface flows that benefit wells withdrawing from alluvial aquifer.

Sedimentation of reservoirs impacts the availability of water for irrigation in that it reduces storage space for the irrigation water within the conservation pool of the reservoir. In one reservoir the irrigation water rights have been leased for maintenance of a higher lake level. In another instance the water right and storage space were sold for other uses. Both changes were reactions to increased unreliability of the availability of water for irrigation, and the costs of storage outweighing the benefits of irrigation. A sale or lease can provide debt relief for the irrigation association.

IRRIGATION FROM FEDERAL RESERVOIRS OUT OF STATE

Two federal reservoirs, John Martin reservoir in Colorado and Harlan County reservoir in Nebraska, are a part of the irrigation supply in Kansas supplying surface flows to the Arkansas and the Republican rivers, respectively. Water stored in John Martin Reservoir is managed through the Kansas-Colorado Arkansas River Compact. The water stored at the Harlan County Reservoir comes under the Republican River Compact between Kansas, Colorado and Nebraska.

John Martin Reservoir, Colorado

John Martin Reservoir is located approximately 60 miles west of the Kansas/Colorado state line on the Arkansas River (Figure 2 below (page 42)). The Arkansas River Compact provides specific rules for the distribution of water stored in John Martin Reservoir. A 1980 operating plan allocates 40% of the water stored in John Martin Reservoir to Kansas and 60% to Colorado, with separate accounts for each state. The compact requires that reservoir releases be applied directly to beneficial use; irrigation is the dominant use of the releases.

The reservoir has a capacity for irrigation water supply of approximately 338,000 acre-feet. Kansas can call for state line flows up to 500 cfs from the Kansas account while storage remains in the reservoir. The compact designates the irrigation season as April through October. The gates are closed during the winter and all inflows are stored. During the irrigation season, river flows needed to supply the canals are released from the dam and excess flows are stored. After the reservoir has been emptied, Kansas is entitled to any flow that reaches the state line after Colorado pre-compact uses.

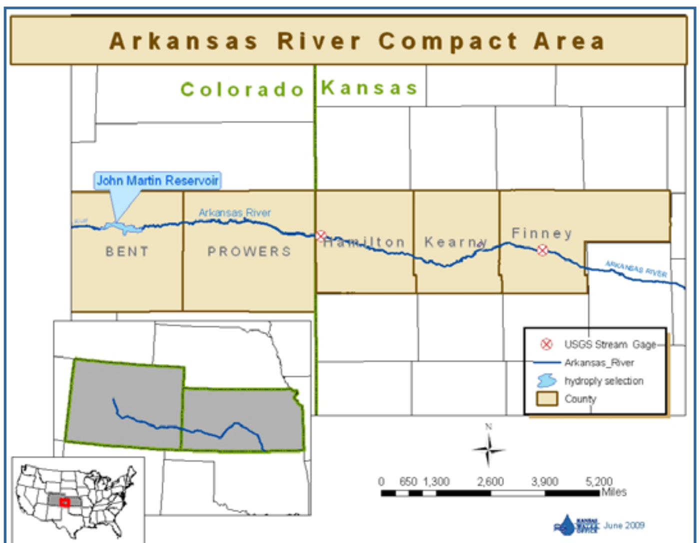

Figure 2.

Six active irrigation ditches; Frontier, Amazon, Great Eastern, Garden City, South Side and Farmers, are supplied from streamflow in the Arkansas River, relying on storage in John Martin Reservoir. Authorized quantity (vested) for all six ditch companies is over 145,800 acre-feet. These irrigation ditches historically served approximately 70,000 acres; more recently, they have provided surface water supply to approximately 44,000 acres in Hamilton, Kearny and Finney counties.

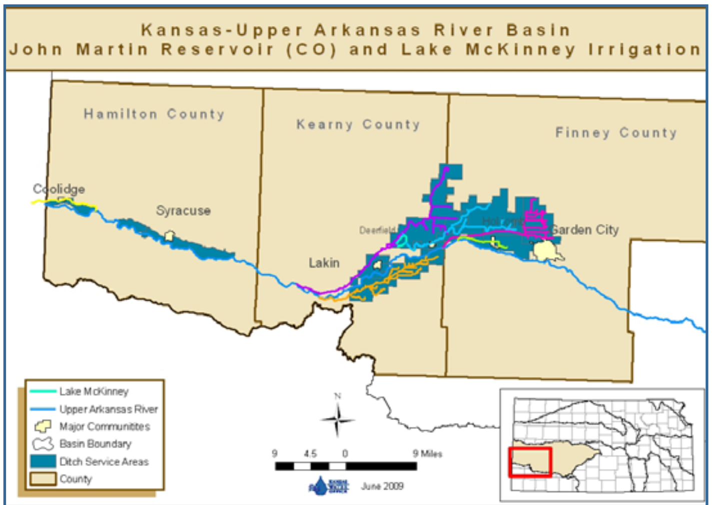

Figure 3.

Harlan County Reservoir, Nebraska

Harlan County Dam is located on the Republican River in Harlan County, Nebraska. The lake storage capacity is 840,561 acre-feet, of which 193,060 acre-feet are allocated to irrigation. There are two irrigation districts that operate as part of this federal project: the Bostwick Irrigation District in Nebraska and the Kansas-Bostwick Irrigation District No. 2. Kansas-Bostwick Irrigation District has a right to the stored water not to exceed 102,521 acre-feet annually with a maximum diversion rate of 700 cfs at the Superior-Courtland Diversion Dam. Due to changing hydrologic conditions in the entire basin, these two districts frequently experience water supply shortages. In recent years, Kansas has taken legal action to enforce compact compliance. Kansas irrigators have suffered with insufficient supplies, with Nebraska's deliveries on the Republican River appear to still be below the legal allocations (2002 – 2007 five-year measurement period).

The Courtland Canal system originates at Superior-Courtland Diversion Dam, at Guide Rock, Nebraska and presently serves 42,500 acres in Kansas. About midway along its length, the canal discharges in Lovewell Reservoir, which regulates the combined flows of the canal and White Rock Creek.

IRRIGATION FROM FEDERAL RESERVOIRS INSTATE

Six dams in Kansas were built as part of the Pick Sloan Missouri Basin Program, authorized by the Flood Control Acts of 1944 and 1946: Norton, Kirwin, Webster, Glen Elder, Cedar Bluff and Lovewell. Under federal law, the Bureau of Reclamation serves as the contractor for irrigation water supplies in federal reservoirs. Benefits of Cheney Lake, a Bureau project authorized by Congress in 1960, included irrigation although irrigation storage was not authorized in the lake. Kanopolis Reservoir, a U.S. Army Corps of Engineers project, also included irrigation water supplies, however an irrigation district never put in diversion works or perfected its water right. Irrigation water supply remains a use at five reservoirs: Keith Sebelius/Norton, Kirwin, Webster, Glen Elder/Waconda and Lovewell. In these reservoirs, irrigation storage is part of the conservation pool storage shared with other water use storage in some reservoirs. According to available information a total of 31,984 acre-feet of storage have been lost in these conservation pools due to sedimentation (Table 1 below (page 43)).

Surplus water within the State's Water Marketing Program has been made available for irrigation on an annual contract basis. Seventy million gallons in 2004 and 2005 and 80 million gallons in 2006, was sold to Jost farms for use April –September for irrigation under annual contracts. These contracts were for excess water from Marion Reservoir. Minimal irrigation use under surplus contract has also been made of Council Grove and Elk City Reservoirs.

Keith Sebelius Reservoir - Almena Irrigation District

The Almena Irrigation District No. 5 is located along the valley of Prairie Dog Creek below Norton Dam/Keith Sebelius Reservoir. The lake was built in 1964. The Almena

Irrigation Related Reservoir Storage

Reservoir/Lake	First year of Storage	Diversion Facility	Irrigated Acres	Original Conservation Pool Storage (AF)	Recent Conservation Pool Storage(AF)	Percent Conservation Pool Storage Lost
Keith Sebelius	1964	Almena	5,764	35,935	34,510	4.0
Kirwin	1955		11,465	99,435	98,154	1.3
Lovewell	1957	Courtland	29,122	41,690	35,666	14.5
Waconda	1967		10,370	241,460	219,420	9.1
Webster	1956	Woodston	8,537	77,371	76,157	1.67
		Total	75,303	495,891	463,907	6.5

Table 1.

District operates Almena Diversion Dam, Almena Main and South Canals, and a system of laterals and drains to serve 5,763 acres with an authorized state water appropriation of 11,280 acre feet. Many of the Almena District acres are also irrigated with ground water rights. A total of 57 irrigation water rights were active in 2004, with 15,915 acre-feet authorized on 7,192 acres between Keith Sebelius Reservoir and Almena.

Almena Irrigation District water use reported to the state since 1970 has been as high as 8,791 acre-feet on 5,764 acres in 1997, with no use reported for 11 years within the period. The lake level has experienced substantial fluctuations since it was built.

In 2008, the Kansas Department of Wildlife and Parks entered into a 10-year lease agreement with the Almena Irrigation District to help maintain a higher lake level. Higher levels provide greater recreational opportunities and help fisheries. When the lake level is at or below 2,285.5 feet Mean Sea Level elevation (msl), no releases for irrigation will be made. If the lake rises above that level, releases can be made for irrigation. This agreement protects about 8 to 10 feet of water from withdrawal. This long term agreement followed a series of one year agreements.

Kirwin Reservoir-Kirwin Irrigation District

Kirwin Irrigation District No. 1, on the North Fork Solomon River, began irrigation in 1958. Diversions for irrigation are through three canals below Kirwin Dam: Main Canal, North Canal and South Canal. The Kirwin District has converted 17.5 miles of open ditch laterals to pipe delivery (BOR, 2009). The Kirwin District holds a water appropriation for 27,679 acre-feet on 11,465 acres. According to the Bureau, 8,000 acres were reported irrigated in 2008 (USACOE, 2008). From 1981-2008, state water use reports indicate 10 years of no irrigation with a maximum use of 25,810 acre-feet in 1997.

Webster Reservoir - Webster Irrigation District

Webster Irrigation District No. 4 operates Woodston Diversion Dam, 16 miles below Webster Dam on the South Fork of the Solomon River. Diversions are through the Osborne Canal. Webster Irrigation District first delivered irrigation water to all of its area in 1961. The Webster District has a storage use right in Webster Reservoir and a natural flow water appropriation of 23,607 acre-feet for irrigation from the South Fork Solomon River on 8,537 acres (BOR, January 2007).

The water supply for irrigation has varied greatly since the facilities were built. In the last 26 years, there were 9 years in which there was no water available for release for irrigation because of low lake levels. These include four years of recent drought, 2005-2008. Since 1981, the maximum water use reported was 6,454 acre-feet in 2000. The effect of ground water depletion on base streamflow and farm conservation practices have greatly reduced inflow to the Reservoir. Since the mid-1950s, the surface water supply in the river basin has decreased significantly. The 10-year moving average inflow to Webster Reservoir has decreased from 81,800 acre-feet in 1955, to 44,200 acre-feet in 1970, to 12,700 acre-feet in 1985, to 11,700 acre-feet in 1992. This decrease in reservoir inflow has drastically changed District operations. The reduced inflow has created lower pool levels.

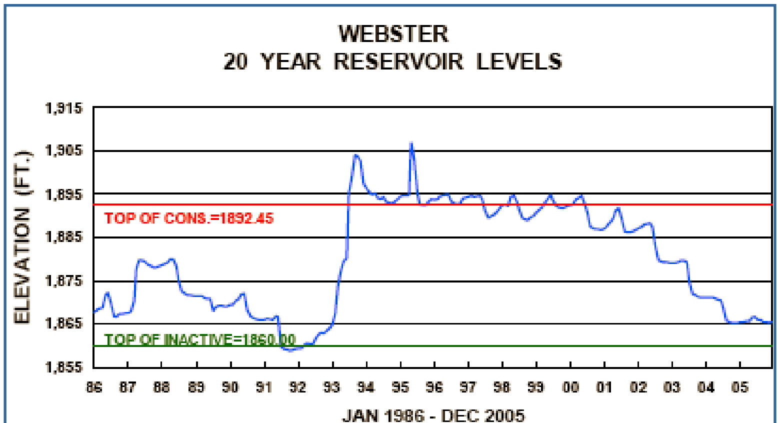

Figure 4. From BOR, January 2007

The Webster Irrigation District No. 4 has discussed a cooperative partnership with the State to achieve a minimum conservation pool in the lake. This pool could provide suitable habitat for fisheries production, safe access to the lake by anglers and boaters, and habitat for water fowl and other wildlife more consistently. Discussions include the possible state purchase or lease of the water rights/storage or maintenance of minimum water levels. Although recreation is an authorized use, no storage space in the lake has been dedicated to that purpose.

Glen Elder Dam/Waconda Lake-Glen Elder Irrigation District

Glen Elder/Waconda is located at the confluence of North and South Forks of the Solomon River. Glen Elder Irrigation District No. 8 was approved in 1976 by the Chief Engineer, Division of Water Resources, Kansas State Board of Agriculture. The original plans called for the Solomon Canal to divert water to irrigate up to 30,000 acres, but no diversion works were ever built. All members of the irrigation district draw water directly from the Solomon River downstream of Glen Elder Dam. A 1984 operational study by the Bureau reduced this estimate to 18,200 acres based on water availability. Diversions of 15,170 acre-feet are currently authorized on 10,370 acres. The federal contract for Glen Elder Irrigation District No. 8 will expire June 24, 2012.

The Bureau reported that 6,693 acres were irrigated in 2007 and 6,700 acres in 2008 (USACOE, 2008). Water use reported to the state since 1976 has been up to 15,986 acre-feet in 2006, with no use reported for 15 years within the period 1976 to 2008.

Lovewell Reservoir - Kansas-Bostwick Irrigation District

Lovewell Reservoir, a Bureau project, is part of the Kansas-Bostwick Irrigation System. The Bureau manages water stored in Harlan County Reservoir, Nebraska and Lovewell as part of a system to service both Bostwick Irrigation District in Nebraska and Kansas Bostwick Irrigation District. Lovewell Reservoir impounds White Rock Creek, and water from the Republican River which is diverted near Guide Rock, Nebraska through the Courtland Canal. The Kansas-Bostwick Irrigation District service area covers 13,378 acres above Lovewell and 29,122 acres below. Kansas-Bostwick Irrigation District holds two water appropriations for a total of 122,221 acre-feet on 42,500 acres. A sediment survey of Lovewell Reservoir was last conducted in June 1995 by the Bureau. The survey indicated that between 1995 and the initial filling in 1957, approximately 6,024 AF of sediment had accumulated, for a storage loss in the active conservation pool of approximately 908 acre feet.

Courtland Canal Sediment Removal.

During 2005 through 2008, not all the service area within Kansas-Bostwick Irrigation District received water due to severe shortages. In 2005 and 2006, lands that received water got an average of 6.6 inches; the base allocation is 15 inches.

There have been several studies by the Bureau on gaining additional storage in the Lower Republican, with one option expanding the storage at Lovewell. One popular proposal is to raise the dike two feet, to the same elevation as the dam, to gain approximately 16,000 AF of new storage.

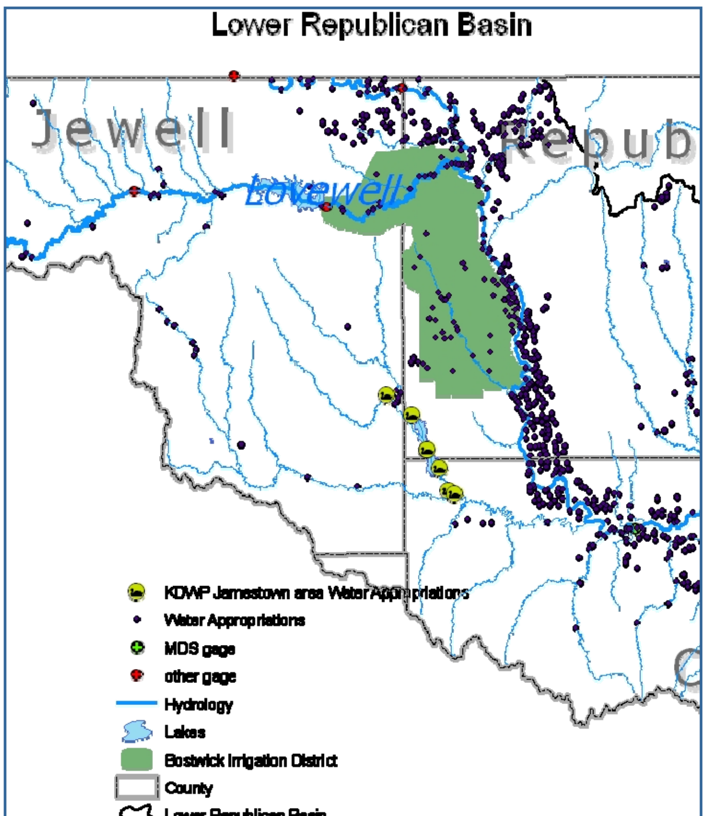

Figure 5.

Cedar Bluff Reservoir

The original authorized purposes for Cedar Bluff included irrigation, flood control, and water supply, with incidental benefits for recreation, fish and wildlife, and water quality. A water right was issued in 1958 to the Cedar Bluff Irrigation District to store 169,230 acre-feet and release 19,035 acre-feet for irrigation purposes. By 1984, the Irrigation District had determined it was not feasible to continue with the Irrigation District. It sold the irrigation rights and associated storage to the State of Kansas in 1987. The general purpose of the agreement was to relieve the Irrigation District of debt and provide increased recreation opportunities for western Kansas in Cedar Bluff Reservoir. In 1992, Congress reformulated the project to create an operating pool for fish, wildlife, and recreation. Included in the reformulation were the continuing municipal storage for the City of Russell and a component to

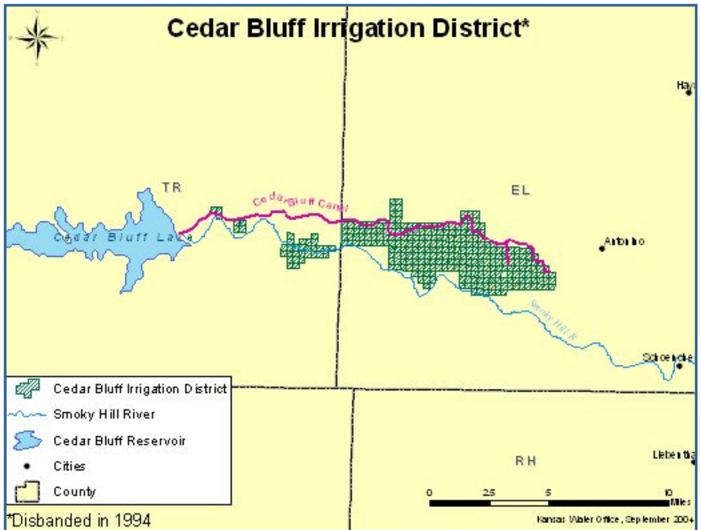

Figure 6.

maintain recharge to the system to replace irrigation return flows. At the time, irrigation was abandoned and the Irrigation District was dissolved.

Kanopolis Reservoir

Kanopolis Dam and Reservoir is operated by U.S. Army Corps of Engineers. It began operation in 1948 solely for flood protection. After the 1951 floods, additional flood control storage was created in the basin with the construction of Cedar Bluff reservoir, and the Corps subsequently provided storage space at Kanopolis for irrigation. The Kanopolis Irrigation District, formed in 1962, obtained authorization to store 42,700 acre-feet of water in Kanopolis Reservoir, to support use of 11,400 acre-feet for irrigation. However, the diversion works were not completed and the water right was never perfected. The District was formally dissolved in 2000. There are, however, irrigators that rely on the Smoky River flows below Kanopolis (see discussion below). Kanopolis Reservoir has had one of the higher sedimentation rates of the federal reservoirs in Kansas.

Irrigation below Reservoirs

Some ground water and surface water diversions may be senior to reservoirs, requiring by-pass releases as if the dam were not present to meet their allocations if their allocations can not be exercised with existing flows.

Cheney Dam and Reservoir

Cheney Dam and Reservoir is on the North Fork of the Ninnescah River. This division of the Bureau's Wichita project provides a supplemental water supply to the City of Wichita, flood control for protection of downstream areas, and recreation and fish and wildlife benefits. Because of the flood control features of the project, approximately 3,700 acres of land downstream from the dam was estimated to potentially be irrigated when the project was proposed. However, no stored water is provided for irrigation purposes. The Chief Engineer has issued surface water irrigation rights to irrigate 3,158 acres along the North Fork of the Ninnescah River below Cheney.

Kanopolis

There are approximately 252 irrigation water rights from surface and ground water associated with the Smoky Hill River below Kanopolis to the confluence with the Saline River. These are authorized to irrigate 18,816 acres. These rely on Smoky Hill River flows for surface diversions or the alluvial aquifer.

In 2009, the Lower Smoky Valley Irrigators Association was formed. The association seeks to organize, represent and educate irrigators in the Smoky Valley below Kanopolis Reservoir. Under current state statutes, irrigators along the lower Smoky Hill River have no rights to water stored in the reservoir. Discussions are on-going between the Kansas Water Office, the Kansas Department of Agriculture – Division of Water Resources, the Association and other water users below Kanopolis on options to access water stored in the reservoir.

IRRIGATION FROM OTHER RESERVOIRS

Irrigation water also is drawn from state, county, city and private lakes. The records at the Kansas Department of Agriculture -Division of Water Resources indicate 17,095 acre-feet are allocated to irrigation from storage in such lakes by approximately 175 entities. Uses are primarily for golf courses, parks and agriculture.


Southwest Kansas Irrigation Ditch.

Irrigation from State Lakes

State-owned lakes are generally not used for irrigation. Historically, Scott and Sheridan County lakes supplied some irrigation water. No irrigation is currently allocated out of Scott Lake.

County and City Lakes

Many city lakes also supply irrigation water, especially in the eastern part of the state. Communities often irrigate green spaces such as parks and golf courses within their jurisdiction. As cities obtain public water supply from alternative or additional sources, often due to the effects of sedimentation, some communities allow the lake to be used for additional irrigation when there is available water.

Lake McKinney

Lake McKinney is a privately owned lake built for irrigation storage. Lake McKinney is located near Deerfield in Kearny County, on the north side of the Arkansas River. Water is delivered to Lake McKinney from the Arkansas River through the Amazon Canal for use in the Great Eastern Canal system. The reservoir was originally constructed in 1907 to a capacity of 30,000 acre-feet at approximate gage height 31.0. The current capacity of the lake is roughly 3,000 AF at gage height 22.0, due to sedimentation and the construction of dikes to reduce surface area and related evaporative losses. Evaporation losses were substantial because of the large lake surface area relative to the amount of storage that is provided. The capacity was restricted in 1977 by the construction of two dikes; one on either end of the reservoir. When the dikes were constructed they cut off relatively shallow areas on the north and south sides of the reservoir, reducing the lake surface area to approximately 800 acres. Work began in 2008 to increase capacity to 7,000 acre-feet.

The reservoir and much of the Great Eastern Canal system is owned and operated by the Garden City Company. Water from the reservoir is released to the Great Eastern Canal, which supplies water to a service area of approximately 20,000 acres. Many irrigated acres are also included on ground water rights to supplement available surface water.

Small Artificial Impoundments ("ponds")

There is a growing development of ponds, both in agricultural settings and increasingly in urban settings. Traditionally, farm ponds have been used for livestock watering. Over the last decade, a number of farm ponds were constructed for irrigation water storage. One example is along the Arkansas River where ponds make an accessible pool for center pivot pumping. In urban settings, ponds offer aesthetic benefits and help to control storm water runoff. Over the last few years, a few farmers along the lower Republican River put in ponds to safeguard a water supply for water rights that were subject to administration during Minimum Desirable Streamflow (MDS). Once water has been stored a minimum of two weeks, the water is no longer subject to release to meet MDS.

It is estimated that ponds intercept and temporarily store 25% of the runoff in the United States, with higher pond densities resulting in a higher percentage of storage (Renwick et al, 2005). Ponds are most dense in areas that have few natural ponds and lakes. (Renwick et al, 2007).

In the 1930s, an estimated one pond per decade was developed. Now, it is estimated that 2,000 ponds are developed annually. The ponds are a sediment trap and potentially a huge carbon sink. The total number of farm ponds in Kansas is estimated at 235,000, although the count could be much higher (Sleezer, ESU, 2004 personal communication).

When ponds store less than 15 acre feet, it is considered a domestic water right, and a permit is not required. A water right permit must be obtained for any structure that stores 15 AF or more. Regulations adopted December 7, 2007 (K.A.R. 5-5-3) restrict the maximum surface water for domestic reservoirs and ponds by county.

Possible Actions Needed to Ensure Future Water Supply From Federal, State and Municipal Impoundments

Statutory change to allow an irrigation district to form and obtain non-project water, possibly through an assurance district, in an upstream reservoir, if storage is available. (Kanopolis, Lovewell)

Statutory change to protect irrigation users below reservoirs, allowing water rights senior to the impoundment to remain viable.

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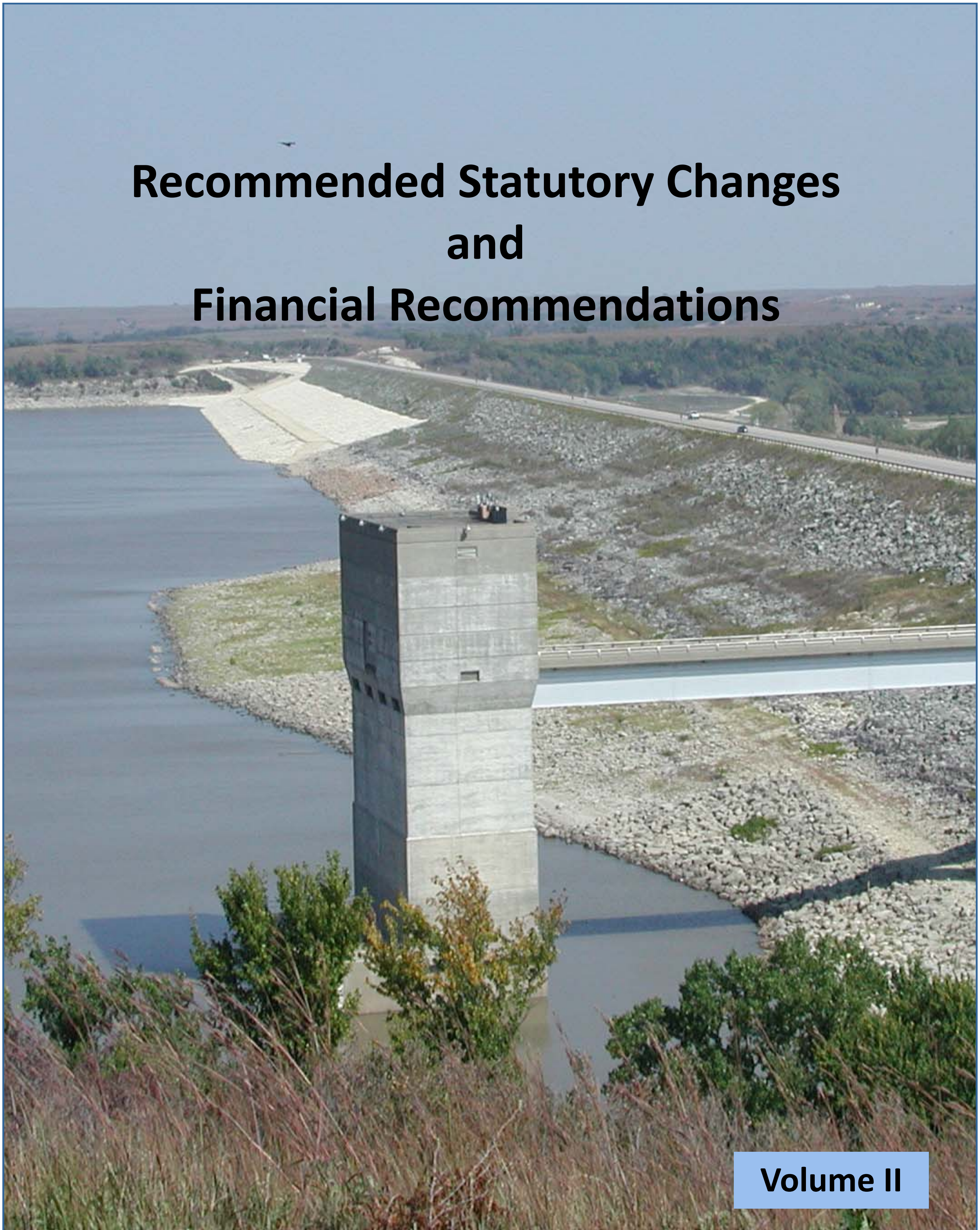


Tuttle Creek Reservoir.

EXECUTIVE SUMMARY

Following is the second volume of the Reservoir Roadmap. Volume II includes the statutory and budget considerations needed to address sustainable water supply. Information in this volume is organized into two chapters: recommended statutory changes and recommended financial resources.

Recommended Statutory Changes. This chapter contains recommended statutory changes to provide authority to the state of Kansas to secure, protect and restore reservoir storage needed to meet the needs of the citizens of Kansas. A review of national and state water resource legislation was conducted as part of the Reservoir Sustainability Initiative. The primary recommendation resulting from this review is to establish a comprehensive Kansas Reservoir Sustainability Act. The components of that conceptual act, along with the recommended statutory changes, are included in this chapter.

Estimated Financial Resources. This chapter contains estimated financial resources needed to secure all available storage in federal reservoirs; protect state and municipal owned storage from losses due to sedimentation and poor water quality impacts; and restore adequate storage to meet anticipated needs. Key budget needs are organized in this chapter by their ability to Secure, Protect, and Restore Kansas water resources.

INTRODUCTION

A review of state and national water resource policy was conducted as part of the Reservoir Sustainability Initiative. Several policies were focused on in the development of the Reservoir Roadmap. Following is a discussion of the statutory issues requiring resolution if the state of Kansas is to secure, protect, and restore the state's reservoirs to meet the needs of the citizens in the 21st century.

Addressing necessary statutory changes could be accomplished in a piecemeal fashion in which individual statutes or regulations are reviewed and modified. However, this process will be labor intensive, require significant staff and legislative time, and may not completely address all aspects of needed change. Therefore, the recommendation is to create a comprehensive Kansas Reservoir Sustainability Act (RSA) with the following goal:

> *The State of Kansas will have the authority to secure, protect and restore reservoir storage needed to meet the water supply needs of the citizens of Kansas.*

Many of the individual recommendations in the Protect and Restore categories were previously considered and approved in the *Enhanced Stream Corridor and Wetland Management to Address Sedimentation* policy section, the *Flood Damage Mitigation and Small Dam Safety* policy section *and Institutional Framework* management section of the *Kansas Water Plan*. Implementation of these recommendations would be included within the Kansas Reservoir Sustainability Act.

Establishment of a comprehensive Kansas Reservoir Sustainability Act (RSA) involves each of the natural resource agencies. With assistance from these agencies, the Kansas Water Authority would maintain the overall responsibility of identifying reservoir sustainability needs through the public process of the *Kansas Water Plan*. Specific projects and activities resulting from the RSA would be identified in the *Kansas Water Plan*, Water Issue Strategic Plans, the Water Marketing/Assurance Programs Capital Development and Storage Maintenance Plan and the Water Resources Capital Development Plan, as appropriate.

SECURE

Debt Service on Storage in Federal Reservoirs

Kansas has contracts with the U.S. Army Corps of Engineers (Corps) for purchase of almost a million acre-feet of storage in 13 reservoirs; just over half of that storage is currently under a repayment agreement. The state makes annual principal and interest payments on that in-service storage. In addition, operation and maintenance costs for the in-service storage are paid annually. Currently, the customers of the Water Marketing Program pay those costs. The ability to cover the increasing costs for principal and interest and operation and maintenance is limited because the majority of revenue in the Water Marketing Program comes from fixed rate contracts. The rate for customers of the Marketing Program that have contracts signed since 1983 changes annually but represents only 20% of the revenue stream.

Efforts to provide additional funds to service this debt and to secure additional storage have been proposed and discussions are underway to determine the best method for doing this. The potential for the federal government to relieve part of the debt is part of the discussion and the state may need statutory authority to partner with the federal government if debt relief agreements can be negotiated.

Unfunded Liability

The storage under contract, but not yet in-service and committed to a customer, represents an unfunded liability in the program. The 2008 Legislature recognized this issue, and the concern that until a repayment agreement is in place, the state does not control use of that storage for the benefit of its citizens. In response, the Legislature created the Reservoir Storage Beneficial Use Fund to be used to buy additional storage before the state has a customer to repay the cost to purchase, operate and maintain the storage. While this is a significant step toward securing storage, the appropriation is insufficient. While no statutory change is needed, there is a significant funding impact.

In addition, state statute requires a commitment on the part of a user to bring the water into service and begin paying for it before the state enters into repayment agreements to the federal government. To secure additional storage in existing reservoirs for future use, this requirement may need to be removed. (See Volume II, Chapter 2 – Funding Needs.)

Purchase of Additional Storage in Federal Reservoirs

There are a few situations in which additional storage could be obtained in existing federal reservoirs. Melvern, Wilson and Kanopolis, while all very different situations, each present an opportunity for providing additional storage. As mentioned above, to secure additional storage in existing reservoirs for future use, the requirement for the water to be in-service may need to be removed.

Expansion of Access to Storage

Though state planning statutes recognize multiple and broad public benefits of reservoirs, the right to use water supply that is stored in Corps reservoirs is currently limited to contracts under the Water Marketing Program, membership in a water assurance district, and in a very few instances, contracts directly with the federal government. In all cases, use of the water is designated either by statute or by contract, for municipal and industrial users only. There are times when a more flexible operation of the river/reservoir system could meet additional needs; however, legal access to storage released is limited. Approaches that will work with current and local conditions to allow the use of storage to meet contemporary needs, yet respecting current commitments under contract, ownership, and appropriation rights are needed.

Development of New Large Reservoirs

From the 1940's through the 1970's the federal government developed large reservoirs in the state of Kansas, constructed primarily for flood control purposes. Other purposes such as water supply, water quality, irrigation, recreation and fish and wildlife habitat were included based on the projected need, and in some cases, local interest.

The state recognized the value of these reservoirs as a public water supply resource and purchased available storage from the federal government. Likewise a number of cities purchased storage in federal reservoirs, notably Wichita and El Dorado. The water was then made available to municipal and industrial users under the Water Marketing and Water Assurance Programs. Two-thirds of the population of Kansas is now directly or indirectly dependent on storage in these reservoirs. As population grows and existing reservoirs fill with sediments, new surface water storage facilities may need to be developed (see Volume I, *Supply and Demand Projections* chapter).

Future water supply storage may also be achieved by off stream storage in some basins. Offstream refers to a water body or system that is not located in a streambed or does not receive significant natural flows from the surrounding watershed. An example is a reservoir that is not located on a streambed, and is supplied by a pipeline, aqueduct or an adjacent stream. Aquifer storage and recharge using excess river flows is also considered to be offstream storage.

The federal government has no plans or authority to develop additional water supply storage in Kansas. Therefore, it is recommended under the Kansas RSA to establish authority for the state to initiate the development of water supply reservoirs and other means of storage.

Secure Reservoir Sites for Future Development

During the time that the federal government was actively developing reservoirs, the Corps and the Bureau of Reclamation (Bureau) selected the most feasible reservoir sites from a cost benefit evaluation. A number of sites were identified, analyzed and eliminated from consideration on this basis. Reservoir sites not initially developed by the Corps are in some cases in close proximity to growing urban areas, enhancing their benefit. Such sites may be threatened by development of suburban growth, potentially precluding their development to meet future water supply needs.

In order to ensure the ability to provide adequate water supply for the future, the state should have the authority to protect reservoir and other storage sites for future water supply from development or other restrictive activities. The RSA should contain authority for the state to identify sites in the best locations for future water storage. A means should be developed to ensure that planned uses of the site do not preclude its suitability for future water storage.

Development of Small Reservoirs

In some areas, additional surface water storage may be needed for water supply. In addition, the value of a lake for local recreational purposes and the associated economic value to the region are recognized. Though the state can participate in public water supply and recreation storage under existing state law, flood control storage must be included as one of the purposes. Since enactment of this statute, the need for water supply reservoirs has emerged in locations where flood control was not a primary issue. This provision has prevented state participation in development of single purpose water supply reservoirs. Under a comprehensive Kansas RSA, authority could be provided to the State of Kansas to cooperate with local units of government or private entities for the development of small lakes for any purpose, whether single or multipurpose. Requirements that flood control be included should be removed.

Minimum Pool Agreements for Recreation

A stable reservoir water pool supports recreational uses for access to boat ramps and fisheries habitat, and increases support to the local economy. The State Water Plan Storage Act recognizes the value of recreation, therefore, no state statutory changes are recommended. However, greater coordination and evaluation efforts are needed to identify reservoirs that could provide greater opportunities for recreation. For example, discussions are underway to determine if irrigation storage can be leased to provide additional recreational benefits at Webster Reservoir. Changes to federal authority for the Bureau of Reclamation may be needed so that they may more freely participate in planning and evaluation of potential minimum pool agreements.

PROTECT

Protect Kansas Reservoirs through the Implementation of Best Management Practices (BMPs)

Water resources within Kansas are vital to the state for not only supplying a growing population but for the economic welfare of the state. The state has a vested interest in protecting the storage in the federal reservoirs in which two-thirds of the population depends on for its water supply. Land surface BMPs in target areas above reservoirs can help to reduce sediment loads. These practices can take the form of terraces, waterways, residue management, grade control structures, dams and other practices that reduce or eliminate sediment and nutrient loading to the reservoirs. There are well established cost share mechanisms for these traditional conservation practices. While no statutory change is needed, the recognition of the vital role these practices play is a component of a comprehensive reservoir sustainability initiative.

Riparian and Wetland Protection and Development

The protection of riparian and wetland areas, when systematically implemented and targeted above water supply reservoirs, may significantly reduce future sediment loads, extending storage capacity. The state currently provides cost-share assistance on wetland and riparian establishment and restoration. When matched with other state and federal programs, the total cost-share allowable to a participant is not to exceed 80% of the total cost of the practice, and in some cases cost share may be 90% of the total cost. In areas above federal reservoirs, the state's interest in the conservation practice may exceed the interest of the individual landowner, who may choose not to participate in the voluntary practice if financial input on his/her part is required. In those instances, the cost for project planning and implementation should be entirely the responsibility of the state. The RSA should give authority for the state to provide 100% funding for conservation project planning and implementation, when substantial state interest is demonstrated.

Protection of high value conservation resources often involves the purchase of a conservation easement. While the state does have the authority to accept donated easements. There is not a dedicated source of funding that could be drawn from to purchase targeted high value easements. The ability should be developed in the RSA to establish a dedicated conservation easement fund.

Protect Streambanks through Stabilization Projects on a Stream Segment Approach

Increasing evidence exists that streambank erosion contributes to significant sedimentation in reservoirs. An approach that targets entire reaches for stabilization, instead of individual scattered sites, is more effective. State statute currently requires that federal funding be available before the state participates in a streambank stabilization project when a systematic approach is utilized. State statute emphasizes local responsibility for a streambank stabilization project. While coordination with local landowners and community members is essential to a successful project, requirement for local sponsorship and cost-sharing can be a significant limiting factor due to the high cost of stream stabilization projects. The recommended statutory approach is to allow for 100% state responsibility in the coordination, planning and implementation of systematic stream stabilization projects in targeted areas. In addition, the statutory requirement for federal funding should be removed.

In May 2009, the Kansas Water Office received funding through the American Reinvestment and Recovery Act to conduct a streambank stabilization and riparian restoration project on an eight-mile reach of the Neosho River above John Redmond Reservoir. Implementation of this project will serve as a pilot, illustrating the type of local coordination and funding needs required for this systematic approach.

RESTORE

Restoration of Water Supply Storage Capacity through Dredging of Municipal, State and Federal Reservoirs
In many reservoirs, especially those in which significant BMPs and streambank stabilization efforts have already been implemented in the contributing watershed, dredging may be a viable alternative for restoring water supply storage capacity. Through successful pilot projects such as at Mission Lake, the state is gaining the knowledge and expertise to facilitate similar projects at other reservoirs. Based on the experience of planning and implementing a pilot dredging project at Mission Lake, a successful dredging project requires coordination with many entities. These agencies include, but are not limited to, the State Conservation Commission, Kansas Water Office, Kansas Department of Health and Environment, Kansas Department of Wildlife and Parks, Kansas Department of Agriculture, Kansas Department of Transportation, the Corps and Bureau, local municipalities, legislators, and local citizens. Coordination among these entities is necessary to provide for complete collaboration and to expedite permitting and review processes. The RSA should provide for clear and comprehensive state authority for coordination of all aspects of a systematic dredging program for the purposes of water supply storage capacity restoration.

Cottonwood River Streambank Restoration Site.

Dam Safety and Rehabilitation
Nearly 6,000 small dams in Kansas are regulated by the Kansas Department of Agriculture, Division of Water Resources. Of these, 180 are classified as high hazard with an additional 247 classified as significant hazard. Most dams were constructed with a 50-year design life and the average age of these dams is 40 years. These dams have been constructed to provide flood control, public water supply, recreation and other benefits. Many were built by local watershed districts using federal or state cost-share assistance and local funds. Others have been constructed by municipalities, private organizations or individuals, and the state.

In November 2005, the Kansas Water Authority adopted a *Kansas Water Plan* policy section for small dam safety and rehabilitation. Recommendations were made for development of breach inundation maps and notification of downstream landowners. Inundation maps for new dams should be filed with the county registrar of deeds. Local downstream landowners should be notified by the registrar and information about the potential flooding if a breach occurs should be attached to the deed.

Where development downstream of an existing dam owned by a public entity such as a municipality or a watershed district results in a hazard class increase, notice should be given to property owners within the breach inundation area of the dam and the levying of a special assessment against these property owners for the purpose of making necessary modifications to the dam consistent with the design standards of the new hazard class should be authorized. The owner of a dam should not be held liable for damages caused by breach of the dam to real property developed after the landowner had been made aware of the location of possible flooding. This limitation should not affect liability for personal injury or death caused by breach of a dam.

Additional watershed and other dams require rehabilitation due to deferred maintenance, age or extreme floods or other natural phenomena. The cost for rehabilitation of existing dams is substantial. A cost benefit analysis for

Internal erosion of a dam.

rehabilitation of these dams should be performed to determine if decommissioning of the dam is more cost effective than repair. When dam repair is the better option, and the dam owner can effectively demonstrate that the needed repairs are not due to negligence, state cost-share could be provided to ensure the safety of the dam.

The state should establish a cost-share program to assist eligible dam owners in paying for needed dam rehabilitation and upgrade measures.

CONCLUSION

The Kansas Reservoir Sustainability Act would provide a comprehensive approach to secure, protect, and restore the state's water resources to meet the needs of the citizens. Equally important to the recommended statutory changes is funding. A discussion of the recommended financial resources to meet anticipated needs is provided in the following chapter.

Introduction

This chapter presents estimated financial resources, based on current planning and subject to change, needed to secure all available storage in existing federal reservoirs; protect state and municipal owned storage from losses due to sedimentation and poor water quality impacts; protect future reservoir sites that may need to be developed; and restore adequate storage in existing reservoirs to meet anticipated needs. Included with the narrative description of recommended financial resources is a table detailing the budget needs for the next 10, 20 and 40 years. As shown in Table 1 (page 61), about $3.9 billion in additional revenue is needed in the next 40 years to secure, protect and restore Kansas reservoirs.

Needs for and options to secure additional storage will vary by basin. Discussion of options presented in this chapter is intended to cover the array of solutions that are available and may be utilized. Volume III, Neosho Basin, represents a detailed plan based on in-depth analysis and modeling to refine and specify options. Each basin will undergo similar evaluation to refine costs.

Included as a subtopic under each of the Secure, Protect and Restore categories is planning and design. As described more fully below, each reservoir sustainability activity will require some level of advanced planning and design. Many items identified in this chapter as needing enhanced funding also require statutory changes to implement. A discussion of the recommended statutory changes can be found in *Volume II: Recommended Statutory Changes*.

SECURE

Debt Service on Storage in Federal Reservoirs

The Water Marketing and Water Assurance Programs are operated to fully pay the capital costs of water supply storage that has been called into service (in service storage) and projected storage that will be called into service (future use storage) by the end of the federal contract. When storage is called into service, the state begins payment on principal and interest. The contracts give the state 50 years from when the first quantity of water is called into service to purchase all the contracted storage or renegotiate for the storage. Over the next 40 years, beginning FY2011, the state will spend approximately $108 million on debt service of storage purchase. Purchase of the future use storage in Big Hill, Milford and Perry is not included in the $108 million and is presented as a separate subtopic below. The reservoirs included in the principal and interest total are Big Hill (portion), Clinton, Council Grove, Elk City, Hillsdale, John Redmond, Kanopolis, Marion and Melvern Reservoirs.

Kanopolis Lake.

Reservoir Operation and Maintenance

In contracts with the federal government, the state pays annual operation, maintenance and repair costs incurred by the U.S. Army Corps of Engineers (Corps) for that portion of storage space the state has called into service. Costs vary from year to year and from reservoir to reservoir. As the reservoirs age and costs grow for personnel and maintenance activities, funding needed to meet operation and maintenance responsibility also grows. Over the life of the current contracts, the cost for operation and maintenance has averaged an increase of 8% per year to meet these growing needs. The funding needs assessment assumes that this percentage increase will continue throughout the 40 year period, amounting to $447 million included in Table 1 (page 57). This total includes the costs for storage committed to the Marketing and Assurance programs, the reserve storage owned by the state but currently uncommitted to either program that is paid by the State Water Plan Fund, and the estimated costs for all of the storage that the state has under contract that is not currently under a repayment agreement (future use).

Unfunded Liability

Under agreements with the federal government, the state made a policy decision in 1986 to defer payments on storage not called into service (future use storage); this includes Big Hill, Clinton, Hillsdale, Milford and Perry reservoirs. As a result, the state does not pay the Corps for principal and interest on the capital cost or operation and maintenance for storage not committed to a user of the

Water Marketing or Water Assurance programs, which represents an unfunded liability in the future. Future use storage accrues interest against the capital cost until such time as it is called into service or at the end of the contract term. A financial review of the marketing program in 2004 identified this cost of future use storage as an unfunded liability in the program.

It is anticipated that the Water Marketing Program will fully utilize the future use storage in Clinton and Hillsdale reservoirs. That cost is included in the Water Marketing Program Capital Development and Storage Maintenance Plan adopted by the Kansas Water Authority. The principal and interest portion of these reservoirs is included above in debt service in Table 1 (page 57), as discussed above.

There is currently no plan to fund the future use storage in Big Hill, Milford and Perry. This debt can be paid by calling water into service and paying both capital and operation and maintenance expenses; waiting until the end of the contract period and paying a balloon payment or setting money aside in an interest bearing escrow account to pay for storage when needed or at the end of the contract period. The financial needs shown in Table 1 (page 57) represents the cost of the future use storage in Big Hill, Milford and Perry at the respective contract terms (2029, 2033 and 2040) amounting to a 20 year total of $21 million and a 40 year total of $68 million.

Purchase of Additional Storage in Federal Reservoirs

In addition to the storage already under contract with the federal government, additional storage may be available in some existing reservoirs. Additional water supply storage could be made available in Melvern Reservoir, but a legislative change at the federal level would be needed for this to occur; therefore, no funding is identified for purchase of storage in Melvern Reservoir in Table 1 (page 57).

An ongoing reallocation study is evaluating the potential for water supply storage to be added in Wilson Reservoir. Table 1 (page 57), assumes that a portion of the reservoir will be available for an estimated cost of $5 million. Likewise, evaluation of the Kanopolis/Smoky Hill River system indicates a need for additional water supply storage in Kanopolis Reservoir to meet all of the proposed demands. The 2002 Corps Reallocation report for Kanopolis indicated that an additional 7,500 acre-feet of storage could be available by permanently raising the level of the reservoir by two feet. Current cost of this pool rise is estimated to be $5 million in FY 2010 dollars. Table 1 (page 57) accounts for projected inflation costs of land and other factors to be about 5% annually with the need of additional storage purchase from federal storage to begin around 2015. Total funding needed for purchase of additional federal storage over the next 40 years is $119 million.

Development of New Large Reservoirs

Two-thirds of the population in Kansas is directly or indirectly dependent on storage in the state's largest reservoirs. As population grows and existing reservoirs become filled with sediments resulting in decreased storage capacity, more water supply storage may need to be developed where dredging or other alternatives are not feasible to meet the needs. *(See Volume I, Supply and Demand chapter.)*

Funding needs for the development of one new large reservoir in Kansas are projected to be as much as $400 million per reservoir in the next 40 years. This cost estimate is based on information in a recent Corps study requested by the Kansas Water Office (KWO), as part of the John Redmond Feasibility study. In this study the Corps identified construction of a new reservoir at a previously federally authorized site as an alternative to dredging John Redmond Reservoir. New reservoir construction and associated stream mitigation costs are estimated at $400 million in FY 2010 dollars. To account for future inflation in construction costs and the projected 20 year time frame for when a new reservoir may be needed, then total cost in FY 2030 dollars will be $1.3 billion.

The location of a new reservoir is yet to be determined. Likewise, other alternatives may prove to be less costly or more environmentally feasible. However, a comprehensive funding look at water supply needs for the future must include the possibility of one or more new large reservoirs.

Development of New Small Reservoirs

Under the proposed Reservoir Sustainability Act the state could cooperate with local units of government or private entities for the development of small lakes for any purpose, whether single or multipurpose. The cost estimates assume state participation to meet future water supply needs at more localized levels.

Development of a single small reservoir, about 5,000 acre-ft of water supply storage, is estimated at a current cost of one to three million dollars. Estimated costs are based on average state cost share dollars of constructed multipurpose small lakes through the State Conservation Commission's Multipurpose Small Lakes Program in the last 24 years. The initial supply and demand analysis in Volume I provides an indication of the extent and timing of need for additional water storage. For planning purposes, an estimate of one single or multipurpose small lake every 3 years for the next 40 years, is used for approximating funding needs at a starting cost of $2 million. An average 20% rate of increase every three years is also accounted for in Table 1 below (page 57) to adjust for future projected construction cost inflation. Total projected need is approximately $97 million.

Minimum Pool Agreement

A stable reservoir water pool supports recreational uses for access to boat ramps, fisheries habitat and also increases support to the local economy. The State Water Plan Storage Act K.S.A. 82a-907 recognizes and supports recreational value of reservoirs. In FY 2007, the state entered into a ten year agreement with the Almena Irrigation District to protect the Keith Sebelius Reservoir recreational pool level. The minimum pool agreement protected roughly eight to ten vertical feet of water from withdrawal, so that fisheries and access to the reservoir could continue to be viable and serve the lake's recreational purposes. A similar agreement has been discussed with the Webster Irrigation District.

With the benefits of minimum pool level agreements for recreation and economic purposes, further minimum pool agreements in the next 20 to 40 years should be incorporated. Based on the $1 million cost of the minimum pool agreement at Keith Sebelius Reservoir, providing for up to three more minimum pool agreements in the future is anticipated. Table 1 below (page 57) accounts for three more minimum pool agreements starting after 2017, the end of the Keith Sebelius agreement, that are amortized over 33 years as part of the effort to protect and promote recreational values of reservoirs. Also accounted for, in Table 1 below (page 57), are cost projections for larger pool level agreements and increased costs. Cost of minimum pool agreements for the capital development 40 year period is $5 million.

Secure Reservoir Sites for Future Development

The population of Kansas is projected to increase by 1 million people, approaching 3.5 million people, in the next 40 years. Regional increases in population and demand for water are expected to exceed water supply availability within the next 10 years in some areas. To en-

Reservoir Roadmap	10 Yr Total	20 Yr Total	40 Yr Total
Secure			
Reservoir Debt Service & Storage Purchase (P & I)	$ 16,000,000	$ 107,000,000	$ 108,000,000
Reservoir Operation and Maintenance	$ 21,000,000	$ 67,000,000	$ 447,000,000
Unfunded Liability	$ -	$ 19,000,000.00	$ 68,000,000
Purchase of Additional Federal Storage	$ 13,000,000	$ 35,000,000	$ 119,000,000
Development of New Large Reservoir	$ -	$ 300,000,000	$ 1,293,000,000
Development of New Small Reservoirs	$ 7,000,000	$ 26,000,000	$ 97,000,000
Minimum Pool Agreement	$ 400,000	$ 2,000,000	$ 5,000,000
Planning and Design	$ 3,000,000	$ 7,000,000	$ 12,000,000
Total Secure	**$ 60,400,000**	**$ 563,000,000**	**$ 2,149,000,000**
Protect			
Implementation of Best Management Practices	$ 19,000,000	$ 57,000,000	$ 189,000,000
Riparian and Wetland Protection and Development	$ 13,000,000	$ 33,000,000	$ 121,000,000
Riparian and Wetland Easments	$ 16,000,000	$ 57,000,000	$ 57,000,000
Streambank Stabilization	$ 32,000,000	$ 115,000,000	$ 115,000,000
Planning and Design	$ 36,000,000	$ 41,000,000	$ 51,000,000
Total Protect	**$ 116,000,000**	**$ 303,000,000**	**$ 533,000,000**
Restore			
Sediment Removal Small Reservoirs	$ 87,000,000	$ 163,000,000	$ 163,000,000
Sediment Removal Large Reservoirs	$ 180,000,000	$ 995,000,000	$ 995,000,000
Dam Safety/ Rehabilitation	$ 35,000,000	$ 44,000,000	$ 84,000,000
Planning and Design	$ 5,000,000	$ 6,000,000	$ 6,000,000
Total Restore	**$ 307,000,000**	**$ 1,208,000,000**	**$ 1,248,000,000**
Total Reservoir Sustainability	**$ 483,400,000**	**$ 2,074,000,000**	**$ 3,930,000,000**

Table 1. Reservoir Sustainability Funding Needs.

sure the ability of the state to provide adequate water supply for a growing population and make up for lost storage from sediment deposition, ways to identify and protect future reservoir sites from development should be examined.

The state recognizes that reservoirs may need to be constructed to replace lost storage capacity or to meet additional needs. In some cases, state or local partners may not be ready to develop the reservoir. However, the ability to be able to protect a selected site from other land use changes that could preclude its use as a reservoir in the future is needed. Funding needs for protection of reservoir sites for future development is not included in Table 1 (page 57).

Planning and Design

To make sound choices in selection of alternatives and locations to secure additional water supply, data collection, sharing and analysis will be needed. The state will be challenged based on actual need, financial constraints and environmental impacts. Success will be based on information and analysis available to address questions and concerns.

Significant efforts in data collection and analysis are already underway and funded primarily through the State Water Plan Fund. For the funding needs assessment, it is assumed that this level of data collection will continue for the next 10 years. Analysis and design costs will increase once large or complex projects are identified. These increases are incorporated in Table 1 (page 57) and a 40 year estimate at $12 million has been projected.

PROTECT

Protect Kansas Reservoirs through Implementation of Best Management Practices

Erosion from crop fields and grazing lands is a major source of sediment in Kansas. Land surface best management practices (BMPs) in target areas above reservoirs can help to reduce these sediment loads. BMPs can take the form of terraces, waterways, residue management, grade control structures, watershed dams and other practices that reduce or eliminate sediment and nutrient loading of the reservoirs. Funding estimates of $1,500,000 are based on cost in watersheds above federal reservoirs where there is landowner interest in voluntary BMPs. Projected future annual costs of land treatment practices are estimated to double due to increased cost and demand by 2021 and reach roughly $4 million by 2030. The implementation of BMPS for the entire 40 year period indicates a $189 million funding need.

Riparian and Wetland Protection and Development

The Riparian and Wetland Protection Program (RWPP) was developed through the State Water Plan and authorized in 1989 by amending K.S.A 2-1915. The goal of RWPP is to protect, enhance, and restore riparian areas, wetlands, and associated habitats by providing technical, educational, and financial assistance to landowners and the public in general. Major objectives of the program are the design and installation of projects which demonstrate the effectiveness of riparian and wetland protection in terms of stream functions, water quality and wildlife benefits, and to increase the knowledge and awareness of landowners, and the general public on the value and benefits of these natural areas. Healthy wetland and riparian areas are very effective at reducing sedimentation and improving water quality.

Streambank Stabilization.

In areas above federal reservoirs, the state's interest in wetland and riparian development and protection may exceed the interest of the individual landowner, who may choose not to participate in the voluntary practice if financial input on his/her part is required. In those instances, the cost for project planning and implementation should be entirely the responsibility of the state. These targeted areas above reservoirs are a priority of the state and funding will initially go toward the protection and development of these sites. When targeted sites are completed, a continuation of this program will be directed outside of targeted areas and toward wetland and riparian areas of greatest need. Currently, the funding needs assessment estimates for the next 40 years totals over $120 million. Requested funding needs beginning in

FY 2011 begin at $1.5 million and have a projected annual increase of costs at 5%.

Riparian and Wetland Conservation Easements

Protection of high value conservation resources often involves the purchase of a conservation easement. Passage of the conservation easement law and recommendations within the *Kansas Water Plan* provide the legal and state policy direction for the establishment of the Riparian and Wetland Easement Program. Under K.S.A. 32-807, K.S.A. 58-3810, *et seq*. landowners voluntarily enroll eligible areas identified within high priority riparian and wetland regions of the state.

For planning purposes an annual need of approximately $1 million in dedicated conservation easement funding is needed for Riparian and Wetland Protection and Development. The value of the land to be protected by an easement would be subject to the location and environmental benefit of that parcel of land. Projected easement cost increase is roughly 10% per year over the next 20 years, for a total of $57 million spent on easements. Both easements funding needs and the riparian and wetland protection site development funding needs are included in Table 1 (page 61).

Protect Streambanks through Stabilization Projects on a Stream Segment Approach

Numerous streambank stabilization projects have been implemented in recent years with state and federal assistance to address stream bank and channel erosion concerns. For maximum effectiveness it is recommended that the state coordinate, plan and implement systematic stream stabilization projects in targeted areas. This approach is being piloted in the Neosho basin. The KWO received funding from the 2009 American Recovery and Reinvestment Act (ARRA) to stabilize a roughly eight mile reach of the Neosho River above John Redmond Reservoir. The total cost of this streambank stabilization and restoration project is $1.3 million.

In Table 1 (page 57), it is assumed that the cost per stream length in the Neosho project will be similar above other federal reservoirs with water supply storage. The total stream length above the federal reservoirs was determined and multiplied by the cost per mile of the Neosho ARRA project. A total protection need of just over $114.5 million was determined using this approach for priority streambank stabilization projects above reservoirs including projected cost increases of 10% per year into the future. This work would be carried out over the next 15 years and is included in Table 1 (page 57).

Planning and Design

The majority of planning and design work for the protection portion of the Reservoir Sustainability Initiative is being managed by the local Watershed Restoration and Protection Strategy (WRAPS) stakeholder leadership teams (SLTs). These locally led groups provide valuable insight into the local needs and opportunities to stabilize and improve the watersheds above the federal reservoirs. Statewide, $2 million per year has been spent in each of the last three years on these efforts. This is a combination of federal Environmental Protection Agency (EPA) funds and State Water Plan Funds. These funds are leveraged with other state, federal and local programs.

Solicitation of proposals for these limited funds has shown a large unmet demand. The funding needs assessment assumes that there is a need of $5 million per year for planning and design for the next five years. The funding for planning and design would then taper off to $500,000 over the following seven years. Funding for protection strategies would then be more focused on implementation of identified projects for the duration of the planning period.

Restore

Restoration of Water Supply Storage through Dredging

Dredging involves the physical removal of accumulated sediment through mechanical, hydraulic, or pneumatic means. Funding is needed to develop and implement an operational program for reservoir dredging and disposal of dredged materials.

The 2007 Legislature amended K.S.A. 82a-2101 to authorize the state to provide funding for the Water Supply Restoration Program. This program is voluntary and incentive-based water and is designed to assist eligible sponsors to restore reservoirs where appropriate watershed restoration and protection strategies are planned or are in place. The program budget is financed from the Clean Drinking Water Fee Fund of the State Water Plan Fund.

Dedication of Dredging Initiative.

Upon announcement of this program in 2007, letters of interest from public water suppliers which had a small reservoir for primary or secondary water supply were solicited. Letters were received for 15 reservoirs. Mission Lake in Horton, Kansas was selected as a pilot project and dredging of the lake is currently underway. The City of Horton is contributing $4 million and the state $2.6 million, for a total project cost of $6.6 million. This funding will provide for the removal and disposal of one million cubic yards (about 629 acre-feet) of sediment from Mission Lake.

For purposes of this needs assessment, it is assumed that all of the 15 reservoirs that indicated interest in the lake restoration program would be dredged within the next 15 to 20 years. It is also assumed that average project costs for these reservoirs would be $6 million with a 10% inflation increase annually; half of which would be paid for by the state and half by the local sponsor. Total estimated cost for this portion of the funding assessment is $163 million.

A report to the Kansas Legislature in 2000 noted at least 35 municipal lakes used as either a primary or secondary water supply. As benefits of the Water Supply Restoration Program are demonstrated, additional local sponsors may become interested in restoring storage in other lakes not on the original 15-lake list.

Dredging may also be a viable alternative for water supply restoration at the larger federal reservoirs. Within the John Redmond Feasibility Study with the Corps, removal of roughly 50,000 acre-feet was evaluated as an alternative to providing future water supply for the Neosho basin. Based on an estimated $6.60 per cubic yard ($10,646/acre-foot) of sediment removal and using John Redmond Reservoir as an example, total cost for this project would be approximately $532 million in FY 2010 dollars. To account for future inflation and construction cost projections, this type of project will cost roughly $995 million.

Dam Safety and Rehabilitation

Nearly 6,000 small dams in Kansas are regulated by the Kansas Department of Agriculture, Division of Water Resources. Of these, 180 are classified as high hazard with an additional 247 classified as significant hazard. Most dams in Kansas have a 50 year design life; the current average age of dams in Kansas is 40 years. These dams have been constructed to provide flood control, public water supply, recreation and other benefits. Many of these dams were built by local watershed districts using federal or state cost-share assistance. Others have been constructed by municipalities, by private organizations or individuals and by the state.

On November 9, 2000, Congress passed the "Small Watershed Rehabilitation Amendments" which authorized NRCS to provide technical and financial assistance to watershed project sponsors in rehabilitating their aging dams of up to 65% of the total cost of the rehabilitation project.

The KWO estimates that within the next 40 years, 280 dams will need to be rehabilitated at a total cost of $84 million coming from local, state and federal cost-sharing. These numbers are based on a 1999 NRCS report that estimated roughly 40 dams were over 50 years old, 300 dams over 30 years old and over 200 were over 20 years old. According to the study an average watershed dam built in 1958 would cost $150,000 to rehabilitate to current safety standards. In 2009 dollars it is estimated that an average privately owned dam costs roughly $150,000 to rehabilitate, while an average watershed dam is estimated at $250,000. With roughly $84 million in rehabilitation needs, this amounts to about seven dam rehabilitation projects every year for the next 40 years; including an annual inflation rate of 5%.

Federal cost-share assistance can come from the NRCS Rehabilitation Program or the Dam Rehabilitation and Repair Act. State cost-share dollars come from both the existing SCC Rehabilitation Program and the proposed state rehabilitation program; while local cost-share dollars come from assessments on watershed district residents.

Planning and Design

To make sound choices in the selection of alternatives and locations to restore reservoirs, increased data collection, sharing and analysis will be needed. The state will be challenged based on actual need, financial constraints and environmental impacts. Success will depend on information and analysis available to address the questions and concerns.

Significant efforts in data collection and analysis are already underway and funded primarily through the State Water Plan Fund. For this funding needs assessment, it is assumed that this level of data collection will continue for the next 10 years. Analysis and design cost will increase once large or complex projects are identified. Funding needs for the next 40 years amount to $6 million, shown in Table 1 (page 57).

Basin Restoration Approach: Neosho

Volume III

Neosho Streambank.

Following is the third volume of the Reservoir Roadmap. Volume III provides a basin approach to reservoir sustainability including restoration, water conservation, and operational activities targeted in the watershed to secure, protect, and restore future water supply availability. Based on results of a supply and demand analysis, the Neosho basin was identified as the watershed of highest priority for developing this basin approach.

Volume III is organized by the following chapters

Neosho Basin Description. Provides background information on the water resource conditions of the basin including water use.

Neosho Basin Water Supply and Demand. Describes results in the Neosho basin from the OASIS (Operational Analysis and Simulation of Integrated Systems) model to analyze water supply and demand in greater detail. A brief description of alternatives for improving water supply reliability in the basin, as well as ongoing and recently completed studies that address these alternatives is also included.

Inventory of Restoration Approaches. Reviews potential restoration alternatives that could be applicable for each reservoir in the Neosho basin, depending on the type and severity of problems at the reservoir. Includes an evaluation of several alternatives using the OASIS model. Alternatives include sediment removal, reallocation, and structural restoration (dams, diversion structures, treatment facilities).

Identification of Water Conservation Opportunities. Maintaining or increasing a reservoir's storage is important in ensuring its reliability as a water supply source, but restoration approaches can be quite expensive and are more likely to be long term solutions. There are times when the availability of water supply needs to increase quickly, inexpensively, or temporarily. This section will identify opportunities for water conservation to improve water supply reliability.

Operation and Management Changes to Improve Supply. Discusses potential operation or management changes for each drinking water reservoir in the Neosho basin.

Mean Annual Sediment Yield. Describes an assessment of the sediment yield in the Neosho basin and results from SWAT (Soil and Water Assessment Tool) model above John Redmond Reservoir.

Identification of Streambank Erosion, Extent and Status of Riparian Areas and Estimates of Restoration Needed. This chapter describes and quantifies the condition of riparian areas and streambanks above water supply reservoirs in the Neosho basin and the potential for their restoration and protection. Estimates of length and cost of riparian area and streambank restoration and protection projects are provided.

Inventory of Watershed Structures and Sediment Yield Reductions. Provides an inventory of the watershed structures above five public water supply reservoirs in the Neosho basin. Data in the inventory of structures that currently exist in the basin include construction date, drainage area and amount of storage at the time of construction. Also included is the number and relative size of structures that are planned but to date have not been constructed. Includes a review of the relation between drainage areas and sediment yields for all or portions of seven watershed districts in the Neosho River basin above John Redmond Reservoir.

Identification of Reservoirs Not Built. One method of reducing the potential vulnerability to drought supplies in the Neosho basin is to evaluate ways to enhance supplies. This can be performed by reviewing past information about previously determined reservoir sites that were never built or using existing topographic information, more accessible by today's standards, to locate entirely new potential reservoir sites.

Recommendations for Reservoir Sustainability Approach in the Neosho Basin. Based on the information provided in each of the previous chapters, a summary of the approaches to reservoir sustainability that should be evaluated in greater detail or implemented are provided.

Proposed Schedule for Other Basins. Each river basin in Kansas with significant water supply reservoirs would benefit from the in-depth evaluation provided this year for the Neosho basin. This chapter outlines the proposed schedule for the remaining basins.

NEOSHO BASIN DESCRIPTION

Background

The Neosho basin covers over 6,300 square miles and encompasses all or part of 18 counties in southeastern Kansas. The Neosho, Cottonwood and Spring are the major rivers. There are three major reservoirs in the basin: John Redmond, Council Grove and Marion reservoirs. Each reservoir supplies the basin's municipalities and industries with water through the Water Marketing Program or Water Assurance District. Currently there are 19 public water suppliers and six industrial users in the basin that use surface water from the federal reservoirs. Surface water use makes up over 77% of the water used in the basin. The ability to store water in the reservoirs is critical to maintain future supply.

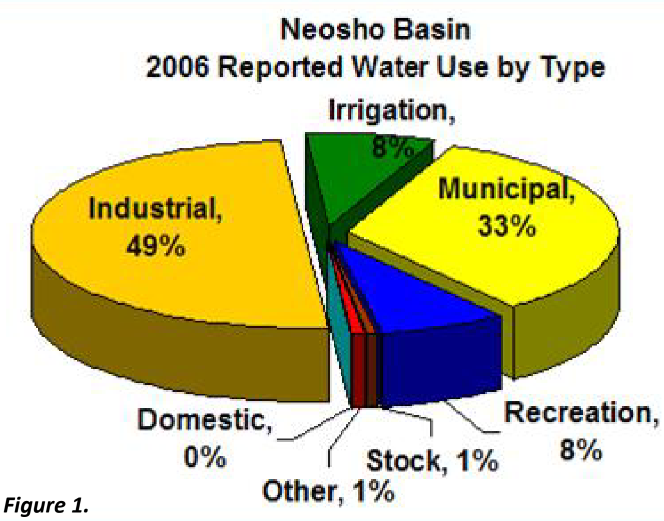


Figure 1.

Hydrology

The Neosho River rises in Morris County and flows southeast to join the Arkansas River near Muskogee, Oklahoma. The Cottonwood River rises in Marion County and joins the Neosho River in Lyon County east of Emporia. The Spring River, in the southeast part of the state, originates in Missouri and drains about 500 square miles in Kansas. It enters Cherokee County in the east, flows across the southeastern corner of that county, and joins the Neosho River in Oklahoma a short distance below the Kansas state line. The focus of this chapter is on the Cottonwood and Neosho Rivers as the Spring River is not dammed to form a reservoir in Kansas.

The larger tributaries of the Cottonwood River are South Cottonwood River, Mud Creek, Clear Creek, Doyle Creek, Cedar Creek, Middle Creek, Diamond Creek, and South Fork Cottonwood River. Tributaries to the Neosho with drainage areas greater than 70 square miles are Rock and Allen Creeks above Emporia, and Eagle Creek, Long Creek, Big Creek, Turkey Creek, Deer Creek, Elm Creek, Owl Creek, another Big Creek, Flat Rock Creek, Lightning Creek, Cherry Creek, and Labette Creek below Emporia. Elevations in the basin range from 1,320 feet in Marion County at the top of the basin to 826 feet in Cherokee County at the bottom of the basin in Kansas.

Eighty percent of the streams in the basin are intermittent and 20% are perennial for a total of 16,696 stream miles. Average stream density is 2.7 stream miles/square mile of land area, the second highest density of the 12 basins in the state.

Reservoirs

Marion, Council Grove and John Redmond are the three federal reservoirs in the Neosho basin. They were constructed by the U.S. Army Corps of Engineers (Corps) and are authorized for water supply purposes. The State of Kansas through the Kansas Water Office (KWO) has purchased storage in each of the reservoirs from the Corps which is then available to contract with municipal and industrial users in the basin.

Marion Reservoir is a 6,200 acre reservoir used as a source of water supply for the cities of Hillsboro, Marion and Peabody; and the Cottonwood and Neosho River Basins Water Assurance District #3 (CNRBWAD #3). The largest towns in the watershed and their population include Canton, 850; Lehigh, 211 and Durham 111. A small percentage of north Hillsboro (population 3,000) is also in the watershed, but the majority of the drainage from the town is south of the watershed.

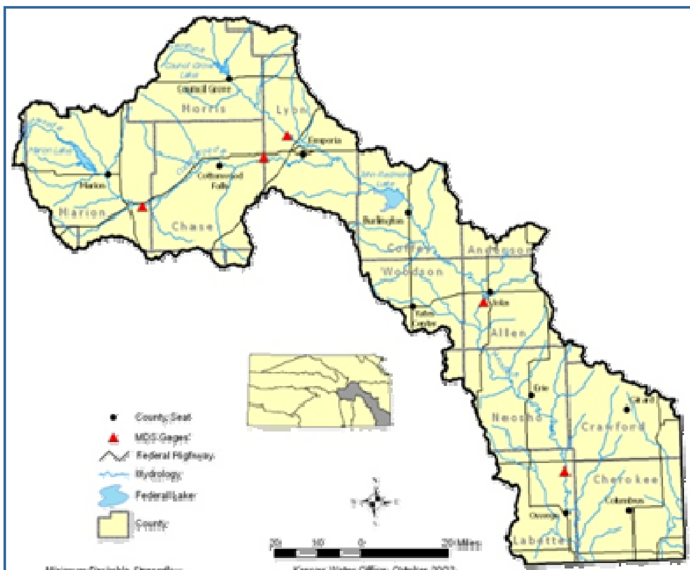


Figure 2.

Marion Reservoir has an approximate capacity of 86,700 acre-feet and is losing capacity at an average rate of 250 acre-feet per year due to sedimentation. Outflow is controlled by three 40-foot by 40-foot tainter gates and one 24-inch gate valve (Figure 2 (page 63)).

Council Grove Reservoir is a 2,700 acre reservoir used as a water supply source for the cities of Emporia and Council Grove; and the CNRBWAD #3. Council Grove Reservoir has an approximate capacity of 47,000 acre-feet and is losing capacity at an average rate of 170 acre-feet per year due to sedimentation. Outflow is controlled by two 17-foot by 7.5-foot gates and one 24-inch gate valve.

John Redmond Reservoir is an 8,400 acre reservoir used as a water supply source for the Wolf Creek Nuclear Generating Station and the CNRBWAD #3. John Redmond Reservoir has an approximate capacity of 53,500 acre-feet and is losing capacity at an average rate of 650 acre-feet per year due to sedimentation. Outflow is controlled by fourteen 40-foot by 35-foot tainter gates, two 24-inch gate valves, and one 30-inch gate valve.


John Redmond Reservoir.

Two city-owned reservoirs also provide water supply in the Neosho basin. These reservoirs do not have the storage capacity to serve multiple users but are important as a more localized water supply.

Council Grove City Lake is a 434 acre lake used as a source of water supply for the City of Council Grove. Council Grove City Lake has an approximate capacity of 7,200 acre-feet and is losing capacity at an average rate of 20 acre-feet per year due to sedimentation. Outflow is controlled by the spillway elevation of 1,344 and several valves at lower elevations.

Parsons City Lake is a 980 acre lake used as water supply source for the City of Parsons. Parsons City Lake has an approximate capacity of 8,300 acre-feet and is losing capacity at an average rate of 25 acre-feet per year. Outflow is controlled by the spillway elevation at 925 and one 12-inch valve.

Wolf Creek Lake (Coffey County State Lake) supplies cooling water for the Wolf Creek Nuclear Generating Station. The lake is approximately 5,200 acres and has an approximate capacity of 116,000 acre-feet at its spillway elevation of 1,088. Wolf Creek operations state that the plant will have to shut down if the lake elevation drops below 1,075. Wolf Creek maintains a lake elevation of approximately 1,088 by pumping from their water right on the Neosho River when flows are sufficient and from their Water Marketing contract from John Redmond Reservoir when Neosho River flows are not sufficient to use their water right.

Land Use/Land Cover

Predominant landscape features in the Neosho basin are the grasslands of the Flint Hills in the northwestern part of the basin, cropland in the flood plains in the basin, and the urbanized areas. Plant communities in the study area include Oak-Hickory forest, floodplain forest, Cross Timbers forest/grassland, Cedar Glades, bluestem prairie, and bluestem-grama prairie. Grassland (56%), and row crops (38%), are the most widespread land cover classes covering about 3,738,540 acres of the basin, or slightly more than 5,800 square miles.

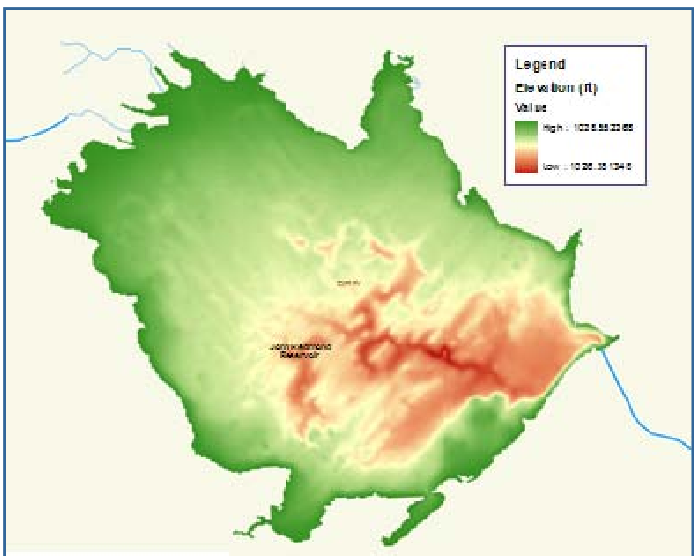
Reservoir	Top of Conservation Pool (Feet)	Original Storage Capacity (Acre-feet)	Capacity at most recent survey (Acre-feet)	Estimated Current Capacity (Acre-feet)	Design Sedimentation Rate (Acre-feet/Year)	Actual Sedimentation Rate (Acre-feet/Year)	Loss of Capacity to Date
Council Grove	1,274.0	54,832 (1963)	47,093 (2008)	46,935	206	172	14%
John Redmond	1,039.0	82,230 (1963)	53,927 (2007)	51,966	404	643	37%
Marion	1,350.5	96,757 (1967)	86,711 (2008)	86,485	94	245	11%

Table 1. Sedimentation estimates for federal reservoirs in the Neosho basin.

According to the 2003 Assessment of Riparian Areas Inventory by the Kansas Geological Survey (KGS), of the 37,257 bank miles of riparian area in the Neosho basin, within a 100 ft corridor along each bank in the basin, the dominant riparian cover is pasture/grassland (31%). The second most common cover is forest land (25%), and third most common cover is a mixture of pasture and trees (20%). The remaining riparian cover types, in descending order of dominance, are cropland, crop land/tree mix, shrubland, urban, urban/tree mix, and barren land. This evaluation was compiled from interpretation of aerial photographs. The condition of these riparian areas is not completely known.

Bathymetric Surveys

Bathymetric surveys of each of the public water supply lakes in the Neosho basin have been completed by the Kansas Biological Survey. Each survey was performed using an acoustic echo-sounding apparatus linked to a global positioning system. The bathymetric surveys were geo-referenced and compared with original pre-impoundment maps to estimate sediment accumulation. In addition, sediment samples were extracted and analyzed at each reservoir. Results of the surveys for the three federal reservoirs in the basin are summarized in Table 1 on page 68.



Bathymetric Survey of John Redmond.

Comparison of the 2008 bathymetric survey data for Parsons Lake to a 1957 pre-impoundment map suggests that while the surface area of the reservoir has not been markedly reduced in the 51-year period, the capacity of the reservoir at the 927 foot elevation pool has been reduced from 10,916 acre-feet to 9,183 acre-feet.

According to a 2008 bathymetric survey, about 16% of the storage capacity has filled with sediment since construction of Council Grove City Lake. Sediment sampling conducted at the lake revealed a greater occurrence of silt in the upper end of the reservoir, while a mid-lake sample was predominantly sand. A bathymetric survey of Wolf Creek Lake is scheduled for October 2009.

Water Supply and Demand

Background

In 2006 the Kansas Water Office (KWO) initiated a review of surface water supply and demand in five basins in eastern Kansas. The intent of the analysis was to identify future potential surface water supply vulnerabilities along main stem river corridors in select eastern Kansas river basins. For the severe drought scenario reviewed in the initial assessment, three of the five basins showed some supply vulnerability within the next 15 years. The Neosho basin was assigned highest priority due to the high rate of supply loss in the basin coupled with the relatively high demand projections.

Another conclusion of the initial assessment was that a more complex model is needed to further refine projections and situations where projected demand may exceed supply on a more local scale, temporally and spatially, within each watershed.

The KWO selected the OASIS (Operational Analysis and Simulation of Integrated Systems) model to analyze water supply and demand in greater detail. The OASIS model has the ability to simulate the interaction of multiple reservoirs and rivers in a system; simulate system management issues; identify areas of concern in a system; and evaluate alternative improvements to the system.

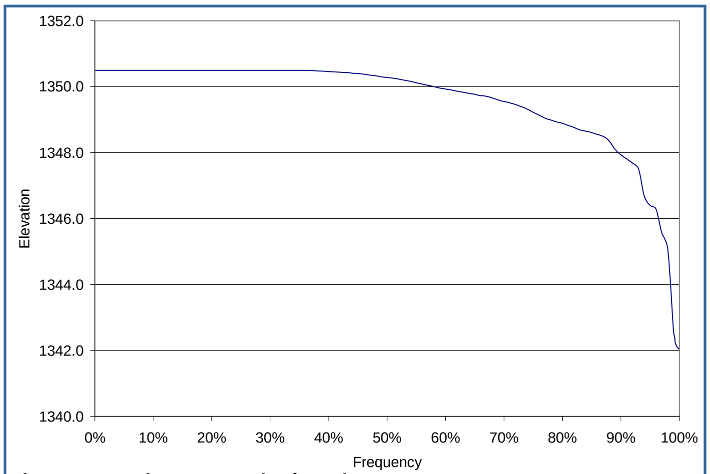


Figure 1. Marion Reservoir Elevation Frequency.

Model Results

The basin-wide approach compared the basin water supply during a severe drought period with the basin demand. Results from OASIS are challenging to compile in this manner. Water supply reliability can be determined by analyzing reservoir elevations and/or storage capacities as well as streamflows at United States Geological Survey (USGS) gages. Municipalities typically use reservoir information as a major component of their conservation plans to trigger drought watches, warnings, and emergencies. Another way to determine water supply reliability is to estimate the potential for water supply shortages for an individual user or group of users during a drought period.

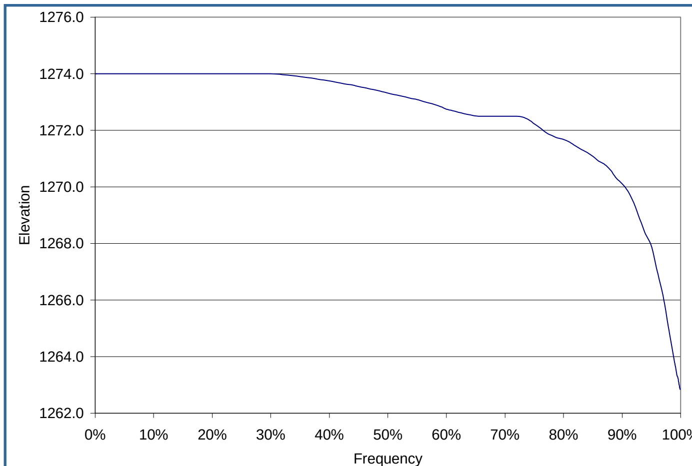


Figure 2. Council Grove Reservoir Elevation Frequency.

Analysis of reservoir elevations is also important for in-lake recreation. As elevation decreases, boat ramps become unusable and structures normally covered with water become boat hazards. Figures 1-3 (page 66) illustrate the percentage of time during the OASIS model drought simulation each reservoir exceeds a given elevation.

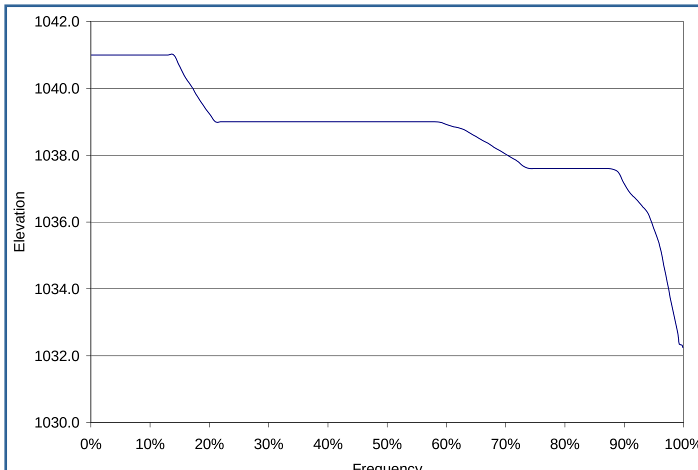


Figure 3. John Redmond Reservoir Elevation Frequency.

The figures show that nearly 90% of the time, the reservoir elevations are within a few feet of the conservation pool elevation; however, the elevations drop significantly in the remaining 10% of model simulations. The stair-stepped elevation at John Redmond Reservoir is due to the lake level management plan.

To determine how reservoir capacities may influence downstream water users, information that may be used in their conservation plans is considered. For the purposes of this analysis, a drought watch goes into effect when a reservoir's storage is less than 75%, a drought warning when storage is less than 50% and a drought emergency when storage is less than 33%. Figures 4-6 below and to the right (page 67) illustrate the percentage of time during the OASIS model simulation each reservoir exceeds a given capacity, and compares to the capacities remaining when a drought watch, warning, and emergency may be triggered.

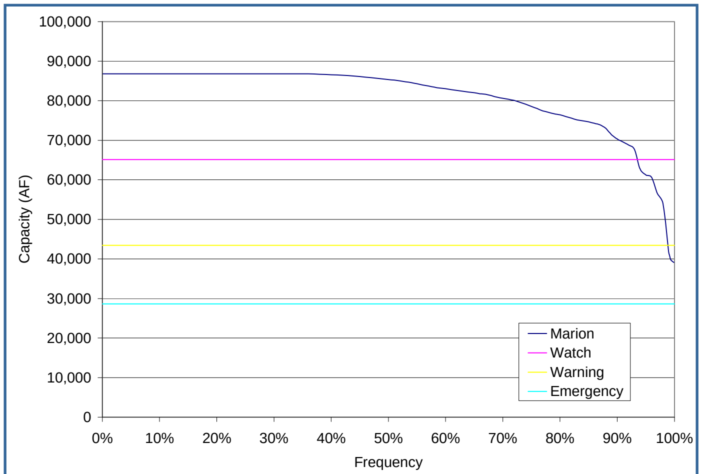


Figure 4. Marion Reservoir Capacity Frequency.

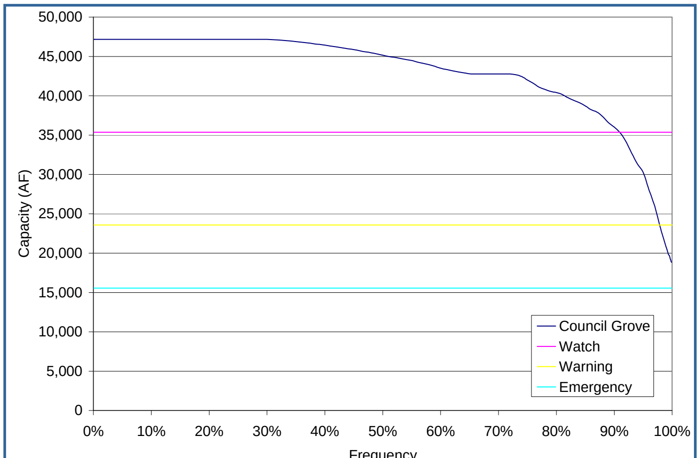


Figure 5. Council Grove Reservoir Capacity Frequency.

John Redmond is the only reservoir that goes into a drought emergency during the model simulation. Marion and Council Grove reservoirs both have some time when their storage is less than half of full capacity, but it is minimal. The reserve capacity storage in each of the reservoirs increases the percentage of storage remaining because that storage is not used to meet downstream demands.

Analyzing each storage pool in the reservoirs is informative to understand how marketing and assurance customers may be affected, as well as instream water quality. If a

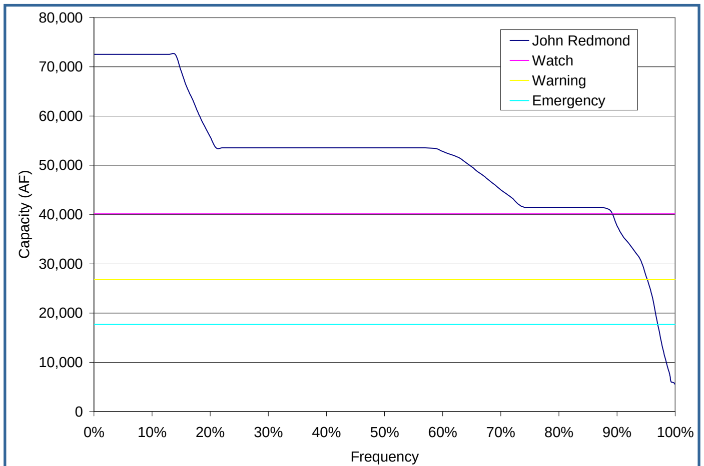


Figure 6. John Redmond Reservoir Capacity Frequency.

marketing or assurance storage pool empties, releases for those customers will not be made and customer shortages may occur for a period of time. If a quality storage pool empties, minimum releases may not be made and downstream targets may not be met. Minimum and maximum storage capacities for each pool are listed in Table 1 (Page 68).

The most significant results shown in the table are the effects on John Redmond reservoir's quality and marketing pools. The quality storage is nearly emptied each year by the lake level management plan in which the conservation pool elevation fluctuates from 1037.6 to 1041.0 feet. The marketing storage briefly empties twice during the 1950's magnitude drought which is significant because it is used to supply the Wolf Creek Nuclear Generating Station's cooling lake.

Evaluation of Alternatives

Water supply reliability can be improved by increasing the water supply, reducing the demand for water, or a combination of the two. Alternatives for improving water supply reliability that are being evaluated include sediment removal, reallocation, structural restoration, demand management, reservoir operational changes, new reservoirs, off-stream storage, and watershed management. Most of these alternatives have been evaluated by the KWO using the OASIS model, and several studies are ongoing or have recently been completed that further evaluate these methods.

The KWO, the U.S. Army Corps of Engineers (Corps), and Watershed Restoration and Protection Strategy (WRAPS) groups in the basin are evaluating efforts on the rivers to reduce the amount of sediment entering the rivers and streams upstream of the reservoirs. This will reduce the amount of sediment entering the reservoirs, reducing the loss of capacity due to sedimentation.

	Marion		Council Grove		John Redmond	
	Min	Max	Min	Max	Min	Max
Quality	8,700	31,100	800	10,700	0	31,800
Marketing	21,700	39,700	4,400	20,500	0	29,900
Assurance	200	400	5,300	7,000	700	3,800
Reserve	8,500	15,600	6,900	9,000	4,300	7,100

Table 1.

The KWO has also initiated a study with the Corps and an engineering consultant to evaluate alternatives to improve water supply availability in the Neosho basin. Some of the alternatives to be studied will include those discussed in previous paragraph.

To address the significant amount of sedimentation that has already occurred in John Redmond Reservoir, the Corps recently completed an assessment of the potential for dredging sediment out of the reservoir. Depending on the amount of sediment to be dredged, resulting storage capacity increases could be similar to that of a pool rise.

Several other alternatives have been analyzed in the OASIS model, including use of other water supply sources such as off-stream or out-of-basin storage, and demand management through conservation practices. Results are varied as these alternatives are focused on a local scale.

Many of the alternatives for improving water supply reliability in the Neosho basin are discussed in greater detail throughout Volume III of the Reservoir Roadmap.

References

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

Inventory of Restoration Approaches

Background

The Neosho basin includes several reservoirs used for water supply purposes. Although the reservoirs vary in many aspects, they are all important due to their water supply capabilities. Sedimentation and poor water quality are affecting these reservoirs and have the potential to reduce their reliability as a source of water. One option to ensure water supply storage capacity in the basin is to construct new reservoirs as the existing reservoirs continue to fill with sediment and decline in water quality; however, most of the best sites for reservoirs have already been utilized. Therefore, restoration of the existing reservoirs may provide the best value to restore water supply reliability. This section will identify potential restoration approaches appropriate for each of the water supply reservoirs in the Neosho basin and strategies for prioritizing the restoration activities.

Potential Restoration Approaches

There are numerous potential restoration alternatives that could be applicable for each reservoir, depending on the type and severity of problems at the reservoir. Alternatives include sediment removal, reallocation and structural restoration (dams, diversion structures, treatment facilities).

Sediment Removal.

Sediment Removal

Sediment is typically removed from a reservoir by dredging. Dredging is the process of excavating sediment from the bottom of the reservoir and disposing of the sediment at a different location. There are several different types of dredges that are typically mounted on a boat or barge for operation in the reservoir. The collected sediment is usually pumped into a sediment basin where it precipitates out of suspension allowing much of the water in the dredge slurry to return to the system. Benefits of dredging include significant removal of sediment to maintain an existing reservoir site. Potential drawbacks include cost, time required to restore reservoir storage capacity, and environmental concerns with sediment disposal. The U.S. Army Corps of Engineers (Corps) is assessing the viability of dredging sediment from John Redmond Reservoir. Initial assessments suggest that the cost of dredging is too high for the benefits gained from the additional storage. Dredging is a potential option in all of the reservoirs in the Neosho basin; however, the benefit per cost may be greatest in reservoirs that have a lower sedimentation rate.

Another method of removing sediment from a reservoir is flushing. Flushing is the process of drawing down the reservoir to create river-like flow conditions in the reservoir, re-suspending sediment that has deposited on the reservoir bottom and transporting it through the gates in the dam to the river downstream. There are several potential problems with using flushing to remove sediment from the reservoir, including a lack of inflow refilling the evacuated storage in a timely manner and what happens with the re-suspended sediment as it travels downstream.

Reallocation

Reallocation of storage is a potential restoration option only in the three federal reservoirs in the Neosho basin. Reallocation of storage is a process by which the Corps changes the designation for a specified portion of storage in a federal reservoir. In the interest of restoring or increasing water supply storage, storage could be reallocated from water quality storage, flood pool storage, or another storage owned by the Corps. If storage is reallocated from flood pool to water supply, a permanent increase in the conservation pool elevation typically results. A reallocation study by the Corps compares the benefits of increased water supply storage to the potential detriments caused by lost flood or water quality storage capacity, shoreline effects caused by the higher permanent pool and environmental effects due to increased backwater upstream of the reservoir.

In 1996, in John Redmond Reservoir, the KWO requested that the Corps reallocate storage on John Redmond Reservoir from the flood pool to the conservation pool to regain water supply storage lost due to greater sedimentation in the conservation pool. When complete, the reallocation will result in a two-foot pool rise at John Redmond Reservoir, increasing the conservation pool storage capacity by approximately 20,000 acre-feet. A comparison in Figure 1 (page 74), of the 2008 storage frequency and the 2048 storage frequency after the pool rise shows that an increase in storage this significant would likely give the water supply use of the reservoir an extra 25 to 30 years of life.

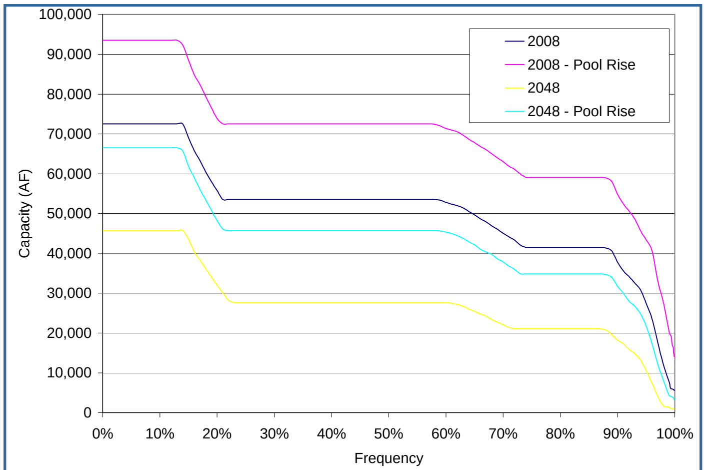


Figure 1. John Redmond Reservoir Capacity Frequency Comparison.

Structural Restoration

Structural restoration is applicable for any structure associated with the reservoir or required to provide water supply from the reservoir, including the dam, water supply diversion structures and water treatment facilities.

The structural restoration most likely to occur at the federal reservoirs is restoration of the gates, valves and other associated mechanical equipment that will reduce the amount of water lost downstream due to leakage. The Corps is currently restoring the tainter gates at John Redmond Reservoir.

Increasing the dam height at a federal reservoir is unlikely for several reasons. An increase in dam height will require the Corps to obtain additional land to compensate for the increase in potential flood storage. The costs associated with land purchase, permits and construction could be quite significant.

Increasing dam height may be the only way to increase the pool elevation at city lakes with no flood pool. The condition of the dam is an important consideration in these lakes because they may be older than the federal dams or not as well constructed. Some of the same factors must also be considered before increasing the dam height of a city lake, especially if the new lake elevation will encroach on private property near the lake. For example, Council Grove City Lake is surrounded by approximately 350 houses, so raising the lake elevation is probably not feasible.

Table 1 below (page 70) summarizes potential restoration approaches for each of the water supply reservoirs in the Neosho Basin.

Strategies for Prioritizing Restoration Alternatives

The effectiveness of restoration approaches will vary depending on the needs of each reservoir. Factors affecting the prioritization of restoration alternatives include feasibility and benefits of the restoration approach, rate of water supply lost due to sedimentation, projected growth of demands, cost of restoration and alternative sources of water supply.

KWO has initiated a study with the Corps and an engineering consultant to evaluate alternatives to improve water supply availability in the Neosho basin. Some of the alternatives to be studied will include those discussed above. Alternatives will be evaluated based on numerous criteria, including:

- Effectiveness – How effective is the alternative at improving and maintaining water supply reliability for specific users and the Neosho basin as a whole?
- Economic – What are the capital costs for the alternative and what are future operation and maintenance requirements?
- Environmental – What permitting requirements are necessary for the alternative?
- Schedule – How much time is required for the alternative to be implemented?

Results of this study may provide recommendations that will help prioritize the restoration alternatives.

Reservoir	Sediment Removal	Pool Rise	Reallocation	Structural Restoration
Marion	X	X	X	X
Council Grove	X	X	X	X
John Redmond	X	X	X	X
Council Grove City Lake	X			X
Parsons City Lake	X			X
Wolf Creek Lake	X			

Table 1. Summary of Potential Restoration Approaches.

Several public water suppliers in the Neosho basin have contracted with engineering firms to evaluate their water supply reliability. These studies may include an analysis of restoration alternatives to their water supply reservoirs. This information will also be used to prioritize the restoration options.

Recommendations

1. Continue working with public water suppliers in the basin to improve water supply reliability.
2. Use the results from the Corps and public water supplier studies to prioritize restoration alternatives.

Opportunities for Water Conservation
Maintaining or increasing a reservoir's storage is important in ensuring its reliability as a water supply source, but restoration approaches can be quite expensive and are more likely to be long term solutions. There are times when the availability of water supply needs to increase quickly, inexpensively or temporarily. This section will identify opportunities for water conservation to improve water supply reliability.

Water Conservation
Water conservation is a management tool that can provide multiple benefits. Water conservation is the most cost-effective and environmentally sound way to reduce demand for water. Conservation has been a priority for the State of Kansas for a number of years. The Kansas Water Resources Planning Act provides statutory authorization for addressing water quantity management in the *Kansas Water Plan*. This Act established long-range goals for the management, conservation and development of the waters of the state, including:

- The prevention of the waste of the water supplies of the state, and;
- The protection and conservation of the water resources of the state in a technologically and economically feasible manner.

In October 1998, the Kansas Water Authority (KWA) approved objectives for the year 2010 as part of the *Kansas Water Plan*. Additional objectives for the year 2015 were added to the FY 2004 *Kansas Water Plan* update. An assessment of current conditions related to each objective provides information for targeting of state program resources to areas of greatest need and benefit.

Kansas Water Plan 2010 and 2015 Objectives

- By 2010, reduce the number of public water suppliers with excessive unaccounted for water by first targeting those with 30 percent or more unaccounted for water.
- By 2010, reduce the number of irrigation points of diversion for which the amount of water applied in acre-feet per acre (AF/A) exceeds an amount considered reasonable for the area.
- By 2015, all non-domestic points of diversion meeting predetermined criteria will be metered, gaged or otherwise measured.
- By 2015, conservation plans will be required for water rights meeting priority criteria under K.S.A. 82a-733 if it is determined that such a plan would result in significant water management improvement.

Municipal and Other Public Water Suppliers

Conservation Plans
Conservation plans, as currently prepared and implemented, provide a management tool for the public water supplier that improves efficiency but may or may not reduce the quantity used. To be most effective the plans

Municipal User	2007 GPCD	2007 Regional Avg GPCD	2007 % Difference	2007 % Unaccounted For	5 Year Avg GPCD
Large					
Emporia	176	135	+31	18	176
Parsons	118	130	-9	11	134
Medium					
Burlington	115	101	+14	14	123
Chanute	130	98	+33	12	126
Chetopa	103	98	+5	4	104
Cottonwood Falls	96	101	-5	4	90
Council Grove	91	101	-10	13	106
Erie	101	98	+3	11	104
Hartford	89	101	-11	26	81
Humboldt	110	98	+12	15	111
Iola	137	98	+40	21	111
Marion	123	101	+22	19	118
Oswego	94	98	-4	4	102
Saint Paul	86	98	-12	7	98
Woodson Co. RWD #01	73	101	-27	15	76

Table 1. Summary of Water Use for Municipal Users in the Neosho Basin OASIS Model.

must be implemented and maintained. Of the 111 public water suppliers in the Neosho basin, 85 have developed a water conservation plan.

Currently, municipal water conservation goals are based on a system's size and the average water consumption in gallons per capita per day (GPCD) for the region. GPCD calculations are based on amounts of water sold for residential and commercial uses, free uses, and unaccounted for water, but do not include sales of municipal water to industries using over 200,000 gallons per year. For this analysis, large utilities are those serving 10,000 people or more; medium utilities are those serving 500 to 9,999 people; and small utilities are those serving fewer than 500 people. The Neosho basin OASIS model includes municipal users that either have a water right on the Neosho or Cottonwood rivers or have a marketing contract with the State of Kansas. A summary of water use for large and medium municipal users in the OASIS model is included in Table 1 (page 72).

Municipalities with a high water use relative to the regional average may improve water supply reliability by implementing conservation practices. Municipalities with a high percentage of unaccounted for water will likely reduce their water use by reducing the amount of unaccounted for water.

Technical Assistance

The Kansas Rural Water Association (KRWA) under contract with the KWO provides technical assistance to public water supply operators, managers and local administrators on issues critical to public water systems. The program includes on-site technical assistance for rural water districts and municipal water systems. KRWA provides bookkeeping assistance, water rate structuring, water conservation plan development, distribution system and treatment plant reviews/analyses, leak detection, meter testing, well and distribution line cleaning and emergency assistance.

Drought Triggers

Public water supply conservation plans include locally determined response to drought triggers. These triggers are developed by and for the local water system. The 2007 Kansas Municipal Water Conservation Plan Guidelines provide suggestions for this planning. The Guidelines also include triggers for water marketing reservoirs.

Municipal drought stage triggers indicate certain levels of water shortage or other drought conditions have been reached. Triggers may be storage or distribution system capacity, peak demand, or some other utility determined condition. Each trigger acts as a signal to begin implementation of appropriate actions for that stage and specific goals are identified as the desired outcome for each stage. Appropriate conservation practices in the areas of education, management and regulation are developed and set under each stage. A public water supplier should enact the appropriate stage whenever a trigger is reached. Delay in action may lead to a major disruption of the water supply system at a later time.

Three to four stages are considered appropriate in response to drought to trigger practices or actions. The first three stages; water watch, water warning and water emergency are appropriate for all public water suppliers. A fourth stage, water rationing, is for possible use by public water suppliers in an extreme emergency. Goals for a water warning and a water emergency should be quantifiable, specifically describing the water status and targeting water user awareness, reducing overall demand, and reducing peak demand.

Evaluation of Conservation

The effects of demand management through conservation practices by municipalities were evaluated using the OASIS model. Results of the model runs for Council Grove Reservoir are shown in Figure 1 below (page 73).

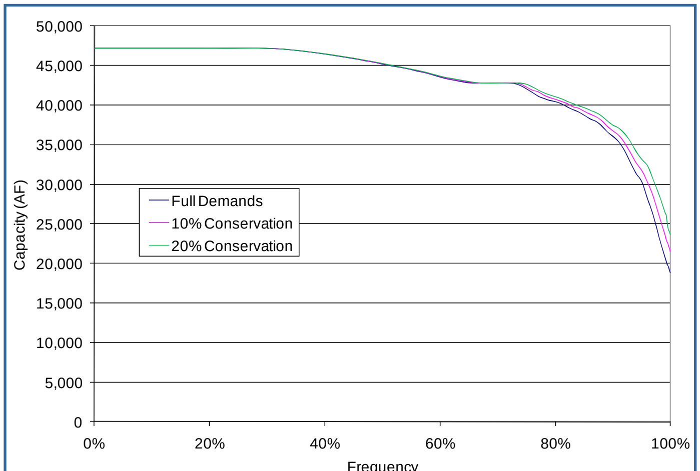


Figure 1. Council Grove Reservoir Capacity Frequency Comparison

The model was run with municipal demands reduced by 10% and 20% based on estimates of potential conservation capabilities provided by municipalities in the Neosho basin. Council Grove Reservoir responded the most to conservation practices due to the relatively large use of storage by the City of Emporia. Marion and John Redmond reservoirs did not respond as much because of the low municipal use from each of those reservoirs.

Industrial Water Use

The 1986 Kansas Industrial Water Conservation Plan Guidelines were prepared for use by industrial water users to assist them in developing a water conservation plan. As members of the Cottonwood and Neosho River Basins Water Assurance District #3, (CNRBWAD) four industrial users in the Neosho basin are required to have water conservation plans. These plans are somewhat limited in total conservation because these industries typically cannot reduce the amount of process water used without reducing production or shutting down.

Irrigation Water Use

While irrigators make up only about 8% of the water use in the Neosho basin, they influence water availability in the system during specific months of the year. Irrigation water conservation plan guidelines were revised in 2006. Conservation plans are generally only required by Kansas Department of Agriculture-Division of Water Resources (DWR) for irrigators who are not in compliance with the terms of their water right; however, continued improvements to irrigation technology may reduce their water use.

Recreation Water Use

Recreational water users also account for about 8% of the water use in the Neosho basin and influences water availability in the system during specific months of the year. Most recreational users in the Neosho basin pump water from the river to create habitat for water fowl. These users coordinate with the DWR to ensure there is sufficient water available for them to pump; conservation measures are not typically required. Water conservation plan guidelines have not been developed for recreational water use.

Recommendations

1. Continue aid to public water suppliers in developing and maintaining water conservation plans.
2. Continue technical assistance to public water suppliers in determining the source of unaccounted for water.
3. Develop drought triggers for water marketing customers.
4. Coordinate with the CNRBWAD#3 to develop consistent water conservation plans and drought triggers for each of their members.

References

State Water Resource Planning Act. K.S.A. 82a-901a.

Kansas Water Office. 1986 Kansas Industrial Water Conservation Plan Guidelines.

Operation and Management Changes to Improve Supply
This section discusses potential operation or management changes for each drinking water reservoir in the Neosho basin.

Reservoir Operational Changes
Operational decisions and management practices of the three federal reservoirs in the Neosho basin can be evaluated for the purpose of improving water supply. The difficulty lies with making changes to these operations because of their potential effects on flood control and environmental issues. The U.S. Army Corps of Engineers (Corps) requires significant study before an operational change can be made to a federal reservoir.

Operational changes that improve water supply can be made by increasing the amount of water stored in the reservoir or by reducing the amount of sediment that settles in the reservoir. The amount of water stored in the reservoir can be increased by changing the minimum release schedule and the lake level management plan (LLMP).

Reservoir Minimum Releases
The minimum release schedule for a federal reservoir is typically set to meet instream flow requirements for wastewater discharge and fish and wildlife support. In the Neosho basin, Marion and Council Grove reservoirs have the following cubic feet per second (cfs) minimum release schedules.

	Month											
Target (cfs)	J	F	M	A	M	J	J	A	S	O	N	D
at Chanute	21	21	21	24	30	39	48	48	36	24	21	21

		Month											
Reservoir		J	F	M	A	M	J	J	A	S	O	N	D
Marion	cfs	1	1	1	2	7	9	13	13	9	7	2	1
Council Grove	cfs	4	4	4	4	5	7	8	8	6	4	4	4

John Redmond Reservoir does not have a minimum release schedule; instead releases are made to meet the following minimum flow requirements on the Neosho River at Chanute, Kansas, which were recommended by the Public Health Service in 1952.

Minimum releases are typically met by inflows that are bypassed through the reservoirs; however, if these inflows are not sufficient to meet the required minimum releases, stored water is released. Typically, these releases are made from water quality storage. As indicated, minimum release schedules for many of the federal reservoirs in Kansas were created over 50 years ago, usually for dilution of a city's wastewater downstream of the reservoir. While wastewater treatment requirements have increased, so have the wastewater treatment technologies. Improved treatment allows for a constant stream flow at the point of wastewater discharge instead of a widely varying release schedule required historically. New release schedules for federal reservoirs based on either the probability of meeting a downstream target or using continuous monitoring and adjustment of releases to meet the target are more efficient ways to manage the reservoir's storage than a set minimum release schedule.

Gage	River	MDS (cfs)
Florence	Cottonwood	10
Plymouth	Cottonwood	20
Americus	Neosho	5
Iola	Neosho	40
Parsons	Neosho	50

While the target at Chanute is based on wastewater treatment requirements, there are several other instream water quality requirements as well. Minimum Desirable Streamflows (MDS) are established to maintain instream benefits in the location where the MDS is set. If the average daily streamflow at the MDS gaging station falls below the MDS for a period of seven consecutive days, the Chief Engineer has the ability to administer water rights with a priority after April 12, 1984. The Neosho River has MDS at the Americus, Iola, and Parsons gages. The Cottonwood River has MDS at the Florence and Plymouth gages.

Neosho River streamflows downstream of John Redmond Reservoir have historically been below MDS for periods of time during droughts. The MDS values are relatively high in comparison to the minimum flow target at Chanute and there are a significant number of water users downstream of John Redmond. MDS is typically met on the Neosho River above John Redmond and on the Cottonwood River because of significant gains of natural flow, fewer water users, and lower MDS values.

Lake Level Management Plans
Lake Level Management Plans (LLMPs) are proposed seasonal fluctuations in the reservoir surface elevation with the goal of increasing the beneficial use of the reservoir. LLMPs are developed through a coordinated effort between the KWO, the Corps, and the Kansas Department of Wildlife & Parks (KDWP), each receiving input from stakeholders with an interest in the reservoirs.

The following table lists guidelines of a typical LLMP:

Time Period	Action	Benefits
Spring	Raise water level elevation to inundate shoreline vegetation	Enhance spawning habitat Increase forage Fish production
Late Spring to Summer	Stable water level	Additional spawning area Boat ramp access Reduce shoreline erosion
Mid to late Summer	Draw down	Revegetation Control of rough fish
Fall	Gradual rise	Food and cover for waterfowl season
Winter	Draw down	Reduce ice and wave damage Additional storage capacity for spring inflows

The LLMPs for each of the three federal reservoirs are shown in the following figures (Figures 1-3 (page 76) :

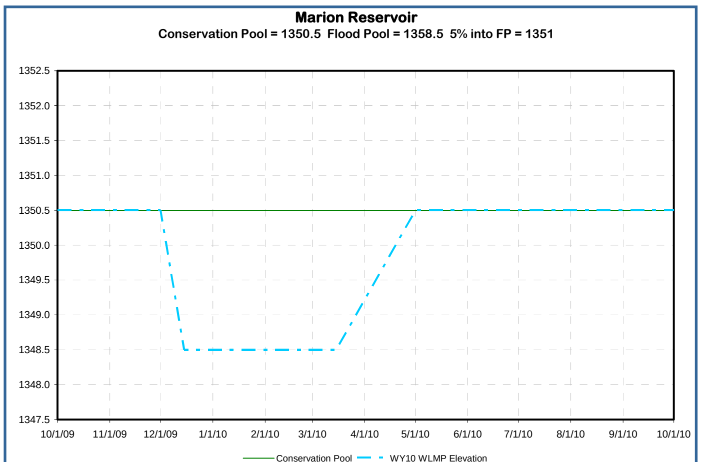


Figure 1. Marion Reservoir Lake Level Management Plan.

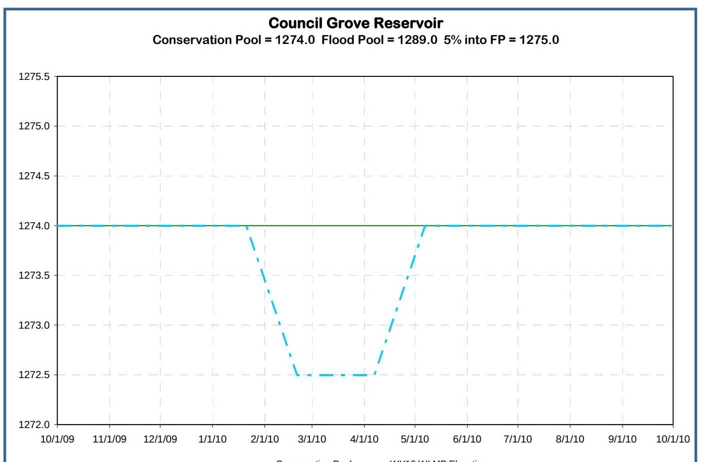


Figure 2. Council Grove Reservoir Lake Level Management Plan.

In each of the three federal reservoirs, storage is evacuated below the normal conservation pool for a period of time during the year. Although most of the evacuated water is attributed to water quality storage, it can affect the amount water supply remaining. The LLMP at John Redmond Reservoir has an inflow trigger that must be met prior to evacuation of storage. The trigger requires that more than 200,000 acre-feet of inflow enters the reservoir in the months of March, April, and May, which effectively eliminates the drawdown during drought years. Triggers could also be effective at Marion and Council Grove reservoirs.

Reservoir Sedimentation Management

Reservoir sedimentation management strategies can include one or more of the following techniques:

- Reducing sediment inflows
- Managing sediment in the reservoir
- Removing sediment from the reservoir
- Replacing lost storage
- De-commissioning the reservoir

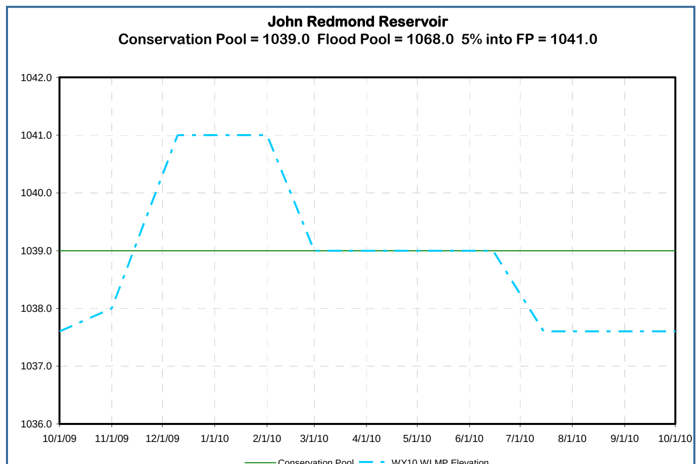


Figure 3. John Redmond Reservoir Lake Level Management Plan.

The focus of this section of the Reservoir Roadmap is reservoir operational changes, which limits this discussion to managing sediment in the reservoir using reservoir operations. Operational techniques for preventing sediment from settling when sediment laden water enters the reservoir or removing accumulated sediment include multi-level selective withdrawal, changes in lake level management plans, inflow routing, sluicing, density current venting, and flushing. Each of these techniques is described in detail by Baker & deNoyelles. Most of the techniques involve reducing the residence time of sediment laden water in the reservoir, thereby reducing sedimentation. One issue may be that the greatest amount of sediment entering the reservoir is during high flow (flood) events, typically the time when reservoir operators want to store the water to avoid downstream flooding. These methods of sediment management will require significant study and changes to the Corps' reservoir water control manuals.

Recommendations

1. Develop triggers for implementation of lake level management plans at Marion and Council Grove reservoirs similar to that at John Redmond Reservoir.
2. Coordinate with the Corps to study the use of reservoir operational techniques to reduce sedimentation in the reservoirs.

References

U.S. Army Corps of Engineers. Marion Reservoir Water Control Manual.

U.S. Army Corps of Engineers. Council Grove Reservoir Water Control Manual.

U.S. Army Corps of Engineers. John Redmond Reservoir Water Control Manual.

Minimum Desirable Streamflows. K.S.A. 82a-703.

Kansas Water Office. Lake Level Management Plans WY 2010 Report.

Baker, Debra & deNoyelles, Frank. Can Reservoir Management Reduce Sediment Deposition?

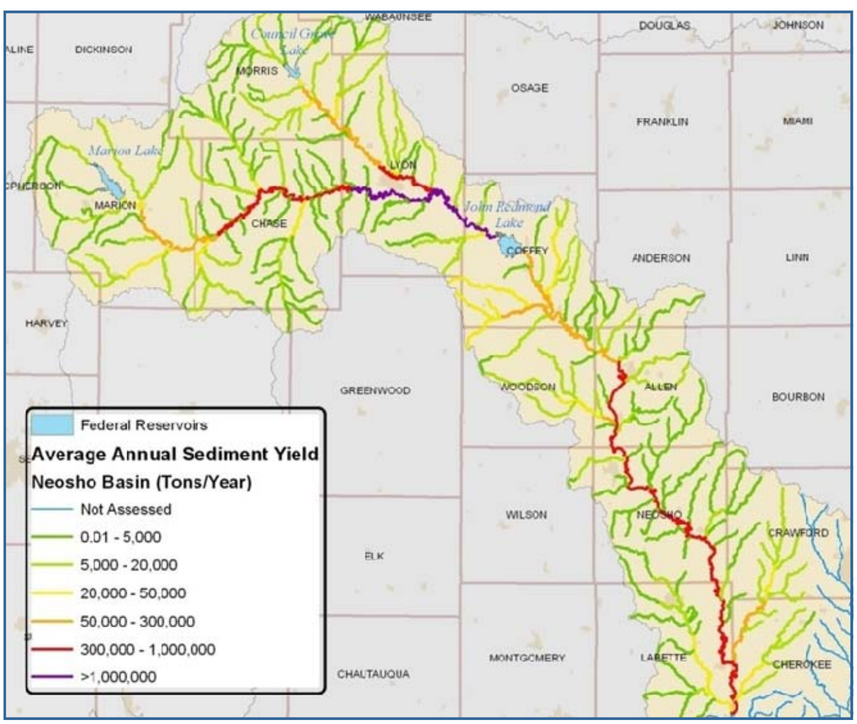
Sediment Yield and Modeling

Mean Annual Sediment Yield

In 2009 the Kansas Water Office (KWO), in response to requests to update previous mean annual sediment yield estimates in the state, reevaluated the Neosho basin suspended sediment yields. The primary data sources used in the 2009 reevaluation for the Neosho basin are Kansas Department of Health and Environment (KDHE) stream chemistry sampling network's total suspended solids data (1990-2008), the unique contributing areas (watersheds) formed by the ambient surface water quality monitoring network and United States Geological Survey (USGS) stream statistics for the registered surface waters of Kansas. In addition, when available, USGS instantaneous flow gage data and USGS suspended sediment concentration data were used to calculate mean annual sediment yields. Mean annual sediment yields in the Neosho basin were created based upon the method described in <u>Sediment Engineering</u> for estimating long-term sediment yields by flow duration-sediment rating curves.

Due to a number of factors outlined within the 2009 yield assessment report (available online at www.kwo.org), the uncertainty and potential sources of error for many of the updated mean annual sediment yield estimates remain high. The resulting estimated yields should only be used at the planning level (final estimates are shown on the map).

The assessment found the sediment yields of the Neosho and Cottonwood Rivers are significantly higher than that of the tributaries feeding into them. This finding reinforces other recent studies performed in the John Redmond drainage area which have pointed to streambank sources along those main stems as being the primary sources of the sediment in the basin.



Sediment Modeling in the Neosho Basin Above John Redmond Reservoir

Kansas State University (KSU) recently produced a report for the Soil and Water Assessment Tool (SWAT) model developed as part of the John Redmond Feasibility Study (available online at <u>www.kwo.org</u>). The SWAT model, whose domain was the John Redmond drainage area below Marion and Council Grove reservoirs, was calibrated to high flow events recorded at the USGS stream gages on the Cottonwood River near Plymouth and the Neosho River at Americus.

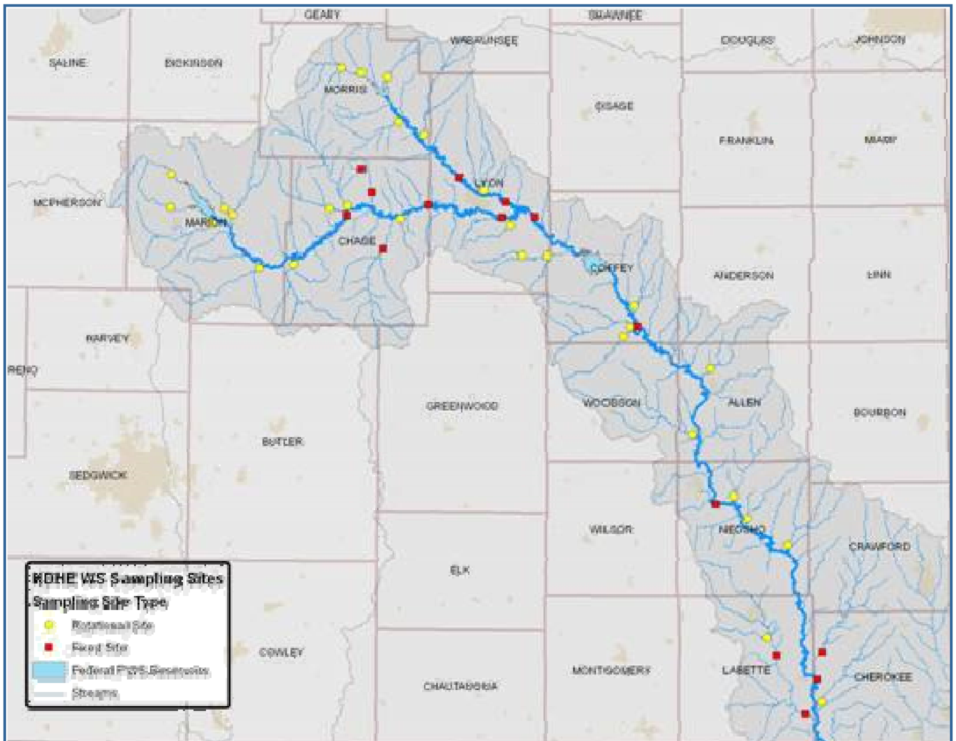
The calibration to high flow events is significant in this study. Most SWAT modeling efforts are directed toward calibration of average flows. Since almost all annualized sediment loads are produced by flow events exceeded 10% of the time or less, KSU spent a considerable amount of time developing their model to be calibrated to those higher flows that transport sediment in the watershed.

In addition to flow data collected at gages on the Cottonwood and Neosho Rivers, USGS collected two years of continuous suspended sediment data at the gage sites. When KSU compared their high flow calibrated SWAT model to the USGS suspended data they found a very large discrepancy (under prediction) between the SWAT model's predicted sediment concentrations and the concentrations observed at the USGS gage monitoring locations. SWAT only accounts for sources of sediment generated from the land surface at this time, such as croplands or grasslands. KSU made numerous adjustments to the land surface model factors within their SWAT model to try and simulate the observed sediment concentrations of high flow events. All attempts simply could not use the land surface sources to even begin to account for the observed sediment concentrations of high flow events.

SWAT does not model the streambank erosion sources as part of its simulation. The inability of the KSU SWAT modeling effort to use land surface sources to account for the observed sediment concentration in the watershed, in conjunction with other recent studies of the potential sources of sediment loads in the John Redmond drainage area, supports the conclusion that streambanks are a primary sediment source in the watershed.

References

Vanoni, Sediment Engineering. 2006.



Sampling site locations of KDHE ambient stream water quality network in the Neosho Basin which were used to estimate mean annual sediment yields in the basin.

Identification of Streambank Erosion and Status of Riparian Areas and Estimates of Restoration Needed

The purpose of this chapter is to describe and quantify the condition of riparian areas and streambanks above water supply reservoirs in the Neosho basin and the potential for their restoration and protection. Estimates of length and cost of riparian area and streambank restoration and protection projects are provided.

Detailed riparian and streambank condition assessments have been done in the watersheds of Marion and John Redmond reservoirs. A Geographic Information System (GIS) based assessment has been completed in the Council Grove Reservoir and Council Grove City Lake watershed. No information is available about the condition of riparian areas and streambanks in the Parsons City Lake watershed. Assessments consistently indicate that in areas in which a stable riparian border exists along the stream, streambanks are in good condition. In areas where the riparian area has been reduced or degraded, the streambanks are typically in poor condition.

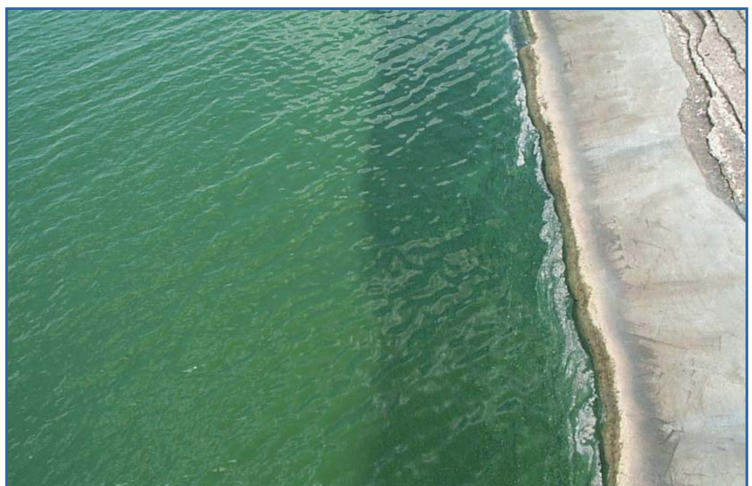
Condition of Streambanks and Riparian Areas Above Water Supply Reservoirs

Marion and John Redmond reservoirs have more information available about the condition of streambanks and riparian areas than do Council Grove Reservoir and Council Grove and Parsons City lakes. This is attributed to two main factors: 1) the establishment of Watershed Restoration and Protection Strategy (WRAPS) groups; and 2) concern about long term water supply in the Neosho basin. When a WRAPS group is formed in a watershed, additional funding through government and other programs may become available to assist in assessing watershed condition and implementing programs and projects to restore and protect the watershed. In addition, available funding is directed to areas where assessments have shown the most benefit to the watershed. While Council Grove Reservoir and Council Grove City Lake have a WRAPS group established, funding has not been directed to assessment to the degree that it has been in Marion and John Redmond. A WRAPS group is being formed above Parsons City Lake but little assessment of the watershed has yet been accomplished.

Marion Reservoir

U.S. Army Corps of Engineers (Corps), Tulsa District began construction of the reservoir in March 1964 for flood control, water supply, water quality control, irrigation and fish and wildlife enhancement. Gates were closed in February 1968 and the conservation pool filled May 1969. The cities of Hillsboro, Marion and Peabody currently use the reservoir as their public water supply source.

The Marion Reservoir watershed covers about 200 square miles in northwest Marion County and the eastern edge of McPherson County. Ninety percent of the watershed is located in Marion County. Over 99% of the watershed is used for agricultural purposes. A detailed land use study compiled by the Natural Resources Conservation Service (NRCS) indicated 63% of the watershed is either in grass or is cropland protected by conservation practices. Of the land in conservation practices, there is a nearly even distribution between cropland and grazing land. Extensive modeling and assessment has been accomplished for the watershed above Marion Reservoir. Recurring nuisance cyanobacterial blooms in the reservoir have resulted in taste and odor problems and the occurrence of toxic compounds in finished drinking water. A high priority total maximum daily load (TMDL) for eutrophication has been developed. Bathymetric surveys indicate that storage capacity in the multipurpose pool which contains the public water supply storage has been reduced by about 14% since the reservoir was filled in 1969, or 40 years ago.



Algae Bloom.

In 2008, the Marion Reservoir WRAPS project used U.S. EPA Section 319 funds and State Water Plan funds to contract with The Watershed Institute (TWI) to complete a Streambank Stability Assessment. The assessment used the Kansas Riparian Inventory to identify and prioritize sub-watersheds having land uses known to contribute to bank instability, conduct stability analysis of identified priority sub-watersheds, and install bank pins at select areas to monitor streambank erosion rates.

Overall, few stream reaches were found to be contributing excess sediment. Stream channels are typically narrow, deep, and connected to a floodplain, a key characteristic influencing erosive potential of the water during high flows. Most of the riparian corridor is comprised of mature woodlands of varying widths. Trees provide roots down through the bank profile, reinforcing the streambanks. Short segments were identified where bank erosion is accelerated, but TWI reports that more damage would take place within the riparian corridor by attempts to correct the in-channel problems.

Log Jam at Jacobs Creek Landing Boat Ramp.

One condition found to be negatively affecting stream channels is accumulations of large woody debris. In multiple reaches, large woody debris jams were observed in channels, banks and on floodplains. Most of the wood appears to be from locally fallen trees, but some material is transported from upstream and deposited by high runoff events. Some of the larger debris jams constrict the channel enough to cause water flow around the jam and into the streambank. It is recommended that these large debris jams be removed or cut-up. Reducing the material size will increase the likelihood that the material will move through the stream system. In some reaches large woody debris exists on the floodplain potentially contributing to in-channel blockages from future high flow events. Removal of the woody material from the stream system by burning or chipping is recommended.

Several gully erosion problems in areas adjacent to the stream reaches were identified. Gully erosion can contribute a tremendous amount of sediment at the watershed scale. The amount of sediment input is based on rainfall/ runoff and gully frequency within a given watershed. In each case, the gullies observed are unstable and will continue to be unless best management practices (BMPs) are implemented. A common BMP for gully erosion is the rock chute. Rock chute designs require bank shaping and the placement of erosion control fabric and sorted rock. Rock chutes are designed to direct flow down through the chute center. The rock creates flow resistance slowing down water velocities.

An additional disturbance is cattle within the riparian corridor. With cyanobacterial blooms a big concern for Marion Reservoir, restricting cattle access to the riparian corridor would help reduce nutrient inputs. Riparian corridors with cattle disturbance usually have low vegetation density and quality. In addition, hoof action degrades the channel bed and banks. There are several BMPs that are effective in controlling cattle disturbances. One is riparian fencing which restricts cattle access to the stream corridor. If some cattle access is needed, cattle can be directed to specific access points. Within the access points, hardened crossings are effective BMPS. These crossings reduce bed and bank disturbance from hoof action. In many cases, streams are the primary water source for cattle. As a result, alternative water supplies should be integrated with riparian fencing. Alternative water supplies can include spring development and installing livestock water wells.

Only three streambank projects in the Marion watershed assessment were recommended for bank restoration. All are located on the North Fork of the Cottonwood River within five miles of Durham. Each streambank restoration project is approximately 125 feet in length. Two of the projects will require approximately $3,100 in restoration and the third project has not had plans developed at this time.

John Redmond Reservoir

John Redmond Reservoir provides critical water supply storage in the basin and has filled with sediment more quickly than the other reservoirs, with an estimated 36% of the multipurpose storage capacity lost since the reservoir filled in 1964, 45 years ago. A medium priority TMDL for silt and eutrophication has been developed for the reservoir. Loss of riparian areas to channel modifications and streamside clearing has been extensive in the watershed although estimates of total losses are not readily available.

The Neosho Headwaters WRAPS group has identified streambank erosion as a concern and funds are being directed at repairing some of these areas. Symptomatic of the sediment problem is an extensive logjam about two miles long that has formed in the mouth of the reservoir, blocking access to the reservoir from a heavily used access point.

Because of the importance of this reservoir, the Kansas Water Office (KWO) contracted with TWI to complete a riparian area/stream channel assessment for the John Redmond Dam and Reservoir. This task was included within a Corps John Redmond Feasibility Study to evaluate stream channel conditions and assess relative contribution of streambanks as a source of sediment loading.

Table 1 below (page 86) is a list of land uses for the study area. Grassland includes grazing land for livestock and may include Conservation Reserve Program (CRP) lands.

Urban Area 1%	Wooded area 3%
Row Crop 27%	Water area 3%
Grassland 64%	Other 2%

Table 1.

The watershed study area is 2,500 square miles. John Redmond Reservoir has a 3,015 square mile watershed, but for the Feasibility Study, the Corps excluded areas above Council Grove Marion reservoirs. In addition to the two federal impoundments, there are ten watershed districts within the study area that build and maintain watershed impoundments for local flood control (see section 3.8).

Streambank erosion.

Detailed fluvial geomorphology surveys were conducted by TWI at ten locations and aerial photographs were interpreted to determine the condition of streambanks and riparian areas. KWO chose the locations or target areas from Kansas Department of Health and Environment (KDHE) stream sediment monitoring data. Survey locations included reaches on the Neosho and Cottonwood rivers, and Allen, Dow and Plumb Creeks. For each survey, data were compiled on the bankfull dimension, pattern, and profile to classify each reach using the Rosgen stream classification system for natural rivers. Bank erosion potential using the Bank Erodibility Hazard Index (BEHI) and channel health using the Pfankuch stream stability evaluation was estimated. General riparian corridor conditions within the survey reach as well as adjacent reaches upstream and downstream were documented. Detailed information on the findings of the ten field surveys is included in the final report and is not repeated, but rather summarized below.

Most streams have a low bankfull width to depth ratio indicating a narrow and deep channel. In comparing study reaches with equivalent stable reference reaches, similar ratios were found. Deep silt loams are found consistently throughout all reaches. Erosion rates for 27 bank conditions within the ten sites were developed. Based on BEHI scores and near bank stress calculations, an erosion average of 0.20 tons/year/foot was estimated. The Pfankuch stream stability evaluations ranged from fair to poor. In comparison to healthy riparian corridors, survey reaches suffer from excessive cutting, mass wasting, and debris jam potential. Excessive cattle grazing in riparian corridors was also observed. In some locations, the herbaceous understory was in poor condition or missing from grazing and hoof action. As a result, the sediment loading potential is greater from within these riparian corridors.

To address observed instability problems, implementing streambank stabilization— using rock vanes—and riparian fencing BMPs is recommended. Rock vanes slow down water velocities and redirect flow away from the near bank region. Riparian corridor restoration should be implemented in conjunction with the rock vanes. Riparian restoration will require bank shaping, riparian tree and shrub planting, native grass seeding, and proper maintenance. For cattle disturbances, riparian fencing BMPs to

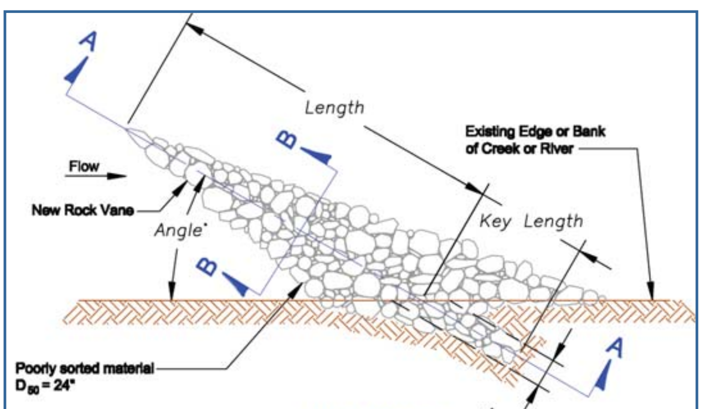


Figure 1.

restrict or limit cattle access to the riparian corridor are recommended. Alternative water BMPs may also be needed to supplement water requirements. Based on the identified hotspots, a cost of nearly seven million dollars to implement BMPs is estimated.

Streambank Erosion Hotspot Identification

TWI and KWO used 1991 rectified aerial photography and 2006 or 2008 National Agriculture Imagery Program (NAIP) aerial photography to identify areas of actively eroding streambanks (hotspots) in the John Redmond drainage area. The TWI photographic assessment covered the Neosho River from the Morris/Lyon County line to John Redmond Reservoir; the Cottonwood River from Middle Creek confluence to Neosho River confluence; Allen Creek from Neosho River confluence upstream; Dow Creek from the Neosho River confluence upstream; and Plumb Creek from Neosho River confluence upstream. For the upstream extent on primary tributaries to the Neosho or Cottonwood River main stems, photographs were reviewed until the resolution made it difficult to discern the channel location. KWO covered the balance of the John Redmond drainage area using the same methodology as TWI. The results shown in the Table 2 below (page 83) are broken down by primary reaches in the drainage area. Those primary reaches can be located using Figure 2 (page 84). The yield loss per bank length column, in Table 2 to the right (page 83), helps to identify the stream reaches in greatest need of bank stabilization.

TWI also provided a qualitative assessment of the riparian condition along the streambank hotspots using the most recent aerial photography available. KWO did the same qualitative assessment for the hotspots they identified. In Table 2 to the right (page 83), the length of streambanks with poor riparian conditions (little to no woodlands adjoining unstable streambanks) are summarized.

Reach	Stream Bank Length (ft)	Hotspots Sed (T/Yr)	Stabilization Cost Est	Hotspots (number)	Yield Loss/ Bank Length	Poor Riparian Condition Stream Bank Length (ft)
N1	16,794	39,720	$1,623,607	11	2.4	15,811
N2	24,978	65,662	$2,414,905	23	2.6	23,548
N3	9,009	15,107	$870,958	25	1.7	6,923
N4	13,267	18,844	$1,282,608	27	1.4	12,384
N5	10,941	19,896	$1,057,763	20	1.8	6,666
N6	7,301	13,213	$705,887	16	1.8	4,493
N7	9,539	15,305	$922,252	22	1.6	5,283
N8	4,616	5,881	$446,281	17	1.3	2,703
N9	2,729	3,191	$263,799	10	1.2	2,272
C1	9,402	26,541	$908,940	18	2.8	8,732
C2	12,311	31,977	$1,190,233	16	2.6	11,321
C3	8,014	13,918	$774,832	22	1.7	7,339
C4	13,468	26,341	$1,302,041	27	2.0	12,661
C5	15,675	16,821	$1,515,471	36	1.1	12,898
C6	5,380	7,708	$520,129	19	1.4	4,157
C7	10,503	17,652	$1,015,419	32	1.7	9,230
C8	5,179	10,303	$500,741	14	2.0	3,656
C9	4,253	11,591	$411,206	11	2.7	3,890
C10	2,793	5,175	$270,017	9	1.9	2,583
Subtotal						
Neosho	99,173	196,818	$9,588,059	171	15.8	80,084
Cottonwood	86,978	168,026	$8,409,029	204	19.9	76,467
Total	186,151	364,844	$17,997,088	375	35.6	156,550

Table 2.

As expected, poor riparian conditions are typical for actively eroding streambanks. Eighty-four percent of the total actively eroding banks identified in the assessment had poor riparian conditions. Those reaches with the higher yield loss/bank length scores tended to have the highest percentages of poor riparian conditions. Overall the Cottonwood River had a slightly higher percent of poor riparian condition by unstable streambank than did the Neosho River (88 % vs. 81%).

To provide the most realistic stabilization/restoration estimate, information from past streambank stabilization projects, distance to the nearest quarry, quarry price quote for estimation only, and NRCS Environmental Quality Improvement Program (EQIP) practice information was used.

For streambank stabilization, the cost estimate is based on rock vanes and establishment of a wooded riparian corridor. Longitudinal peaked stone toe protection (LPSTP) may be used in some cases, but it is difficult to quantify this amount without information from a detailed survey. LPSTP are typically constructed two to four feet high—requiring 1 to 1.5 tons of rock per linear foot—based on bank height and stream depth. Also not estimated are the rock chutes, and alternative watering supplies because not enough information is available to estimate a cost. There are many field drainage ways that discharge directly into the stream systems surveyed. It is difficult to quantify the number of occurrences where the drainage way is degrading from active gully erosion. This potentially could occur in many locations at the watershed scale. Finally, cost estimates incorporate a 10% contingency to help account for additional time and materials increases. This cost estimate is reflective of 2007 prices and may fluctuate based on material prices changes and fuel costs.

For their portion of the assessment above John Redmond Reservoir, TWI estimated stabilization/restoration cost of $96.68 per linear foot of streambank. KWO used the same linear foot estimate in creating the total dollar estimates by reach in Table 2 (page 83).

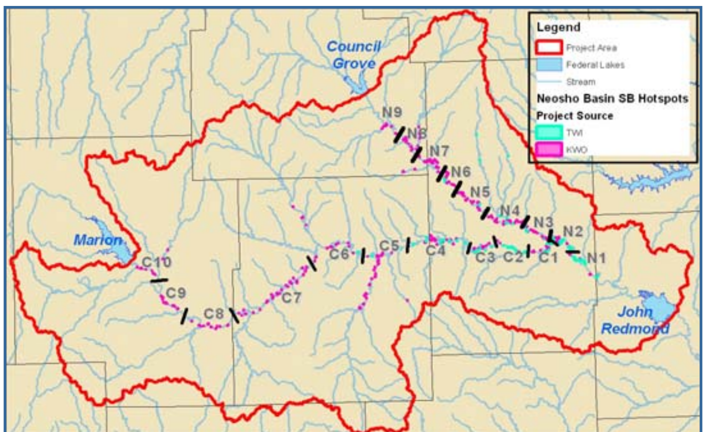


Figure 2. Map of Streambank Erosion Hotpots.

In estimating soil volume losses from streambank erosion, TWI's field surveys of the Cottonwood, Neosho and primary tributaries were used to assign typical bank heights on the main stem and tributary streams. The surficial change between the streambank location in 1991 to the 2006 or 2008 location multiplied by the estimated bank heights provided an estimate of the soil volume loss from streambanks for the period. Assuming a typical soil weight of 89 lbs/cubic foot of soil for the predominate soil types in the John Redmond drainage area created the estimate for mass of soil loss per year by main stem reach in the table above. If the entire average annual streambank loss from erosion was deposited in John Redmond reservoir, and assuming an average bulk density of 45 lbs/cubic foot, streambank hotspot sources of sedimentation would account for just over half of the average annual sediment deposited at the reservoir.

Although streambank stabilization and riparian restoration of all the hotspots identified in this assessment would not be expected to be 100% efficient (there will always be a baseline sediment load from streambank sources in Kansas stream systems), such an effort would substantially reduce the excessive sediment loading to John Redmond from this source and significantly reduce the average annual sedimentation rate of the reservoir.

Streambank Stabilization Funding from American Recovery and Reinvestment Act

KWO has received $863,000 in funding from the American Reinvestment and Recovery Act (ARRA) and $300,000 from the state's Reservoir Beneficial Use Fund to address sedimentation in the Neosho River basin above John Redmond Reservoir. An 8.3-mile reach of the Neosho River, identified in the study described above as high priority for stabilization and having a very high Yield Loss/Bank Length score in the table above (a portion of stream segment N2 in that table), will be stabilized using these funds. Restoration of the riparian buffer adjacent to the stream is also a goal of this project. Based on sediment transport estimated from TWI and the USGS, this project has the potential to reduce downstream sediment contribution by 50,000 tons/year.

Surveying and designs were completed in September 2009. Based on the proposed design, an Invitation for Bids (IFB) was issued by the KWO for construction of the streambank stabilization project. Through an agreement with the Corps, KWO and the USGS will be monitoring the changes in turbidity of the Neosho River before, during, and after the streambank restoration project is completed. The purpose of the monitoring is to assess sedimentation, sediment quality, and upstream channel stability, as well as characterize the effect of streambank stabilization on sediment transport.

Council Grove Reservoir and Council Grove City Lake

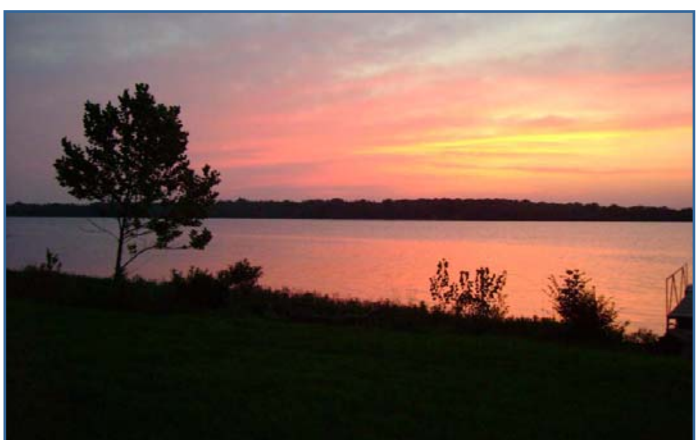
Council Grove Reservoir is important in assuring that the Neosho/Cottonwood Rivers Water Assurance District has sufficient water to supply demand. The reservoir has a surface area of 2,928 acres and the watershed draining into it is 246 square miles. The multipurpose pool was filled in 1965 and in the 44 years since then, approximately 30% of the storage capacity has filled with sediment. The reservoir has high priority TMDLs for both eutrophication and siltation.

Council Grove City Lake, a 434 acre multi-use lake, constructed in 1942 on Canning Creek, is surrounded by 348 waterfront cabins and homes. It serves as the primary water supply for the City of Council Grove. The city lake is in the southwest part of the watershed of the reservoir and the outflow from the lake flows into the reservoir. According to a 2008 bathymetric survey, about 16% of the storage capacity has filled with sediment since construction.

According to a desktop assessment of the watershed using aerial photographs, there are approximately 518 miles of streams in the major hydrologic HUC unit (HUC) (11070201010) that drains into the Council Grove Reservoir watershed in Morris County. Most of these streams are bordered by an approximate 200 ft corridor of riparian land cover. Land use in the watershed is approximately 30% cropland and 64% grassland. In the entire watershed of both water bodies, it is estimated that about 77% of the riparian areas are in good to excellent condition and do not need restoration, but should be protected. The remaining approximately 23% of the riparian area is in need of restoration as determined by lack of riparian cover in the aerial photos. As discussed above it is likely that the streambanks associated with these degraded riparian areas are eroded and in need of restoration. More specific field surveys of these sites are needed to develop realistic costs for restoration. An estimated 103 miles of streambanks may be in need of restoration in this watershed but more detailed stream surveys will be needed to determine a more accurate estimate.

Parsons City Lake

Lake Parsons, owned by the City of Parsons and used as its principal water supply, is located three miles north on highway 59 and three miles west on 20th Road from the City of Parsons. The lake was formed by damming Labette Creek in Labette County in 1959. The surface area is about 800 acres and an additional 1,000 acres of public use land surround the lake. Fishing, camping, picnicking, boating, and a gravel beach swimming area are popular activities. The entire drainage area is about 37 square miles. According to a 2008 bathymetric survey about 15% of the lake has filled with sediment.



Parson City Lake.

Medium priority TMDLs have been established for both siltation and eutrophication. This lake is included within the area of a WRAPS group that is under development in the Middle Neosho watershed and the lake is expected to be a high priority for assessment as the group identifies goals and objectives, due to its public water supply role. Land use in the watershed is about 42% cropland and 49% grassland.

Conclusions/Recommendations

Kansas State University Soil and Water Assessment Tool (SWAT) modeling, KWO sediment yield re-assessment of streams in the Neosho Basin, and TWI/KWO evaluation of actively eroding streambanks on the Neosho and Cottonwood Rivers above John Redmond Reservoir all point toward main stem streambank sources, which includes gully erosion, as being the primary source of the excessive sediment loads delivered to John Redmond Reservoir should be developed.

If the cost of removing the estimated average annual volume of sediment contributed from streambank hotspot sources via dredging the same volume from Redmond (using a conservative $10/cu yd estimate) is compared to the previously estimated cost of stabilization and riparian restoration, the result is for every $1 spent in prevention, about $10 in sediment removal cost is saved.

For the Neosho basin below Marion and Council Grove Reservoirs, KWO continues to recommend streambank stabilization/riparian restoration projects as the most cost effective method of reducing sediment delivery to John Redmond Reservoir from these sources. Streambank stabilization is likely needed in some reaches of streams above Council Grove Reservoir and City Lake and more detailed evaluations should be conducted to determine the extent of degradation. Continued land treatment and streambank protection is recommended for Marion Reservoir. The developing WRAPS group covering Parsons City Lake should use assessment funds to evaluate streambank stabilization and riparian restoration needs in that watershed.

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Inventory of Watershed Structures and Sediment Yield Reductions

The purpose of this chapter is to provide an inventory of the watershed structures above five public water supply reservoirs in the Neosho basin. Data in the inventory of structures that currently exist in the basin include construction date, drainage area and amount of storage at the time of construction. Also included is the number and relative size of structures that are planned but to date have not been constructed. The relation between drainage area and sediment yield is also discussed.

Background

Most small watershed impoundments and flood control structures in Kansas were authorized by the Flood Control Act of 1944 (PL78–534) and the Watershed Protection and Flood Prevention Act of 1953 (PL83–566). There are 1,439 flood control and grade stabilization structures in Kansas; 830 were constructed with financial assistance from the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). Most of the structures in the NRCS database are small watershed dams; however, the database also includes small stock ponds and other flood control structures such as bank stabilization structures.

The Kansas State Conservation Commission (SCC) administers a watershed dam construction program and since 1974 has provided financial assistance for construction of small watershed impoundments in Kansas. The SCC receives funding from the State Water Plan Fund for construction and maintenance of small watershed impoundments and other conservation projects. There are currently 539 small watershed impoundments in Kansas constructed with SCC funds.

Some small watershed impoundments provide a source of water for small towns and rural water districts and have recreational uses; however, none of the small impoundments in the Neosho basin are used for water supply. Watershed impoundments help control flooding and improve water quality in the watershed immediately downstream of the structure because they are designed to trap sediment and contaminants. It is this latter benefit that can be a predominant factor in reducing sediment transport in a watershed, especially if a large number of small impoundments are located within the watershed. There are 83 watershed districts in Kansas that plan and administer the construction and maintenance of small watershed impoundments in the state.

The relationship between the percentage of the watershed affected by impoundments and suspended sediment concentration indicates that, as the number of impoundments in the watershed increases, suspended sediment concentration decreases (USGS, 2003).

Inventory of Watershed District Structures in the Neosho Basin

There are five public water supply reservoirs in the Neosho basin: Council Grove Reservoir, Council Grove City Lake, John Redmond Reservoir, Marion Reservoir and Parsons City Lake. Of those, only John Redmond and Parsons Lake have watershed districts within their drainage basin. The first structures in the basin were built in 1965 by Silver Creek Watershed District No. 25 with cost-share funding from the NRCS; the newest structure was finished in 2009 with SCC cost-share funding. A total of 104 structures have been completed with 71% of the structures completed between 1980 and 1999.

Structures Built

John Redmond Reservoir

There are 10 watershed districts above John Redmond: Allen Creek No. 89, Diamond Creek No. 61, Doyle Creek No. 86, Eagle Creek No. 77, Jacobs-Phenis Creeks No. 94, Middle Creek No. 62, Peyton Creek No. 71, Rock Creek No. 84, Silver Creek No. 25 and South Creek No. 76 (Figure 1 below (page 87).

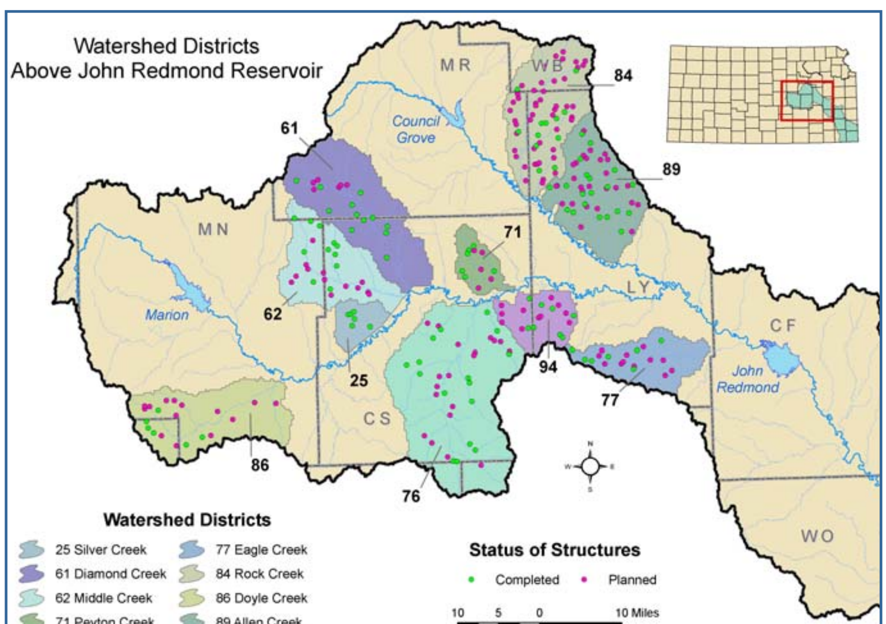


Figure 1.

Summary Statistics for Existing Watershed Structures Above John Redmond Reservoir				
Description (104 Structures)	Total	Average	Minimum	Maximum
Age of Structure in Years	--	22	0	44
Top of Dam Storage in Acre Feet	70,223.3	675.0	74.0	5,257.0
Principal Spillway Storage in Acre Feet (Sediment Volume)	8,735.7	84.0	9.6	2,497.0
Principal Spillway Area in Acres (Sediment Pool)	1,320.2	12.7	3.0	37.0
Drainage Acres	124,438.8	1,196.5	180.0	8,530.0

Table 1.

Parsons Lake

Parsons City Lake is at the upper end of the Labette-Hackberry Creeks Joint Watershed District No. 96; three watershed structures have been built above Parsons; two were built in 1982 and 1992 with funds from the SCC; one was built with local funds in 1999.

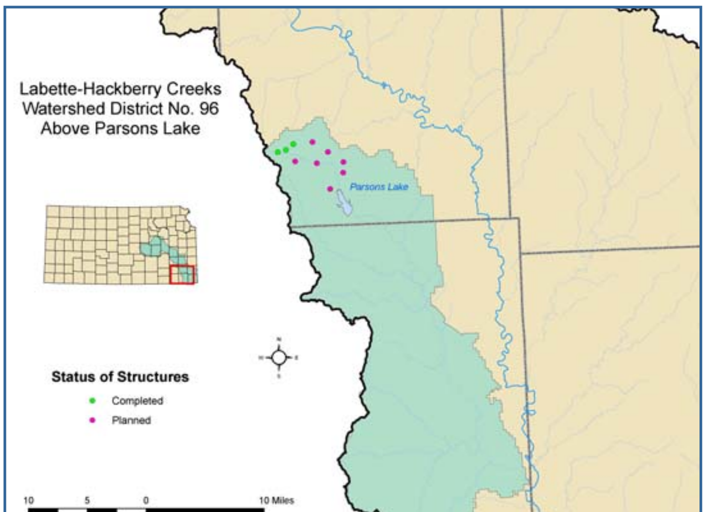


Figure 2.

Summary Statistics for Existing Watershed Structures Above Parsons Lake				
Description (3 Structures)	Total	Average	Minimum	Maximum
Age of Structure in Years	--	18	10	27
Top of Dam Storage in Acre Feet	1,019.5	339.8	171.0	462.3
Principal Spillway Storage in Acre Feet (Sediment Volume)	155.9	52.0	18.7	97.7
Principal Spillway Area in Acres (Sediment Pool)	45.8	15.3	8.7	19.9
Drainage Acres	1,749.0	583.0	286.0	778.0

Table 2.

Structures Planned

John Redmond Reservoir

A total of 155 watershed structures were originally planned for the 10 watershed districts above John Redmond Reservoir. If all of the planned structures were built, 17% of the drainage area for John Redmond Reservoir would be regulated by watershed impoundments. Fifteen percent (15%) of John Redmond's drainage area is currently regulated by Council Grove Reservoir (with a drainage area of 157,440 acres) and Marion Reservoir (with a drainage area of 128,000 acres), which means a total of 32% of the drainage area for John Redmond would be regulated if all watershed structures were built as summarized in Table 4 (page 89).

Seventy-five structures (48% of the total planned) were planned for Allen Creek No. 89 and Rock Creek No. 84, the two watershed districts in the Neosho River drainage area between Council Grove Reservoir and the confluence of the Cottonwood River.

Parsons Lake

Labette-Hackberry Creeks No. 96 planned for an additional seven structures above Parsons City Lake. If the seven planned structures were built, 42% of the drainage area for the lake would be regulated by watershed impoundments as summarized in Table 5 (page 89).

Sediment Yield Reductions

The Kansas Water Office (KWO) reviewed the relation between drainage areas and sediment yields for all or portions of seven watershed districts in the Neosho River basin above John Redmond Reservoir. The estimated sediment yields derived from nine of the Kansas Department of Health and Environment (KDHE) ambient water quality sampling sites and United States Geological Survey's (USGS) estimated stream statistics were first compared to the total drainage area at the water quality sampling location and then to the total drainage area *not* controlled by watershed structures (the uncontrolled drainage). The uncontrolled drainages area explained more of the variation in the estimated sediment yields of the nine watersheds (covered by the seven watershed districts) than did the total drainage area by itself.

The result of sediment yield by uncontrolled drainage area regression is shown in Figures 3 and 4 (page 90). The two watersheds formed by the two water quality sites

Watershed Name	Total Wtrshd Area (ac)	Current Uncontrolled D.A. (ac)	Potential Uncontrolled D.A. (ac)	Est. Current Sed Yld (T/Yr)	Pred Sed Ld by Current Uncontrolled D.A. (T/Yr)	Pred Sed Ld By Potential Uncontrolled D.A. (T/Yr)	Sed Yld Reduction (T/Yr)	Pred Total Structure Cost
ROCK CREEK (DUNLAP)	79,788	73,217	35,713	23,286	24,996	13,348	-11,648	$5,527,500
ALLEN CREEK	75,250	63,174	30,860	33,765	21,877	11,841	-10,036	$4,119,072
DIAMOND CREEK	97,309	88,019	58,713	20,541	29,593	20,491	-9,102	$2,679,201
MIDDLE CREEK (ELMDALE)	74,042	60,151	43,044	15,560	20,938	15,625	-5,313	$2,200,393
BLOODY CREEK	16,084	11,636	6,554	2,385	5,870	4,292	-1,578	$662,890
S. FK COTTONWOOD RIVER	151,742	115,966	96,164	31,023	38,273	32,123	-6,150	$2,208,735
DOYLE CREEK	89,465	84,288	61,658	44,785	28,434	21,406	-7,028	$2,696,574
EAGLE CREEK (UPPER)	23,563	18,960	10,557	3,175	8,145	5,535	-2,610	$1,122,014
EAGLE CR (AT FLINT HILL NWR)	26,649	25,449	15,324	13,767	10,161	7,016	-3,145	$1,121,773
Totals					188,287	131,677	**-56,610**	$22,338,151

Table 3.

Summary Statistics for Planned Watershed Structures Above John Redmond Reservoir				
Description (155 Structures)	Total	Average	Minimum	Maximum
Top of Dam Storage in Acre Feet	66,641.6	429.9	59.5	2,350.0
Principal Spillway Storage in Acre Feet (Sediment Volume)	12,505.3	80.7	11.6	445.0
Principal Spillway Area in Acres (Sediment Pool)	2,483.6	16.0	2.1	72.0
Drainage Acres	209,100.0	1,349.0	143.0	9,350.4

Table 4.

Summary Statistics for Planned Watershed Structures Above Parsons Lake				
Description (7 Structures)	Total	Average	Minimum	Maximum
Top of Dam Storage in Acre Feet	2,503.0	357.6	152.0	553.0
Principal Spillway Storage in Acre Feet (Sediment Volume)	474.0	67.7	29.0	105.0
Principal Spillway Area in Acres (Sediment Pool)	226.0	32.3	13.0	71.0
Drainage Acres	8,115.2	1,159.3	492.8	1,792.0

Table 5.

within the Eagle Creek Watershed District were partly located within a different ecoregion than all the other comparison watersheds (Central Irregular Plains versus the Flint Hills ecoregion for the other watersheds). They were included in the relation but are noted in the regression graph with red markers.

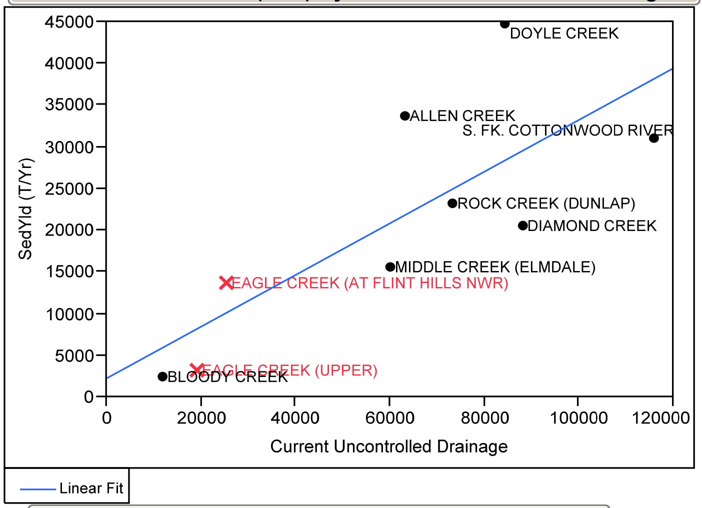
A number of watershed structures within the seven study watershed districts are still pending construction. The drainage area controlled by the pending structures is known.

Using the relation between predicted sediment yield and uncontrolled drainage previously developed, a prediction for the sediment yields in each of the 9 watersheds was created by subtracting the drainages of the pending structures from the uncontrolled drainages. The change from the predicted current sediment yield to the potential sediment yield, if all pending structures were built, formed the estimate for sediment yield reduction from the pending watershed structures. That estimated reduction totaled 56,610 tons/year (Table 3 above (page 89)).

The estimate for the cost of building the pending structures was created by comparing the total cost of the most recent 30 watershed structures built in watershed districts in eastern Kansas to the drainage area of those structures. The regression relation is shown in Figures 3-4 (page 90). Three structures and the cost were excluded from the relation (marked with ‘X’s’ in Figures 3 and 4 (page 90)). Those three structures were in the same watershed district and their construction cost appeared unusually high compared to most of the rest of the structures in cost, given their drainage area size. The most recently built watershed structures in the Neosho basin are marked with ‘+’s’ in Figure 4 (page 90).

For each of the pending watershed structures in the studied watershed districts the total cost was estimated and then summed by the drainages that coincide with the KDHE sampling locations and sediment yield estimates that were created there. The total costs to build pending

Bivariate Fit of SedYld (T/Yr) By Current Uncontrolled Drainage



Linear Fit

SedYld (T/Yr) = 2256.5467 + 0.3105763*Current Uncontrolled Drainage

Summary of Fit

RSquare	0.604672
RSquare Adj	0.548197
Root Mean Square Error	9448.225
Mean of Response	20920.78
Observations (or Sum Wgts)	9

Analysis of Variance

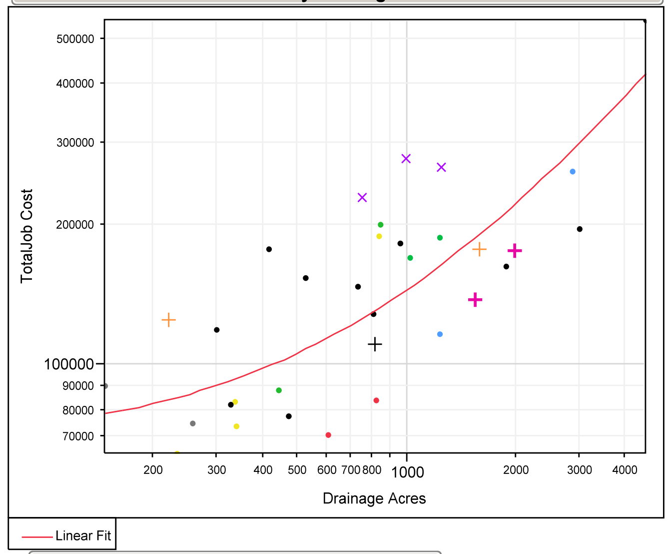
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	955787959	955787959	10.7068
Error	7	624882750	89268964	Prob > F
C. Total	8	1580670710		0.0136*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2256.5467	6515.704	0.35	0.7393
Current Uncontrolled Drainage	0.3105763	0.094916	3.27	0.0136*

Figure 3.

Bivariate Fit of TotalJob Cost By Drainage Acres



Linear Fit

TotalJob Cost = 67007.676 + 77.703732*Drainage Acres

Summary of Fit

RSquare	0.72438
RSquare Adj	0.714536
Root Mean Square Error	48384.93
Mean of Response	148280.6
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.7228e+11	1.723e+11	73.5890
Error	28	6.5551e+10	2.3411e+9	Prob > F
C. Total	29	2.3783e+11		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	67007.676	12953.61	5.17	<.0001*
Drainage Acres	77.703732	9.058065	8.58	<.0001*

Figure 4.

structures by the watersheds formed by the KDHE sampling sites are shown in the final column in Table 3 (page 89).

The estimated total cost for all pending structures in the studied watershed districts was slightly over $22 million to reduce the sediment load by 56,610 tons/year. For comparison, the estimated sediment reduction from streambank sources using bank stabilization and riparian restoration (assuming an 85% efficiency of that practice) was just over 310,000 tons/year with an estimated total cost of $18 million. Assuming a relatively low dredging cost at federal reservoirs of $10 per cubic yard (or $13.47 per ton using a bulk density of sediment of 55 lbs per cubic foot), the streambank stabilization/riparian restoration practice would pay for itself in dredging costs in less than 5 years. The reduction in sediment loads from the watershed structure management practice would pay for itself in dredging costs in about 29 years.

In conclusion, for areas in the Neosho Basin where data was available, this analysis found that the greater the controlled area in a watershed the greater the reduction to the sediment yield of that watershed; implying watershed structures may reduce sediment yields. Although further study would be necessary to make a final determination, it appears that the benefits from the reductions to sediment yields associated with watershed structures make that option more attractive than the dredging alternative. However, given the magnitude of the reductions to sediment yields and the costs to implement those reductions, the streambank stabilization/riparian restoration alternative appears the most cost-effective option for sediment yield reductions in the Neosho Basin.

References

Kansas Water Resources Institute, 2008. Sedimentation in Our Reservoirs: Causes and Solutions. http://www.kwo.org/Reports%20%26%20Publications/KWRI_Book.pdf

U.S. Geological Survey, 2003. Trends in Suspended-Sediment Concentration at Selected Stream Sites in Kansas, 1970-2002. http://ks.water.usgs.gov/pubs/reports/wrir.03-4150.pdf

Identification of Reservoirs Not Built

Background

One method of reducing the potential vulnerability to drought supplies in the Neosho basin is to evaluate ways to enhance. This can be performed by reviewing past information about previously determined reservoir sites that were never built or using existing topographic information, more accessible by today's standards, to locate entirely new potential reservoir sites.

Previously Identified Reservoir Sites Review: Cedar Point Lake

Cedar Point Lake was a federally authorized project from the Flood Control Act of 1950 and Water Supply Act of 1958. Its proposed location was on mile 4.2 of Cedar Creek, a tributary to the Cottonwood River above John Redmond Reservoir, about six miles east of Florence, Kansas in Chase County. The primary purposes of the project were flood control and water supply, but other purposes listed were mitigation of fish losses and recreation. As of 1982, the project is in deferred status pending resolution of water supply repayment assurances by the State. Preconstruction planning for the reservoir was completed.

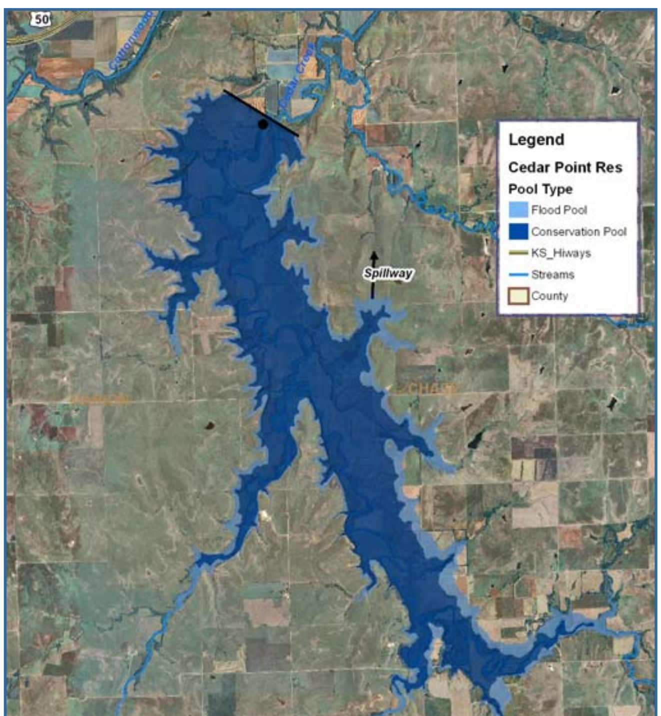


Figure 1.

Using information about the proposed location of Cedar Point dam and the originally planned conservation pool elevation, the KWO, using Geographic Information System (GIS) techniques, created a model of the proposed lake (Figures shown in each column (page 91)). Based upon flow data collected on Cedar Creek from a United States Geological Survey (USGS) gage at the proposed site, mean annual sediment yield estimates developed by the KWO and resulting volume and area data from the previous GIS step, the estimated 2% drought, water supply yield 40 years after initial reservoir fill from Cedar Point Reservoir would be about 16 million gallons per day.

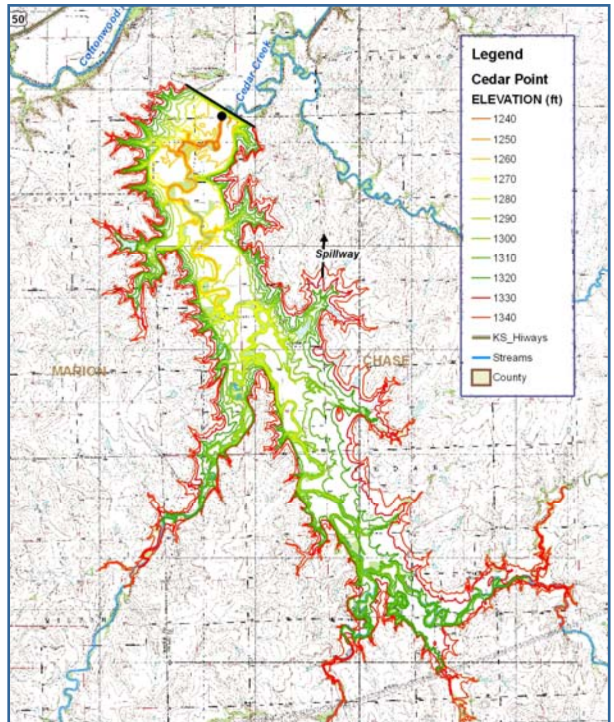


Figure 2.

New Reservoir Sites Review

To review entirely new reservoir sites that were not previously located through another plan, the KWO has entered into a Planning Assistance to States (PAS) agreement with the Tulsa District of the U.S. Army Corps of Engineers (Corps) to perform a Neosho basin water supply study. A portion of that agreement will be for the Corps subcontractor to evaluate alternatives to improve water supply reliability in the basin. Those alternatives would include off-stream storage facilities that collect runoff or are filled by pumping water from a river and new reservoir site identification including size, location and potential designated uses for new sites. The evaluation criteria include effectiveness at improving and maintaining water supply reliability for end users; initial capital costs plus future operation and maintenance requirements; environmental permitting requirements; and time required to implement the various alternatives.

References

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

Recommendations for Reservoir Sustainability Approach in the Neosho Basin

Volume III provides an overview of the current and projected condition of the Neosho River basin and its reservoirs. Also contained in this volume is a comprehensive discussion of many alternatives for approaching reservoir sustainability in the basin. Alternatives for improving water supply reliability in the basin that were evaluated include sediment removal, reallocation, structural restoration, demand management, reservoir operational changes, new reservoirs, off-stream storage and watershed management. Details about the feasibility of each alternative are described within the previous chapters in this volume. A combination of many of these actions is necessary for securing, protecting and restoring a sustainable water supply in the Neosho basin. Below is a summary of the recommended approach to reservoir sustainability in this basin.

Watershed Management

For the Neosho basin below Marion and Council Grove Reservoirs, the Kansas Water Authority (KWA) continues to recommend streambank stabilization/riparian restoration projects as the most cost effective method of reducing sediment delivery to John Redmond Reservoir from these sources. Streambank stabilization is likely needed in some reaches of streams above Council Grove Reservoir and City Lake and more detailed evaluations should be conducted to determine the extent of degradation. Continued land treatment and streambank protection is recommended for Marion Reservoir. The developing WRAPS group covering Parsons City Lake should use assessment funds to evaluate streambank stabilization and riparian restoration needs in that watershed.

Reallocation

Reallocation of storage is a potential restoration option only in the three federal reservoirs in the Neosho basin. The KWO and the U.S. Army Corps of Engineers (Corps) are currently engaged in a review of a reallocation of storage for water supply at John Redmond Reservoir. Although the project is delayed, both parties are committed to completion of the reallocation request. When complete, the reallocation will result in a two-foot pool rise at John Redmond Reservoir, increasing the conservation pool storage capacity by approximately 20,000 acre-feet.

Reservoir Operational Changes

Operational decisions and management practices of the three federal reservoirs in the Neosho basin can be evaluated for the purpose of improving water supply.

The following actions related to changes in reservoir operations are recommended for the Neosho basin:

- Develop triggers for implementation of lake level management plans at Marion and Council Grove reservoirs similar to that at John Redmond Reservoir.
- Coordinate with the Corps to study the use of reservoir operational techniques to reduce sedimentation in the reservoirs.

Structural Restoration

Structural improvements of the gates, valves, and other associated mechanical equipment in each of the reservoirs in the basin may reduce the amount of water lost downstream due to leakage. Restoration of the tainter gates at John Redmond Reservoir should continue and structural improvements at the other reservoirs in the basin should be evaluated.

Demand Management

Water conservation, or demand management, is a tool that can provide multiple benefits. Water conservation is the most cost-effective and environmentally sound way to reduce our demand for water.

Based on OASIS model analysis, Council Grove Reservoir responded the most to conservation practices due to the relatively large use of storage by the City of Emporia. Marion and John Redmond reservoirs did not respond as much because of the low municipal use from each of those reservoirs.

To enhance and continue opportunities for demand management in the basin, the following items should be implemented:

- Continue aid to public water suppliers in developing and maintaining water conservation plans.
- Continue technical assistance to public water suppliers in determining the source of unaccounted for water.
- Develop drought triggers for water marketing customers.
- Coordinate with the Cottonwood & Neosho Water Assurance District #3 to develop consistent water conservation plans and drought triggers for each of their members.

Potential Restoration Approaches Needing Additional Assessment

The basin approach described in this report also included an analysis of alternatives, such as structural modifications, operational changes, and construction of new reservoir sites, which will need additional analysis. KWO has initiated a study with the Corps and an engineering consultant to evaluate alternatives to improve water supply availability in the Neosho basin. Several public water suppliers in the Neosho basin have contracted with engineering firms to evaluate their water supply reliability. These studies may include an analysis of restoration alternatives to their water supply reservoirs. Information from these studies will be used to prioritize future restoration options.

Proposed Schedule for Other Basins

The Kansas Water Office (KWO) reviewed in 2006 the surface water supply and demand in five basins in eastern Kansas. From that review the Neosho basin was assigned highest priority due to the high rate of supply loss in the basin coupled with the relatively high demand projections. For that reason, the Neosho basin was selected as the first to develop a basin approach to reservoir sustainability in the Reservoir Roadmap.

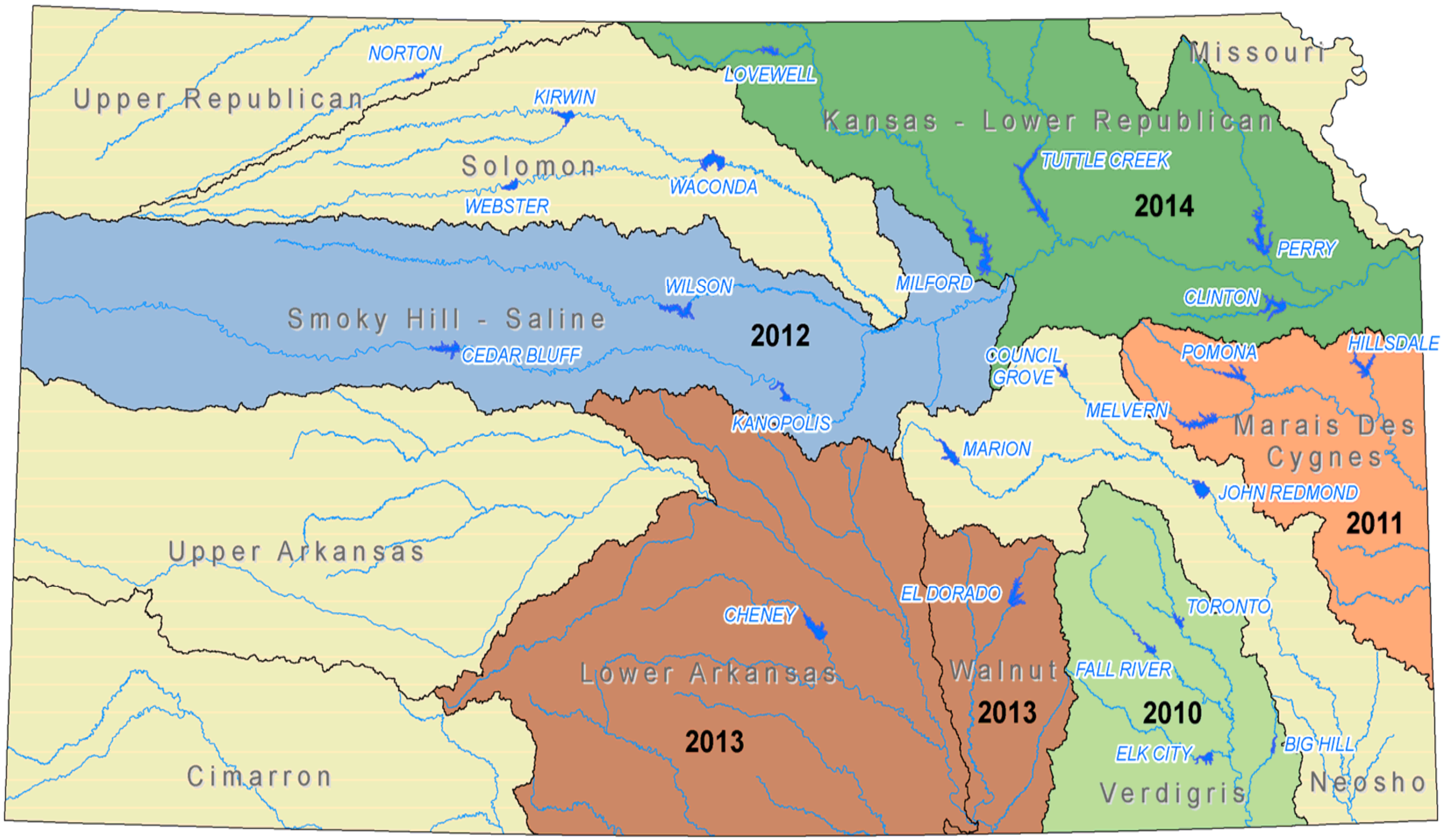
The surface water demand and the supply for that demand have been reviewed for the main stem river corridors in four additional eastern Kansas basins. For the severe drought scenario reviewed in this assessment, two basins, in addition to the Neosho, show some supply vulnerability within the next 15 years. In order of most vulnerable to least, the supply-demand findings were: Neosho, Marais des Cygnes, Walnut, Verdigris and Kansas River corridors.

Not included in the 2006 surface water supply and demand analysis was the Smoky Hill-Saline basin. The KWO and Kansas Geological Survey (KGS) have been evaluating the water supply in this basin through hydrologic modeling. Kanopolis Reservoir, a major source of municipal and industrial water to more than 12,000 customers, has experienced a significant reduction of inflows since the 1950s. With increasing demand on this reservoir, the Smoky Hill-Saline basin would also benefit from a basin approach to reservoir sustainability.

In 2011, the results of the national decadal census will be available. Information from the census will be useful in improving these supply and demand projections, especially for those basins influenced by urban development.

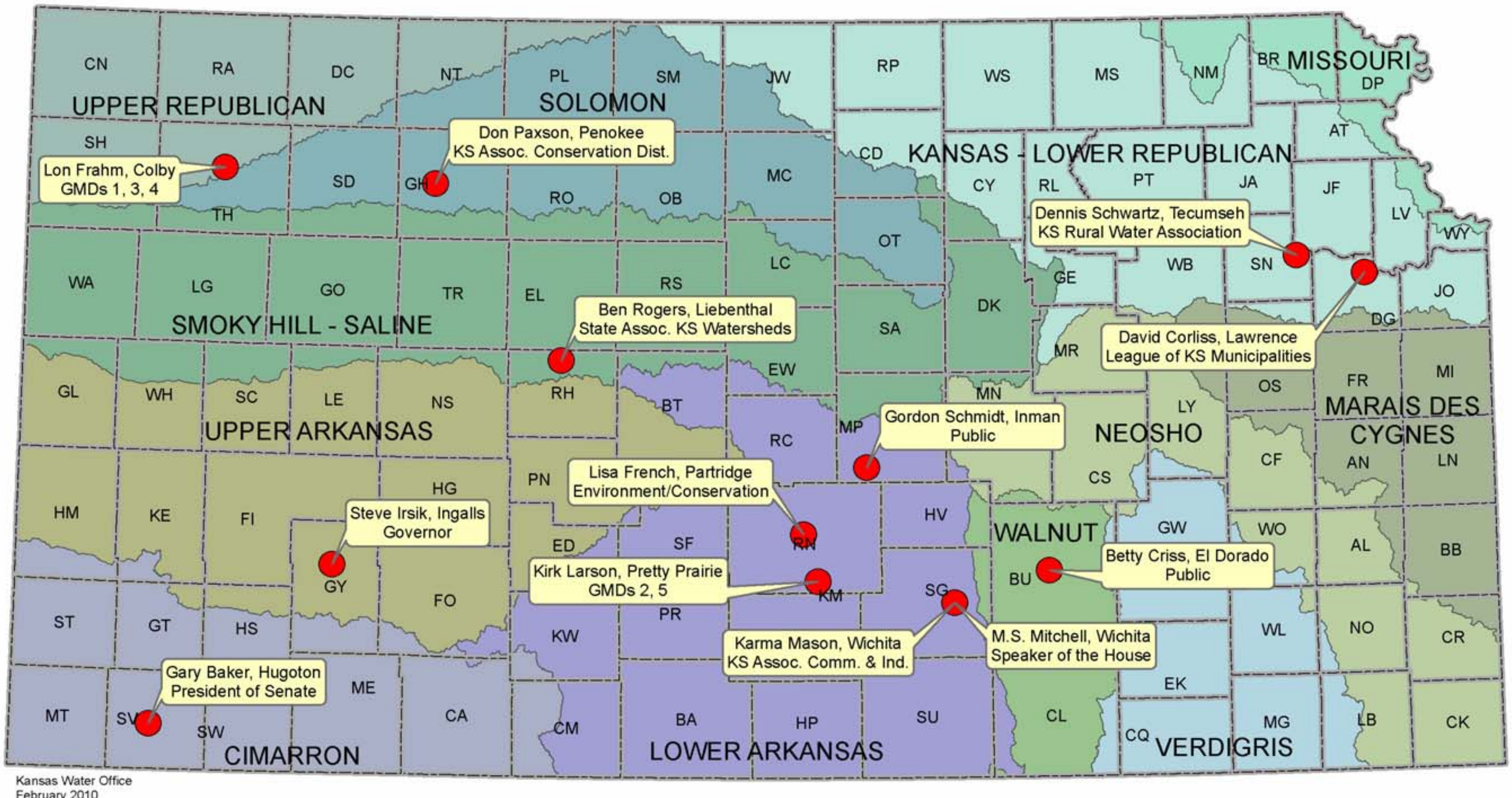
The proposed schedule for providing an approach to reservoir sustainability mirrors the supply-demand findings, but delays implementation of three of the basins pending recent population data. In 2010, the Kansas Water Authority (KWA) will conduct a similar analysis of reservoir sustainability for the Verdigris basin, followed by the Marais des Cygnes (2011), Smoky Hill-Saline (2012), Walnut (2013) and Kansas River (2014) basins.

Completion of the basin approach for the Neosho basin for the Reservoir Roadmap marks a significant milestone in the planning for achieving reservoir sustainability in this basin. As the KWA initiates development of a basin approach for the other basins, implementation of the highest priority recommendations for the Neosho basin will continue. Systematic streambank stabilization and riparian revegetation will continue as piloted by the 12 projects on the Neosho River above Neosho Rapids. Cooperation with the U.S. Army Corps of Engineers (Corps) for the reallocation of storage in John Redmond Reservoir will remain a high priority. The basin approach described in this report for the Neosho basin also included an analysis of alternatives, such as structural modifications, operational changes, and construction of new reservoir sites, which will need additional analysis. More detailed evaluation of the cost, utility and feasibility of these alternatives will be the focus of the next phase of planning for the Neosho basin.



Map of proposed basin schedule for analysis.

Kansas Water Authority Members



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