US Army Corps of Engineers ®
Kansas City District

MISSOURI NATURAL RESOURCES

North Central Missouri Water Supply Reliability Study – 2016 Final Report

Prepared by

HDR

June 15, 2016

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Acronyms and Abbreviations

AF	Acre-feet
CCWWC	Clarence Cannon Wholesale Water Commission
CIP	Cast iron pipe
COP	Certificate of Participation Bonds
D/DBP	Disinfectants/disinfection by-product
DWW	MDNR Drinking Water Watch
GO	General obligation bonds
GPD	Gallons per day
GPM	Gallons per minute
GCPD	Gallons per capita per day
GWR	Groundwater rule
HAA5	Haloacetic acids (five)
HDR	HDR Engineering, Inc.
LRAA	Locational running annual average
LT2ESWTR	Long-Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum containment level
MDNR	Missouri Department of Natural Resources
MGD	Million gallons per day
MHI	Median household incomes
MRWA	Missouri Rural Water Association
MSDIS	Missouri Spatial Data Information Service
NCMO	North central Missouri
NCMRWC	North Central Missouri Regional Water Commission
NOV	Notice of violation
NRCS	Natural Resource Conservation Service
NTNC	Non-transient non-community
PWS	Public water supply
RESOP	USDA Natural Resource Conservation Service Reservoir Operations Computer Program
RTCR	Revised Total Coliform Rule
SWP I	Missouri State Water Plan Technical Volume I
SWP II	Missouri State Water Plan Technical Volume II
TDS	Total dissolved solids
TMU	Trenton Municipal Utilities
TTHM	Total trihalomethanes
USACE	U.S. Army Corps of Engineers
WSS	MDNR 2011 Missouri Water Supply Study
WTP	Water treatment plant

Introduction

The U.S. Army Corps of Engineers (USACE) and the Missouri Department of Natural Resources (MDNR) coordinated the development of a North Central Missouri (NCMO) Water Supply Reliability Study (Study). The intent of the Study is to assess public water supply availability, water quality, regulatory compliance, and source water reliability within the Study Area. The goal of the Study is to assist future planning efforts by determining the need for future public water supply and distribution projects that may benefit from state and/or federal funding assistance.

The Study focuses on a 17-county area in north central Missouri. The counties include Adair, Caldwell, Carroll, Chariton, Daviess, Grundy, Harrison, Knox, Linn, Livingston, Macon, Mercer, Putnam, Randolph, Schuyler, Scotland and Sullivan counties. There are a total of 99 public water systems within the Study Area comprised of municipalities and public water supply districts.

Information on the public water systems within the Study Area and the sources for which they depend on is provided by MDNR, USACE, the Missouri Rural Water Association (MRWA), North Central Missouri Regional Water Commission (NCMRWC or Commission), and other readily available sources. The information gathered from these sources is presented in more depth below in Topic 1 Availability, Topic 2 Quality, and Topic 3 Regulatory Compliance. Information presented in these sections may differ from the information each individual water system has with regards to their system. Information is based on the sources noted, however comments on inaccuracies in reference material has been noted and may be investigated in future phases.

To gain a more in-depth understanding of source reliability within the 17-county area, a survey of ten (10) selected public water systems was performed by HDR Engineering, Inc. (HDR) and MRWA. The ten systems designated for the survey were identified as selected water systems in collaboration with MDNR, HDR, and MRWA. These selected systems were chosen based on source water reliability, state drinking water regulations compliance, and technical, managerial, and financial capacity. The selection was also based on systems purchasing water from out-of-state suppliers, consecutive suppliers purchasing from a supplier with a limited or stressed source, treatment plant capacity limitations, and distribution system limitations.

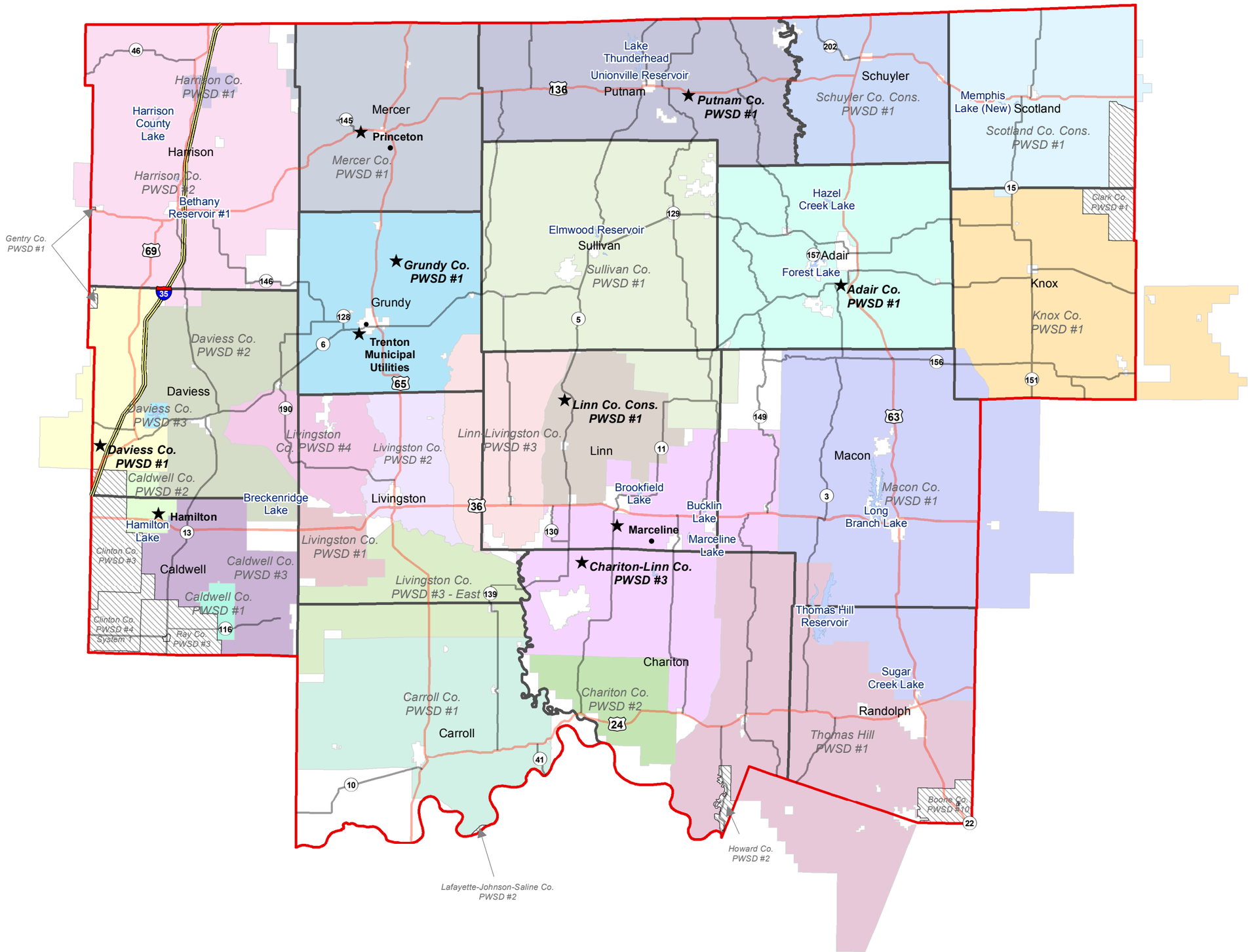
The ten selected public water systems are as follows:

1. Adair Co. PWSD 1
2. City of Hamilton (Caldwell County)
3. Daviess Co. PWSD 1
4. Grundy Co. PWSD 1
5. Trenton Municipal Utilities (Grundy County)
6. Chariton Linn Co. PWSD 3 (Linn County, Chariton County, Macon County)
7. City of Marceline (Linn County, Chariton County)
8. Linn Co. Cons. PWSD 1
9. City of Princeton (Mercer County)
10. Putnam Co. PWSD 1

These ten selected public water systems are located within 7 of the 17 counties within the Study Area: Adair, Caldwell, Chariton, Grundy, Linn, Mercer, and Putnam counties.

Figure 1 depicts the 17-county Study Area. The identification of the selected water systems and the information gathered as part of this effort contributed to the development of this Study and are presented in more detail in Topic 4 Reliability.

Based on the information gathered as part of the site surveys and collected from other sources, a potential water distribution system was evaluated for the 10 selected water systems. The conceptual transmission routing options and estimated costs are presented in more detail in Topic 5 Conceptual Distribution System.



LEGEND

- County Boundary
- Study Area Boundary
- Study Area PWSD
- Non-Study Area PWSD
- City
- Selected Water System
- State Highway
- US Highway
- US Interstate

FIGURE 1 - NORTH CENTRAL MISSOURI STUDY AREA

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Topic 1 Availability

The focus of Topic 1 is the existing surface water and groundwater sources within the Study Area and available capacity of those sources for public water systems. Section 1.1 presents the regional use of water supply by public water systems and the effects of regional residential, agricultural and industrial users. Section 1.2 and 1.3 present the availability of groundwater and surface water on a regional basis. Section 1.4 presents the specific sources and available capacity for each of the 17 counties within the Study Area. The availability discussion and conclusions presented below are based on assessments completed for the region by MDNR and other engineering consultants. The reliability of the water sources identified is presented in Topic 4.

1.1 Regional Water Use

Missouri's waters are put to a variety of uses both consumptive and non-consumptive. Only a small percentage of the total water use in the State is attributed to domestic and municipal water supply for consumptive use. The larger consumptive water users within the State are industrial users, agricultural users, and thermal electric generation. Non-consumptive uses include recreation, commercial navigation, and hydroelectric power generation.

The focus of this Study is the water use by public water systems within the Study Area. MDNR defines public water systems as those that provide water for human consumption through pipes, or similar means, to at least 15 service connections or serves an average of 25 people for at least 60 days per year. Municipalities have been authorized by the Missouri Revised Statues, as sanctioned by the State General assembly, to construct and operate water facilities (i.e., public water systems) and, if necessary, to contract with other municipalities or corporations (public and private) to obtain drinking water. Additionally, the Statutes have authorized the formation of public water supply districts in an effort to extend public water supply benefits to rural areas.

1.2 Regional Groundwater Availability

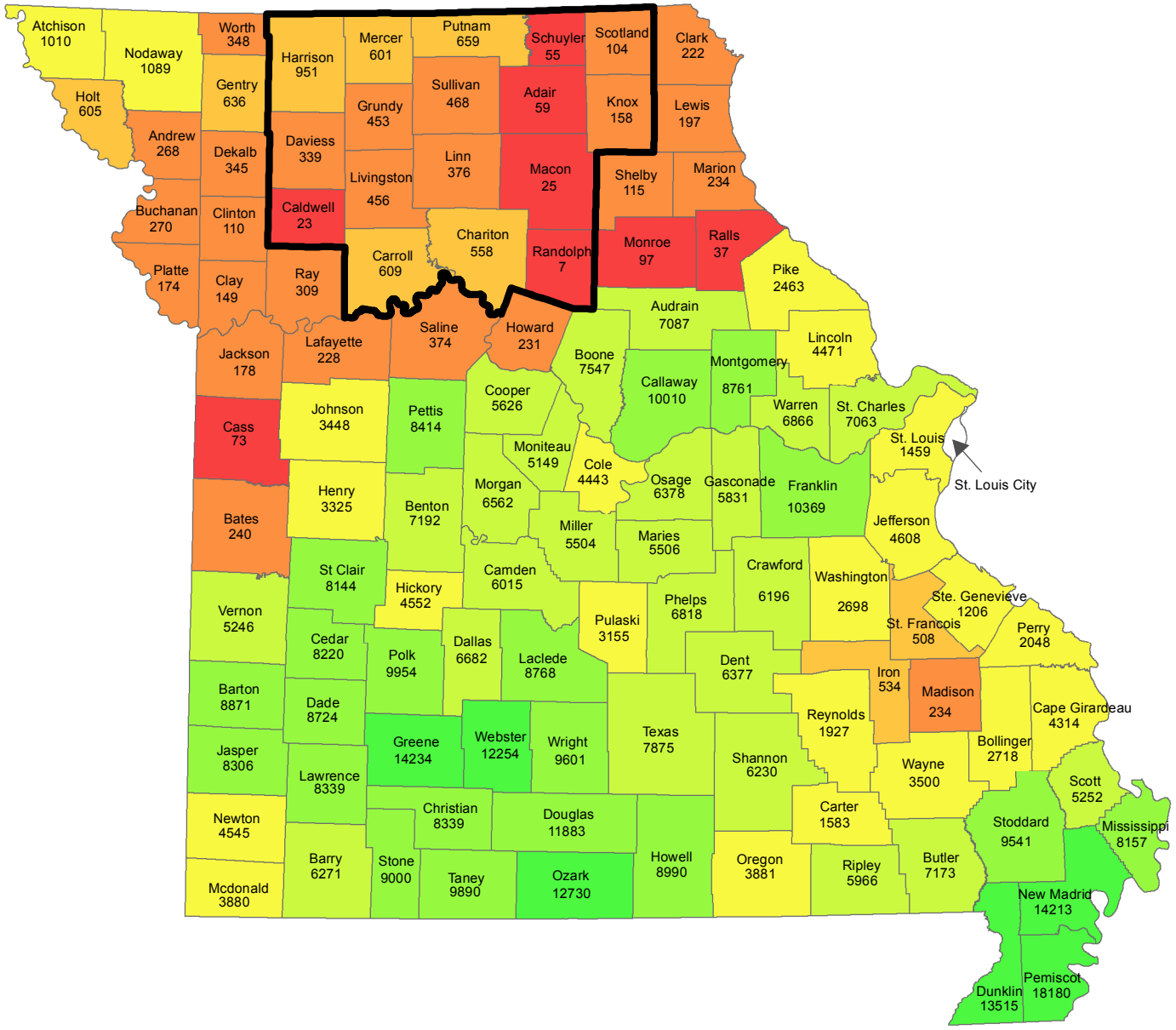
Missouri is comprised of numerous major groundwater aquifers with varying depths and extents. Groundwater in Missouri is considered by the MDNR to be an outstanding resource base. However, the majority of this vital resource type is located south of the Missouri River, outside the boundary of this Study Area. Southern Missouri accounts for approximately 86.7 percent of the State's potable groundwater, according to the Missouri State Water Plan Technical Volume II (Missouri SWP II). Northern Missouri, which contains the entirety of this Study Area, accounts for the remaining 13.3 percent.

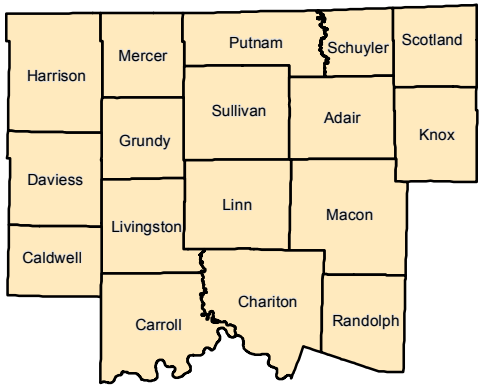
As part of the Missouri SWP II the available groundwater in billion gallons within Missouri aquifers was estimated for each of the counties in Missouri (see Figure 1-1). The locations of the public water supply wells dependent on Missouri aquifers are depicted in Figure 1-2. As mentioned above, the majority of the public groundwater wells are located in Southern Missouri, south of the Missouri River divide.

To better evaluate the variability of the groundwater resources, the State has been divided into seven groundwater provinces differentiated by groundwater aquifer boundaries, aquifer types, groundwater

quality, geologic features and vulnerability of the aquifer to contamination. The Missouri groundwater provinces and sub-provinces are presented in Figure 1-3.

Figure 1-4 depicts the general geologic and hydrogeologic groundwater regions of Missouri as determined by MDNR Geologic Survey Program (GSP). Figure 1-4 also includes the freshwater-saline water transition zone. The entire Study Area is located north of the freshwater-saline water transition zone, which finds aquifers becoming increasingly mineralized and containing excessive dissolved solids, chloride, and sulfate. Additionally, areas near the transition zone may find aquifers with gross alpha emissions exceeding the maximum levels allowed for drinking water. Altogether, the water quality found north of the transition zone accounts for aquifers that may likely require excessive treatment in order to be potable. The quality of current groundwater supplies within the Study Area is discussed in more detail in Topic 2.1.





LEGEND

- Missouri Counties
- Study Area Boundary

bg = billion gallons

- <100 bg
- 100 - 499 bg
- 500 - 999 bg
- 1,000 - 4,999 bg
- 5,000 - 7,999 bg
- 8,000 - 11,999 bg
- >12,000 bg

DATA SOURCES:

MISSOURI STATE WATER PLAN TECHNICAL VOL II
MISSOURI SPATIAL DATA INFORMATION SERVICE

FIGURE 1-1 GROUNDWATER STORAGE IN MISSOURI COUNTIES

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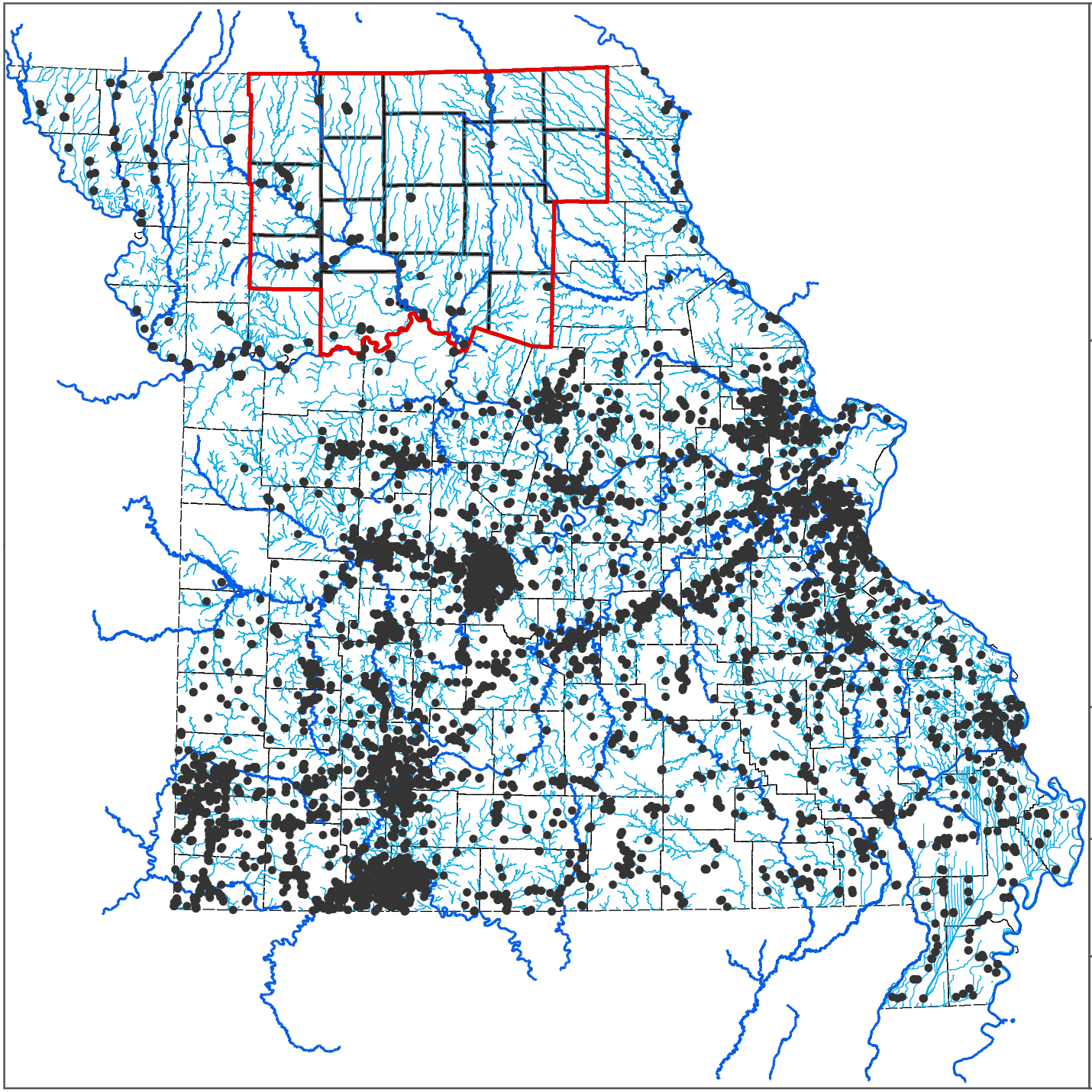

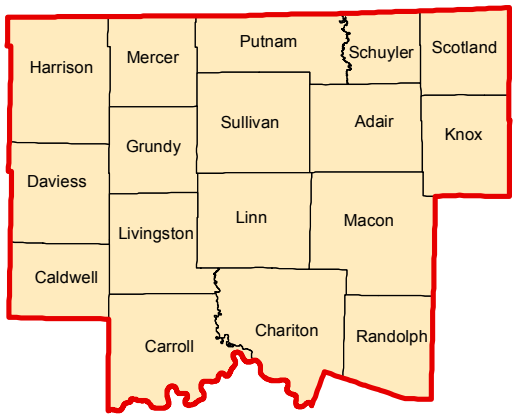

LEGEND

- Study Area Boundary
- Missouri Counties
- Public Wells
- Major Rivers
- Perennial Streams

DATA SOURCES:

MDNR GIS DATA
WELLS DATE FROM 1993-2015
MISSOURI SPATIAL DATA INFORMATION SERVICE

FIGURE 1-2 PUBLIC WATER SUPPLY WELLS IN MISSOURI

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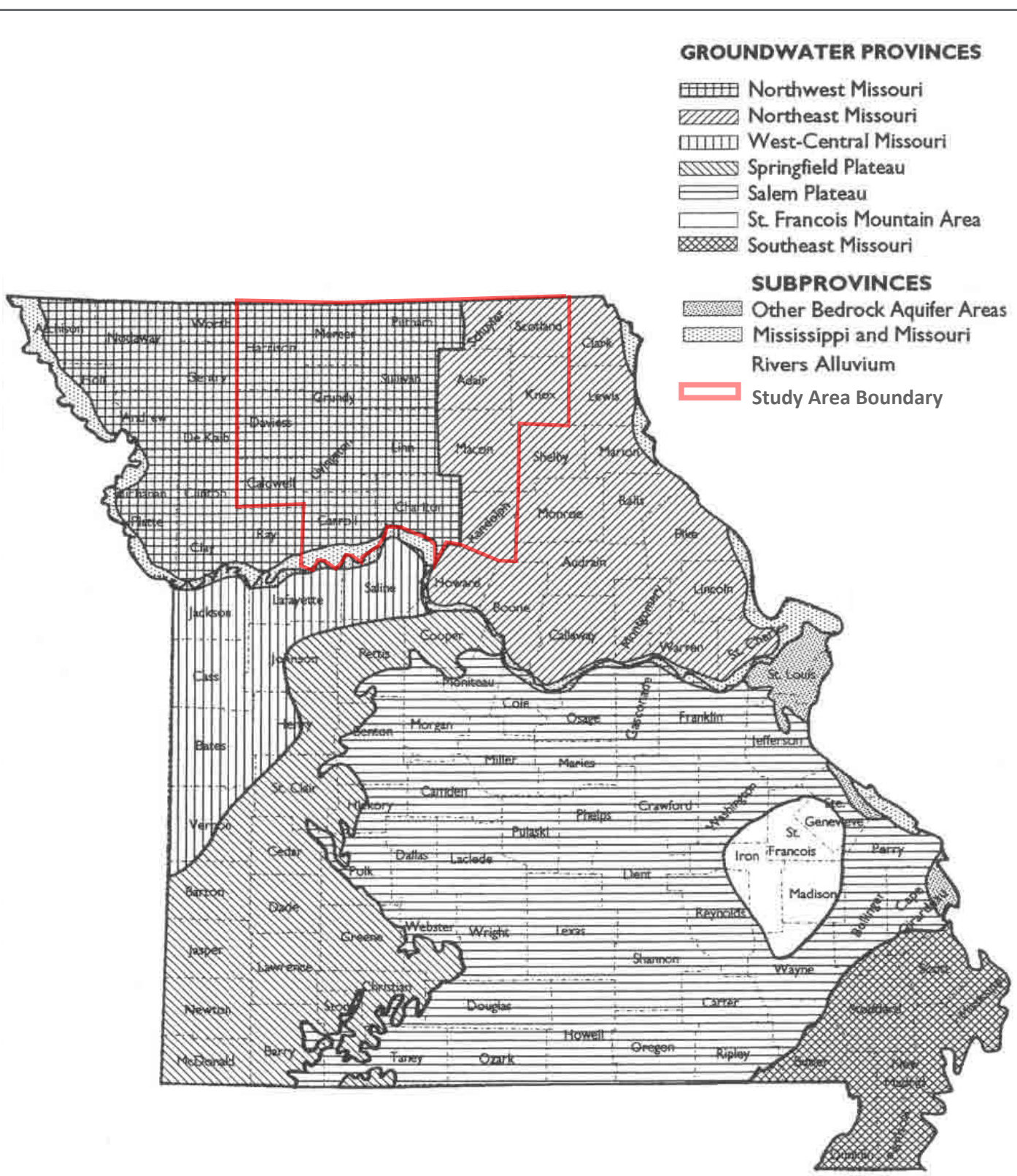

DATA SOURCES:

1997 Missouri State Water Plan Technical Volume II Groundwater Resources of Missouri

US Army Corps of Engineers ®
Kansas City District

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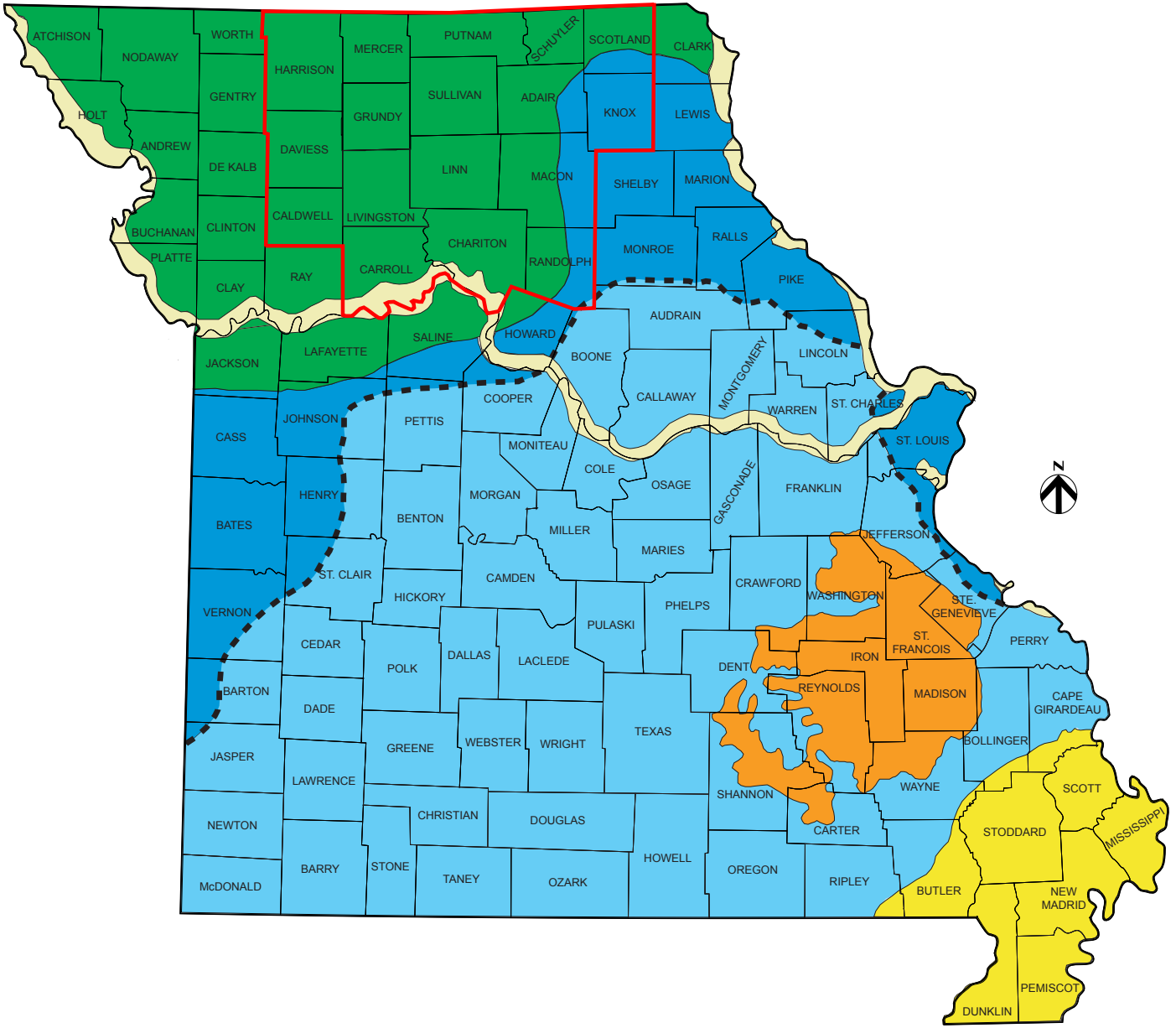
FIGURE 1-3 GROUNDWATER PROVINCES AND SUB-PROVINCES OF MISSOURI



MISSOURI AND MISSISSIPPI RIVER ALLUVIUM
Yield is normally 1,000+ gallons per minute (gpm), water is suitable for irrigation. Softening and iron removal recommended for drinking water.

GLACIAL DRIFT AND ALLUVIUM
Yield is normally 1-15 gpm. Drift-filled preglacial channels locally yield 200 to 500 gpm. Alluvium in lower reaches of major rivers can locally yield 400+ gpm. Iron removal and disinfection is recommended. Bedrock aquifers generally yield mineralized water.

CRETACEOUS AND TERTIARY SANDS, AND ALLUVIUM
Alluvium typically yields 1,000+ gpm; Tertiary sands, 500 to 1,000 gpm. Both contain high iron. Wells in Cretaceous sands typically produce 150 to 1,000 gpm, have lower iron, are softer, have higher temperature waters, and may be artesian.

PENNSYLVANIAN AND MISSISSIPPIAN LIMESTONES AND SANDSTONES
Yield 1 to 15 gpm to depth of about 400 feet. Aquifers below 400 feet yield mineralized water. Wells in shallow Mississippian limestones yield 1 to 10 gpm. Deeper high-yield aquifers yield mineralized water.

MISSISSIPPIAN LIMESTONES (SOUTHWEST MISSOURI), ORDOVICIAN AND CAMBRIAN DOLOMITES AND SANDSTONES
Yield 15-500 gpm, depending on depth and producing formations. Yields locally exceed 1,000 gpm in some areas including Springfield, Columbia and Rolla. Yields diminish substantially east of the St. Francois Mt. region. Highly-productive aquifers become mineralized north of freshwater-salinewater transition zone.

CAMBRIAN AND PRECAMBRIAN ROCKS
Dolomites typically yield 15 to 50 gpm. Lamotte Sandstone locally yields 300+ gpm. Precambrian igneous rocks normally yield 0 to 15 gpm.

FRESHWATER-SALINEWATER TRANSITION ZONE
North of this line, high-yielding aquifers contain water too mineralized to be used without extensive treatment.

Study Area Boundary

FIGURE 1-4 GEOLOGIC AND HYDROGEOLOGIC GROUNDWATER REGIONS OF MISSOURI

DATA SOURCES:

Missouri Department of Natural Resources
2002

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Of the seven, distinct groundwater provinces identified in the Missouri SWP II, the North Central Missouri Study Area is comprised of two provinces: the Northwest Missouri province and the Northeast Missouri province. A very small portion of the Study Area, the southern extents of Carroll and Chariton counties, is within the Missouri River Alluvium sub-province, which falls within the boundaries of the Northwest Groundwater Province.

Northwest Missouri Groundwater Province

The Northwest Missouri Groundwater Province contains 23 counties, 11 of which are within the boundaries of this Study and accounts for 2.1 percent of the State's potable groundwater. According to MDNR, groundwater resources in much of the Northwest Province are poor with an estimated yield of approximately one to 15 gallons per minute (gpm) (Missouri SWP II, 1997).

Bedrock aquifers found in northern Missouri can contain vast quantities of water, but typically yield water too highly mineralized to be considered potable. These bedrock aquifers are similar to those found in Southern Missouri, yet are present at a much greater depth in the northwestern portion of the State. The Pennsylvanian strata contain useable quantities of groundwater; however, the yields are historically low and the water quality only marginal. Yields from the glacial deposits found in the Northwest Province range from zero to 500 gpm and are dependent on the thickness and texture of the deposits. Alluvial deposits in this Province have small yields with the exception of the Missouri River alluvium, which is discussed in more detail below. The SWP II concludes that the cause for poor yields is due to alluvium sediments from the smaller rivers that are finer-grained and more poorly sorted than those of the Missouri River. There are exceptions near the mouths of major rivers within the Northwest Province, where yields may be suitable for public water supply.

According to SWP II, groundwater recharge rates and velocities are relatively low within the Northwest Province, both in the unconsolidated and bedrock aquifers. Contamination of the aquifers is possible which has been documented by numerous cases of local groundwater pollution from private septic systems and agricultural activities. The wells at the greatest risk for contamination are those found in the upper portion of the glacial drift region. Although meager in supply, glacial drift is often the only source available for rural use.

Northeast Missouri Groundwater Province

The Northeast Missouri Groundwater Province consists of 21 counties, 6 of which are within the boundaries of this Study and accounts for 11.2 percent of the State's potable groundwater. The Province is bordered on the east by the Mississippi River and on the south by the Missouri River. However, none of the Study Area counties in this Province fall within the Mississippi or Missouri River Alluvium.

The Northeast Missouri Groundwater Province shares several geologic similarities with the Northwest Province. According to SWP II, the Northeast consists of glacial drift, Pennsylvanian bedrock, Mississippian bedrock, and Cambrian-Ordovician strata. Although geologic similarities with the Northwest Province exist, the Northeast is comprised of significantly more diverse groundwater conditions. Due to this diversity, the Northeast Groundwater Province is more difficult to accurately

characterize. According to MDNR DGLS the groundwater yields within this Province can range from one to 500 gpm with yields exceeding 1,000 gpm in some areas. However, for the purposes of this Study, the six counties that fall within the Northeast Missouri Groundwater Province have a typical groundwater yield of one to 15 gpm.

Approximately two-thirds of the Northeast Province lies north of the freshwater-salinewater transition zone. According to the SWP II, the glacial sediments found within the Northeast Province are generally thinner and less permeable having less groundwater production potential and the quality is marginal to poor. However, the bedrock units within this Province are more likely to yield potable groundwater than those in the Northwest Groundwater Province. Very deep bedrock can yield highly mineralized groundwater that requires extensive treatment to be potable. South of the transition zone within the Northeast Province but outside of the Study Area, wells generally yield enough water for domestic and farm purposes. Deeper wells within this area penetrating the Ordovician and Upper Cambrian strata can yield sufficient groundwater for irrigation, municipal and rural public water supply.

As detailed previously the Northeast Province consists of a variety of aquifers and geologic conditions; thus, the groundwater contamination potential is highly varied. South of the transition zones, outside of the Study Area, bedrock aquifers are not particularly prone to contamination. The shallow groundwater wells found within the glacial drift north of the transition zone, within the Study Area, are susceptible to contamination from septic systems and agricultural activities. Bacterial and nitrate levels within these sediments may be problematic.

Missouri River Alluvium Sub-Province

The Missouri River Alluvium is a sub-province bordering the West-Central and Northwest groundwater regions. The Missouri River Alluvium contains 25 counties, two of which are within the boundaries of this Study and accounts for 0.66-percent of the State's portable groundwater (SWP II, 1997). Only the most southern extents of Carroll and Chariton counties fall within the Missouri River Alluvium. The most significant aquifers within the Northwest Missouri Province are within the Missouri River Alluvium Sub-Province located along the Missouri River. According to SWP II, there is direct interchange between the Missouri River and the Alluvium. Groundwater levels are directly related to the stage of the river, although there is a delayed response of several days between the higher river stages and higher groundwater levels. According to MDNR GSP, yields within the River Alluvium are normally greater than 1,000 gpm.

Southern Carroll County lies within Reach 2 of the Missouri River, which runs from Kansas City to Miami, Missouri. Pennsylvanian-age limestone, shale and sandstone underlie the alluvium throughout most of the Reach. These formations tend to have very low hydraulic conductivities and the water found within them is generally highly mineralized. The total use of alluvial water within Reach 2 is less than 0.003-percent of the total estimated alluvial aquifer storage for Reach 2 per SWP II. It is not uncommon for production wells drilled through the more permeable zones in the alluvium of Reach 2 to achieve yields of 1,000 to 1,500 gpm. Water treatment to reduce iron and manganese is necessary for most potable water supply wells within this Sub-Province.

Southern Chariton County lies within Reach 3 of the Missouri River, which runs from Miami to Jefferson City. Similar to Reach 2, only a small percentage of the total estimated alluvial aquifer storage for Reach 3 is currently being utilized. Additionally, the alluvium within Reach 3 overlie bedrock formations that contain highly mineralized water; however, the permeability within Reach 3 is greater than those upstream. In the upstream reaches of Reach 3, within Chariton County, the primary water quality concerns are incrustation of well screens due to excessive calcium carbonate, elevated iron and manganese concentrations, and concern of organic contaminants due to high permeability of the aquifer.

1.3 Regional Surface Water Availability

Surface water is a significant asset in Missouri's water portfolio. Surface water throughout Missouri is utilized from flows diverted from rivers, streams, and reservoirs. The groundwater availability in northern Missouri is limited, as previously presented in Section 1.2. Therefore, surface water plays a very important role for municipal water systems in northern Missouri.

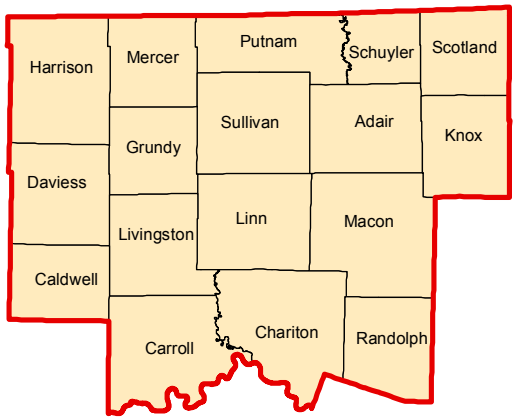
Figure 1-5 presents the rivers and lakes within Missouri. Figure 1-6 depicts the public water supply surface water intakes within Missouri, primarily located in northern Missouri, inverse to the groundwater supply predominately located in southern Missouri.

The physical geography and geology of northern Missouri has direct impacts on the surface water resources throughout the region. The glacial drift found through the north has low infiltration and high runoff. According to Missouri State Water Plan Technical Volume I (SWP I) this low permeability combined with the lowest average rainfall in the region and the limited groundwater inflow to streams allows for extremely low base flows during dry weather. Additionally, the agricultural demands of the region, including extensive row cropping coupled with the easily erodible glacial till, results in high loading of suspended solids in many of the region's streams, rivers and reservoirs.

Similar to groundwater, the surface water in Missouri is supplied and replenished by precipitation. Only a portion of precipitation that falls in Missouri makes it to the groundwater and surface water. The majority of water is lost through evaporation and transpiration. Additionally, the highest annual precipitation (usually in the spring months) does not necessary coincide with the time of greatest need (generally in the summer months).

Figure 1-7 depicts the average annual precipitation from 1981 to 2010 based on data provided by the PRISM Climate Group at Oregon State University (http://www.prism.oregonstate.edu, map created 2014). As depicted in Figure 1-7, rainfall varies from lowest in northwestern Missouri to highest in southeastern Missouri. The majority of the Study Area receives between less than 38 inches to about 40 inches of rainfall per year on average. There is a small portion of the Study Area that has historically received a slightly higher average annual rainfall (42 to 44 inches). The average annual runoff volume within the Study Area is approximately 8 inches (Atlas HA-710).

The Mississippi River receives all waters draining from Missouri either directly or indirectly (see Figure 1-8). According to SWP I, approximately 52.4 percent of the drainage area of the State contributed to the Mississippi River is conveyed via the Missouri River. Upstream of St Louis, 11.2 percent of the State drains directly into the upper Mississippi. The remaining portions drain into the lower Mississippi, downstream of St Louis either directly, or conveyed to the lower Mississippi via the Arkansas and White Rivers. For the purposes of this Study, the focus will be primarily on the Upper Mississippi River tributaries in Missouri and the Missouri River tributaries north of the Missouri River, presented in Figure 1-9 and Figure 1-10, respectively.



LEGEND

- Study Area Boundary
- Rivers
- Lakes

DATA SOURCES:

USGS National Atlas of the United States of America

FIGURE 1-5 MISSOURI RIVERS AND LAKES

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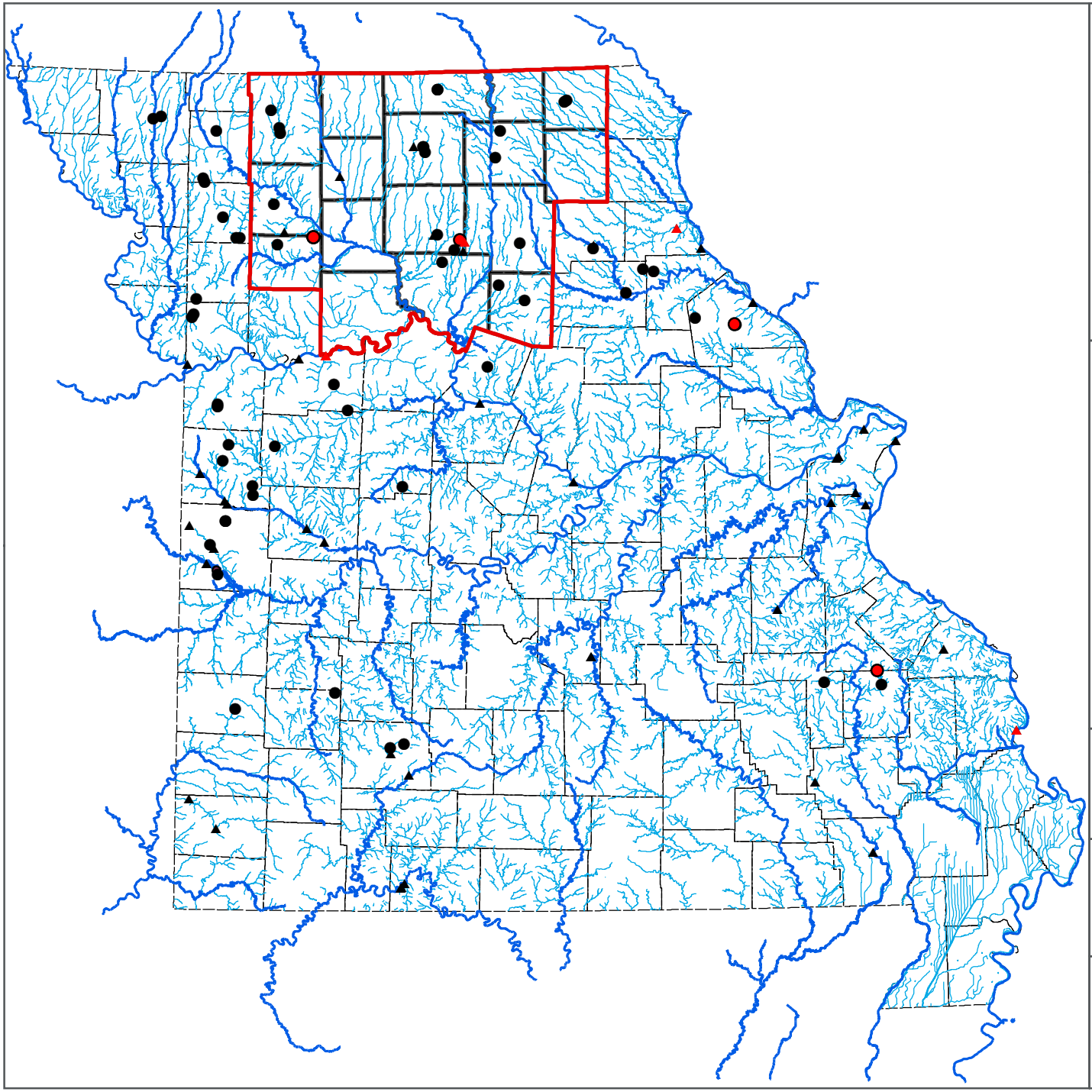

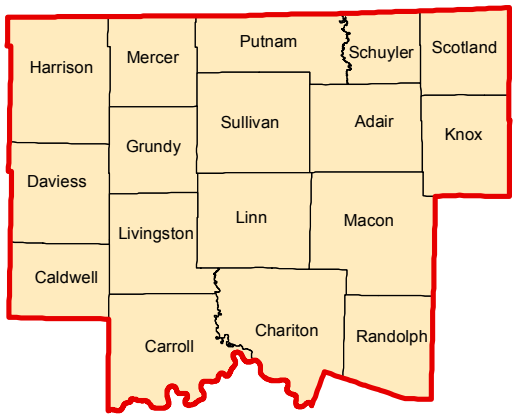

LEGEND

- Study Area Boundary
- Missouri Counties

Surface Water Intakes:

- Located on lakes
- Located on rivers

Emergency Surface Water Intakes:

- Located on lakes
- Located on rivers
- Major Rivers
- Perennial Streams

DATA SOURCES:

MDNR GIS DATA
INTAKE DATES FROM 1996-2014
MISSOURI SPATIAL DATA INFORMATION SERVICE

FIGURE 1-6 PUBLIC WATER SUPPLY
SURFACE WATER INTAKES IN MISSOURI

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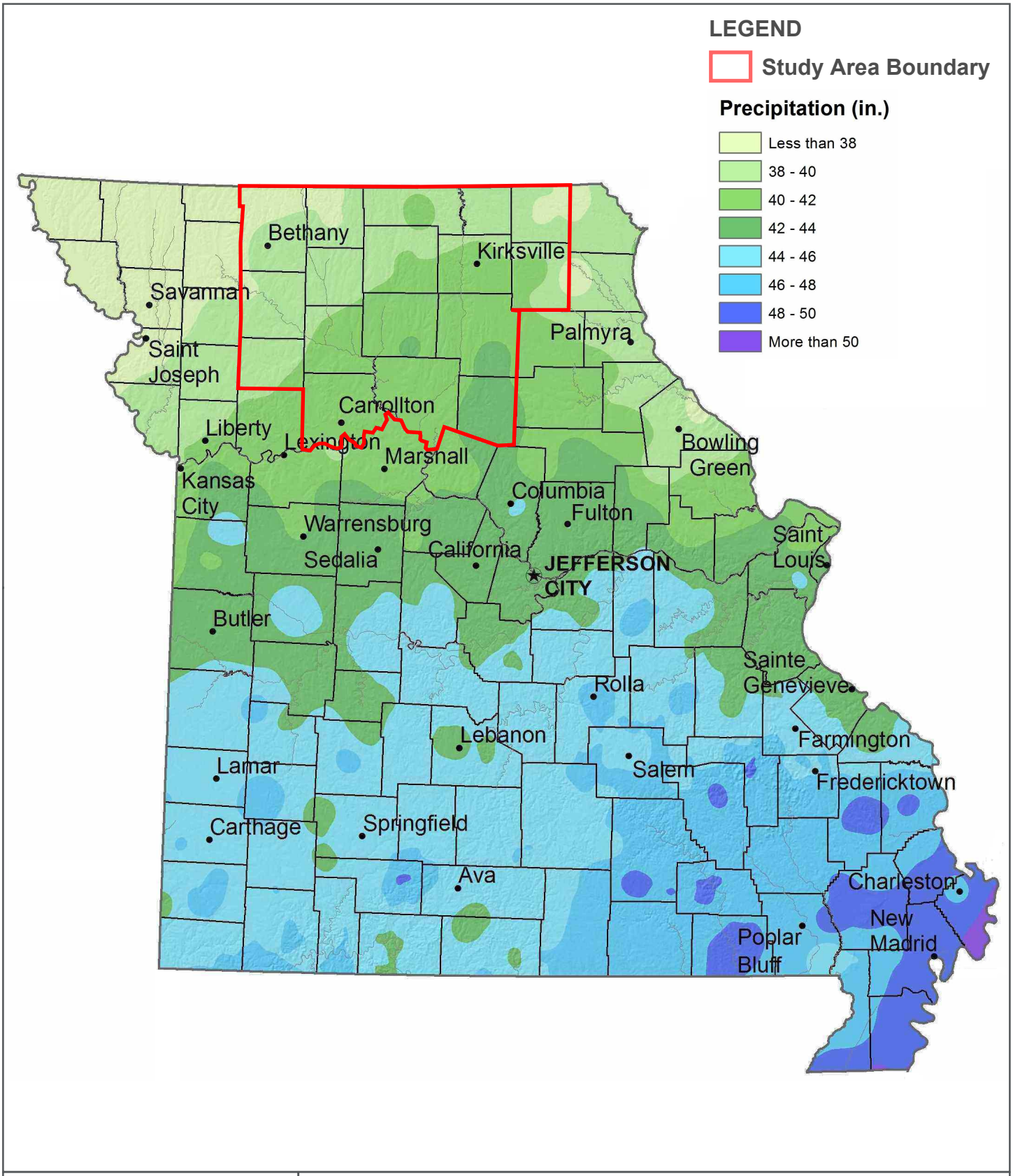

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DATA SOURCES:

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FIGURE 1-7 Average Annual Precipitation in Missouri (1980-2010)

LEGEND

- Upper Mississippi River Basin
- Missouri River Basin
- Arkansas-White River Basin
- Red River Basin
- Lower Mississippi River Basin
- Ohio River Basin

FIGURE 1-8 MAJOR TRIBUTARIES OF THE MISSISSIPPI RIVER

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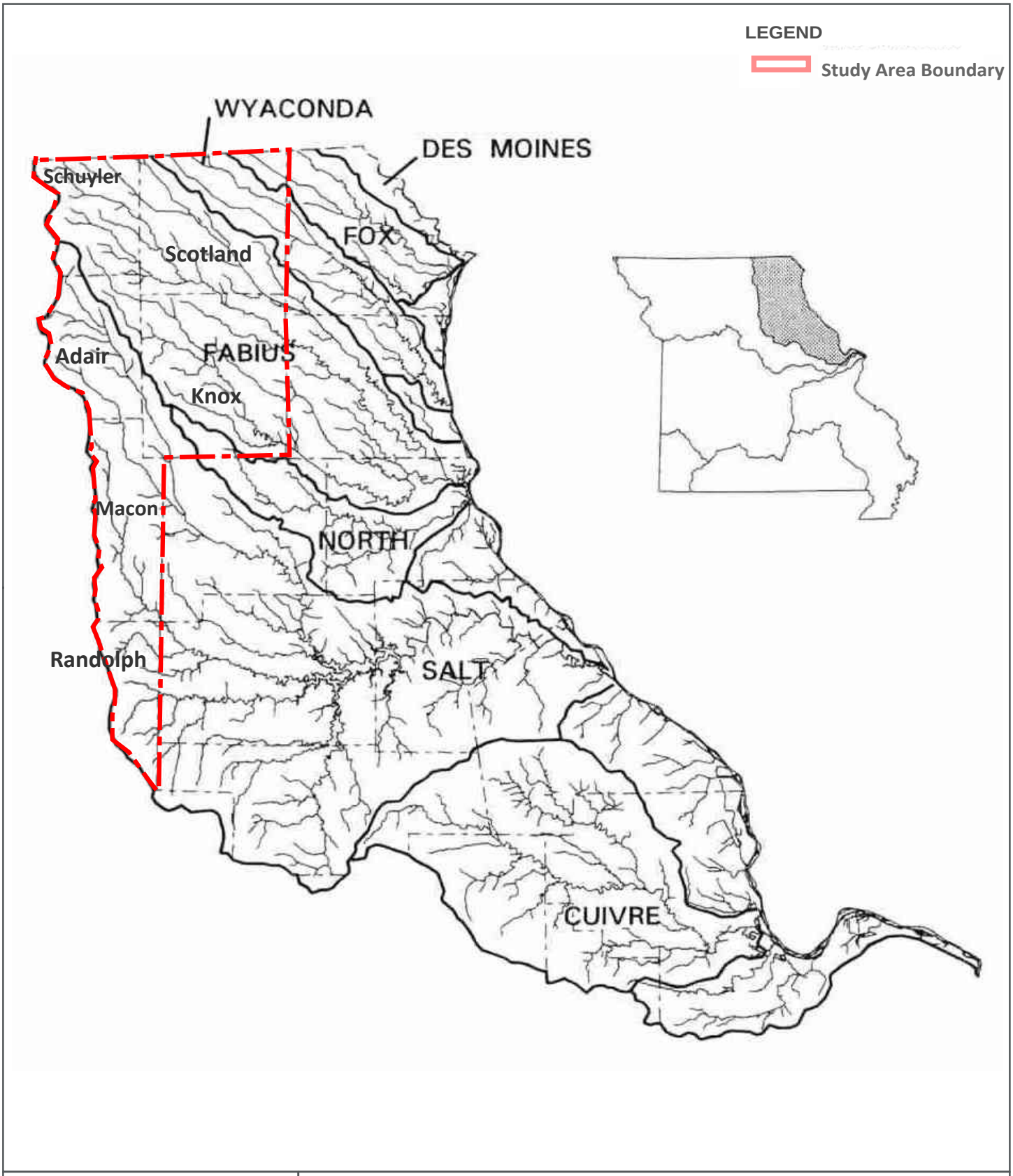

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DATA SOURCES:

1995 MISSOURI DEPARTMENT OF NATURAL RESOURCES
WATER RESOURCES REPORT 45

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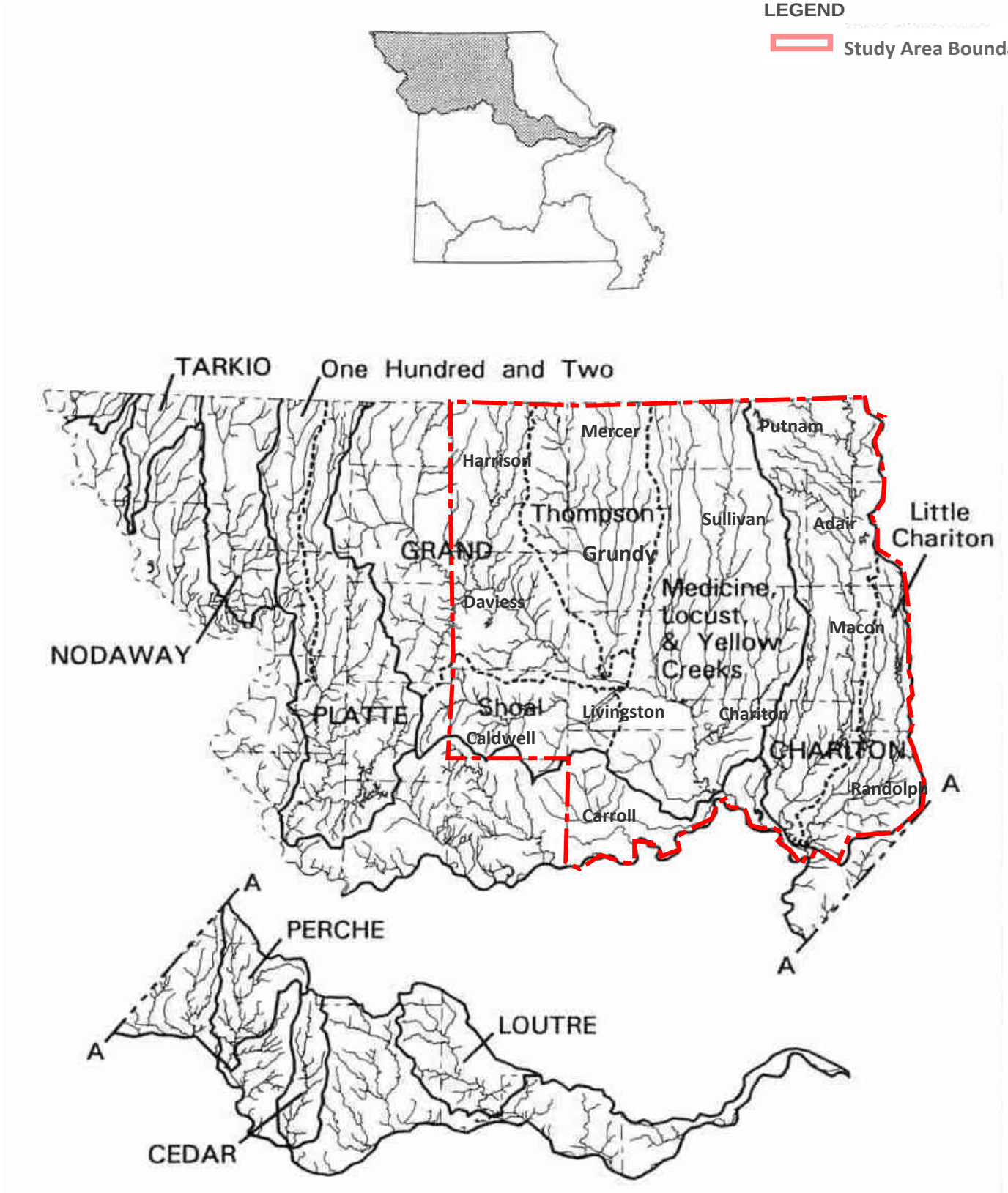
FIGURE 1-9 UPPER MISSISSIPPI RIVER TRIBUTARIES IN MISSOURI



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DATA SOURCES:

1995 MISSOURI DEPARTMENT OF NATURAL RESOURCES
WATER RESOURCES REPORT 45

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FIGURE 1-10 MISSOURI RIVER TRIBUTARIES NORTH OF THE MISSOURI RIVER

Upper Mississippi River Tributaries in Missouri

According to SWP I, the upper Mississippi river, north of the confluence with the Missouri River, drains approximately 7,800 miles of the State and accounts for about 11.2 percent of the Missouri drainage area. Watersheds within this basin trend southeast and are relatively long with respect to the river width. Several of the tributaries have headwaters in Iowa. Figure 1-9 depicts the upper Mississippi River basin in Missouri and denotes the names and locations of the major tributary streams within the basin.

Tributaries to the Upper Mississippi within Missouri typically receive very low inflow from groundwater, even during wet weather events. There are periods of no flow demonstrated in some of these streams during extended drought. The Fabius and Salt Rivers are the two tributaries of the Upper Mississippi River that provide surface water within the Study Area.

Fabius River: The Fabius River headwaters originate in southeastern Iowa. According to the SWP I, the total drainage area within Missouri is approximately 1,470 square miles. The entire basin, including the portions within Iowa, is 80 miles long and nearly 25 miles wide. The Fabius watershed encompasses most of Schuyler and Knox counties, and a portion of Scotland, Lewis, Adair and Marion counties. At the time the SWP I was developed, there were six public water systems utilizing surface water reservoirs in the Fabius River Basin; four of which are located within the Study Area. Since the development of the SWP I Report, three of the four public water systems within the Study Area have modified the designation of the reservoirs to *inactive*, and have switched to purchasing surface water. The specific sources for the water systems within the Study Area are presented in more depth in Section 1.4.

It should be noted the SWP I indicates that Baring, Missouri utilized an 81-acre reservoir at a local country club for public water supply. However, the City of Baring does not presently operate its own public water supply system. It is currently served by Knox County Public Water & Sewer District 1. It is unknown whether the country club reservoir is still utilized for public drinking water supply.

Salt River: The Salt River basin is the largest Mississippi River tributary north of the Missouri River. The Salt River headwaters originate in Schuyler County. According to the SWP I, the total drainage area is approximately 2,920 square miles all within Missouri. The entire basin is about 125 miles long and nearly 40 miles wide. The Salt watershed encompasses portions of Adair, Knox, Callaway, Macon, Pike, Shelby, Randolph, Boone, Monroe, Ralls, and Audrain counties.

At the time the SWP I was developed, there were nine public water systems utilizing reservoirs in the Salt River Basin, not including Mark Twain Lake; only one of which, Schuyler County Consolidated PWSD 1, is located within the Study Area. Since the development of the SWP I Report, Schuyler Co. Cons. 1 has modified the designation of its source to *inactive*. Schuyler 1 currently purchases surface water from Rathbun Regional Water Association, located in Rathbun, Iowa.

Mark Twain Lake was constructed by the U.S. Army Corps of Engineers and is the only major reservoir in northeastern Missouri within the Mississippi River basin. According to SWP II, construction of the Clarence Cannon Dam was completed in 1984, which impounds water in Ralls and Monroe counties. The Clarence Cannon Wholesale Water Commission (CCWWC) distributes water from the Mark Twain

reservoir at an average daily production rate of 4.3 million gallons per day (MGD) according to MDNR Drinking Water Watch (MDNR DWW).

Although outside of the Study Area, the CCWWC provides surface water from Mark Twain Lake to five of the public water systems within the Study Area: the City of Edina (Knox County); the City of Huntsville (Randolph County); Knox Co. PWSD 1; Macon Co. PWSD 1; and Thomas Hill PWSD 1. This is presented in more detail in Section 1.4.

Missouri River Tributaries North of the Missouri River

According to SWP I, an estimated area of 37,000 square miles of Missouri drains into the Missouri River, approximately 52.4 percent of the State; 44 percent of which lies north of the River. Figure 1-10 depicts the Missouri River Tributaries North of the Missouri River and denotes the names and locations of the major tributary streams within the basin. The SWP I states that surface water quality within the northern tributaries of the Missouri River is generally good. However, discharges from abandoned coal mines within the Chariton River basin have contributed to diminished quality in the receiving streams, especially during low flows.

The Grand and Chariton Rivers are the two northern Missouri tributaries of the Missouri River that provide surface water within the Study Area.

Grand River: The Grand River headwaters originate in southeastern Iowa. The Grand is the largest tributary north of the Missouri River. The major tributaries within the Grand River basin include the Thompson River, Shoal Creek, Yellow Creek, Locust Creek, and Medicine Creek. The watershed includes the counties of Harrison, Daviess, Caldwell, Mercer, Grundy, Livingston, Carroll, Putnam, Sullivan, Linn, and Chariton. The Grand River basin encompasses 11 of the 17 counties within the Study Area. At the time the SWP I was developed, there were 17 public water systems utilizing surface water reservoirs in the Grand River basin; 15 of which are located within the Study Area. Since the development of the SWP I, seven of the 15 public water systems within the Study Area have modified designation of the reservoirs to either *inactive* or *emergency* sources, and have switched to purchasing surface water or groundwater. The specific sources for the water systems within the Study Area are presented in more depth in Section 1.4.

Chariton River: The Chariton River headwaters originate in south central Iowa. It is the second largest tributary in north of the Missouri River. The watershed includes portions of Schuyler, Putnam, Sullivan, Adair, Linn, Macon, Chariton, Randolph, and Howard counties. To counteract flooding within certain reaches, the Chariton River has been artificially straightened. This modification left the largest tributary within Chariton basin, the Little Chariton River basin, as a separate drainage basin. At the time the SWP I was developed, there were seven public water systems utilizing surface water reservoirs in the Chariton River basin all of which are located within the Study Area. Since the development of the SWP I, four of the seven public water systems within the Study Area have modified designation of the reservoirs to either *inactive* or *emergency* sources, and have switched to purchasing surface water or groundwater. The specific sources for the water systems within the Study Area are presented in more depth in Section 1.4.

Rathbun Lake, located within Appanoose County, Iowa, is one of the only major impoundments within the Chariton River basin. It was constructed and is currently operated by the USACE. Although outside of the Study Area, water is withdrawn from the lake by Rathbun Regional Water Association, which supplies surface water to four of the public water systems within the Study Area: Mercer Co. PWSD 1; Putnam Co. PWSD 1; Schuyler Co. PWSD 1; and Scotland Co. PWSD 1.

Little Chariton River: The Little Chariton River headwaters originate in Adair County draining parts of Adair, Macon, Randolph, Chariton, and Howard counties. The basin is impacted by two major impoundments within its two major basin tributaries the East Fork and Middle Fork. The East Fork within Macon County was impounded to form the Long Branch Reservoir, constructed and operated by the USACE. The City of Macon distributes water from this Reservoir. The Middle Fork tributary, within Randolph County, was impounded to form the Thomas Hill Reservoir. Associated Electric Cooperative owns and operates the reservoir primarily to supply cooling water. In addition to Long Branch Lake and Thomas Hill Lake, a smaller water supply reservoir known as Sugar Hill Reservoir is utilized for public water supply by the City of Moberly. The specific sources for the water systems within the Study Area are presented in more depth in Section 1.4.

1.3.1 Missouri Water Supply Study (2011 WSS)

MDNR performed a study of 44 vulnerable water systems in Missouri which rely on surface water for public water supply. The goal was to provide community water systems with assistance and an understanding on how to better allocate water supply during critical droughts. The analysis utilized the USDA Natural Resource Conservation Service (NRCS) reservoir operations computer program (RESOP). The optimum yield of the reservoirs during a drought was determined based on the water demands (at the time of the Study) from the water system's surface water source. The drought of record, between 1951 and 1959, was most often used to determine the adequacy of the reservoir supply. The summary of the 2011 WSS RESOP Analysis for the surface water reservoirs within the Study Area is presented in Table 1-1.

Optimum yield is not easily translated to rivers. For purposes of diverting water from a river, minimum in-stream flow requirements must be met. These requirements are in place to ensure water quality can be maintained through adequate mixing zone flows during low-flow periods. The mixing zone flow is estimated based on the seven-day average low flow that has a recurrence interval of once in 10 years, also known as the 7Q10. According to the 2013 MDNR Minimum Design Standards for Missouri Community Water Systems, when a river or stream is to be used as the sole source of water, the flow in the river or stream shall exceed the current registered and future downstream uses, instream flow recommendations (usually the 7Q10 flow rate), and the design year future water system demand. The 2011 WSS also utilized the United States Geological Survey (USGS) hydrograph separation computer program (HYESP) to determine hydrograph separation for stream flows. The summary of the 2011 WSS HYSEP Analysis for JGratzer: Not sure what you want us to check.streams within the Study Area is presented in Table 1-2.

It should be noted that the data and conditions analyzed as part of the 2011 Missouri Water Supply Study (2011 WSS) were accurate at the time of the Study; however, the results of the study may not

reflect current water use or the system's storage capability due to a variety of factors such as reservoir sedimentation. Therefore, as part of this 2015 Study, water demand data compiled in the MDNR Major Water User database (2006 to 2014) has been projected upon the optimum yield determined as part of the 2011 WSS analysis. This does not presume that the current demands will have the same impact on the surface water supply; that would require the existing demands to be analyzed using the RESOP or HYSEP software with updated field data. However, this projection of 2006 to 2014 demands enables the reader to better understand how the current demands of the water system may impact the existing surface water supply. The projection of the more recent demands on the surface water supply within the Study Area is presented in more detail in Section 1.4.

Table 1-1 Summary of Lake Analysis within Study Area (2011 WSS)

County	City or PWSD	Lake Name	Drainage Area Sq. Miles	Annual Demand[1] MGD	Optimum Yield[2] MGD	Optimum Yield with Pumping[3] MGD	Year of Analysis	Notes
Adair	Kirksville	Forest Lake	14.71	2.06	3.53	-	2005	
		Hazel Creek Reservoir	8.07	0.84	1.95	-	2005	
Caldwell	Breckenridge	City Lake	0.65	0.06	0.05	-	2004	
	Hamilton	City Lake	1.78	0.26	0.19	0.26	2000	Lake and Marrowbone Creek
	Little Otter Creek	County Lake	7.53	1.20	1.20	-		Cooperation with NRCS PL-566 Program
Daviess	Jamesport	City Lake	1.41	0.06	0.07	-	2000	
	Daviess Co. PWSD 3	Lake Viking	14.13	0.50	2.46	-	2006	Private Lake
Harrison	Bethany	Harrison County Lake	17.2	0.22	0.59	-		Pumped to New Lake
		Bethany North Lake	1.17	0.18	0.17	-		Pumped to Old Lake
		Bethany South Lake	0.34	0.05	0.05	-		Old Lake to WTP
		Supply System	18.71	0.37	0.82	-	2002	
	Harrison Co PWSD1	Lake	4.7	0.09	0.04	-	2003	
		Lake and Basin	0	-	0.09	-		Storage Basin added for Volume
	Ridgeway	Rock House Lake	8.94	0.04	0.25	-	2003	
Linn	Brookfield	City Lake	1.04	-	0.21	0.23		Lake Only
		City Lake + Stream	-	-	-	0.62		Lake plus West Yellow Creek
		Supply System	-	0.67	-	0.67	2000	
	Bucklin	City Lake	0.47	0.09	0.05	0.09	2007	
	Marceline	Newer City Lake	3.73	0.45	0.41	-	2003	
		Older City Lake	0.42	0.00	0.06	-		
		Supply System	4.15	0.45	0.47	-	2003	
Randolph	Moberly	Sugar Creek Reservoir	11.05	1.54	1.20	1.54	2003	East Fork Chariton River
	Unionville	Lake Mahoney	2.97	0.38	0.28	-	2004	Supplemental connection to Lake Thunderhead (2000)
		Lake Thunderhead	22.96	-	3.36	-	2004	Private Lake not intended for water supply
Scotland	Memphis	Lake Show Me	2.66	0.42	0.78	-	2002	
		Old City Lake	1.51	0.00	0.10	-	2001	Downstream of New Lake
		Total	4.17	0.42	0.88	-	2001	
Sullivan	Green City	City Lake	1.25	0.18	0.15	-	2000	
	Milan	Elmwood Lake	6.41	1.65	0.74	1.65	2000	Locust Creek
		Golf Course Lake	1.06	0.00	0.12	0.12	2000	
		Supply System	7.47	1.65	0.85	1.77	2000	Lake and Stream
		Shatto	0.26	0.00	0.08	-	2000	Private Lake not intended for water supply

[1] Annual raw water demand based on MDNR reported use data for the year of analysis indicated in the table.

[2] The optimum yield is based on projecting the reported water demands through the drought of record and optimizing that demand to establish the optimum yield.

[3] Optimum yield with pumping is based on projecting the reported water demands through the drought of record with surface water supply augmented by an additional source (either a stream or lake).

Table 1-2 Summary of Low Flow Streams within Study Area (2011 WSS)

County	City or PWSD	Stream Name	Drainage Area Sq. Miles	Annual Demand MGD	Low Flows (7Q10)[1,2] cfs	Low Flows (7Q10)[1,2] MGD	Lowest Mean Monthly Low Flows (1 year in 50) cfs	Lowest Mean Monthly Low Flows (1 year in 50) MGD	Mean Base Flow (Year 2000) cfs	Notes
Grundy	Trenton	Thompson River	1,670	1.9	9	5.81	7.5	4.48	55	Off Channel Storage

[1)] 7-day, 10-year (7Q10) annual low-flow statistics based on an annual series of the smallest values of mean discharge computed over any 7-consecutive days of minimum flow with a 10-year recurrence interval.

[2)] According to 2011 WSS, the Thompson River discharge should exceed 9 cfs (5.81 MGD) prior to diverting water.

1.3.2 Potential Additional Sources

There are two future reservoir projects that are being planned within the Study Area: Little Otter Creek Reservoir, to be located in Caldwell County, and East Locust Creek Reservoir, to be located in Sullivan County.

While privately owned reservoirs may not be planned for additional supply it is important to note the available capacity of these private supplies; should major events such as extended drought, source supply contamination, or storage failure illicit the immediate need for additional emergency supply. The private reservoirs with available capacity within the Study Area include Lake Viking and Lake Thunderhead.

Lastly, reservoirs originally constructed for potable water supply that may not have been utilized to the full design potential, such as Long Branch Reservoir in Macon County.

1.3.2.1 *Little Otter Creek Reservoir*

Little Otter Creek Reservoir is being planned as a surface water source in the northwest Missouri region. According to the 2011 WSS, located approximately 70 miles north east of Kansas City in Caldwell County the reservoir is designed for flood control, sediment storage, recreation and water supply. Little Otter Creek Reservoir is designed to provide 1.2 MGD of potable surface water supply. The reservoir project has received local, State and Federal funding assistance, and is currently about one year away from the start of construction, with approximately a two to three year period for the reservoir to fill after construction is completed.

1.3.2.2 *East Locust Creek Reservoir*

East Locust Creek Reservoir is being planned as a surface water source in Sullivan County, located approximately 5 miles north of the City of Milan. Similar to Little Otter Creek Reservoir, East Locust is designed for flood control, sediment storage, recreation, and water supply. According to a 2015 Preliminary Engineering Report, East Locust Reservoir, will be operated by North Central Regional Water Commission (NCRWC) and is designed to provide 7 MGD of potable surface water supply. The reservoir project has received local, State, and Federal funding assistance.

1.3.2.3 *Lake Viking*

The privately owned Lake Viking is located in central Daviess County along South Big Creek, within the Grand River Basin. Lake Viking provides drinking water to a subdivision located adjacent to the Lake. Daviess Co. PWSD 3 operates the WTP and distribution system which supplies the community's average day demand of 0.05 MGD. According to the 2011 WSS, the Lake has an optimum yield of 2.46 MGD. The WSS determined that Lake Viking has sufficient supply to meet current demands during the modeled drought of record. Lake Viking is used primarily for recreational purposes. Section 1.4 presents the availability of Lake Viking in further detail.

1.3.2.4 *Lake Thunderhead*

Lake Thunderhead is located outside the City of Unionville in Putnam County along the Chariton River. The Lake is a privately owned and is not designed as a water supply reservoir; however, it has the capabilities of providing emergency water supply. According to 2011 WSS, Lake Mahoney would have

been deficient in the drought of record but with supplement from Lake Thunderhead, the Unionville demands could have been met. In 2000, a supply line was installed from Lake Thunderhead to the City of Unionville for emergency supply. Section 1.4 presents the availability of Lake Thunderhead in more detail.

1.3.2.5 *Long Branch Reservoir*

Lastly, one federal reservoir, Long Branch Reservoir, in Macon County was originally constructed for potable water supply storage and has remaining water supply storage available. Long Branch Reservoir is located outside of the City of Macon in Macon County along the East Fork Little Chariton River. The Reservoir was originally constructed with 24,400 acre-feet (AF) of storage for potable water supply. Currently about 4,400 AF of that storage is contracted by the City of Macon for water supply.

1.4 Drinking Water Sources by County

The Study Area is comprised of 99 public water systems: 68 municipal public water systems and 31 public supply districts including two NTNC water systems operated by Associated Electric and Smithfield Farmland Corporation. Of the 99 water systems within the Study Area, 21 are groundwater suppliers, 24 purchase groundwater, 13 are surface water suppliers, and 41 purchase surface water.

The total population served within the Study Area is 186,735 people. The average daily usage per capita within the Study Area is approximately 124.3 gallons per capita per day (GCPD). The rate is based on the average daily flows according to the MDNR Drinking Water Watch database and the total population served. This estimated rate does not include the population or demands of communities that did not report average daily flow values to MDNR or non-transient non-community (NTNC) water systems. The rate of 124.3 GCPD trends higher than typical residential water usage and may be due to the larger consumptive agricultural users within the Study Area.

The following section presents the water sources (groundwater and surface water) for the public water systems within the 17-county Study Area including the counties of Adair, Caldwell, Carroll, Chariton, Daviess, Grundy, Harrison, Knox, Linn, Livingston, Macon, Mercer, Putnam, Randolph, Schuyler, Scotland and Sullivan.

Adair County

Adair County is located in the eastern portion of the Study Area within north central Missouri (see Figure 1-11). There are four public water systems within Adair County: Adair Co. PWSD 1 and the cities of Kirksville, Brashear, and Novinger. Of the four public water systems, one is a surface water supplier (Kirksville) and the remaining three are all purchasers of that surface water. One system, Adair Co. PWSD 1, supplements by purchasing surface water from two systems outside of Adair County.

Figure 1-12 illustrates the supplier and customers in Adair County. Table 1-3 presents the general water system information for each system within Adair County including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR Drinking Water Watch, the four public water systems within Adair serve a total population of 25,642.

Adair 1 was designated as a selected water system. The results of the selected water system site visits are presented in Topic 4.

Current Groundwater Suppliers

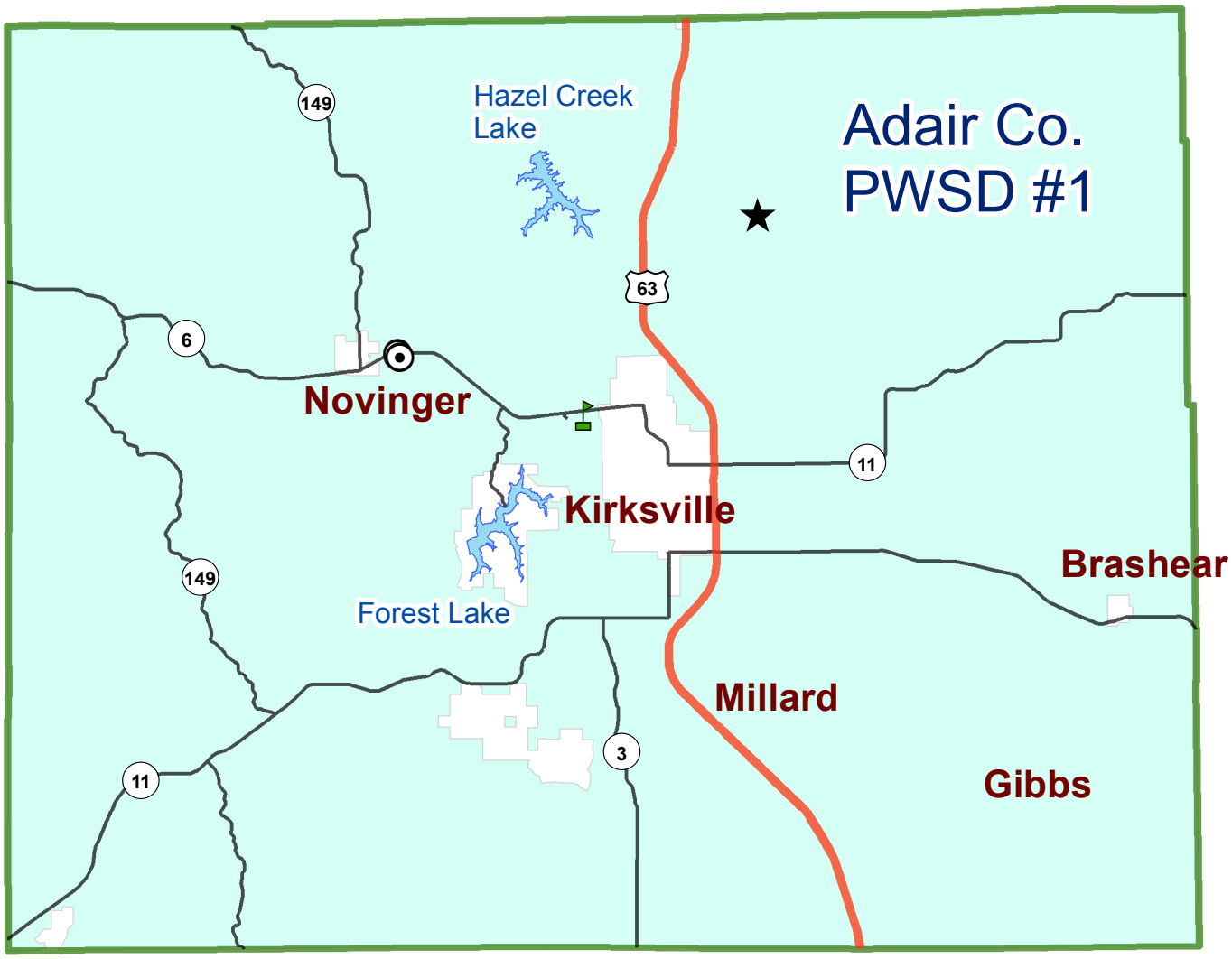
Adair County does not have any groundwater sources or have any systems that purchase from groundwater suppliers.

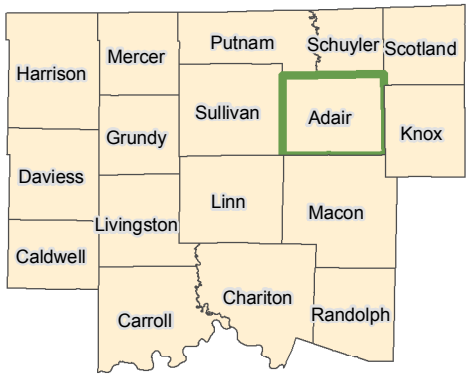
Current Surface Water Suppliers

The City of Kirksville supplies its municipality and the majority of surface water for Adair Co. PWSD 1 from two sources: Forest Lake and Hazel Creek Lake. Both reservoirs are located along Chariton River tributaries. According to the 2011 WSS, Forest and Hazel Creek Reservoirs demonstrate that Kirksville's demand will be met for the foreseeable future. Forest Lake supplies the majority of water to Kirksville. According to the 2011 WSS, the optimum yield for Forest Reservoir is 3.5 MGD.

Figure 1-13 depicts the total annual demand verses the optimum yield for Forest Lake and Hazel Creek. As part of this study, the optimum yield determined in the 2011 WSS has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the demands projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source. It should be noted that the City of Kirksville water demands in 2010 and 2011 were not included in the Major Water Users Database; therefore, these years were not included in Figure 1-13.

Adair Co. PWSD 1 purchases its remaining water supply from Schuyler Co. PWSD 1 and has an existing connection with Putnam Co. PWSD 1, although this connection is not currently being utilized. Schuyler Co. PWSD 1 and Putnam Co. PWSD 1 systems purchase surface water from Rathbun Regional Water Association in Iowa. Putnam Co. PWSD 1 also purchases additional surface water from the City of Unionville in Putnam County.





LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstate
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plant
- Well
- Selected Water System

FIGURE 1-11 ADAIR COUNTY MAP

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Kansas City District

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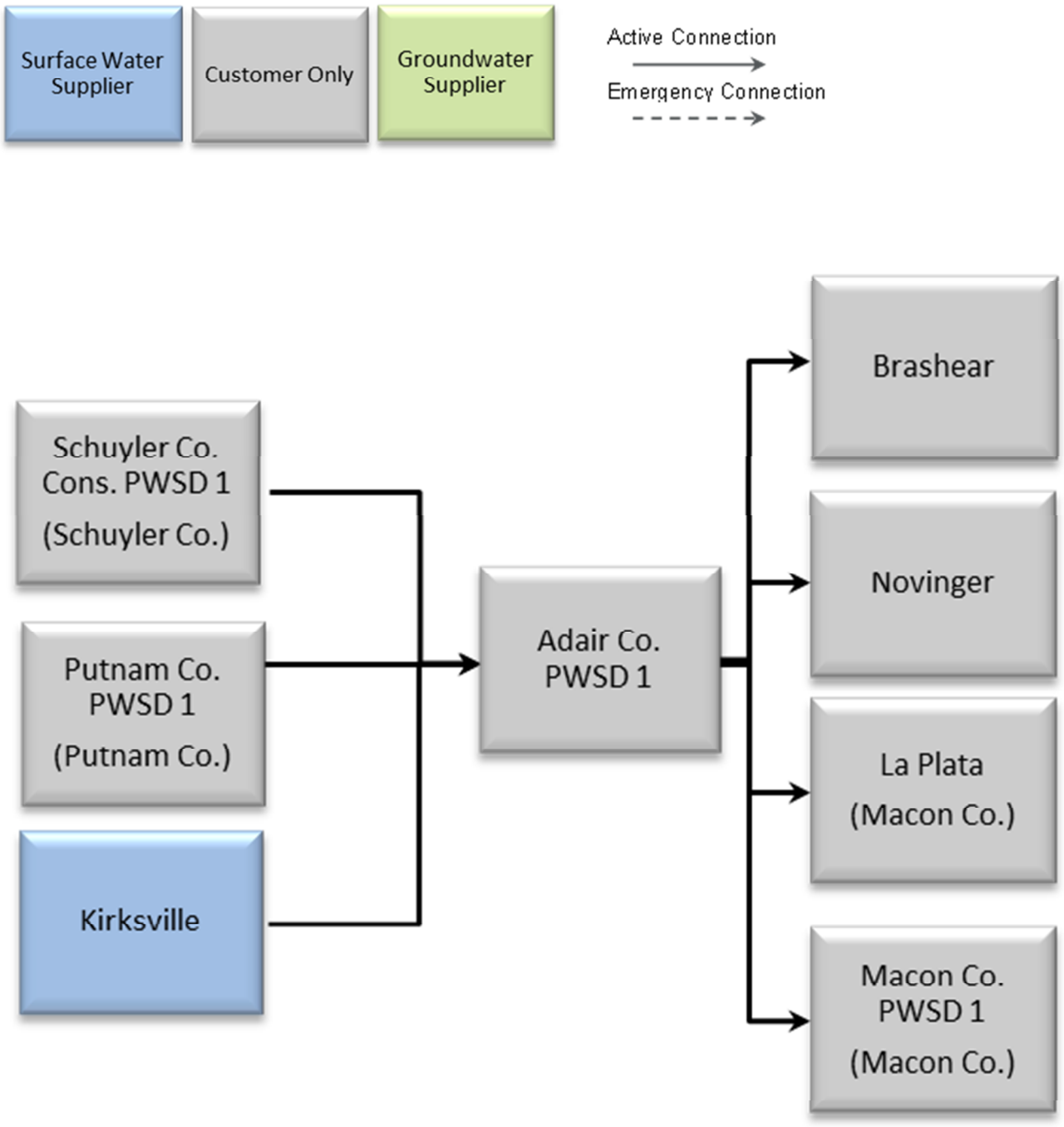


Figure 1-12 Adair County Water Suppliers and Customers

Table 1-3 Adair County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Name[2]	Source Capacity (MGD)[2]
ADAIR CO PWSD 1 MO2024000	3,027	7,500	0.64	1.07	0.17	SW Purchase		Purchase
BRASHEAR MO2010097	119	288	0.02	NR	0.02	SW Purchase		Purchase
KIRKSVILLE MO2010429	6,840	17,304	2.65	6.00	3.50	2 Lakes	Forest Lake Hazel Creek Lake	5.48
NOVINGER MO2010587	201	550	NR	NR	NR	SW Purchase		Purchase
Totals	**10,187**	**25,642**	**3.30**	**7.07**	**3.69**			

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2011 RESOP Analysis

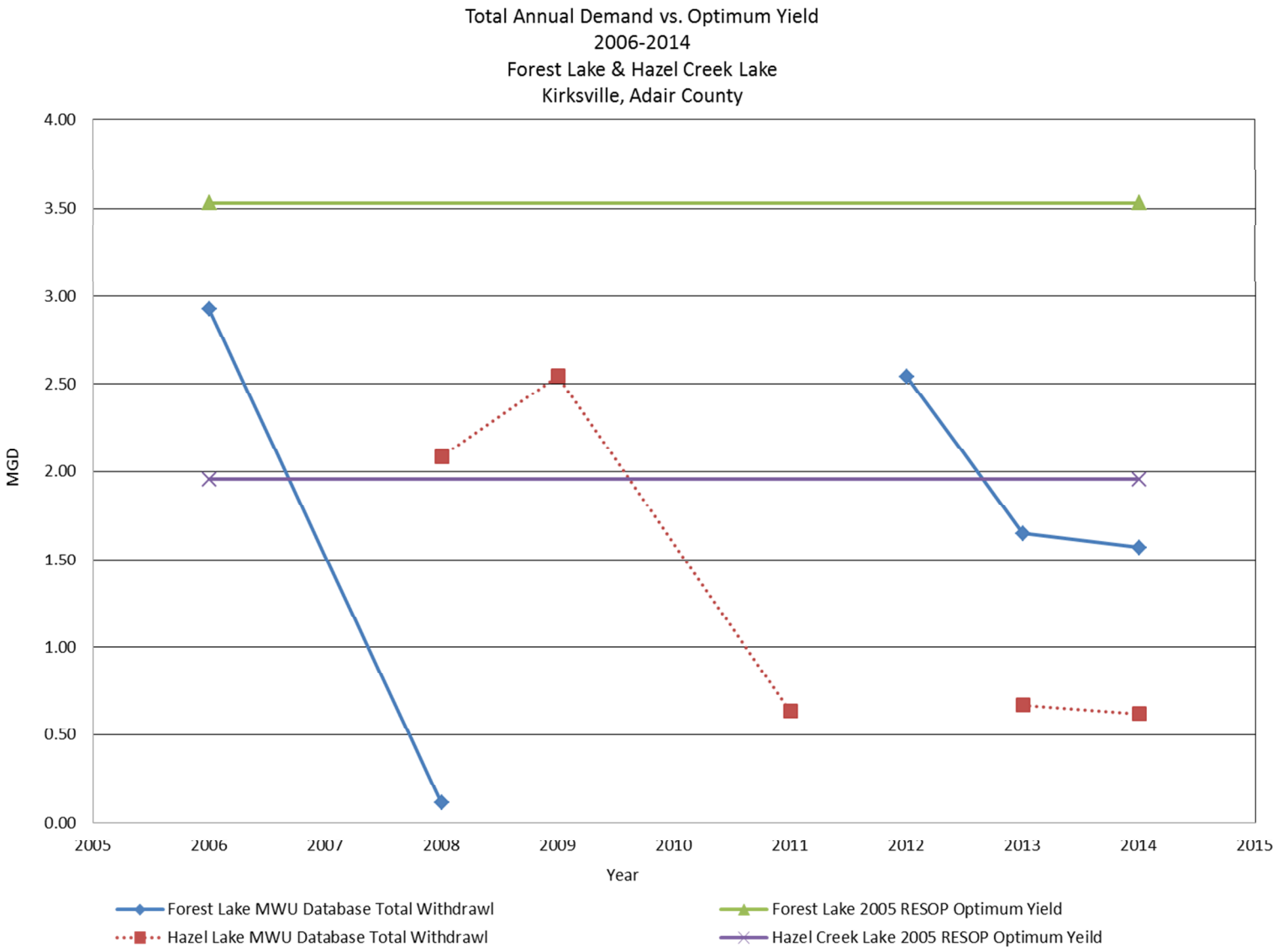


Figure 1-13 Demand Compared to 2005 Calculated Optimum Yield from Forest Lake

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

Caldwell County

Caldwell County is located within western portion of the Study Area within north central Missouri (see Figure 1-14). There are eight public water systems that fall within Caldwell County: Caldwell Co. PWSD 1, 2, and 3, the cities of Braymer, Breckenridge, Hamilton, Kingston, and Polo. Of the eight public water systems, one is a surface water supplier (Hamilton) and three are groundwater suppliers. The remaining systems purchase water supply from other sources.

Figure 1-15 illustrates the suppliers and customers within Caldwell County. Table 1-4 presents the general water system information within Caldwell County including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR Drinking Water Watch, the eight public water systems within Caldwell serve a total population of 6,328.

The City of Hamilton was designated as a selected water system. The results of the selected water system site visits are presented in Topic 4.

Current Groundwater Suppliers

According to the 2007 Groundwater Evaluation, water from the alluvium wells within Caldwell County is hard, high in iron and manganese and requires routine acidification to maintain production capacity. The evaluation concludes that the life expectancy of wells may be optimized if operated at less than seventy-five percent of rated capacity. Within the County, all groundwater sources are not considered sufficient to become regional suppliers. Groundwater sources within Caldwell are described in more detail below.

City of Braymer**:** The City of Braymer is served by four protected shallow gravel walled wells located within the floodplain. According to the 2007 Groundwater Evaluation, the Water Treatment Plant (WTP) is in need of replacement.

Caldwell County PWSD 1: The District is served by two protected shallow gravel walled wells located within the floodplain. According to the 2007 Groundwater Evaluation, the wells and WTP are in need of replacement.

City of Kingston: Kingston is served by three protected shallow gravel walled wells located within the floodplain. According to the 2007 Groundwater Evaluation, bonds have been passed for the City to fund construction of a new treatment plant, an elevated storage tank to provide required system pressures, and a new water production well.

City of Polo: The City of Polo previously utilized two protected shallow gravel walled wells. For unknown reasons, the City has modified the designation of these wells to inactive. Currently, Polo purchases groundwater from Ray Co. PWSD 3.

Current Surface Water Suppliers

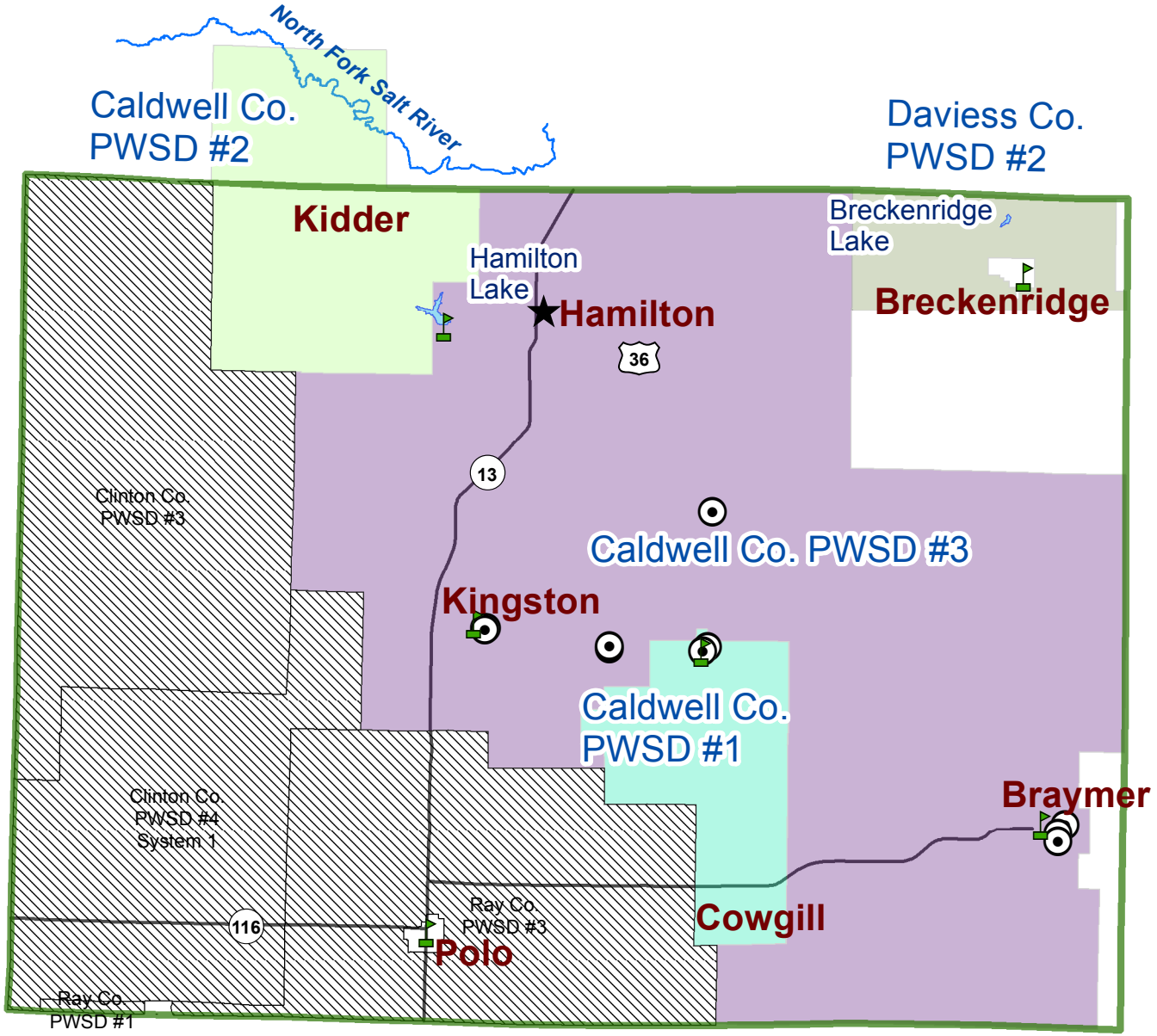
Hamilton Lake is a reservoir along Tom Creek in the Shoal Creek watershed. Shoal Creek is a major tributary to the Grand River. According to 2011 WSS, Hamilton Lake has an optimum yield of 0.19 MGD and is the primary source for the City of Hamilton. Water quality and quantity from the City-owned

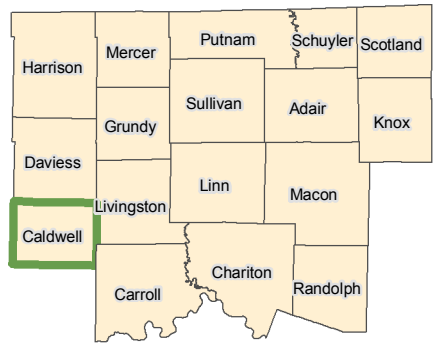
reservoir is severely cut during periods of extended drought and does not meet demands. Demands can be met by pumping water from Marrowbone Creek. Supplemental supply from Marrowbone Creek could increase the optimum yield from Hamilton Reservoir to meet the 0.26 MGD demand (2011 WSS).

Figure 1-16 depicts the total annual demand verses the optimum yield for Hamilton Reservoir. As part of this 2016 Study, the optimum yield determined in the 2011 WSS has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. It should be noted that within the year 2008 the total withdrawal from the Lake exceeded the optimum lake yield. However, the demands projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source.

Historically, the City of Breckenridge listed the Breckenridge Lake as a source. The Lake was supplemented from an adjacent groundwater well. According to the 2011 WSS, the reservoir had an optimum yield of 0.052 MGD, and the WSS concluded that the lake was not capable of meeting demands during the drought of record. Currently, the City purchases groundwater from Livingston Co. PWSD 4.

Little Otter Creek Reservoir has recently been planned as a surface water source in the northwest Missouri region. According to the 2011 WSS, the reservoir is located approximately 70 miles north east of Kansas City in Caldwell County and is designed for flood control, recreation and water supply. Little Otter Creek Reservoir is designed to provide 1.2 MGD of potable surface water supply. The reservoir project has received local support and state and federal funding assistance.





LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstate
- U.S. Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plant
- Well
- Selected Water System

FIGURE 1-14 CALDWELL COUNTY MAP

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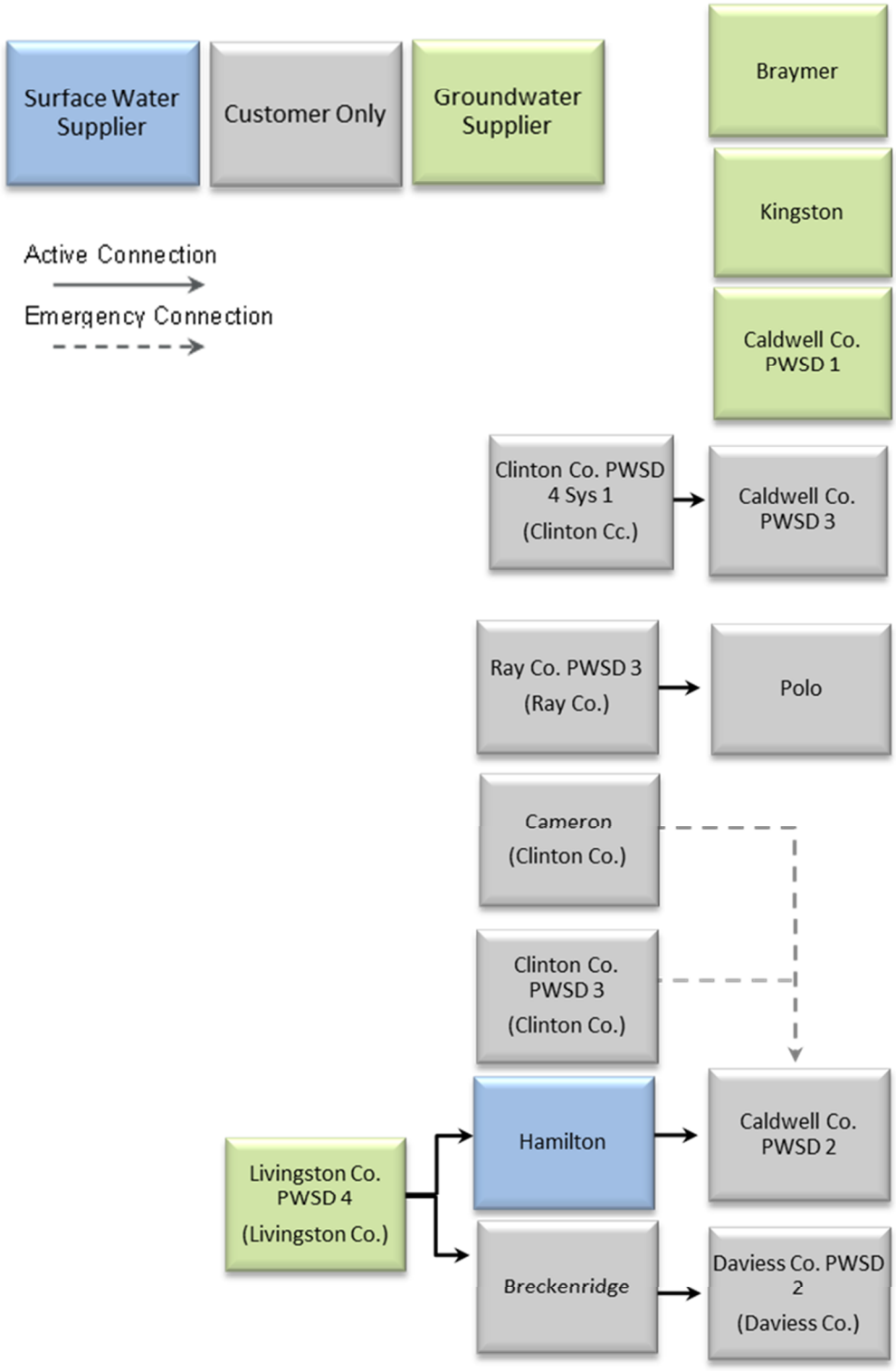


Figure 1-15 Caldwell County Water Suppliers and Customers

Table 1-4 Caldwell County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2],[3]	Source Name[2]	Source Capacity (MGD)[2],[3]
BRAYMER MO1010098	395	868	0.06	0.14	0.08	4 Wells		0.12
BRECKENRIDGE MO1010099	133	454	0.05	0.14	0.05	GW Purchase		Purchase
CALDWELL CO PWSD 1 MO1024078	160	480	0.02	0.04	0.04	2 Wells		0.07
CALDWELL CO PWSD 2 MO1024079	272	665	0.03	NR	0.03	SW Purchase		Purchase
CALDWELL CO PWSD 3 MO1021318	464	1,125	0.09	0.21	NR	SW Purchase		Purchase
HAMILTON MO1010342	824	1,813	0.24	0.58	0.44	1 Lake, 1 Creek	Hamilton Lake Marrowbone Creek	0.19
KINGSTON MO1010426	140	348	0.03	0.07	0.04	3 Wells		0.24
POLO MO1010653	245	575	0.04	0.08	0.05	GW Purchase		Purchase
Totals	**2,633**	**6,328**	**0.56**	**1.26**	**0.73**			

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2011 RESOP Analysis

[3]MDNR 2007 Groundwater System Evaluation

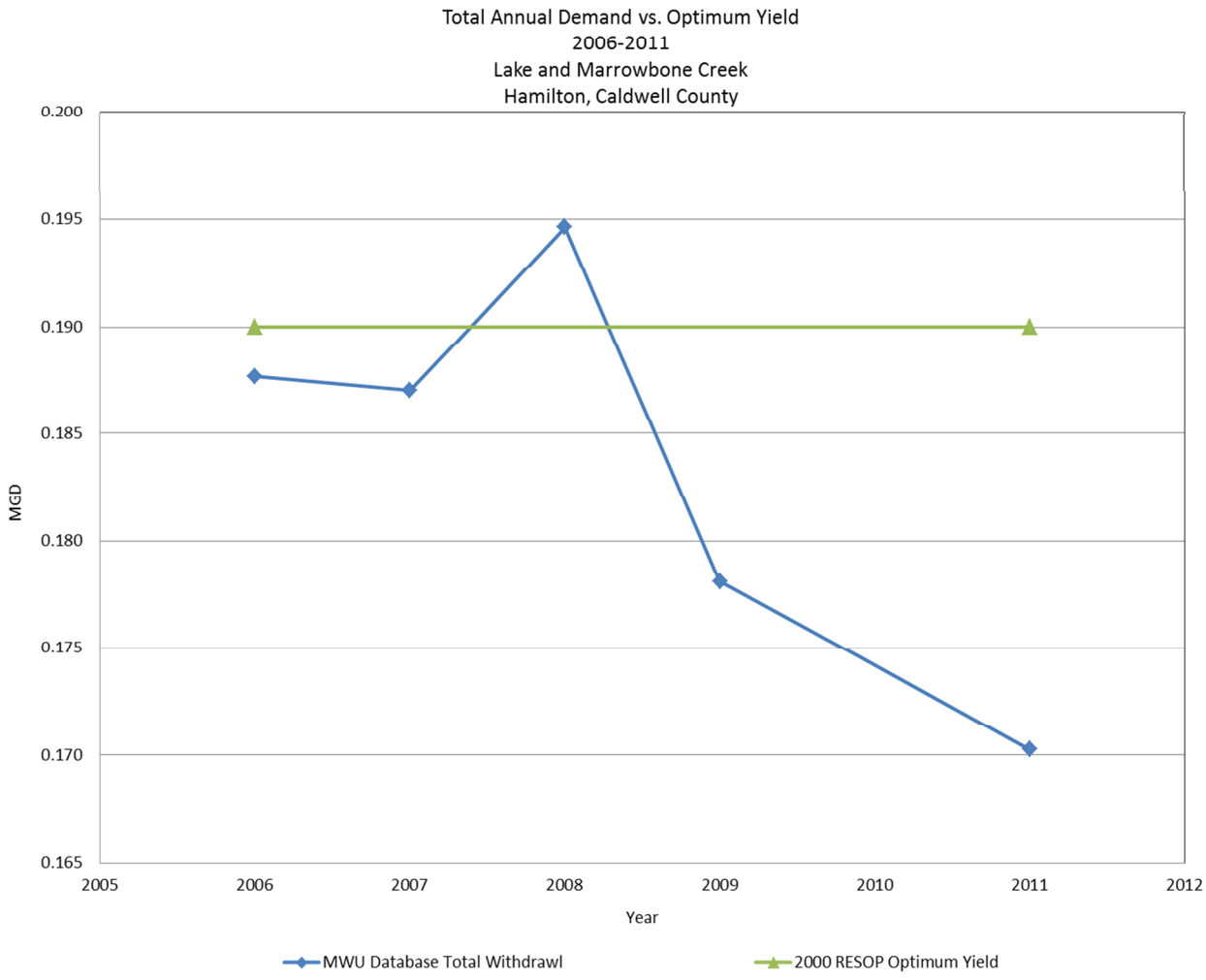


Figure 1-16 Demand Compared to 2000 Calculated Optimum Yield from Hamilton Lake and Marrowbone Creek

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

Carroll County

Carroll County is located at the most southwestern extents of the Study Area boundary (see Figure 1-17). There are eight public water systems within Carroll County: the cities of Bogard, Bosworth, Carrollton, De Witt, Hale, Norborne, Tina, and Carroll Co. PWSD 1. Of the eight public water systems, there are four groundwater suppliers. Carroll Co. PWSD 1, supplies groundwater to three water systems within the county and supplements its groundwater supply by purchasing groundwater from Livingston Co. PWSD 3. The remaining system purchases its entire supply from Livingston 3.

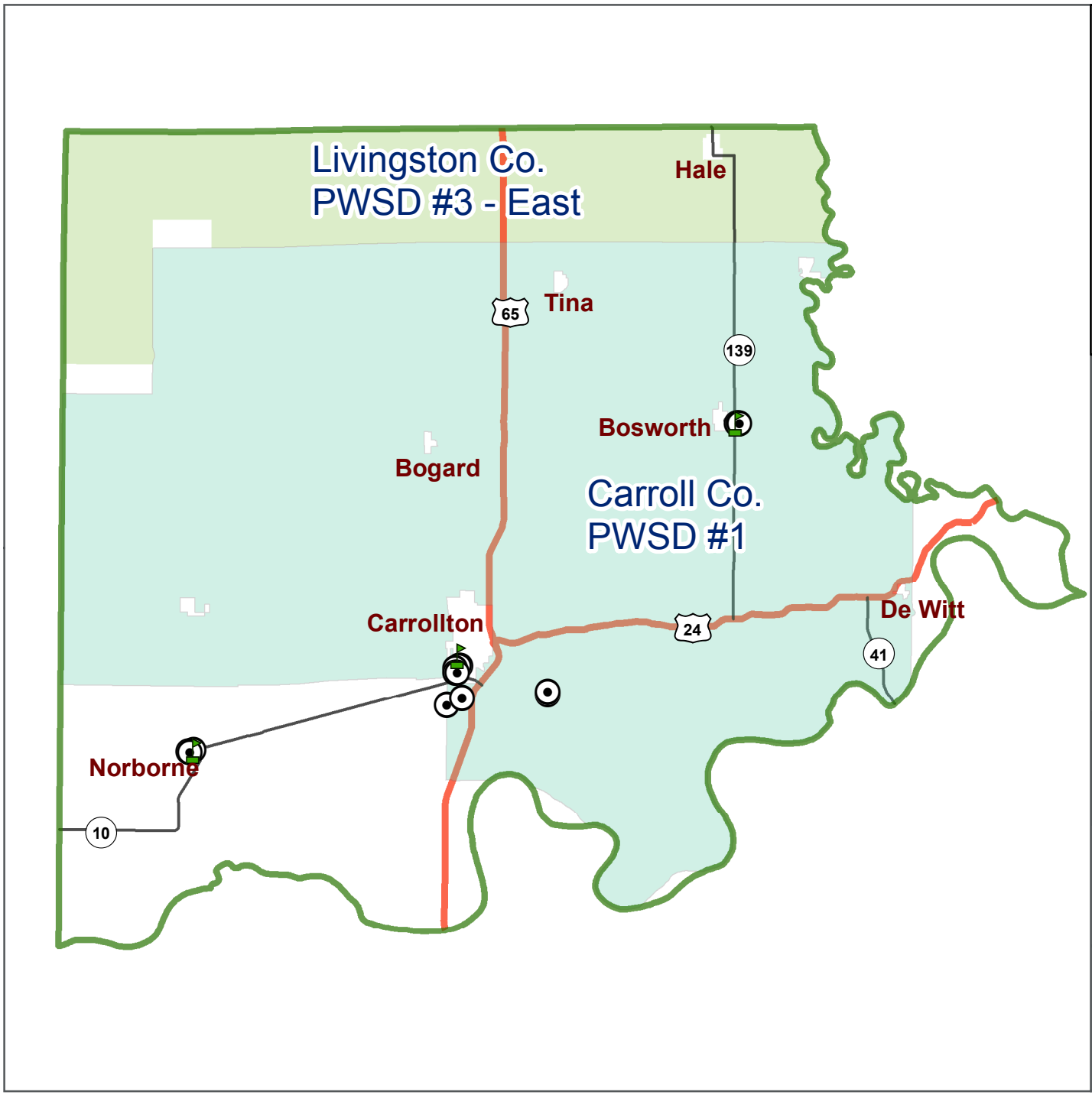
Figure 1-18 illustrates the suppliers and customers Carroll County. Table 1-5 presents the general water system information for each system within Carroll County including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to MDNR Drinking Water Watch, the 8 public water systems within Carroll serve a total population of 8,312.

Current Groundwater Suppliers

Carroll County has 4 groundwater supply systems. The cities of Carrollton, Bosworth, and Norborne each meet municipality needs with its own groundwater supply. Carroll Co. PWSD 1 provides groundwater supply to the cities of Bogard, De Witt, and Tina. The City of Hale purchases groundwater from Livingston Co. PWSD 3.

Current Surface Water Suppliers

Carroll County does not have any surface water suppliers or customers.



LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstate
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plant
- Well

FIGURE 1-17 CARROLL COUNTY MAP

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US Army Corps of Engineers ®
Kansas City District

MISSOURI NATURAL RESOURCES

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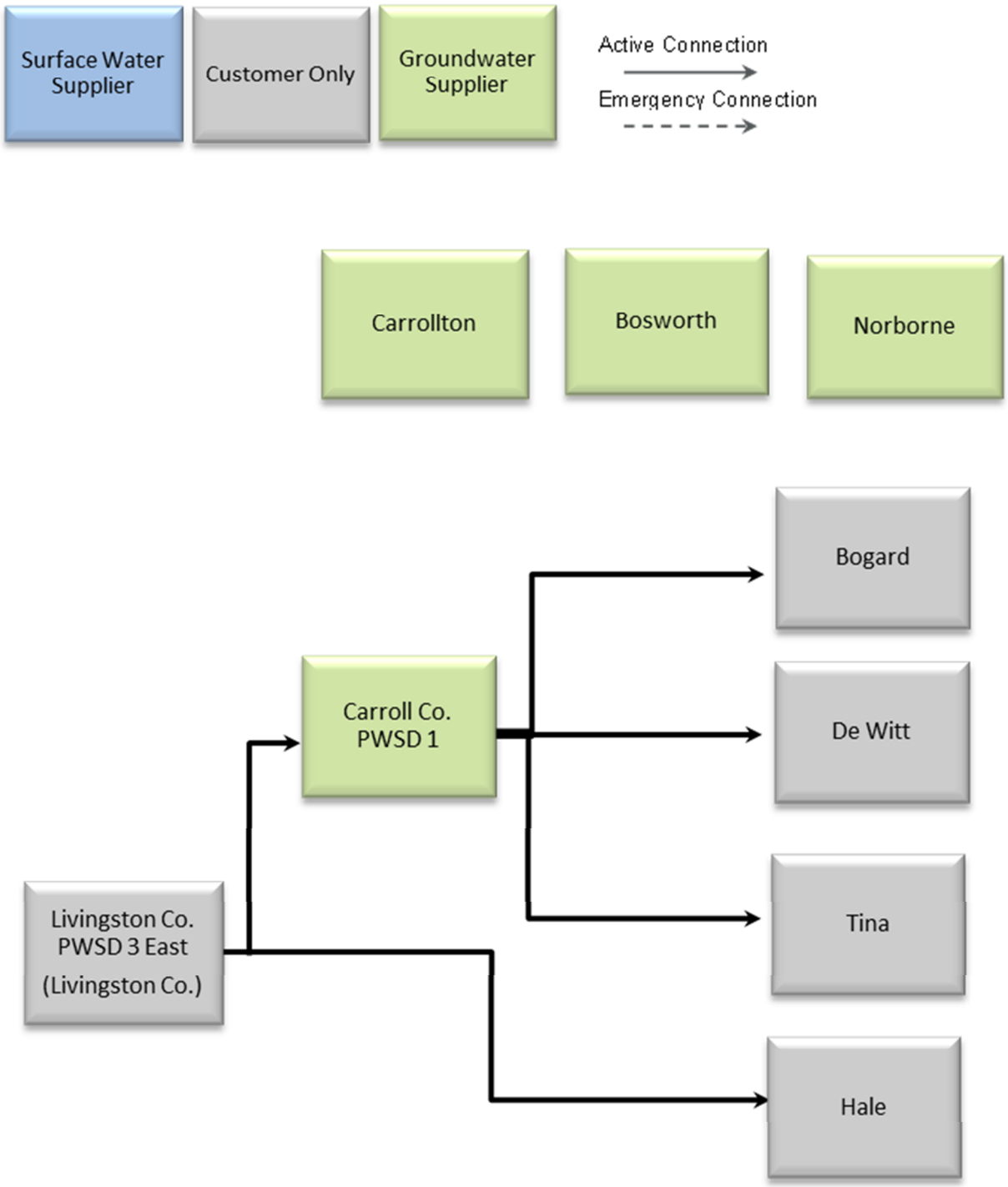


Figure 1-18 Carroll County Water Suppliers and Customers

Table 1-5 Carroll County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Capacity (MGD)[2]
BOGARD MO2010082	92	260	0.01	NR	0.01	GW Purchase	Purchase
BOSWORTH MO2010091	126	305	0.02	0.09	0.06	3 Wells	NR
CARROLL CO PWSD 1 MO2024105	1,192	2,980	0.20	0.73	0.08	2 Wells	NR
CARROLLTON MO2010140	1,767	3,300	0.60	2.40	1.40	3 Wells	NR
DE WITT MO2010215	60	125	0.01	NR	0.01	GW Purchase	Purchase
HALE MO2010338	204	480	NR	NR	NR	GW Purchase	Purchase
NORBORNE MO2010578	333	708	0.06	0.36	NR	2 Wells	NR
TINA MO2010790	78	154	0.01	NR	0.01	GW Purchase	Purchase
Totals	**3,852**	**8,312**	**0.90**	**3.58**	**1.57**		

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2007 Groundwater System Evaluation

Chariton County

Chariton County is located in the southern portion of the Study Area within north central Missouri (see Figure 1-19). There are five water systems within the Chariton County: the cities of Keytesville, Mendon, and Salisbury, and Chariton Co. PWSD 2, and a private system, Mo American Brunswick. Of the five public water systems, three are groundwater suppliers and the remaining two purchase surface water. Chariton Co. PWSD 2, which purchases groundwater from the City of Keytesville, supplements this supply by purchasing surface water from a system outside of Chariton County.

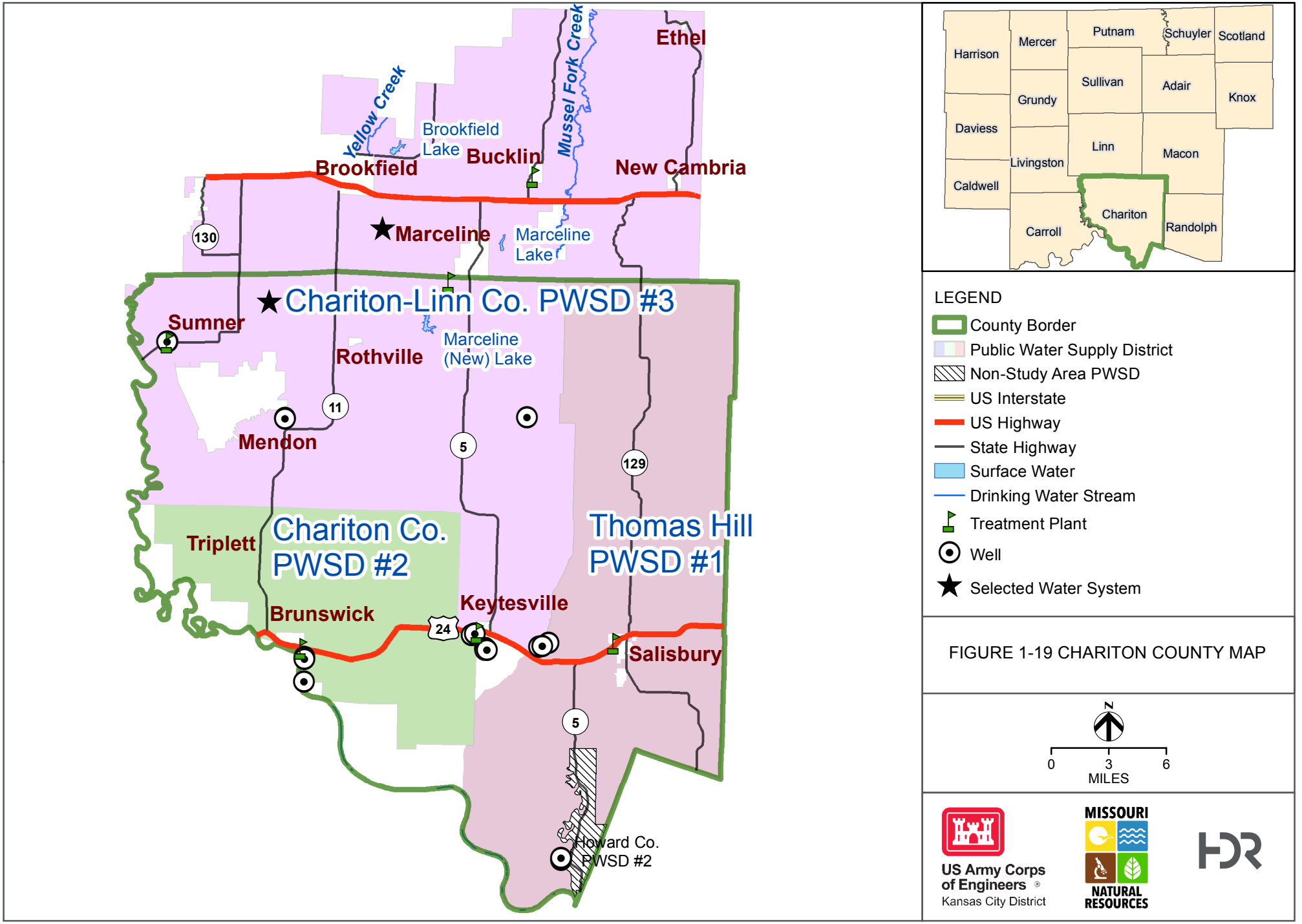
Figure 1-20 illustrates the supplier and customers Chariton County. Table 1-6 presents the general water system information for each system per DWW including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the five public water systems within Chariton County serve a total population of 4,213.

Current Groundwater Suppliers

The Missouri American Brunswick and the cities of Keytesville and Salisbury in Chariton County have groundwater sources. While the Keytesville and Salisbury average daily demands are well under treatment capacity, Mo. American Brunswick has treatment plant capacity that can accommodate only half of the average daily flow according to the MDNR Drinking Water Watch database.

Current Surface Water Suppliers

Chariton County does not have any surface water sources that provide drinking water; however, Chariton Co. PWSD 2 and the City of Mendon purchase surface water from Chariton Linn Co. PWSD 3.


Ethel
Yellow Creek
Mussel Fork Creek
Brookfield Lake
Bucklin
Brookfield
New Cambria
130
Marceline
Marceline Lake
Chariton-Linn Co. PWSD #3
Sumner
Marceline (New) Lake
Rothville
11
Mendon
5
129
Triplett
Chariton Co. PWSD #2
Thomas Hill PWSD #1
Brunswick
Keytesville
24
Salisbury
5
Howard Co. PWSD #2
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Livingston
Macon
Caldwell
Carroll
Chariton
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
Selected Water System
FIGURE 1-19 CHARITON COUNTY MAP
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US Army Corps of Engineers
Kansas City District
MISSOURI
NATURAL RESOURCES

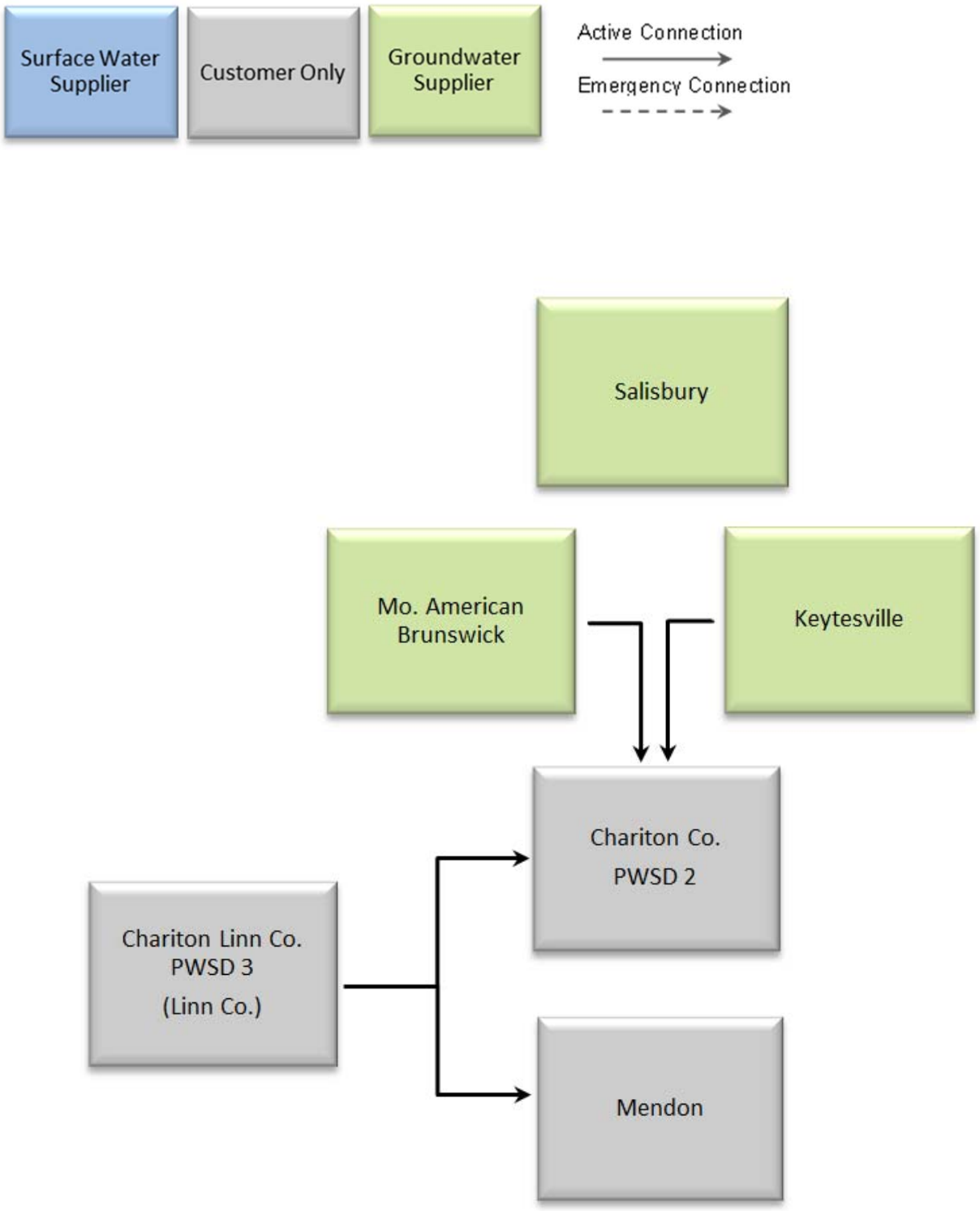


Figure 1-20 Chariton County Water Suppliers and Customers

Table 1-6 Chariton County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Capacity (MGD)[2]
CHARITON CO PWSD 2 MO2024125	443	1,078	0.05	0.14	0.11	SW Purchase	Purchase
KEYTESVILLE MO2010420	276	450	0.05	0.17	0.12	3 Wells	NR
MENDON MO2010514	122	207	0.02	0.03	0.01	SW Purchase	Purchase
MO AMERICAN BRUNSWICK MO2010109	409	858	0.84	0.43	0.29	3 Wells	NR
SALISBURY MO2010722	874	1,620	0.20	0.50	0.48	3 Wells	NR
Totals	**2,124**	**4,213**	**1.16**	**1.28**	**1.01**		

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2007 Groundwater System Evaluation

Daviess County

Daviess County is located in western portion of the Study Area within north Central Missouri (see Figure 1-21). There are nine public water systems within Daviess County: Daviess Co. PWSD 1, 2 and 3 and the cities of Altamont, Coffey, Gallatin, Jameson, Jamesport, and Pattonsburg. Of the nine public water systems, one is a surface water supplier (Daviess Co. PWSD 3) and two are groundwater suppliers. The remaining six public water supply systems either purchase from these sources or from outside of the County.

Figure 1-22 illustrates the supplier and customers in Daviess County. Table 1-7 presents the general water system information for each system within Daviess including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR Drinking Water Watch, the nine public water systems within Daviess serve a total population of 8,218.

Daviess Co. PWSD 1 was designated as a selected water system. The results of the selected water system site visits are presented in Topic 4.

Current Groundwater Suppliers

Two systems have groundwater sources in Daviess County: the cities of Gallatin and Pattonsburg. Both facilities operate wells drilled into alluvium deposits. The City of Pattonsburg also uses groundwater derived from glacial deposits. According to MDNR, water is generally hard, high in iron and commonly requires well acidification for maintenance. According to the 2007 Groundwater Evaluation, both systems have groundwater sources and treatment plants considered insufficient to become regional suppliers.

City of Gallatin: According to the 2007 Groundwater Evaluation, the city is served by two shallow gravel walled wells drilled into pre-glacial stream channels. A third well is not utilized due to low production. It is difficult and costly to establish additional wells; however, the Groundwater Evaluation concludes that at least one additional well is needed to meet current demand and the treatment plant requires renovations to meet current demands. The City currently supplies groundwater to Daviess Co. PWSD 2.

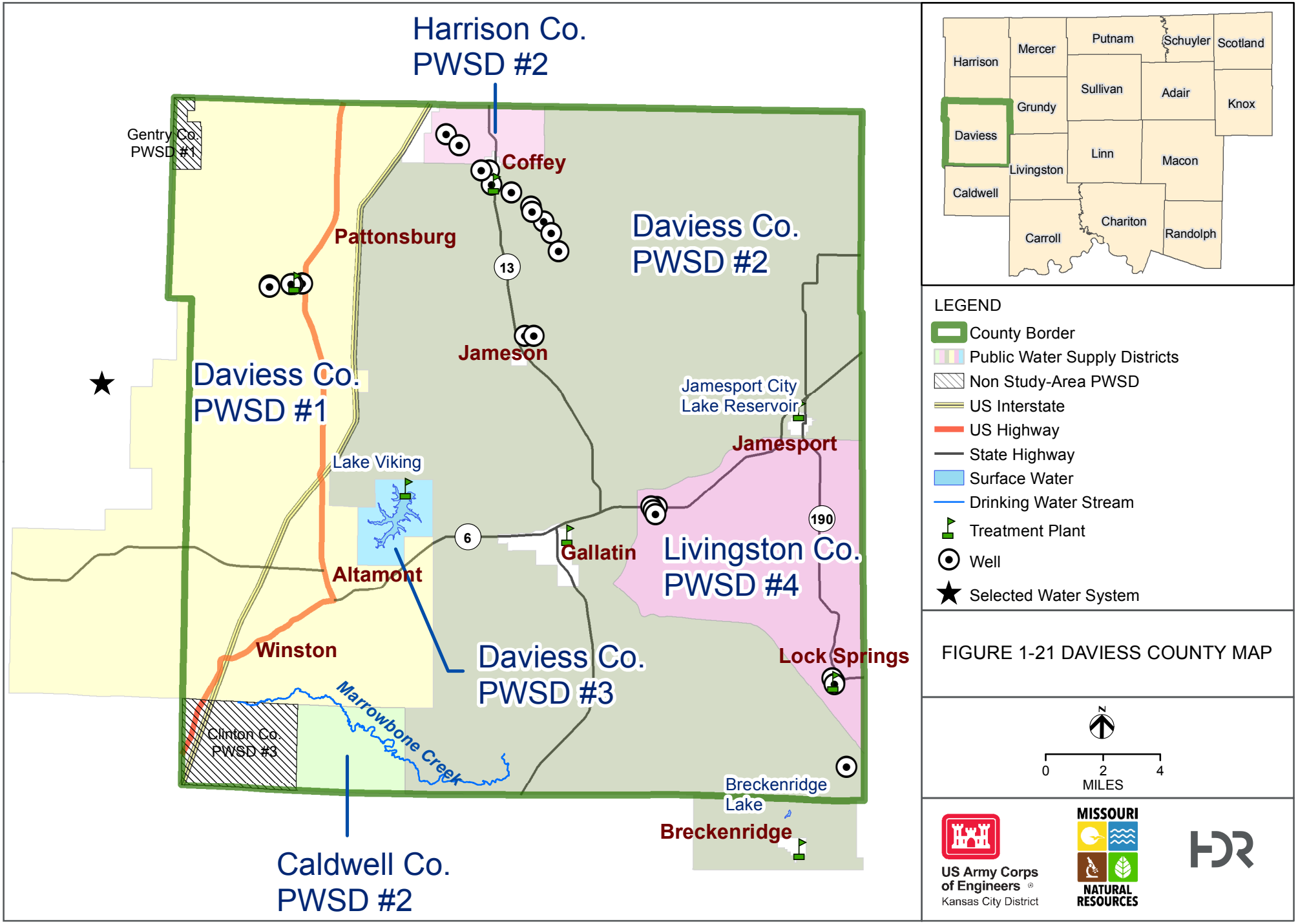
City of Pattonsburg: The City of Pattonsburg is served by four protected shallow gravel walled wells located within the floodplain. According to the 2007 Groundwater Evaluation, three additional wells have been abandoned due to low production but the WTP is in fair physical condition. The groundwater source is currently capable of meeting production needs. The City of Pattonsburg currently sells to Daviess Co. PWSD 1 which then supplies the City of Altamont.

Current Surface Water Suppliers

Daviess County has two surface water reservoirs: Lake Viking and the Jamesport Reservoir. The privately owned Lake Viking, located in central Daviess County, is operated by Daviess Co. PWSD 3 and provides drinking water supply to a community subdivision only. The community has an average day demand of 0.05 MGD. The lake is located along South Big Creek within the Grand River Basin. According to 2011 WSS, the Lake has an optimum yield of 2.46 MGD and sufficient supply to meet the current demands during the modeled drought of record. Lake Viking is used primarily for recreational purposes.

Figure 1-23 depicts the total annual demand verses the optimum yield for Lake Viking. As part of this study, the optimum yield determined in the 2011 WSS has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the demands projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source.

Jamesport Reservoir is located in east central Daviess County, two miles north of the City of Jamesport. The Reservoir previously served Jamesport. Currently, the Jamesport Reservoir is listed as *inactive* on the MDNR Drinking Water Watch database. Jamesport currently purchases groundwater from Livingston Co. PWSD 4.


Harrison Co.
PWSD #2
Gentry Co.
PWSD #1
Coffey
Pattonsburg
Daviess Co.
PWSD #2
13
Jameson
Daviess Co.
PWSD #1
Jamesport City
Lake Reservoir
Jamesport
Lake Viking
6
Gallatin
190
Livingston Co.
PWSD #4
Altamont
Winston
Daviess Co.
PWSD #3
Lock Springs
Marrowbone Creek
Clinton Co.
PWSD #3
Breckenridge
Lake
Breckenridge
Caldwell Co.
PWSD #2
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Livingston
Linn
Macon
Caldwell
Carroll
Chariton
Randolph
LEGEND
County Border
Public Water Supply Districts
Non Study-Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
Selected Water System
FIGURE 1-21 DAVIESS COUNTY MAP
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MILES
US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES
HDR

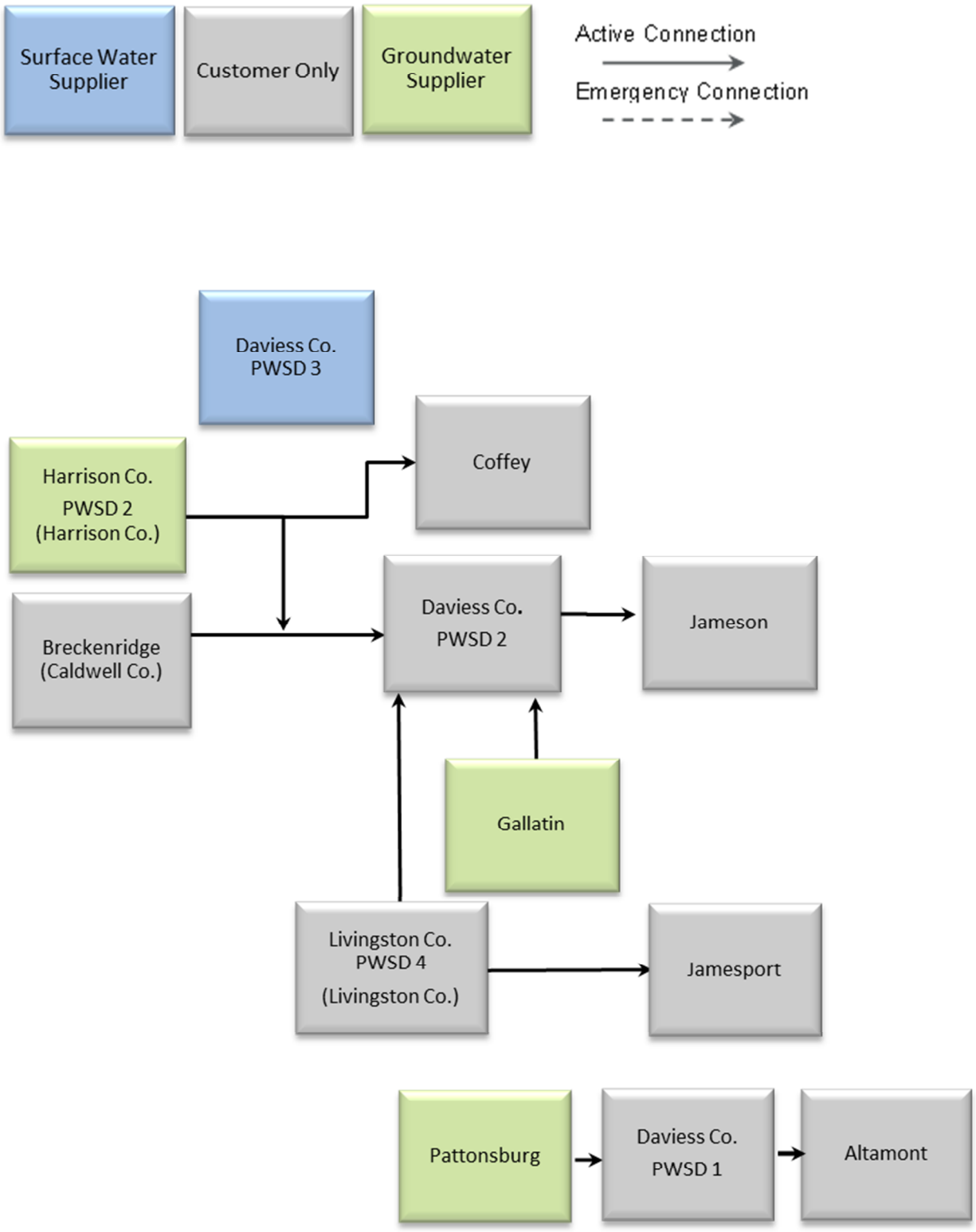


Figure 1-22 Daviess County Water Suppliers and Customers

Table 1-7 Daviess County – Water System Information

System/ID #	Connections [1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2],[3]	Source Name [2]	Source Capacity (MGD)[2],[3]
ALTAMONT MO1010010	75	200	0.01	NR	0.03	GW Purchase		Purchase
COFFEY MO1010179	76	85	0.01	0.09	0.05	GW Purchase		Purchase
DAVIESS CO PWSD 1 MO1024186	858	2,062	0.10	NR	0.29	GW Purchase		Purchase
DAVIESS CO PWSD 2 MO1021080	842	2,800	0.11	NR	0.11	GW Purchase		Purchase
DAVIESS CO PWSD 3 MO1036130	624	337	0.05	0.20	0.05	1 Lake	Lake Viking	2.46
GALLATIN MO1010299	813	1,761	0.23	0.72	0.10	3 Wells		NR
JAMESON MO1010405	60	121	0.01	0.04	0.03	GW Purchase		Purchase
JAMESPORT MO1010406	330	524	0.04	0.14	0.08	GW Purchase	Jamesport Reservoir	Purchase
PATTONSBURG MO1010632	153	328	0.24	0.03	0.13	5 Wells		1.01
Totals	**3,831**	**8,218**	**0.79**	**1.22**	**0.86**			

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2011 RESOP Analysis

[3]MDNR 2007 Groundwater System Evaluation

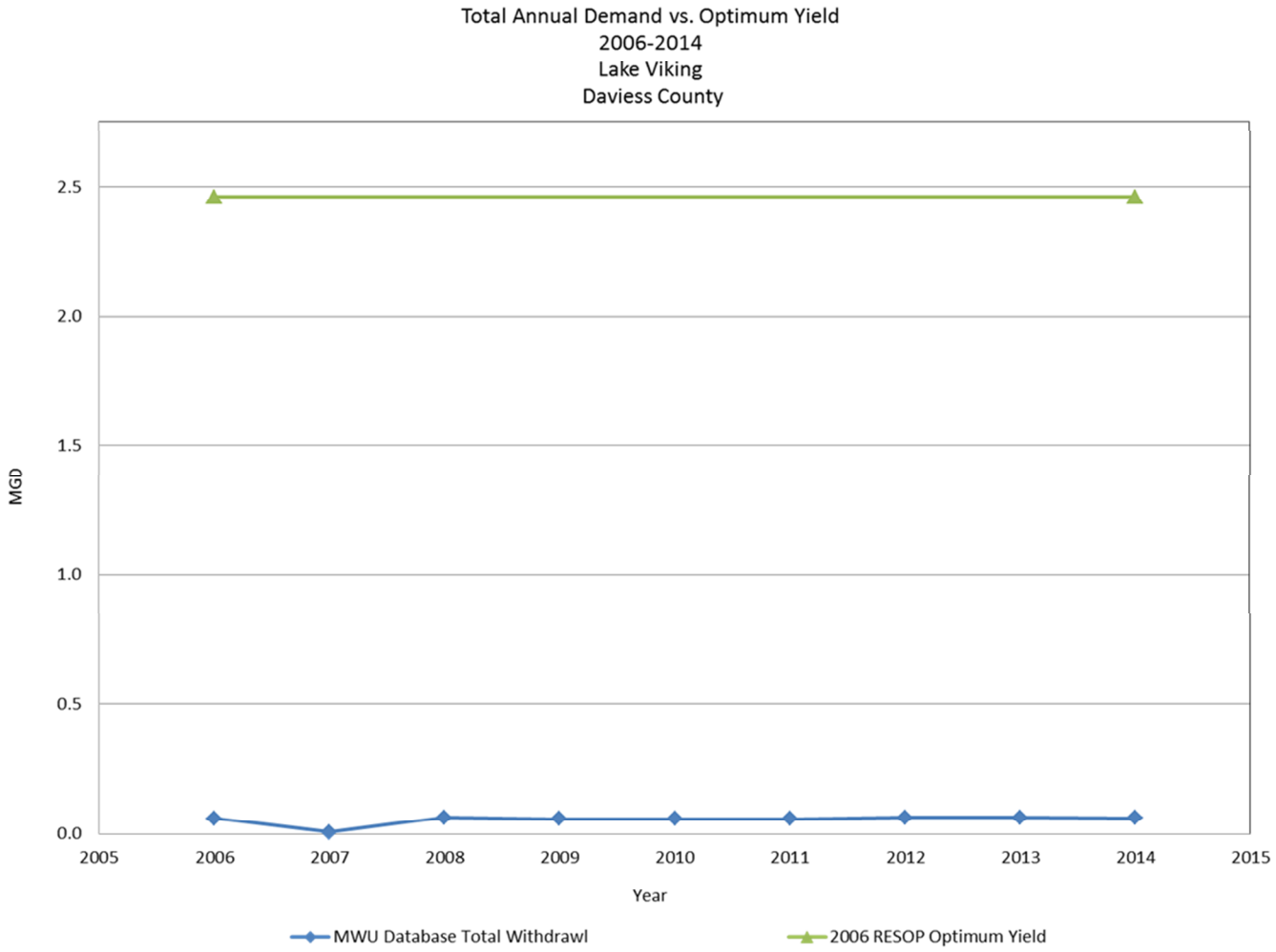


Figure 1-23 Demand Compared to 2006 Calculated Optimum Yield from Lake Viking

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

Grundy County

Grundy County is located in west central portion of the Study Area within northern Missouri (see Figure 1-24). There are five public water systems within Grundy County: Grundy Co. PWSD 1, and the cities of Trenton, Galt, Laredo, and Spickard. Figure 1-25 illustrates the suppliers and customers in Grundy County. Of the five public water systems, one is a surface water supplier (Trenton) and the remaining four are purchasers of either surface water or groundwater. One system, Laredo, purchases groundwater from a system outside of Grundy County.

Table 1-8 presents the general water system information for each system within Grundy including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the five public water systems within Grundy serve a total population of 10,519.

Trenton Municipal Utilities was designated as a selected water system. The results of the selected water system site visits are presented in Topic 4.

Current Groundwater Suppliers

Grundy County does not have any groundwater sources that provide drinking water. The City of Laredo purchases groundwater from Linn Livingston Co. PWSD 3.

Current Surface Water Suppliers

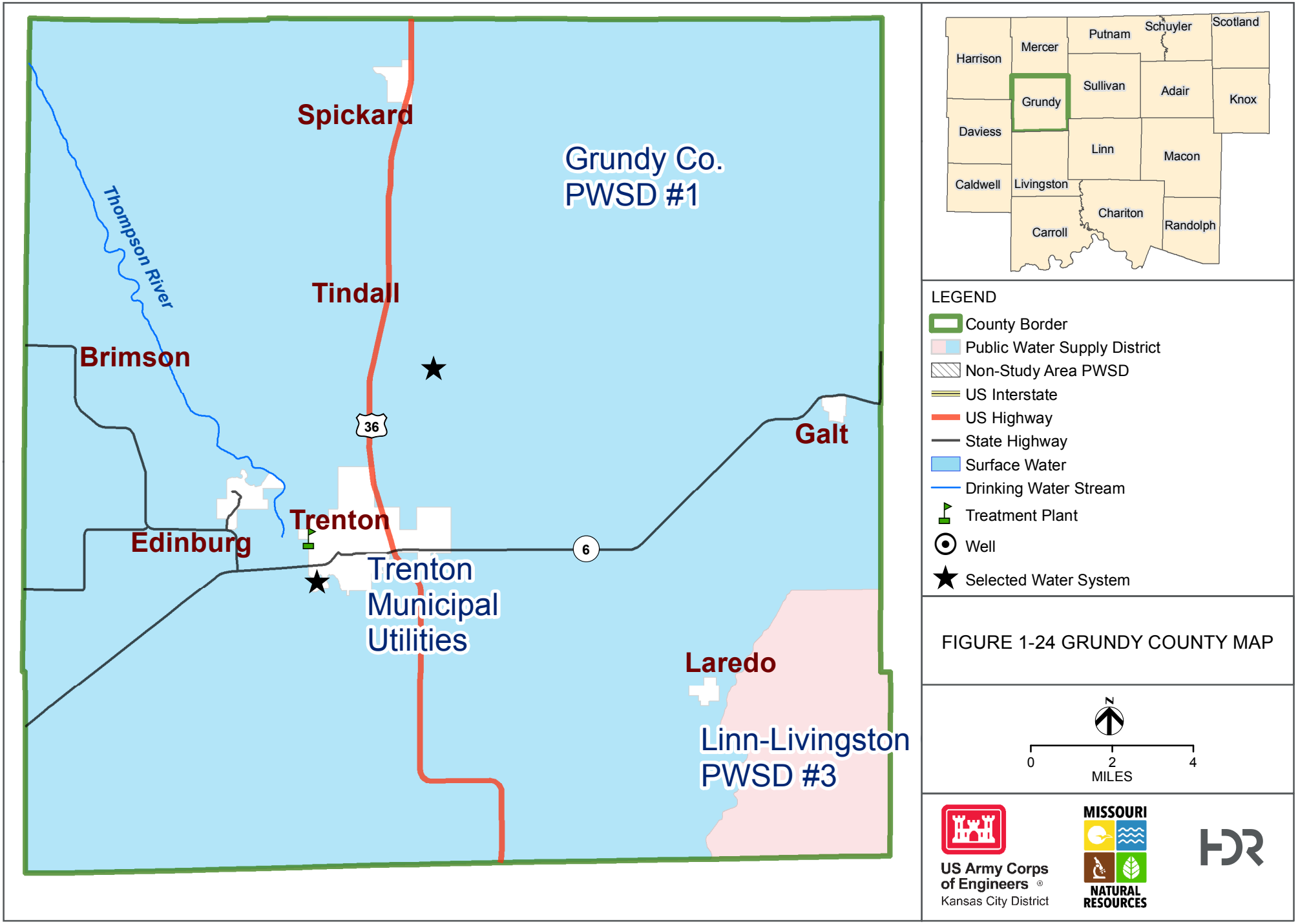
The Thompson River currently supplies surface water in Grundy County. It is the largest tributary of the Grand River, located just outside of the City of Trenton. Trenton Municipal Utilities (TMU) has two raw storage reservoirs, with a combined storage volume of 164.5 million gallons (MG), which are filled by the Thompson River. TMU provides finished surface water to its municipality customers and to Grundy Co. PWSD 1.

The minimum in-stream flow requirements (7Q10) for the Thompson River was determined as part of the 2011 WSS to be 9 cfs (5.81 MGD). Figure 1-26 depicts the flow deficit for Thompson River resulting from meeting the 7Q10 and the municipal demand during 1-percent chance non-exceedance flows. The 1-percent chance non-exceedance flows or 1 year in 100 low flows were established in the 2011 WSS from stream flow data for the years 1950 through 2000. As part of this study, mean daily flow determined in the 2011 WSS has been overlain with the 7Q10 requirement and more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the updated demands were not analyzed using HYSEP, it is merely an aide to the reader to better understand the availability of the source.

According to the 2011 WSS HYSEP analysis, during the drought of record there were five 30 day periods that flow in the River was not adequate to allow for pumping; however, storage of raw water in the reservoirs was sufficient to meet the City demands during these periods.

Trenton was designated as a selected water system. The selected system site visit was performed on September 21, 2015. It was noted the configuration of the raw water storage tanks must be modified to

eliminate short circuiting. The system may also benefit from additional raw water intakes at higher river levels.


Spickard
Grundy Co.
PWSD #1
Thompson River
Tindall
Brimson
36
Galt
Trenton
Edinburg
6
Trenton
Municipal
Utilities
Laredo
Linn-Livingston
PWSD #3
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Randolph
Carroll
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
Selected Water System
FIGURE 1-24 GRUNDY COUNTY MAP
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US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES
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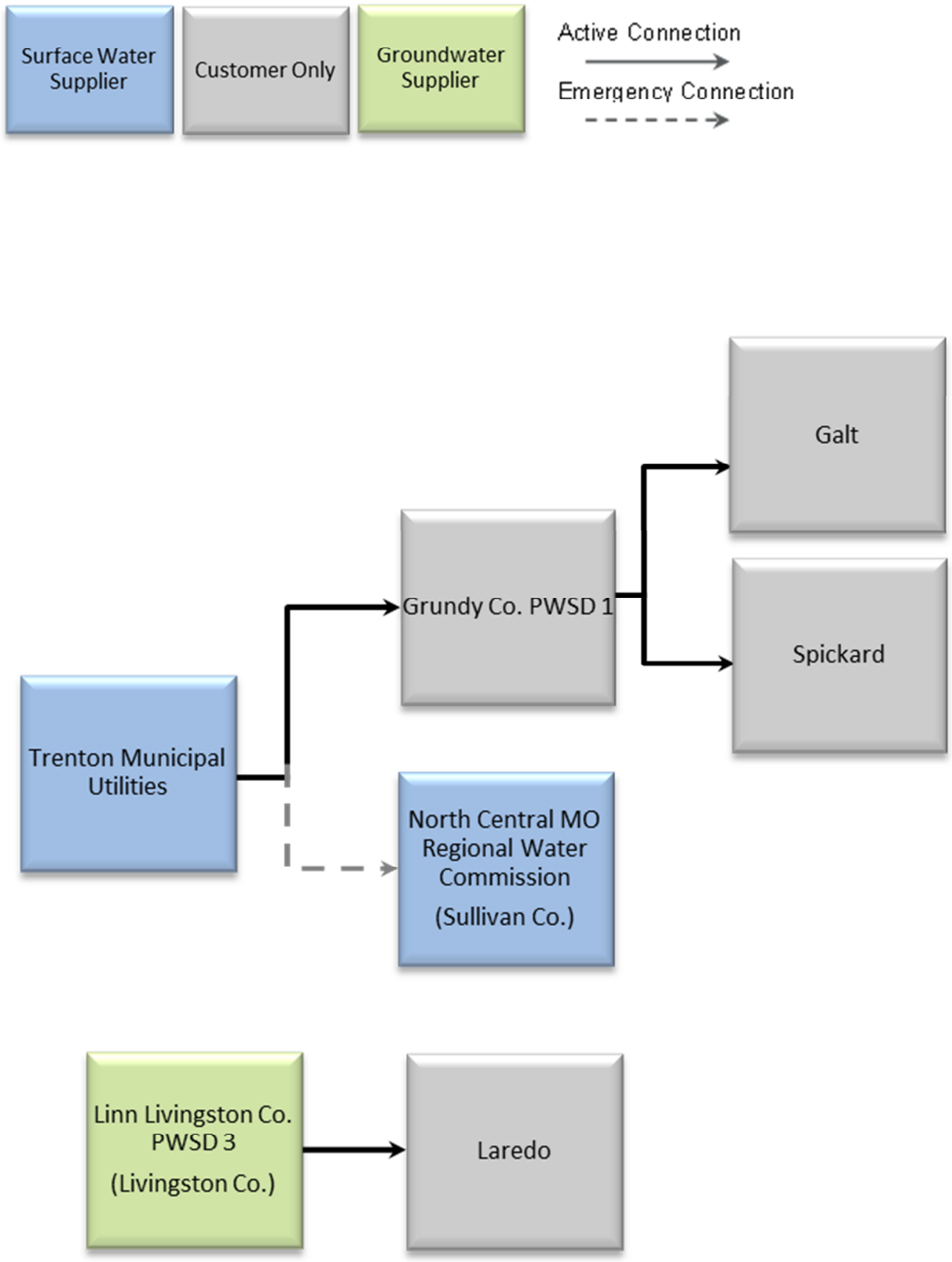


Figure 1-25 Grundy County Water Suppliers and Customers

Table 1-8 Grundy County – Water Supply Information

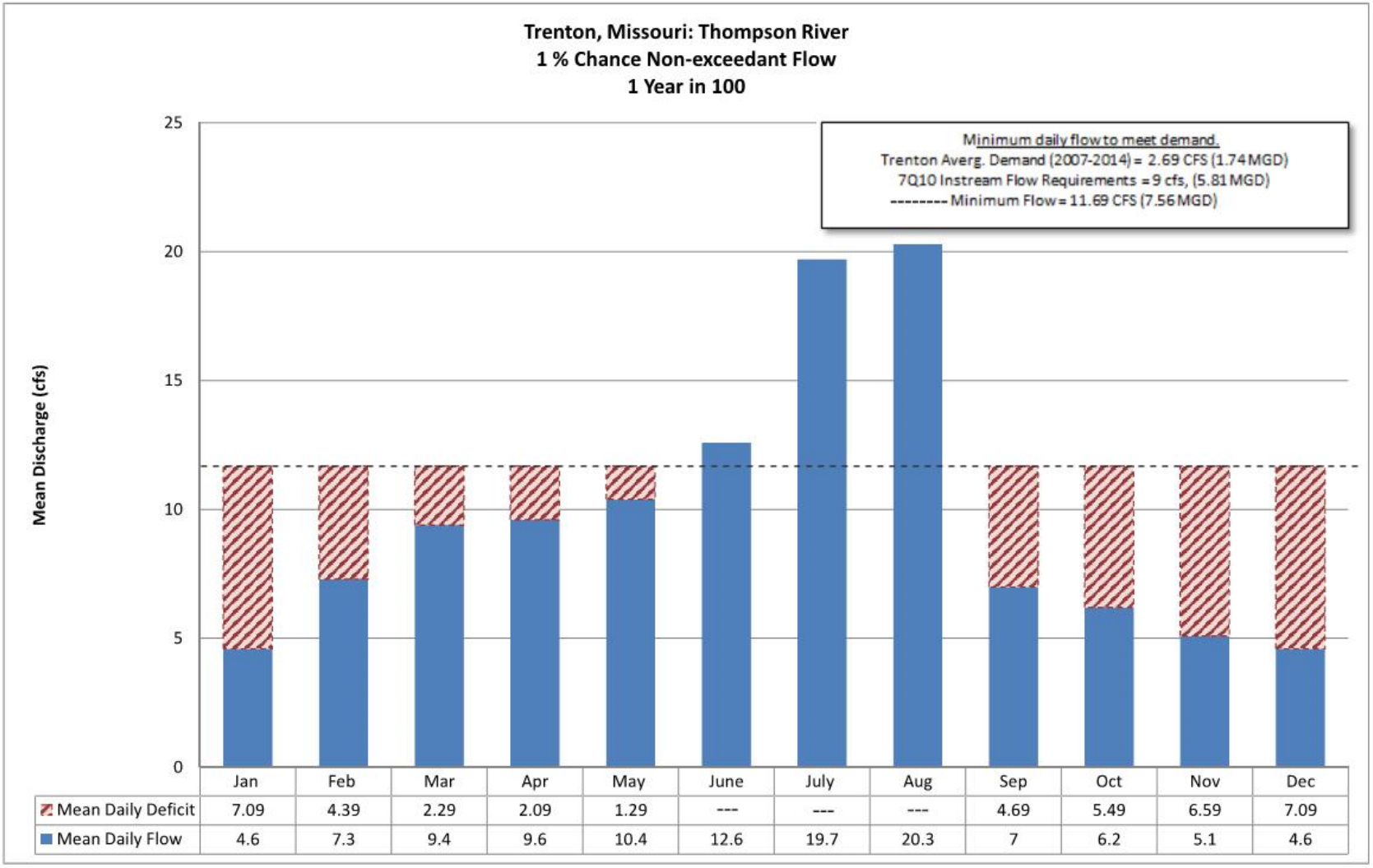
System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Name[2]	Source Capacity (MGD)[2]
GALT MO2010300	111	253	0.02	NR	0.02	SW Purchase		Purchase
GRUNDY CO PWSD 1 MO2024237	1,487	3,710	0.29	0.60	0.65	SW Purchase		Purchase
LAREDO MO2010452	98	240	0.01	NR	0.02	GW Purchase		Purchase
SPICKARD MO2010753	127	315	0.03	NR	0.03	SW Purchase		Purchase
TRENTON MUNICIPAL UTILITIES MO2010796	2,750	6,001	1.66	4.50	2.86	1 River	Thompson River	Variable*
Totals	**4,573**	**10,519**	**2.01**	**5.10**	**3.58**			

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2011 WSS Analysis

* According to 2011 WSS, the Thompson River discharge should exceed 9 cfs (5.81 MGD) prior to diverting water.



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Mean Daily Deficit	7.09	4.39	2.29	2.09	1.29	---	---	---	4.69	5.49	6.59	7.09
Mean Daily Flow	4.6	7.3	9.4	9.6	10.4	12.6	19.7	20.3	7	6.2	5.1	4.6

Figure 1-26 Demand and 7Q10 Compared to 1% Chance Non-Exceedance Daily Flow in the Thompson River

Note: The in-stream flows projected above were not analyzed using HYSEP. It is merely an aide to better understand the availability of the source.

Harrison County

Harrison County is located within the northwestern portion of the Study Area in north central Missouri (see Figure 1-27). There are seven public water systems that fall within Harrison County: Harrison Co. PWSD 1, 2 and the cities of Bethany, Cainsville, Gilman City, New Hampton, and Ridgeway. Of the seven public water systems, one is a surface water supplier (Bethany), one is a groundwater supplier (Harrison 2), and the remaining five purchase groundwater.

Figure 1-28 illustrates the suppliers and customers within Harrison County. Table 1-9 presents the general water system information for each system within Harrison including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the seven public water systems within Harrison serve a total population of 8,220.

Current Groundwater Suppliers

Harrison Co. PWSD 2 is the only groundwater supplier for Harrison County and supplies six systems: Cainsville, Ridgeway, Gilman City, Harrison Co. PWSD 1, Coffey (Daviess County), and Daviess Co. PWSD 2. The Harrison 2 WTP is located in Daviess County. Groundwater is pumped from nine protected gravel walled wells are drilled into alluvium, glacial, and bedrock deposits. The wells require routine acidification to maintain capacity. According to the 2007 Groundwater Evaluation, water levels measured in all production wells have steadily decreased since construction.

The 2007 Groundwater Evaluation states that establishing additional wells within Harrison County is challenging and costly. Additionally, there are concerns of low aquifer water levels. According to the 2001 Geology and Hydrology Report, a potential issue for drilling new sources may be interference caused by wells installed in too close of a proximity to one another. Optimum well performance can be achieved if wells are operated at less than seventy five percent of rated capacity. The Groundwater Evaluation concludes that the sources of Harrison Co. PWSD 2 and the treatment plant are considered insufficient for the District to expand supply as a regional water supplier.

Current Surface Water Suppliers

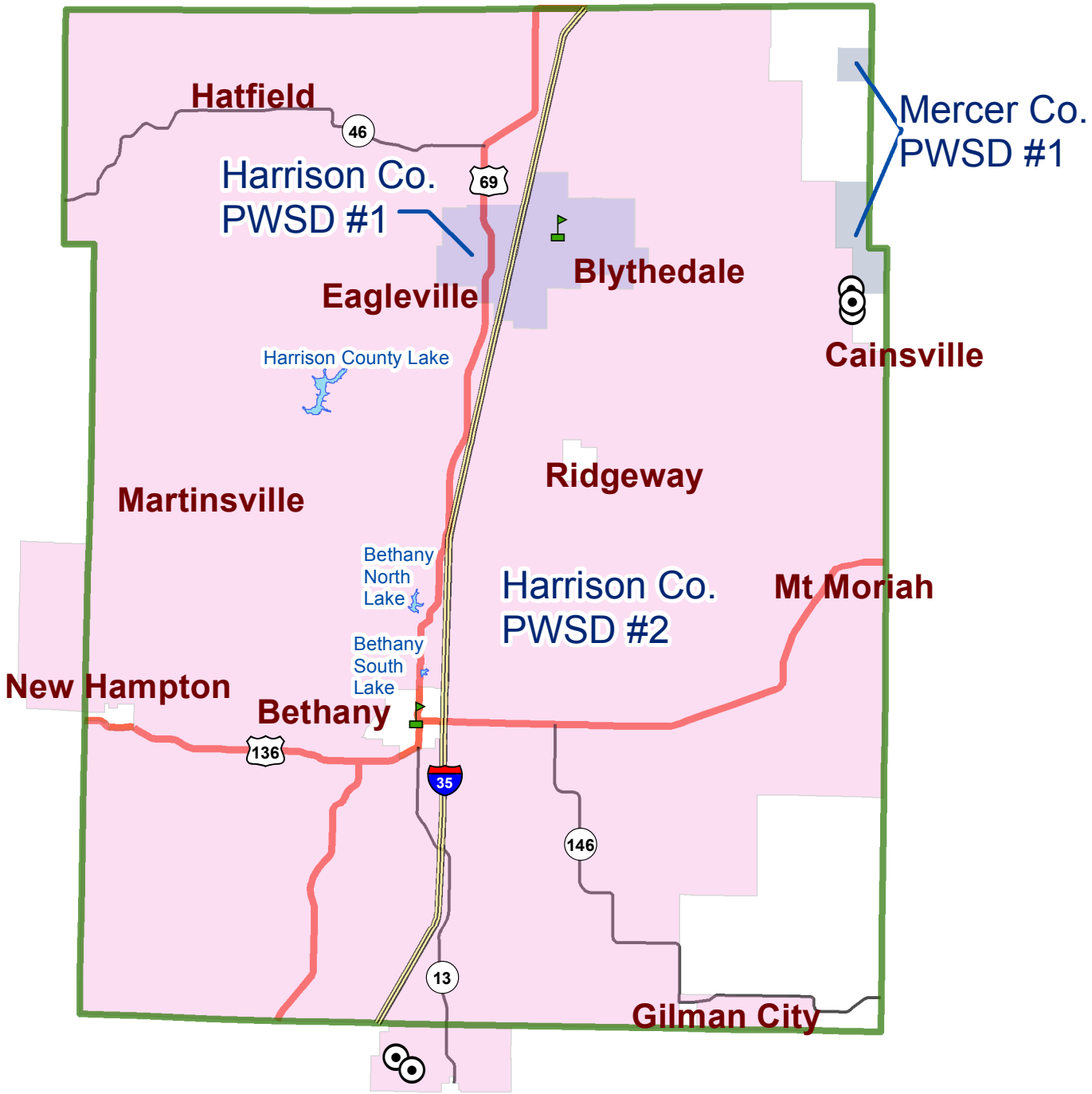
Harrison County is located in the Grand River basin, the largest tributary of the Missouri River in the State. There are three reservoirs within Harrison County: Harrison County Lake, Bethany North Lake, and Bethany South Lake. The Lakes are the primary source of water for the City of Bethany. Water is transferred from the Harrison County Lake and the Bethany North Lake to the Bethany South Lake. The Treatment Plant treats water conveyed from the South Lake. According to the 2011 WSS RESOP analysis, the Harrison County Lake has an optimum yield of 0.59 MGD. If the recreation allocation of the Lake is utilized for potable water supply, the optimum yield would increase to 1.32 MGD. North and South Bethany Lakes have optimum yields of 0.175 MGD and 0.051 MGD, respectively. According to the 2011 WSS RESOP analysis, Harrison County Lake meets current demands during the drought of record.

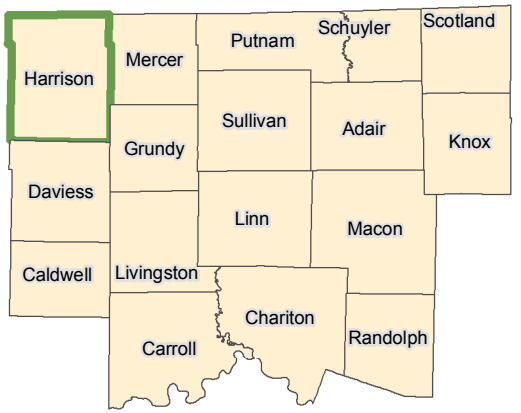
Figure 1-29 depicts the total annual demand verses the optimum yield for all three lakes. As part of this study, the optimum yield determined in the 2011 WSS has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the demands

projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source.

Rockhouse Lake is located near the City of Ridgeway and was built as part of the NRCS Panther Creek (PL-566) watershed project. At one time, Rockhouse Lake was the water source for Ridgeway. However, Ridgeway currently purchases groundwater from Harrison Co. PWSD 2. The designation of Rockhouse Lake has been modified to *inactive* according to the MDNR Drinking Water Watch database.

Harrison Co. PWSD 1 previously utilized Eagleville Lake as a drinking water source. Harrison Co. PWSD 1 currently purchases groundwater from Harrison Co. PWSD 2. Eagleville Lake designation has been modified to *inactive* according to the MDNR Drinking Water Watch database.





LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstate
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plant
- Well

FIGURE 1-27 HARRISON COUNTY MAP

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US Army Corps of Engineers ®
Kansas City District

MISSOURI NATURAL RESOURCES

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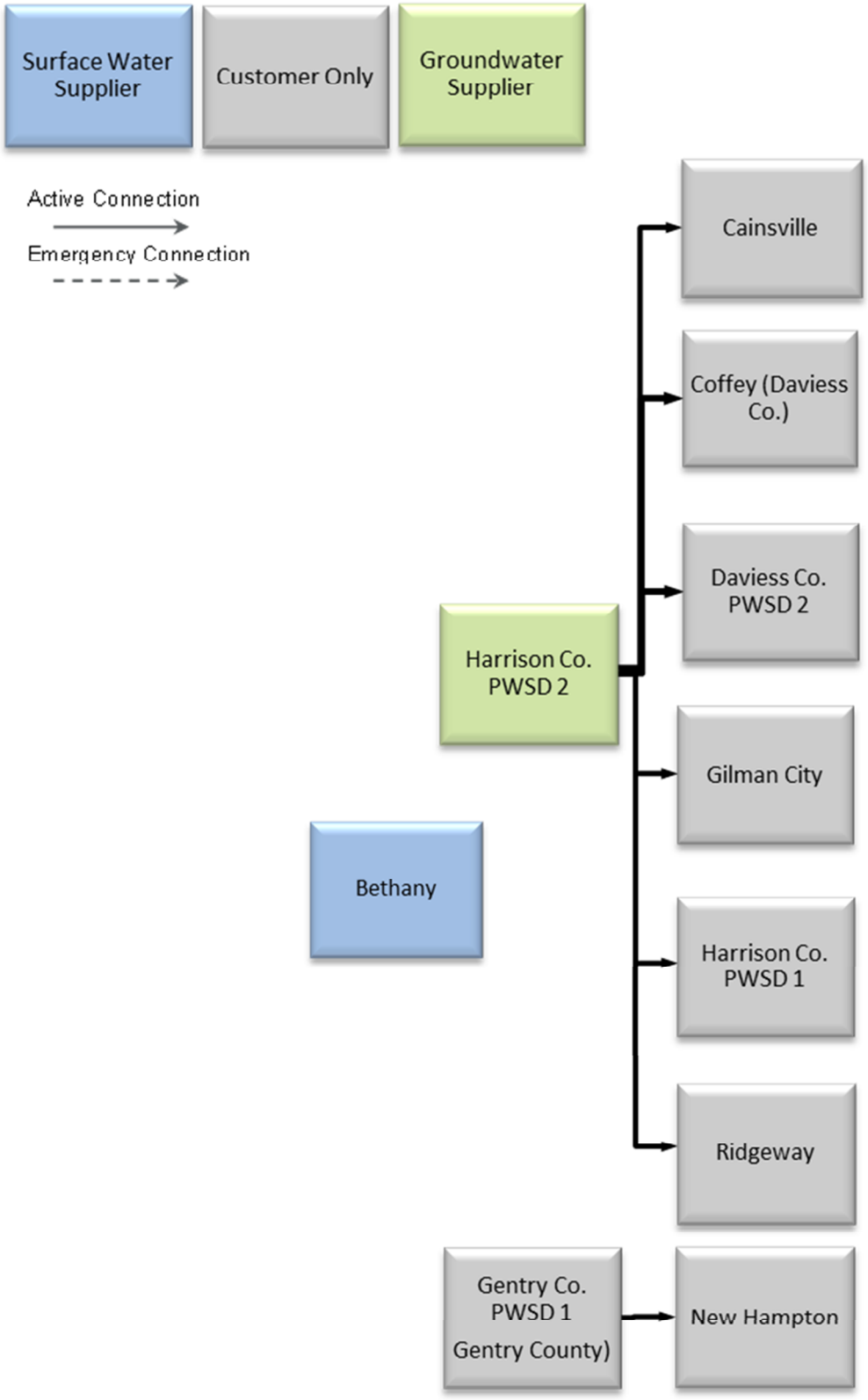


Figure 1-28 Harrison County Water Suppliers and Customers

Table 1-9 Harrison County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Name [2]	Source Capacity (MGD)[2]
BETHANY MO1010068	1,623	3,292	0.35	1.44	1.09	3 Lakes	Harrison County Lake, Bethany North Lake, Bethany South Lake	0.816
CAINSVILLE MO1010122	147	296	0.02	0.02	0.03	GW Purchase		Purchase
GILMAN CITY MO1010306	209	460	0.02	NR	NR	GW Purchase		Purchase
HARRISON CO PWSD 1 MO1024241	181	500	0.03	0.10	0.04	GW Purchase		Purchase
HARRISON CO PWSD 2 MO1024242	1,423	2,950	NR	0.46	NR	9 Wells		NR
NEW HAMPTON MO1010567	125	258	0.02	0.03	0.01	GW Purchase		Purchase
RIDGEWAY MO1010688	231	464	0.02	0.05	0.04	GW Purchase		Purchase
Totals	**3,939**	**8,220**	**0.45**	**2.10**	**1.21**			

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2011 RESOP Analysis

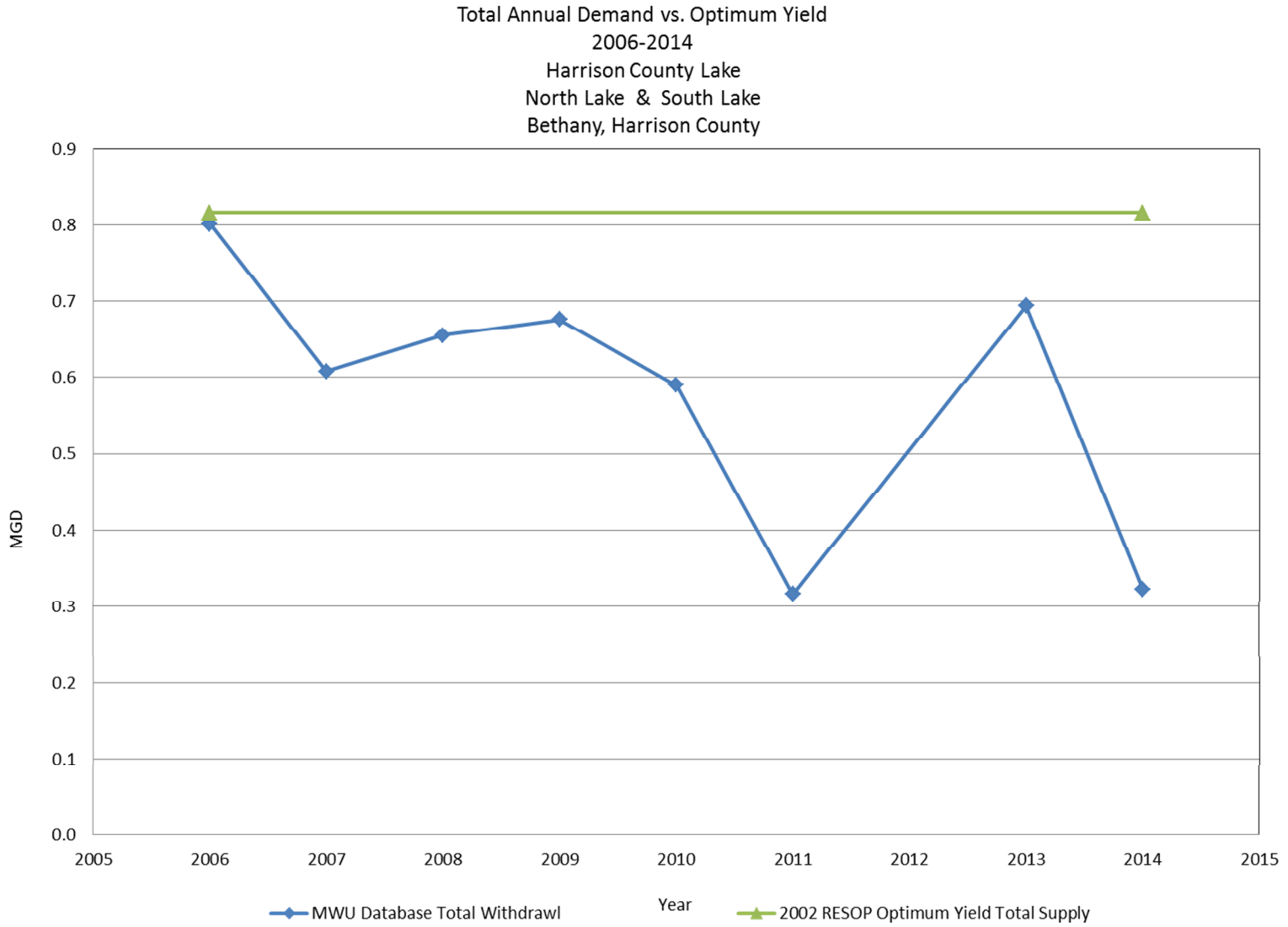


Figure 1-29 Demand Compared to 2002 Calculated Optimum Yield from Harrison County Lake, Bethany North and South Lakes

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

Knox County

Knox County is located in northeastern portion of the Study Area in north central Missouri (see Figure 1-30). There are two public water systems within Knox County: Knox Co. PWSD 1 and the City of Edina. Neither of the water systems in Knox County have water sources. Both systems purchase finished surface water from Clarence Canon Wholesale Water Commission at Mark Twain Lake.

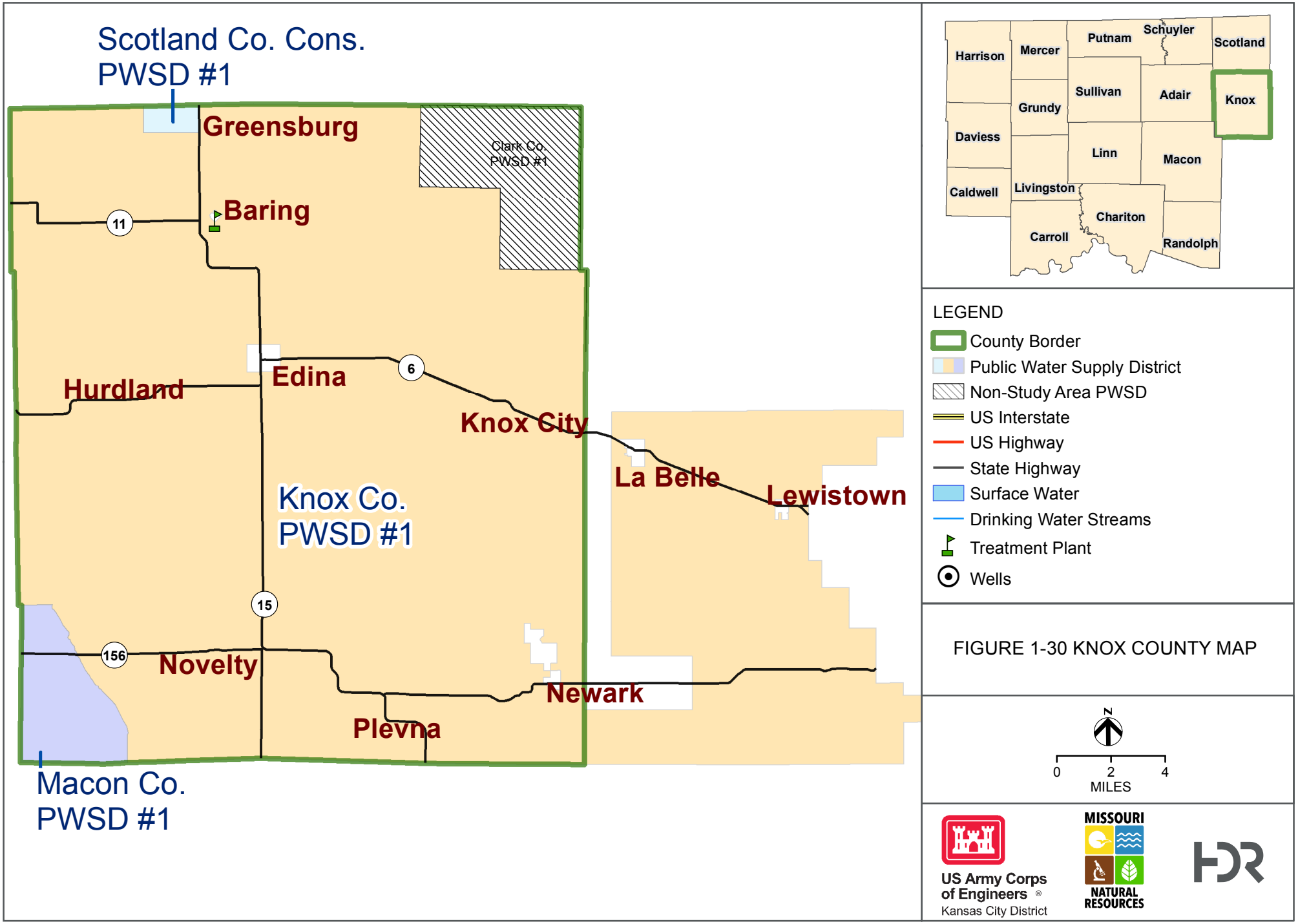
Figure 1-31 illustrates the customers in Knox County. Table 1-10 presents the general water system information for each system within Knox County including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the two public water systems within Knox serve a total population of 5,451.

Current Groundwater Suppliers

Knox County does not have any groundwater sources or systems that purchase groundwater.

Current Surface Water Suppliers

Knox County does not have any surface water sources that provide drinking water. Clarence Cannon Wholesale Water Commission currently supplies both Knox 1 and Edina with finished surface water from Mark Twain Lake.


Scotland Co. Cons.
PWSD #1
Greensburg
Clark Co.
PWSD #1
Baring
11
Hurdland
Edina
6
Knox City
La Belle
Lewistown
Knox Co.
PWSD #1
15
156
Novelty
Newark
Plevna
Macon Co.
PWSD #1
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Carroll
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Streams
Treatment Plant
Wells
FIGURE 1-30 KNOX COUNTY MAP
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US Army Corps
of Engineers ®
Kansas City District
MISSOURI
NATURAL
RESOURCES
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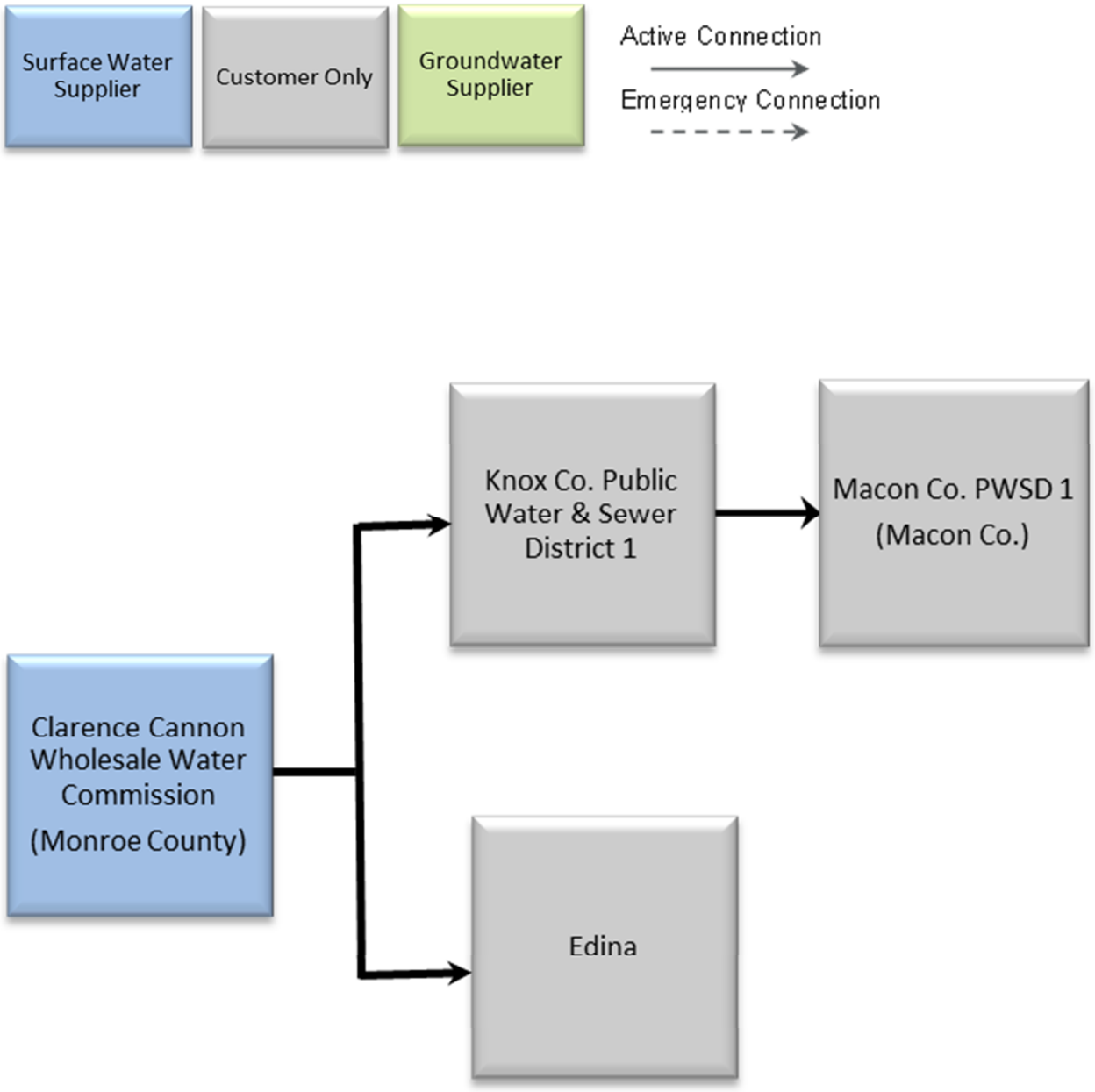


Figure 1-31 Knox County Water Suppliers and Customers

Table 1-10 Knox County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1]	Source Capacity (MGD)[1]
EDINA MO2010238	614	1,153	0.07	0.50	0.37	SW Purchase	Purchase
KNOX CO PUBLIC WATER & SEWER DISTRICT 1 MO2024313	1,728	4,298	0.25	0.37	0.04	SW Purchase	Purchase
Total	**2,342**	**5,451**	**0.32**	**0.87**	**0.41**		

NR = Not Reported

[1]MDNR Drinking Water Watch

Linn County

Linn County is located in the middle of the Study Area in north central Missouri (see Figure 1-32). There are nine public water systems within Linn County: Chariton Linn Co. PWSD 3, Linn Co. PWSD 1, and the cities of Brookfield, Browning, Bucklin, Laclede, Linneus, Marceline, and Meadville. Of the nine public water systems, two are surface water suppliers (Marceline and Brookfield) and two are groundwater suppliers (Meadville and Linn Cons. 1). Three of the systems purchase finished surface water either from a Linn County surface water supplier or through a consecutive connection of the supplier. The remaining two systems purchase groundwater from outside of Linn County.

Figure 1-33 illustrates the suppliers and customers in Linn County. Table 1-11 presents the general water system information for each system within Linn including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the nine public water systems within Linn serve a total population of 16,380.

Chariton Linn Co. PWSD 3, Marceline, and Linn Co. Cons PWSD 1 were designated as selected water systems. The results of the selected water system site visits are presented in Topic 4.

Current Groundwater Suppliers

There are two groundwater suppliers within Linn County. The City of Meadville and Linn Co. Cons PWSD 1. Both draw from alluvial groundwater wells. The City of Meadville has emergency supply provided by Linn Livingston Co. PWSD 3.

Current Surface Water Suppliers

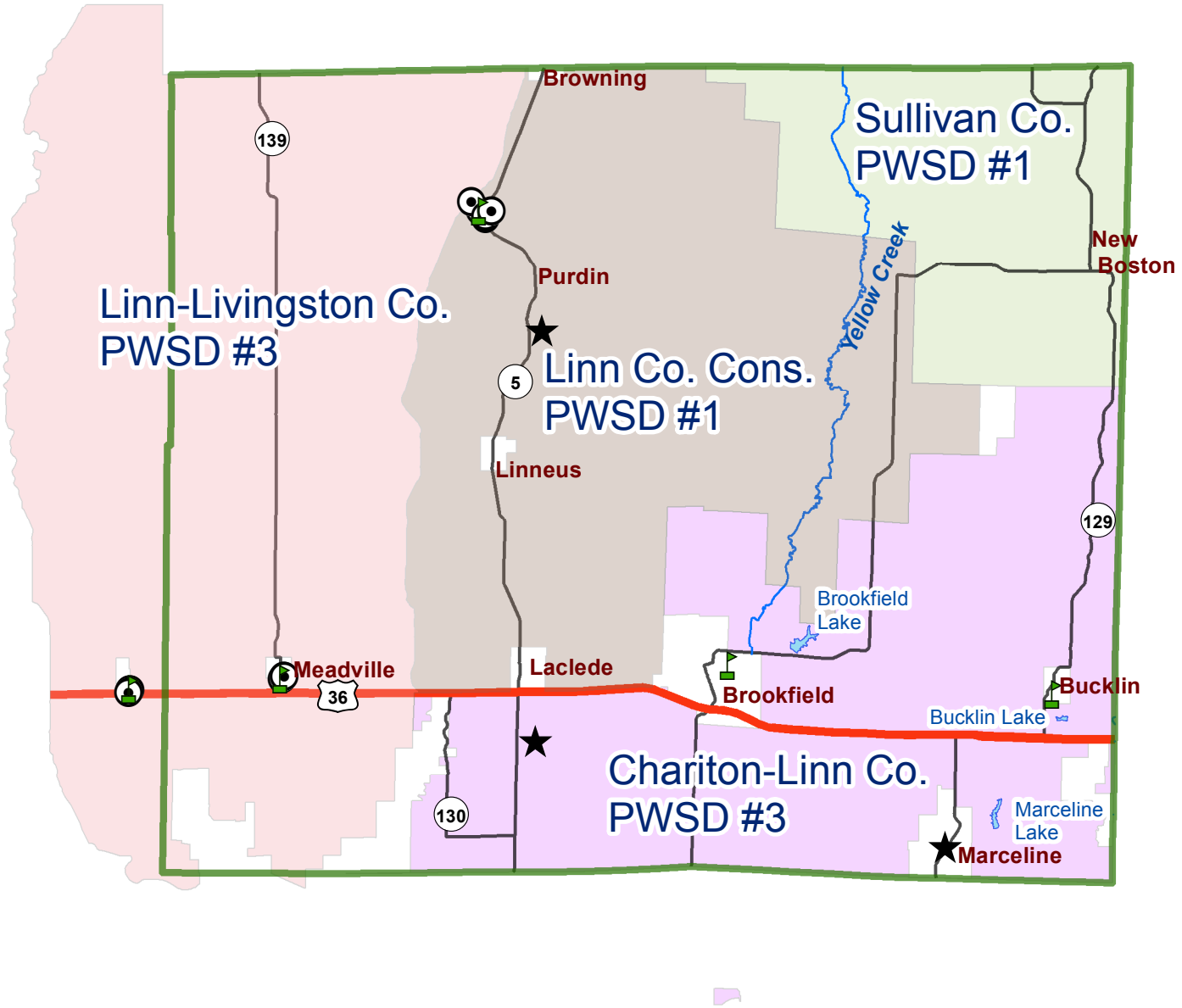
Linn County has two surface water suppliers in the cities of Brookfield and Marceline. Brookfield and Marceline provide finished surface water for their respective municipalities as well as for Chariton-Linn PWSD 3. Brookfield also supplies the City of Laclede.

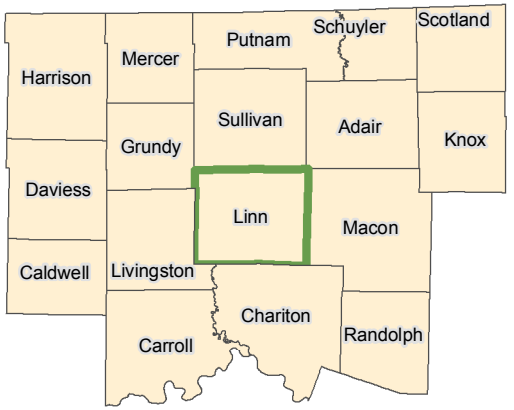
Brookfield Lake and West Yellow Creek are the primary sources of water supply for the City of Brookfield. According to the 2011 Water Supply Study, during a drought event, the Brookfield Lake is not able to meet the community's demand and supplemental water must be pumped from the West Yellow Creek into the lake. Figure 1-34 depicts the total annual demand verses the optimum yield for the Brookfield Reservoir and the optimum yield achieved by pumping West Yellow Creek.

The City of Marceline utilizes the Marceline City Reservoir (New) and the North Lake (Old) for its surface water supply. Supplemental supply may be diverted by pumping from Mussel Fork Creek into the Old Reservoir. However, according to the 2011 WSS, flow in Mussel Fork Creek at the intake location would be too low during drought periods to withdraw additional supply. During the selected system site visit, Marceline staff indicated that in 2012 the Creek was pumped dry. The 2011 WSS RESOP analysis determined that the New Marceline Reservoir is capable of meeting Marceline's water demand; however, the reservoir volume would be at great risk of not meeting the demand during a drought event. Figure 1-35 depicts the total annual demand verses the optimum yield for the Marceline reservoirs.

As part of this study, the optimum yield determined in the 2011 WSS has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the demands projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source.

There is an emergency surface water source in the City of Bucklin. According to the MDNR Drinking Water Watch database, the designation of the Bucklin Lake is *emergency* only. The reservoir does not have enough storage to meet Bucklin's water supply needs.





LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstate
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plant
- Well
- Selected Water System

FIGURE 1-32 LINN COUNTY MAP

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US Army Corps of Engineers ®
Kansas City District

MISSOURI NATURAL RESOURCES

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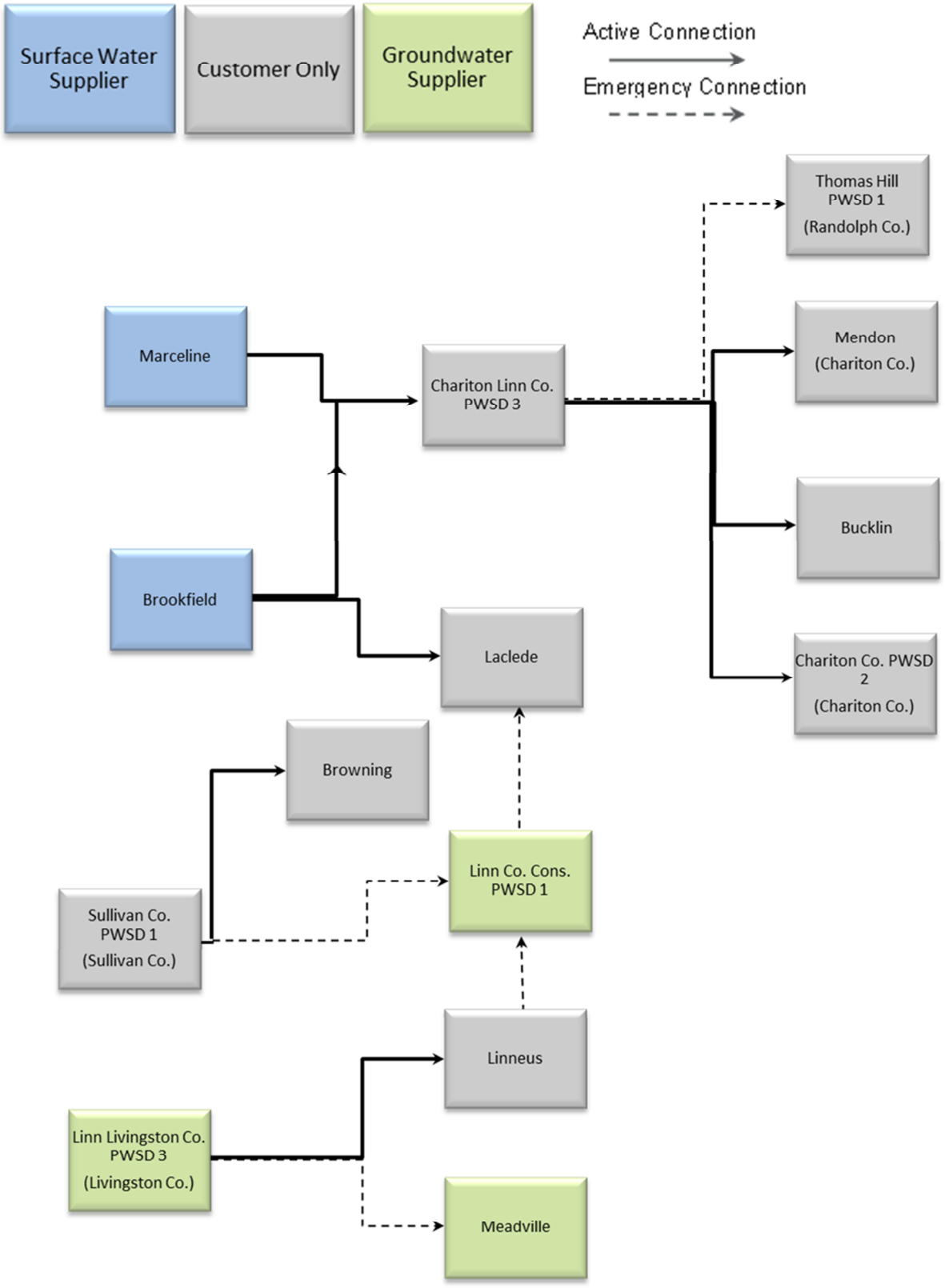


Figure 1-33 Linn County Water Suppliers and Customers

Table 1-11 Linn County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/ Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2],[3]	Source Name[2]	Source Capacity (MGD)[2],[3]
BROOKFIELD MO2010105	2023	4,542	0.494	1.25	1.00	1 Lake, 1 Creek	Brookfield Lake West Yellow Creek	0.21*
BROWNING MO2010108	109	265	0.02	0.05	0.02	SW Purchase		Purchase
BUCKLIN MO2010112	230	467	NR	NR	NR	SW Purchase		Purchase
CHARITON LINN CO PWSD 3 MO2024128	2,365	5,913	0.40	1.00	0.35	SW Purchase		Purchase
LACLEDE MO2010437	220	345	0.03	0.07	0.03	SW Purchase		Purchase
LINN CO CONS PWSD 1 MO2024346	547	1,620	0.09	0.12	0.20	5 Wells		NR
LINNEUS MO2010472	144	278	0.03	0.22	0.19	GW Purchase		Purchase
MARCELINE MO2010497	1,089	2,500	0.50	2.16	0.41	1 Lake, 1 Creek	City Lakes	0.47
MEADVILLE MO2010512	192	450	0.03	0.07	1 GPD	3 Wells		NR
Totals	**6,919**	**16,380**	**1.59**	**4.94**	**2.19**			

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2011 RESOP Analysis

[3]MDNR 2007 Groundwater System Evaluation

*Lake only

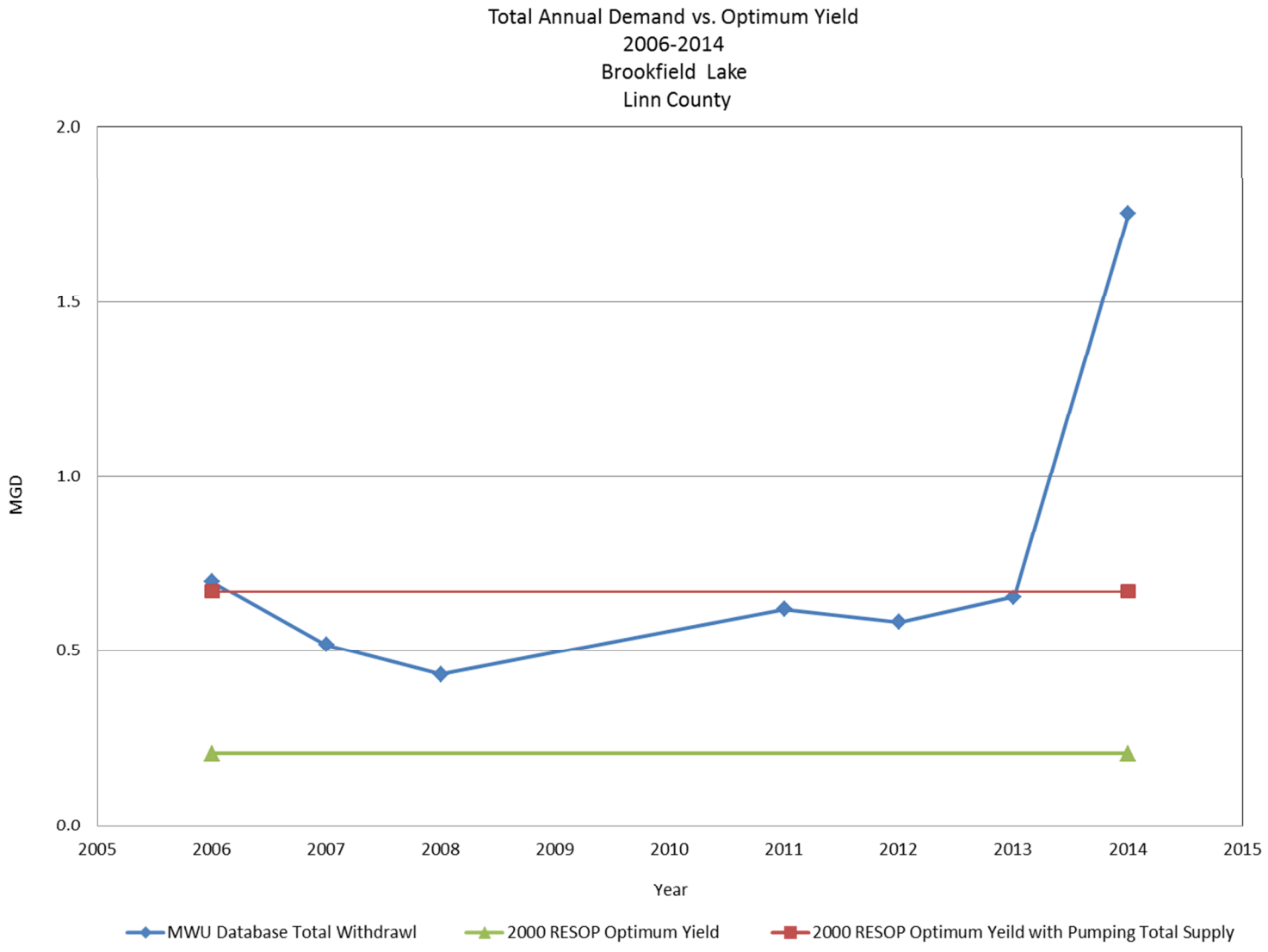


Figure 1-34 Demand Compared to 2000 Calculated Optimum Yield from Brookfield Reservoir

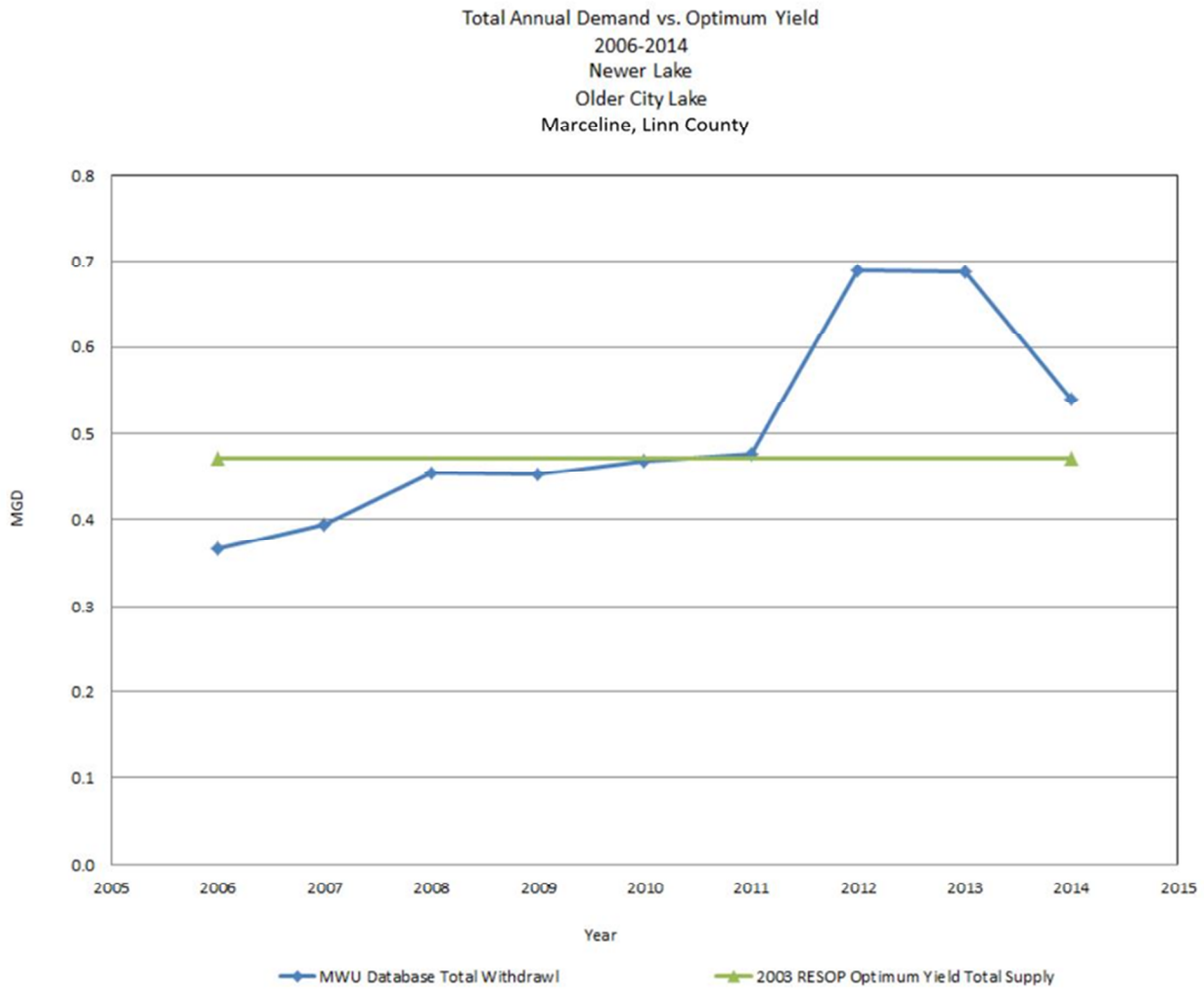


Figure 1-35 Demand Compared to 2003 Calculated Optimum Yield from Marceline Lakes

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

Livingston County

Livingston County is located within the northwestern portion of the Study Area in north central Missouri (see Figure 1-36). There are eight public water systems within Livingston County: Chillicothe Municipal Utilities, Linn Livingston Co. PWSD 3, Livingston Co. PWSD 1, 2, 3 East, 4 and the cities of Chula and Wheeling. Of the eight public water systems, four are groundwater suppliers and the remaining four purchase drinking water from these suppliers.

Figure 1-37 illustrates the suppliers and customers in Livingston County. Table 1-12 presents the general water system information for each system within Livingston including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the eight public water systems within Livingston serve a total population of 18,274.

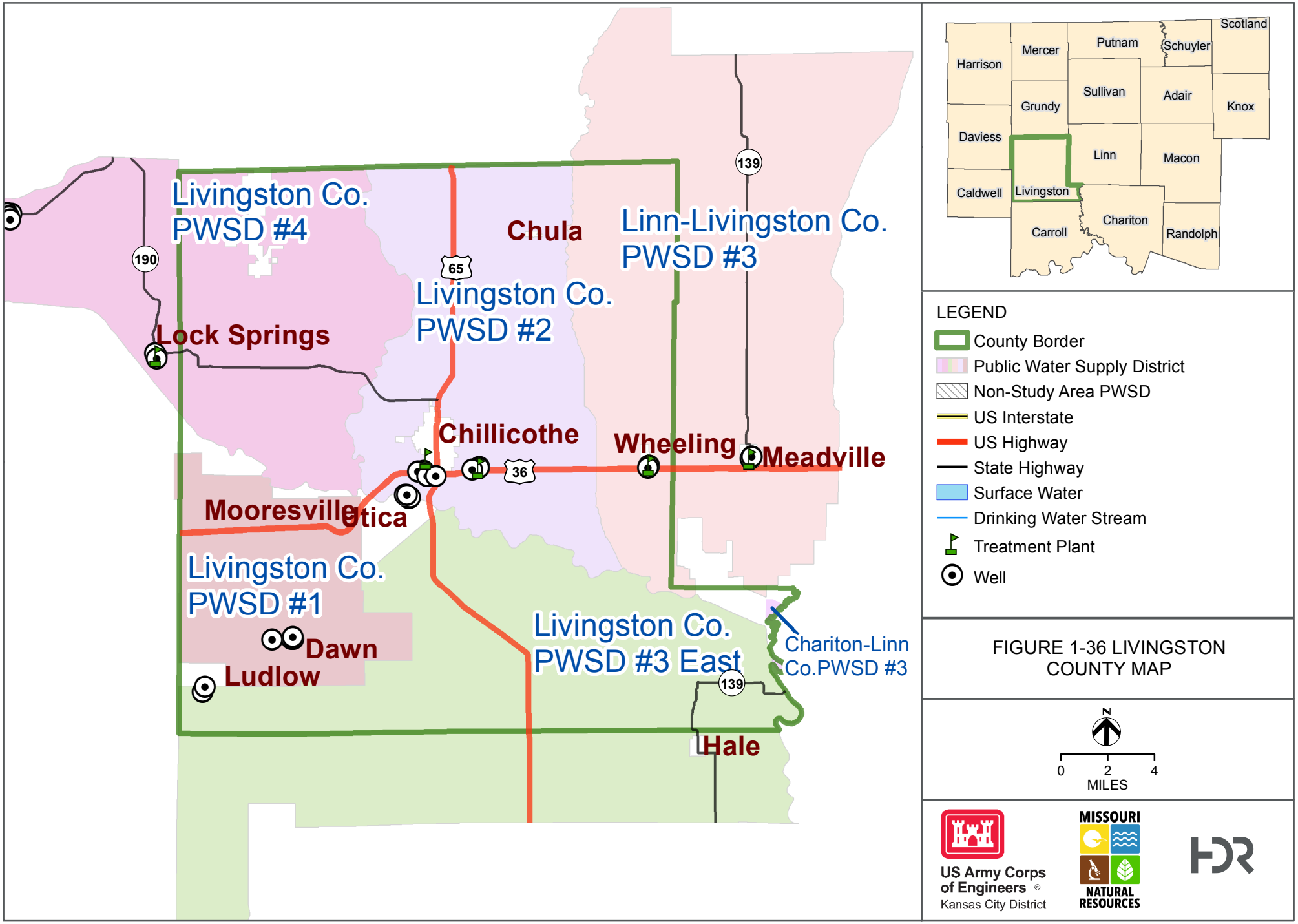
Current Groundwater Suppliers

The four systems that supply groundwater in Livingston County include Chillicothe Municipal Utilities, Livingston Co. PWSD 2, Livingston Co. PWSD 4, and Linn Livingston Co. PWSD 3. Aside from supplying finished groundwater to their respective municipalities and the remaining water systems within Livingston County, these suppliers are also a supplier to systems in Carroll, Grundy, Linn, Caldwell and Daviess counties.

MDNR staff has indicated that Livingston 4 has the groundwater source capacity to potentially serve as a regional supplier. However, the newly expanded Livingston 4 treatment plant has reached its capacity and would require an additional expansion to serve more public water system within the region.

Current Surface Water Suppliers

Livingston County does not have any surface water sources that provide drinking water.


Livingston Co.
PWSD #4
Chula
Linn-Livingston Co.
PWSD #3
Livingston Co.
PWSD #2
Lock Springs
Chillicothe
Wheeling
Meadville
Mooresville
Utica
Livingston Co.
PWSD #1
Dawn
Ludlow
Livingston Co.
PWSD #3 East
Chariton-Linn
Co.PWSD #3
Hale
190
65
139
36
139
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Carroll
Chariton
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
FIGURE 1-36 LIVINGSTON
COUNTY MAP
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of Engineers
Kansas City District
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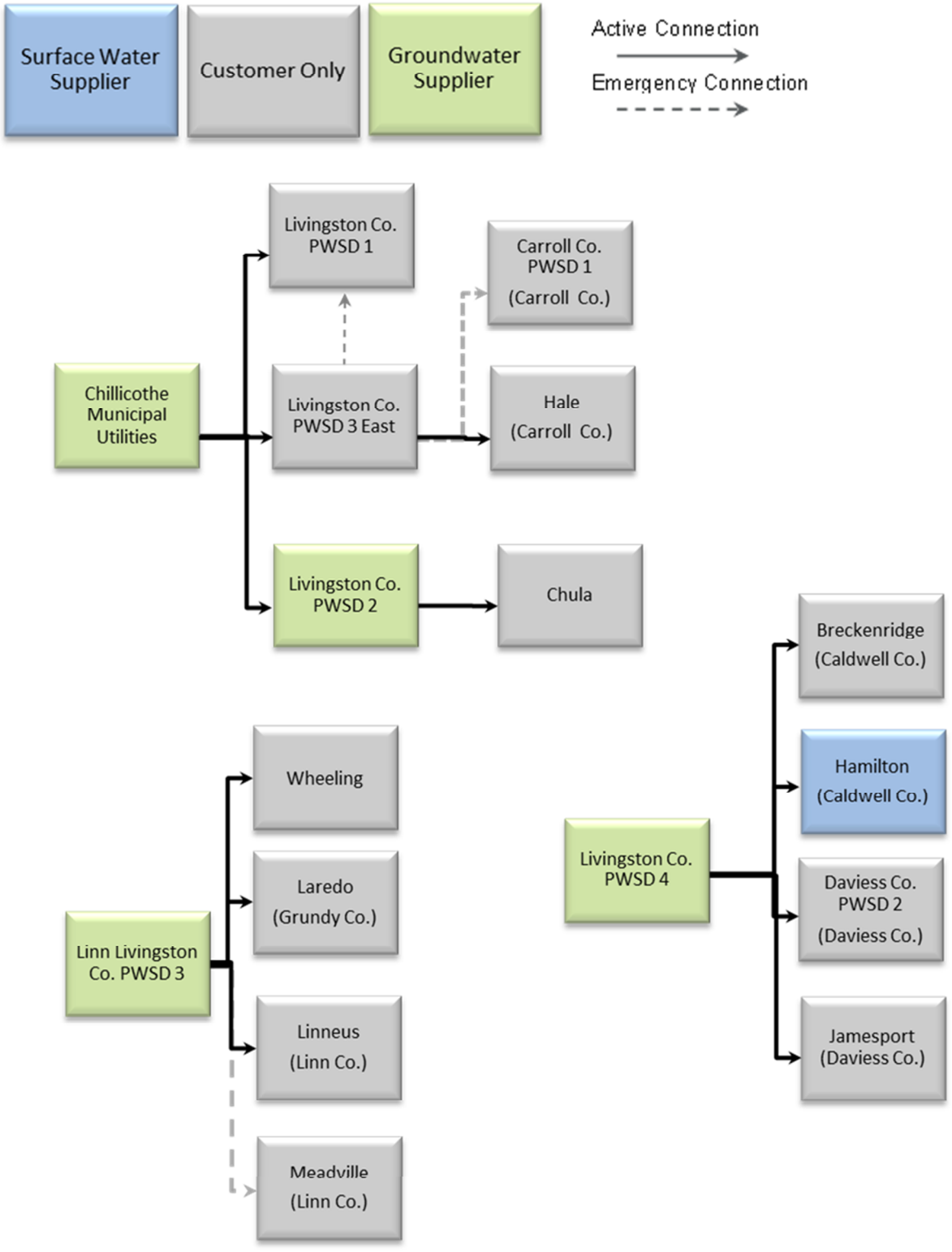


Figure 1-37 Livingston County Water Suppliers and Customers

Table 1-12 Livingston County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2],[3]	Source Capacity (MGD)[2],[3]
CHILLICOTHE MUNICIPAL UTILITIES MO2010162	3,800	9,515	1.30	4.50	3.05	6 Wells	NR
CHULA MO2010163	102	210	0.01	0.03	0.02	GW Purchase	Purchase
LINN LIVINGSTON CO PWSD 3 MO2024350	545	1,350	0.17	0.36	0.24	4 Wells	NR
LIVINGSTON CO PWSD 1 MO2024352	496	1,320	0.08	0.24	0.14	GW Purchase	Purchase
LIVINGSTON CO PWSD 2 MO2024353	837	2,053	0.10	0.43	0.10	3 Wells	NR
LIVINGSTON CO PWSD 3 EAST MO2024354	840	2,087	0.20	0.43	0.09	GW Purchase	Purchase
LIVINGSTON CO PWSD 4 MO2024355	597	1,455	0.11	0.29	0.18	4 Wells	NR
WHEELING MO2010857	107	284	0.02	NR	0.02	GW Purchase	Purchase
Totals	**7,324**	**18,274**	**1.98**	**6.29**	**3.85**		

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2011 RESOP Analysis

[3]MDNR 2007 Groundwater System Evaluation

Macon County

Macon County is located within the southeastern portion of the Study Area in north central Missouri (see Figure 1-38). There are seven public water systems within Macon County: Macon Co. PWSD 1, and the cities of Macon, Atlanta, Bevier, Callao, Elmer, and La Plata. Of the seven public water systems, one system is surface water supplier, two systems purchase drinking water from this suppliers and the remaining four systems purchases finished surface water from a supplier outside of Macon County.

Figure 1-39 illustrates the supplier and customers in Macon County. Table 1-13 presents the general water system information for each system within Macon including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the seven public water systems within Macon serve a total population of 20,034.

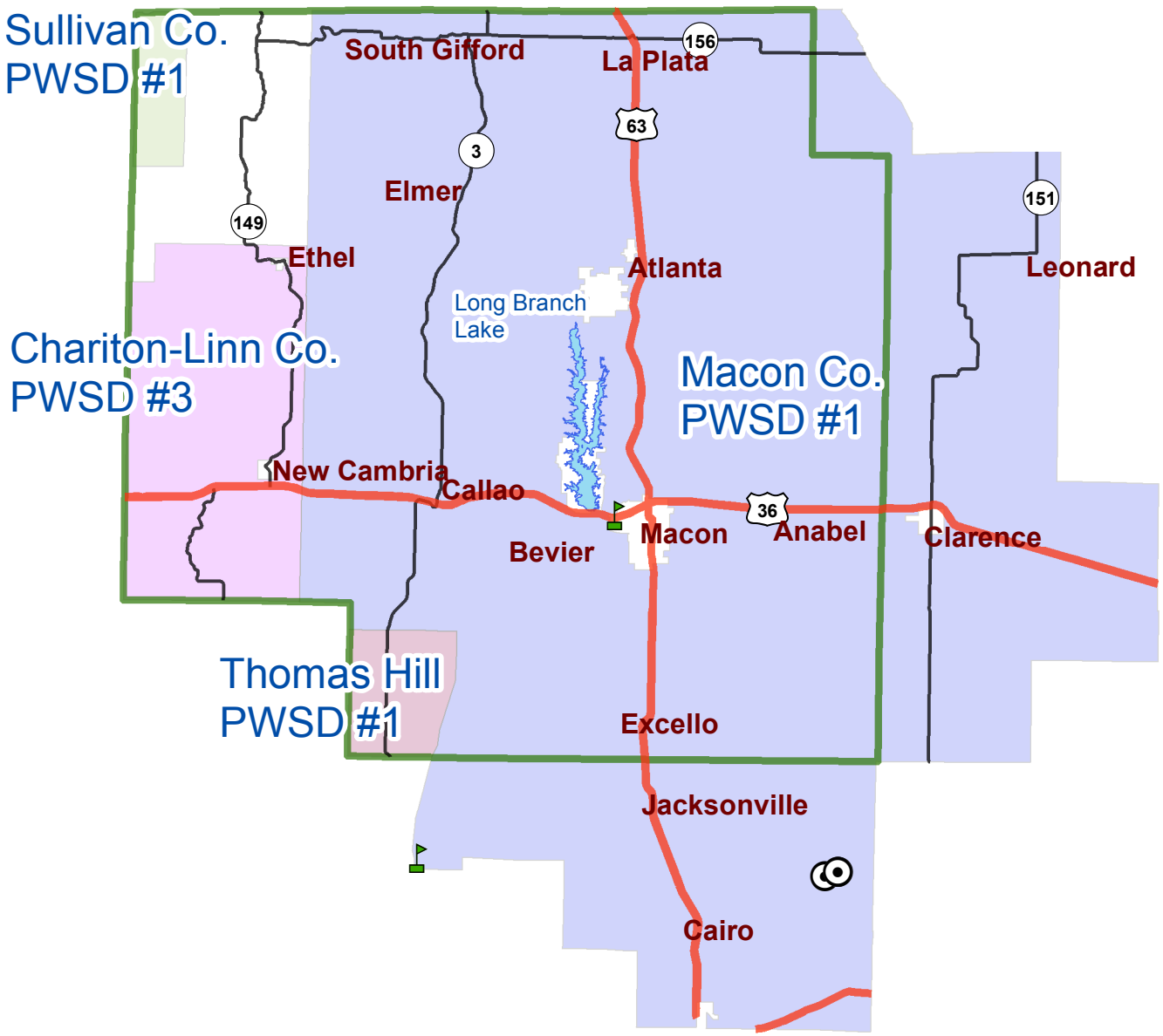
Current Groundwater Suppliers

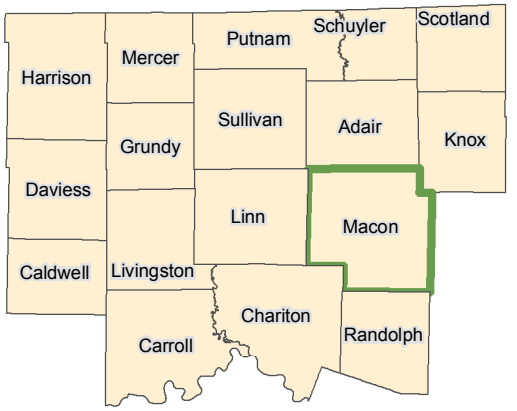
Macon County does not have any groundwater sources or systems that purchase groundwater.

Current Surface Water Suppliers

Macon County currently has the only surface water source, the Long Branch Reservoir, located within the Little Chariton River Basin. The Reservoir began filling in 1978 by impounding the East Fork Little Chariton River near the confluence with Long Branch. According to the 2011 WSS, water releases from the reservoir can have downstream effects on the water supply of East Fork Little Chariton River and, subsequently, the City of Moberly and the Sugar Creek Reservoir, both of which are downstream of Long Branch.

Macon County formerly had additional surface water reservoirs utilized for water supply by Atlanta, Armstrong, Elmer, Callao, and the City of Macon. La Plata, at one time, had two Reservoirs but currently purchases surface water from Adair County PWSD 1. Excluding the City of Macon, all other systems purchase surface water from additional systems including Adair County PWSD 1 and Clarence Cannon Wholesale Water Commission.





LEGEND

- County Border
- Public Water Suppy District
- Non-Study Area PWSD
- US Interstate
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plant
- Well

FIGURE 1-38 MACON COUNTY MAP

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US Army Corps of Engineers
Kansas City District

MISSOURI NATURAL RESOURCES

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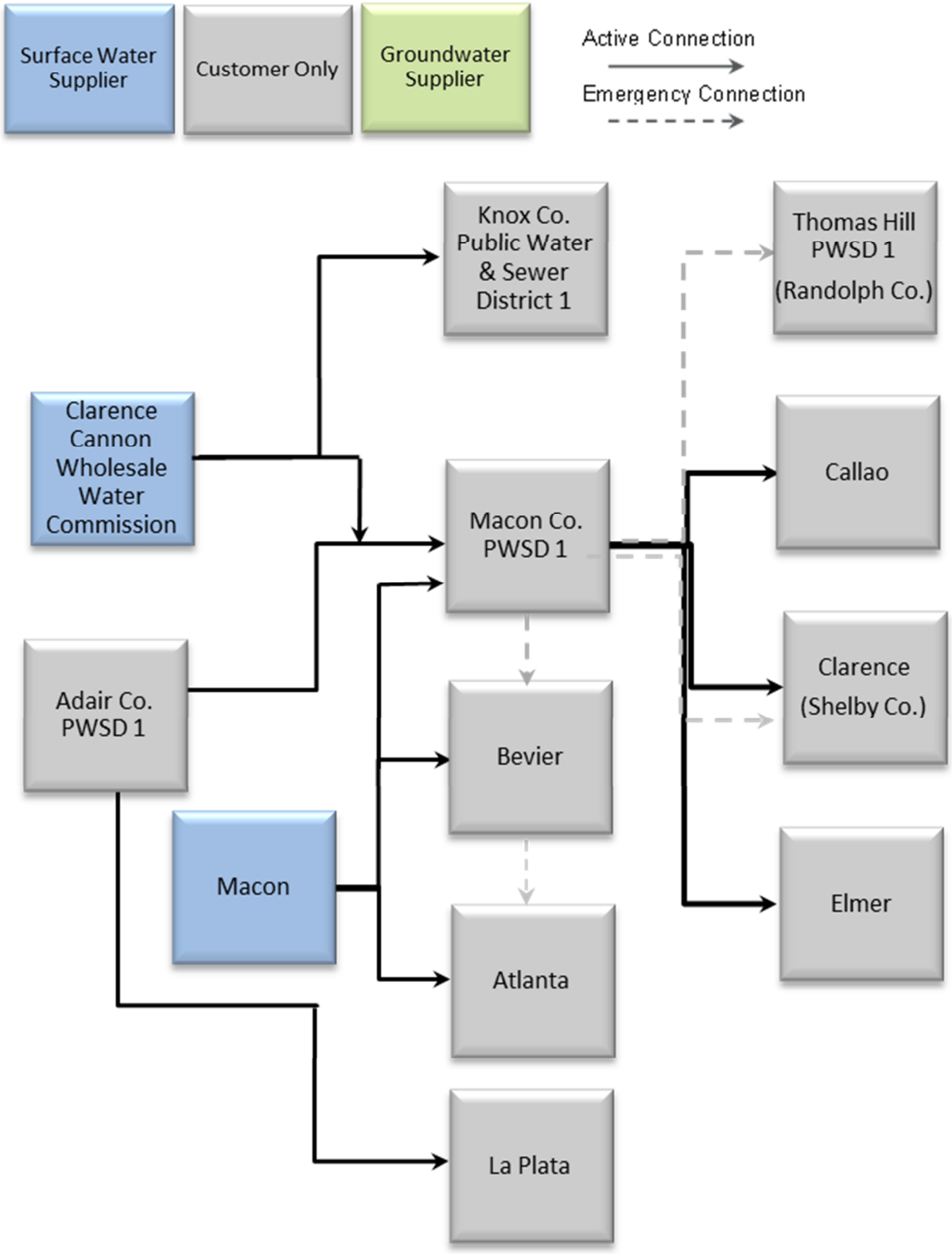


Figure 1-39 Macon County Water Suppliers and Customers

Table 1-13 Macon County – Water System Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Name[2],[3]	Source Capacity (MGD)[2]
ATLANTA MO2010035	176	385	0.02	0.07	0.05	SW Purchase		Purchase
BEVIER MO2010881	367	762	0.06	NR	0.06	SW Purchase		Purchase
CALLAO MO2010125	135	311	0.02	0.04	0.02	SW Purchase		Purchase
ELMER MO2010247	46	115	0.01	0.05	0.04	SW Purchase		Purchase
LAPLATA MO2010451	591	1,366	0.09	0.20	0.09	SW Purchase		Purchase
MACON CO PWSD 1 MO2024363	4,642	11,606	1.30	1.73	0.65	SW Purchase		Purchase
MACON MO2010487	2,684	5,489	2.50	4.32	2.56	1 Lake	Long Branch Reservoir	NR
Totals	**8,641**	**20,034**	**4.00**	**6.42**	**3.47**			

NR = Not Reported
[1]MDNR Drinking Water Watch
[2]MDNR 2011 RESOP Analysis
[3] 2010 NMRW Water Supply Transmission System Study Phase III

Mercer County

Mercer County is located within the northwestern portion of the Study Area in north central Missouri (see Figure 1-40). There are three public water systems within Mercer County: Mercer Co. PWSD 1 and the cities of Mercer and Princeton. Of the three public water systems, one is a groundwater supplier (Princeton) and the remaining two purchase the finished groundwater supplied by this system. One system purchases additional from Rathbun Regional Water Association in Iowa and Putnam Co. PWSD 1 in Putnam County.

Figure 1-41 illustrates the suppliers and customers in Mercer County. Table 1-14 presents the general water system information for each system within Mercer including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the three public water systems within Mercer serve a total population of 4,679.

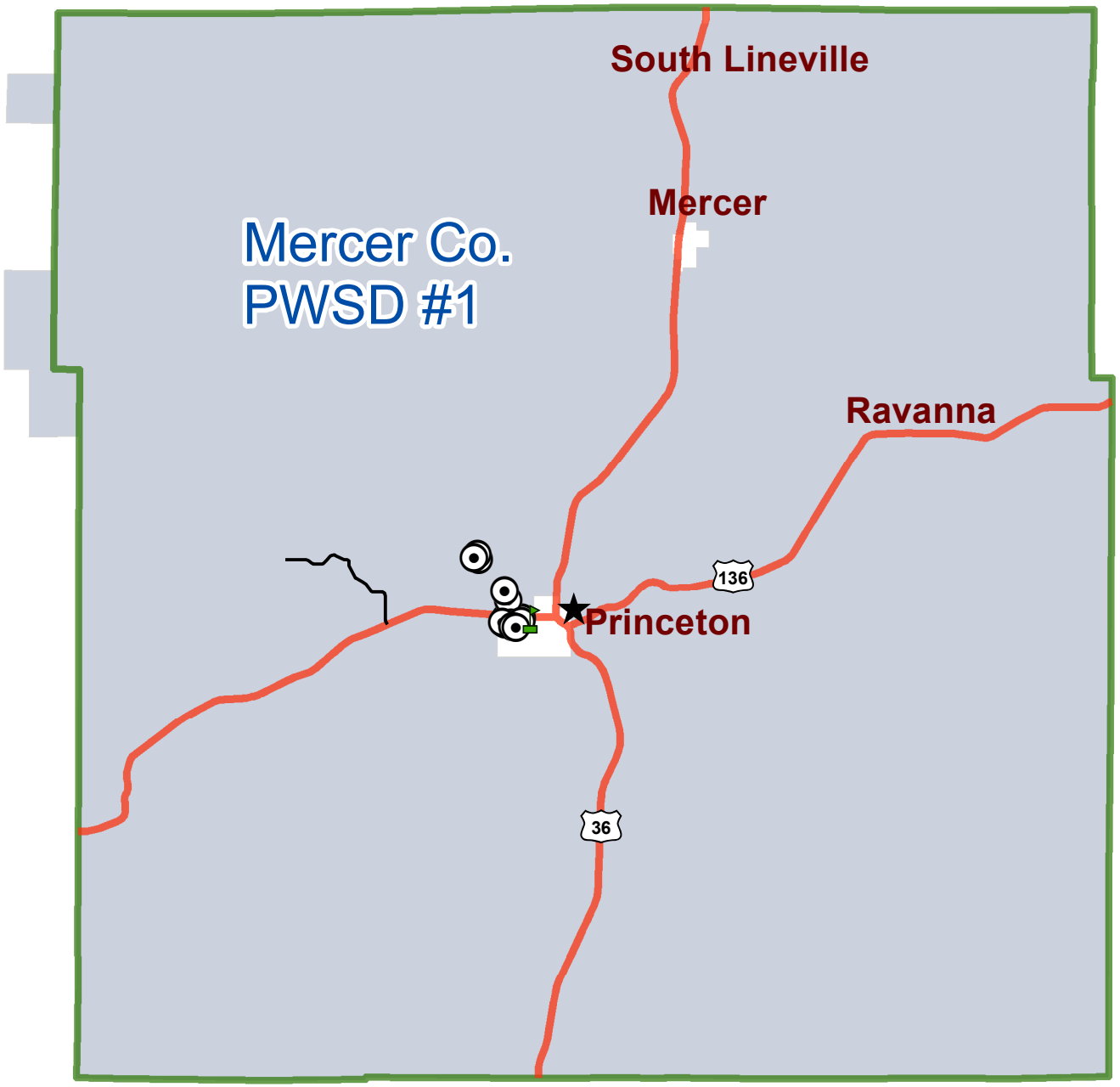
The City of Princeton was designated as a selected water system. The results of the selected water system site visits are presented in Topic 4.

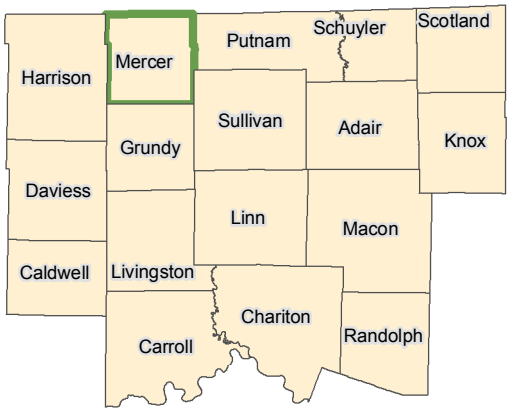
Current Groundwater Suppliers

The City of Princeton is the only groundwater supplier to provide finished drinking water to Mercer County. Currently, three wells are required to be pumped in order to meet average day demand. The WTP has not been updated since installation in 1975. Two of the system's seven wells are currently infected with iron bacteria. Iron removal maintenance is required once per year.

Current Surface Water Suppliers

Mercer County does not have any surface water sources or system's which purchase surface water.





LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstate
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plant
- Wells
- Selected Water System

FIGURE 1-40 MERCER COUNTY MAP

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Kansas City District

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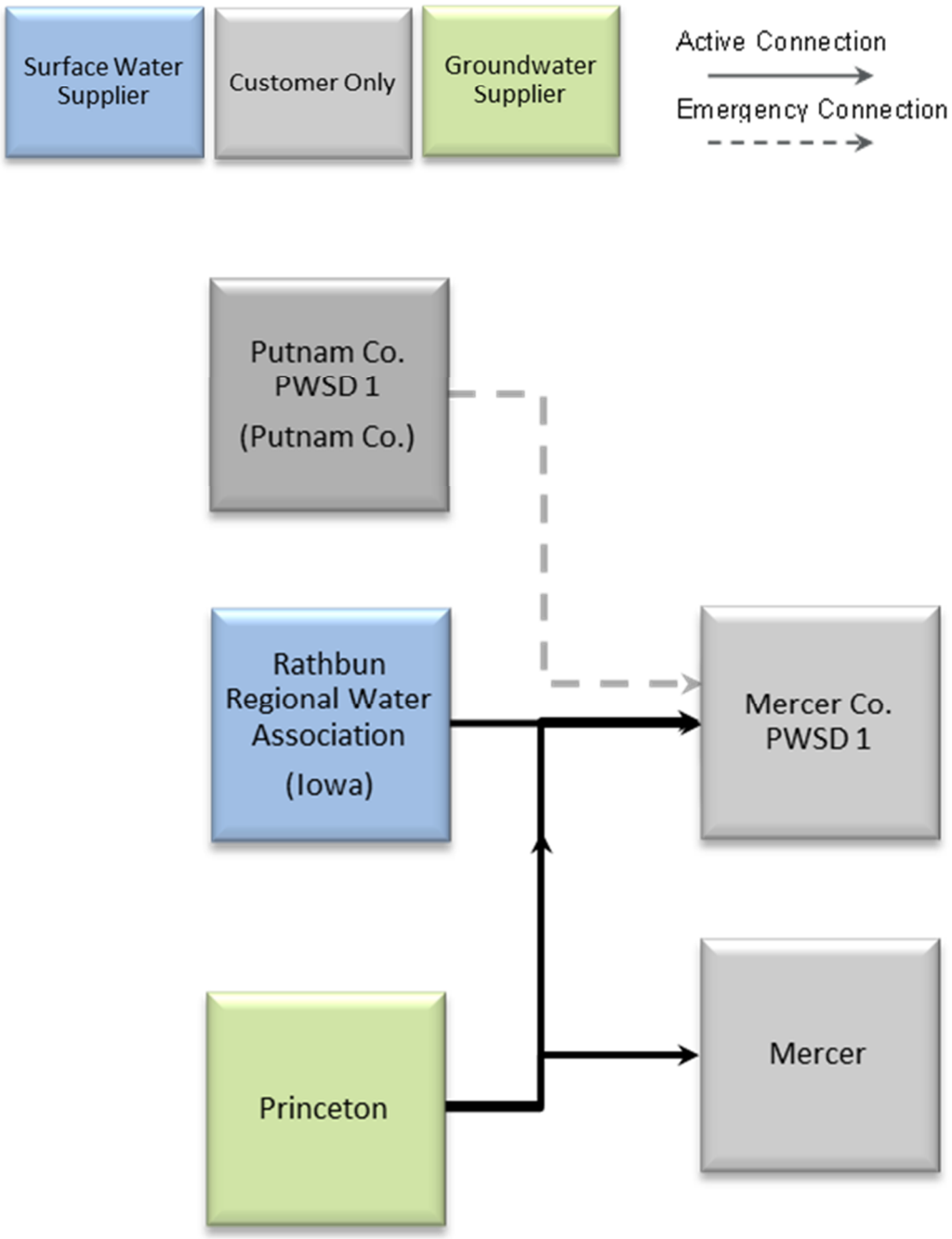


Figure 1-41 Mercer County Water Suppliers and Customers

Table 1-14 Mercer County – Water Supply Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Capacity (MGD)[2]
MERCER CO PWSD 1 MO2024382	1,375	3,195	0.19	0.35	0.10	SW Purchase	Purchase
MERCER MO2010515	184	318	0.02	0.07	0.05	GW Purchase	Purchase
PRINCETON MO2010664	546	1,166	0.14	0.52	0.32	6 Wells	NR
Totals	**2,105**	**4,679**	**0.36**	**0.94**	**0.47**		

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2007 Groundwater System Evaluation

Putnam County

Putnam County is located within the north central portion of the Study Area in Missouri (see Figure 1-42). There are three public water systems within Putnam County: Putnam Co. PWSD 1, Lake Thunderhead, and the City of Unionville. Of the three public water systems, only one is a surface water supplier (Unionville). The remaining two purchase the finished surface water supplied by this system and additional supply from Rathbun Regional Water Association in Iowa.

Figure 1-43 illustrates the supplier and customers in Putnam County. Table 1-15 presents the general water system information for each system within Putnam including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the three public water systems within Putnam serve a total population of 5,497.

Putnam Co. PWSD 1 was designated as a selected water system. The results of the selected water system site visits are presented in Topic 4.

Current Groundwater Suppliers

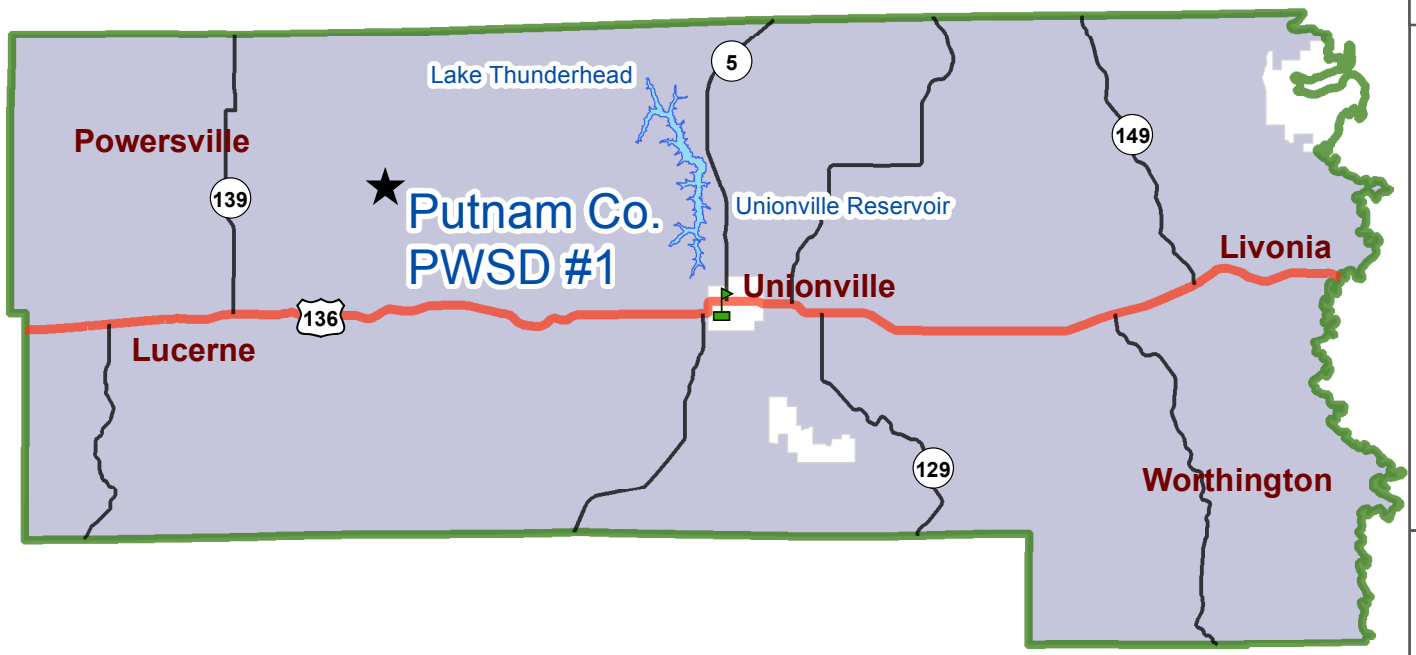
Putnam County does not have any groundwater sources or purchasers of groundwater.

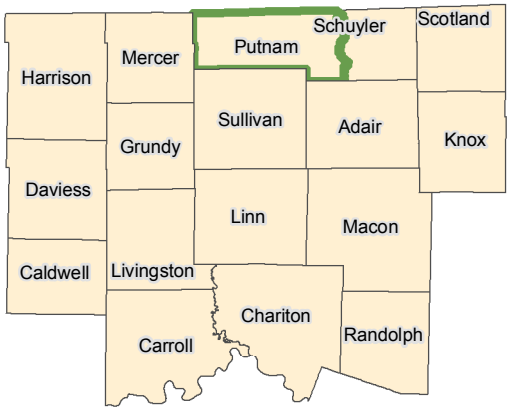
Current Surface Water Suppliers

Putnam County has two surface water sources, Lake Mahoney and Lake Thunderhead, which are part of second largest Missouri River tributary in the state, the Chariton River. Lake Mahoney supplies surface water to the City of Unionville. Unionville supplies approximately 50 percent of the water supply for Putnam Co. PWSD 1. Putnam Co. PWSD 1 purchases the remainder of its water supply from Rathbun Regional Water Association in Iowa.

According to the 2011 WSS drought assessment, Lake Mahoney is at risk of not meeting the community's demand for water during times of drought. The optimum yield for Lake Mahoney as determined by the 2011 WSS RESOP Analysis is 0.283 MGD. Figure 1-44 depicts the total annual demand verses the optimum yield for the Lake Mahoney. As part of this study, the optimum yield determined in the 2011 WSS has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the demands projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source. As illustrated in the Figure 1-44, there are periods when the Unionville demands may be exceeding the Lake Mahoney optimum yield.

Lake Thunderhead is a privately owned lake and is not designed as a water supply reservoir; however, it has the capabilities of providing emergency water supply during periods of extreme droughts. In 2000, a supply line was installed from Lake Thunderhead to Unionville. The combined optimum yield, determined in the 2011 WSS, for Lake Mahoney and Lake Thunderhead is 3.644 MGD.





LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstates
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plants
- Wells
- Selected Water System

FIGURE 1-42 PUTNAM COUNTY MAP

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US Army Corps of Engineers ®
Kansas City District

MISSOURI NATURAL RESOURCES

HDR

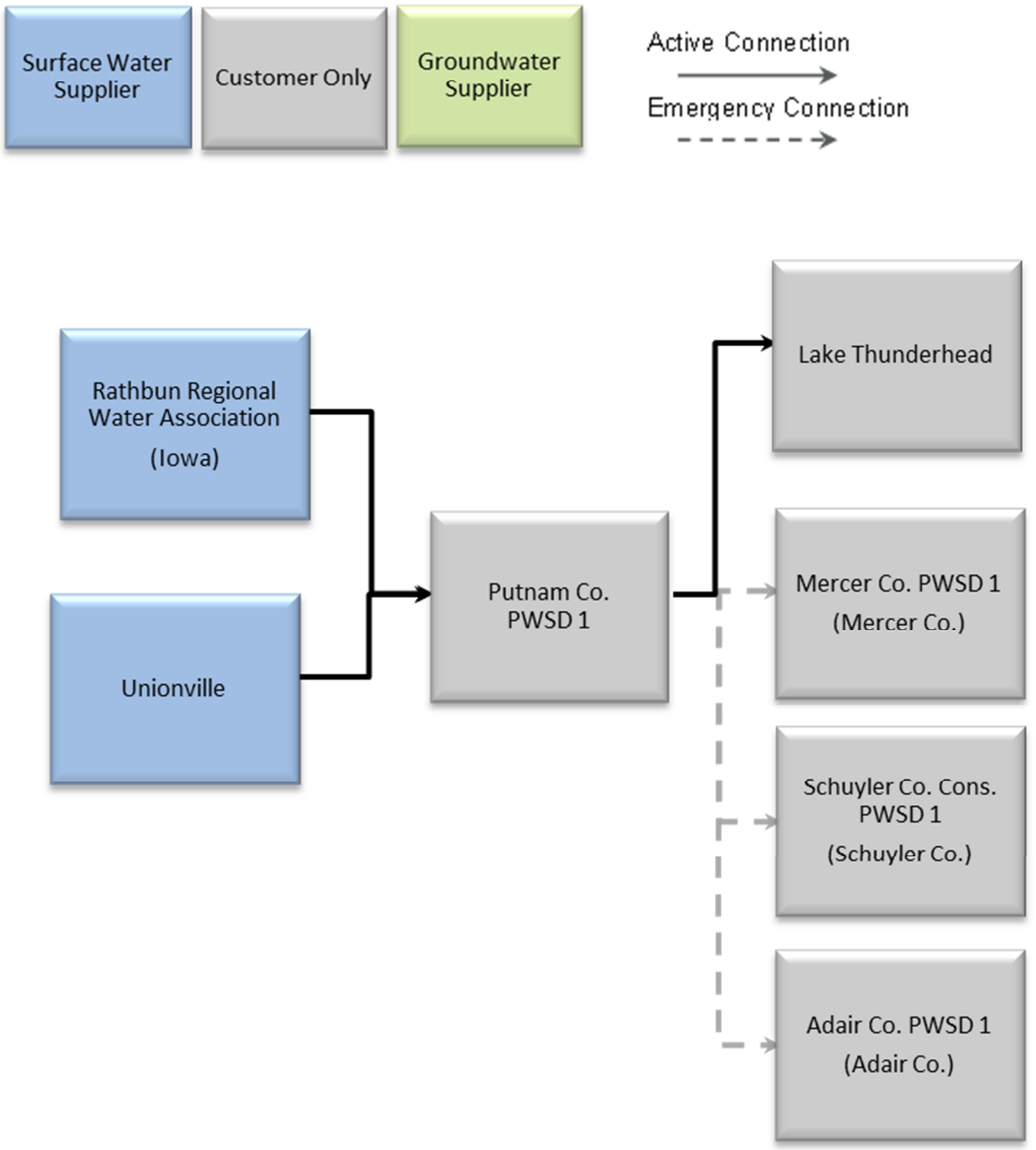


Figure 1-43 Putnam County Water Suppliers and Customers

Table 1-15 Putnam County – Water Supply Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Name	Source Capacity (MGD)[2]
LAKE THUNDERHEAD MO2036165	574	400	0.02	NR	0.02	SW Purchase	-	Purchase
PUTNAM CO PWSD 1 MO2024495	1537	2,997	0.23	0.47	0.14	SW Purchase	-	Purchase
UNIONVILLE MO2010804	958	2,100	0.25	0.90	0.58	2 Lakes	Lake Mahoney Lake Thunderhead	3.64
Totals	**3,069**	**5,497**	**0.50**	**1.37**	**0.73**			

NR = Not Reported
[1]MDNR Drinking Water Watch
[2]MDNR 2011 RESOP Analysis

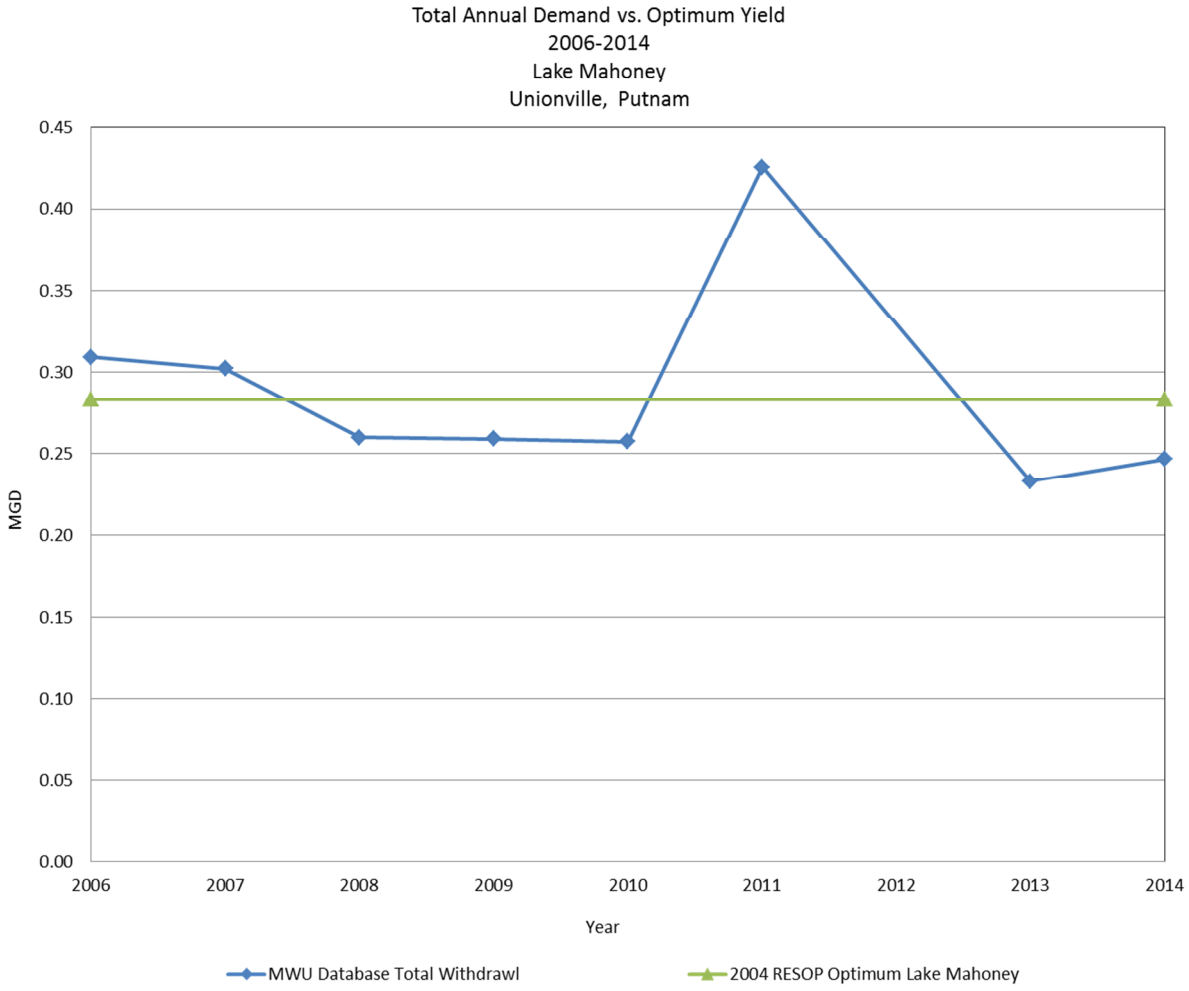


Figure 1-44 Demand Compared to 2005 Calculated Optimum Yield from Lake Mahoney

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

Randolph County

Randolph County is located within the southeastern portion of the Study Area in Missouri (see Figure 1-45). There are five public water systems within Randolph County: Thomas Hill Co. PWSD 1 and the cities of Clark, Higbee, Huntsville, and Moberly. There is one private non-transient non-community (NTNC) water system within Randolph County operated by Associated Electric.

Figure 1-46 illustrates the suppliers and customers in Randolph County. Table 1-16 presents the general water system information for each system within Randolph including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the six public water systems within Randolph serve a total population of 26,307.

Current Groundwater Suppliers

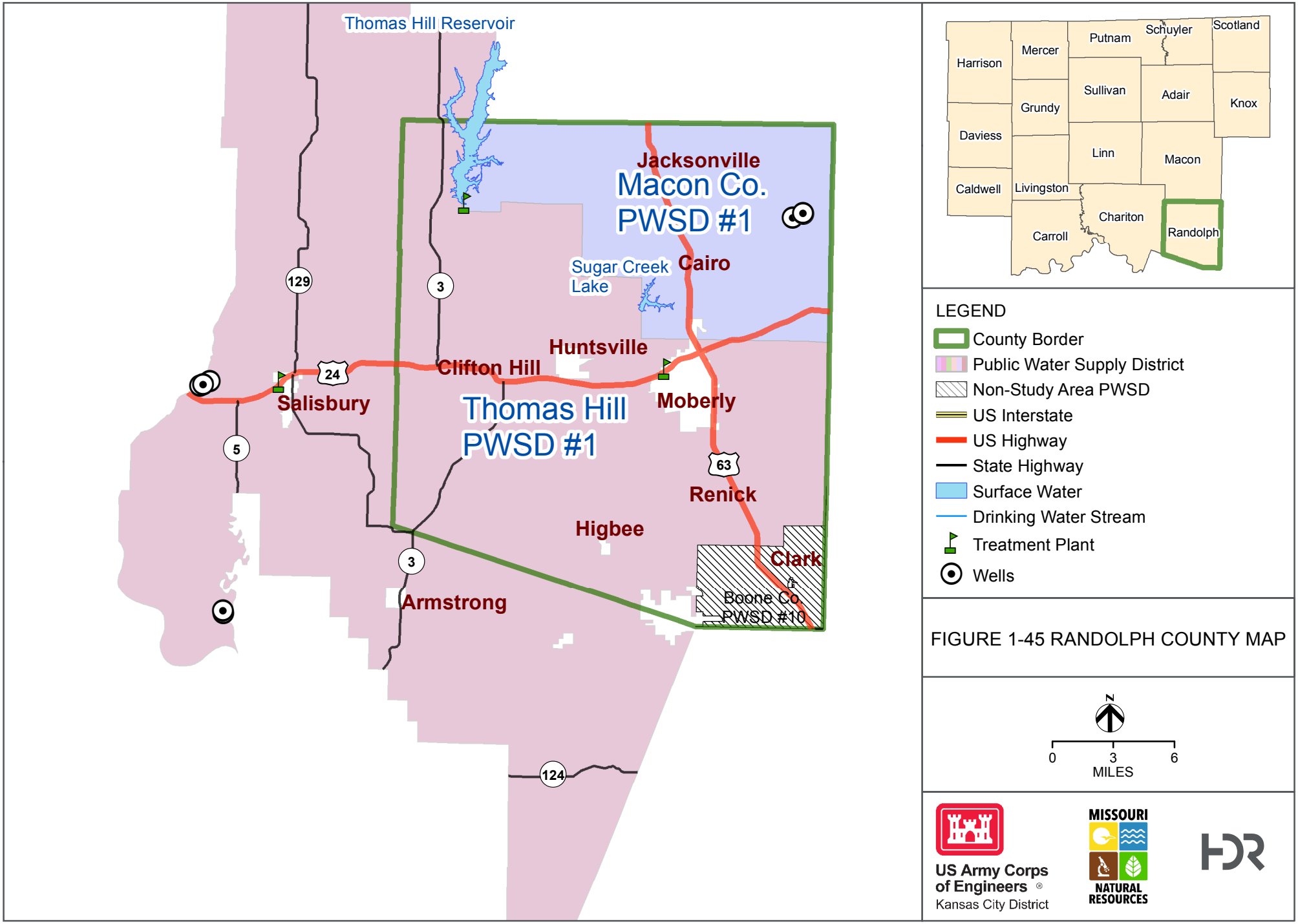
Randolph County does not have any groundwater sources that supply drinking water but the City of Clark purchases groundwater from Boone Co. PWSD 10 in Boone County.

Current Surface Water Suppliers

Randolph County has two surface water sources that include the privately owned Thomas Hill Lake and the Sugar Creek Reservoir located in Moberly, Missouri. Thomas Hill Lake surface water supply serves the non-transient non-community system operated by Associated Electric.

The Sugar Creek Reservoir is operated by the City of Moberly. Alone, Sugar Creek Reservoir is unable to meet normal demand. According to the 2011 WSS, the optimum yield from the lake without supplemental water supply is 1.2 MGD. The optimum yield is increased to 1.54 MGD when water is diverted from the East Fork Chariton River into Sugar Creek Reservoir. If flow from the East Fork Chariton River is insufficient, water can be purchased and released from Long Branch Reservoir at Macon.

Figure 1-47 depicts the total annual demand verses the optimum yield for the Sugar Creek Reservoir and the optimum yield achieve by pumping East Fork Chariton River. As part of this study, the optimum yield determined in the 2011 WSS RESOP Analysis, has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the demands projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source.


Thomas Hill Reservoir
Jacksonville
Macon Co.
PWSD #1
Cairo
Sugar Creek
Lake
Huntsville
Clifton Hill
Moberly
Salisbury
Thomas Hill
PWSD #1
Renick
Higbee
Clark
Armstrong
Boone Co.
PWSD #10
129
3
24
5
63
3
124
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Carroll
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Wells
FIGURE 1-45 RANDOLPH COUNTY MAP
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US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES

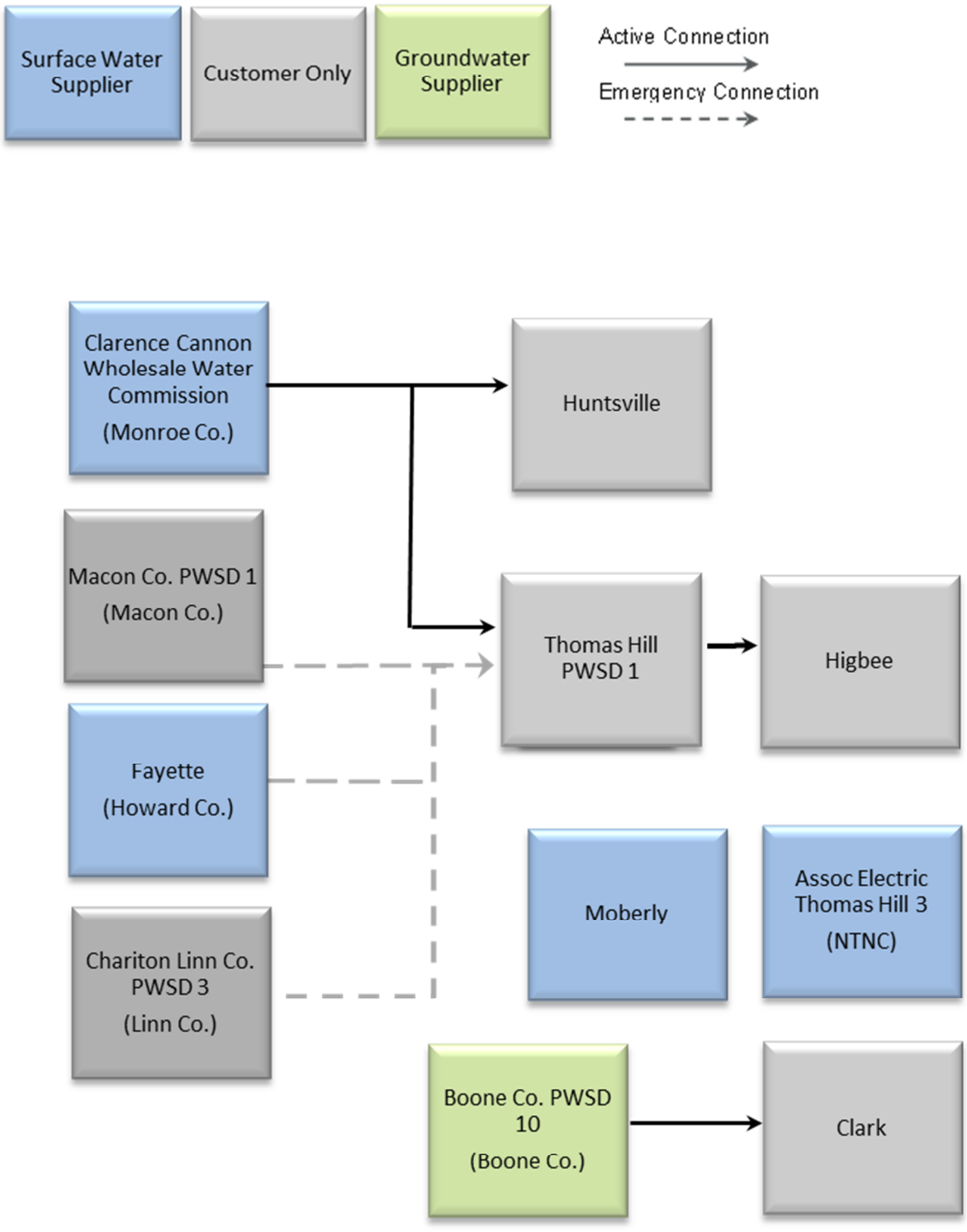


Figure 1-46 Randolph County Water Suppliers and Customers

Table 1-16 Randolph County – Water Supply Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Name[2]	Source Capacity (MGD)[2]
ASSOC ELECTRIC THOMAS HILL 3 MO2182290	5	265 (NTNC)	1.00	1.51	0.43	1 Lake	Thomas Hill Lake	NR
CLARK MO2010882	121	300	0.02	0.12	0.10	SW Purchase		Purchase
HIGBEE MO2010362	242	568	0.03	0.07	0.09	SW Purchase		Purchase
HUNTSVILLE MO2010393	653	1,563	NR	NR	0.13	SW Purchase		Purchase
MOBERLY MO2010533	5,271	13,741	1.23	5.00	3.56	1 Lake	Sugar Creek Lake	1.01
THOMAS HILL PWSD 1 MO2024504	3,984	9,870	0.60	1.22	0.67	SW Purchase		Purchase
Totals	**10,276**	**26,042**	**2.87**	**7.93**	**4.98**			

NR = Not Reported NTNC = Non-Transient Non-Community
[1]MDNR Drinking Water Watch
[2]MDNR 2011 RESOP Analysis

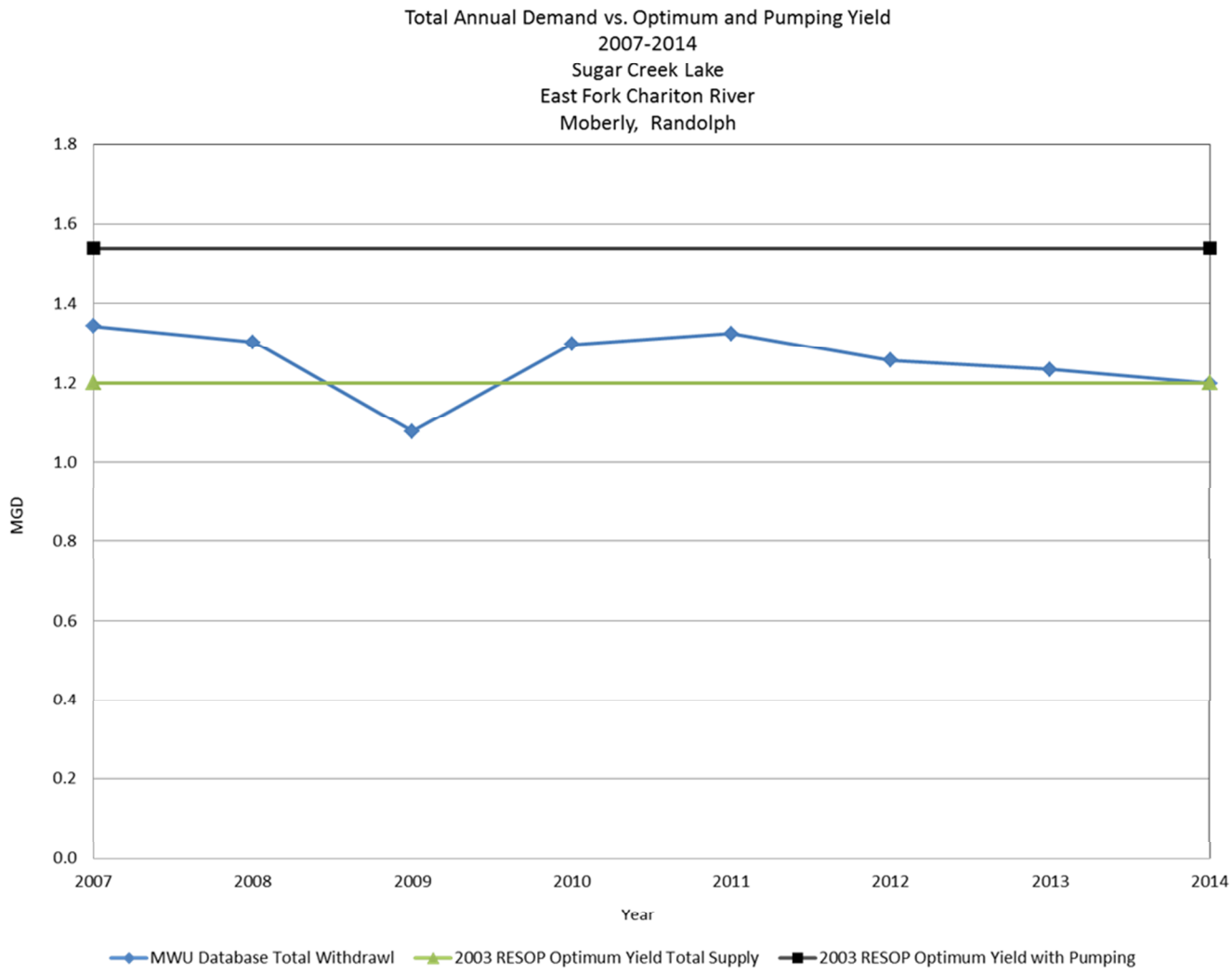


Figure 1-47 Demand Compared to 2003 Calculated Optimum and Pumping Yield from Sugar Creek and East Fork Chariton River

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

Schuyler County

Schuyler County is located within the northeastern portion of the Study Area in north central Missouri (see Figure 1-48). There are five public water systems within Schuyler County: Schuyler Co. PWSD 1, Liberty Prairie Water Co. and the cities of Downing, Glenwood, and Lancaster. Schuyler County does not have any groundwater or surface water supplies. All five systems purchase potable drinking water from Rathbun Regional Water Association in Iowa.

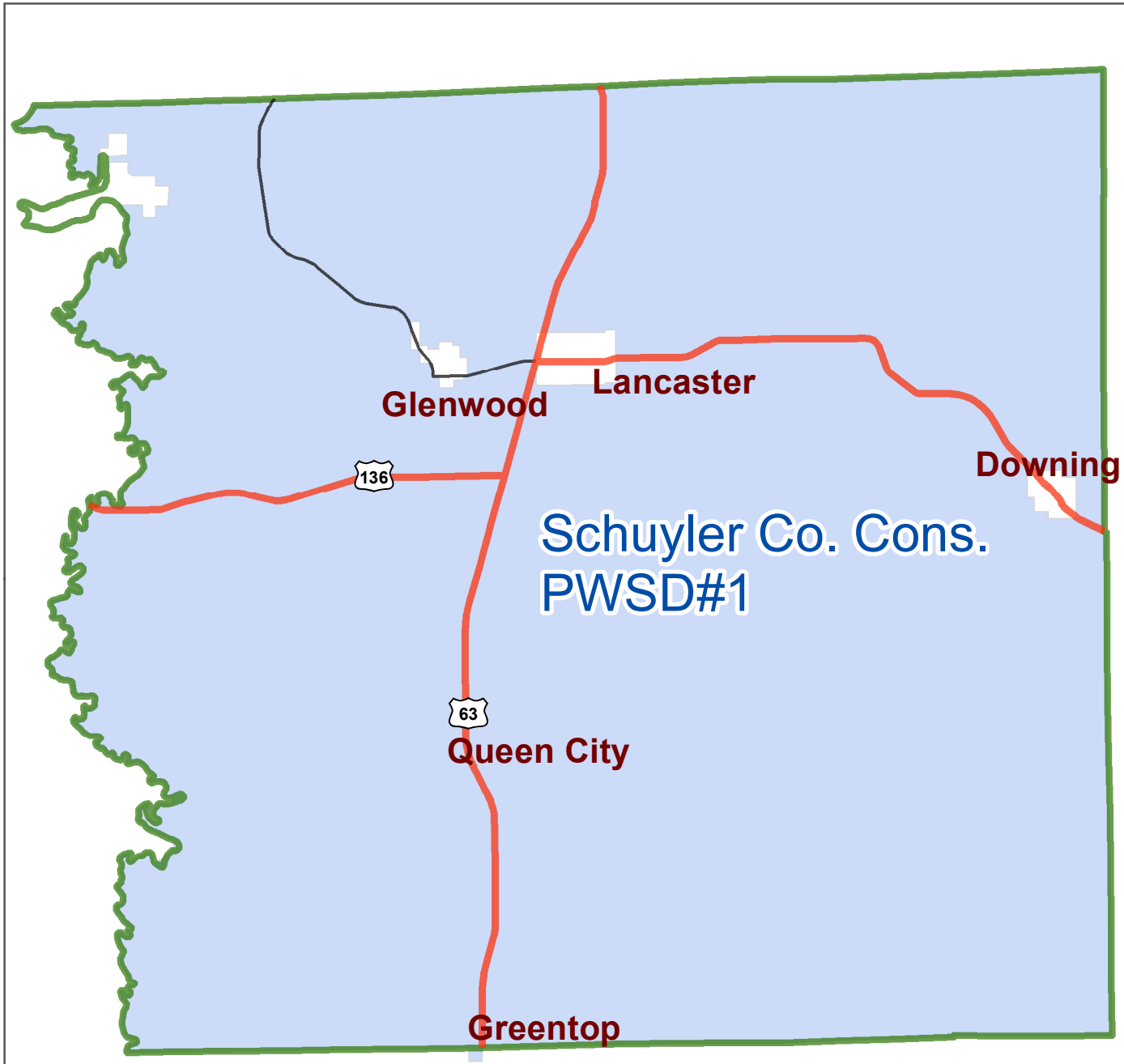
Figure 1-49 illustrates the supplier and customers in Schuyler County. Table 1-17 presents the general water system information for each system within Schuyler including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the five public water systems within Schuyler serve a total population of 4,740.

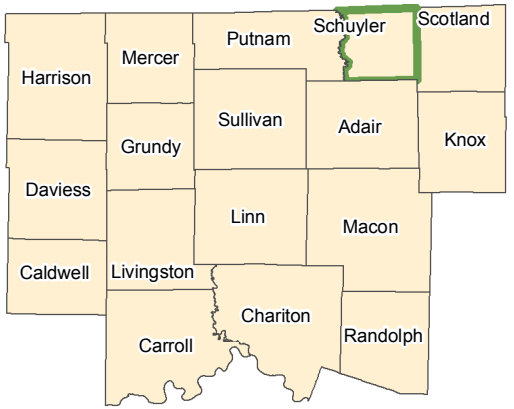
Current Groundwater Suppliers

Schuyler County does not have any groundwater sources or any systems which purchase groundwater.

Current Surface Water Suppliers

The water systems within Schuyler County all purchase finished surface water from suppliers outside of Schuyler County. Previously there had been three surface water reservoirs utilized as water supply by Downing, Lancaster, and Schuyler County PWSD 1. All three have subsequently been designated as *inactive*.





LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstate
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment_Plant
- Well

FIGURE 1-48 SCHUYLER COUNTY MAP

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MILES

US Army Corps of Engineers ®
Kansas City District

MISSOURI NATURAL RESOURCES

HDR

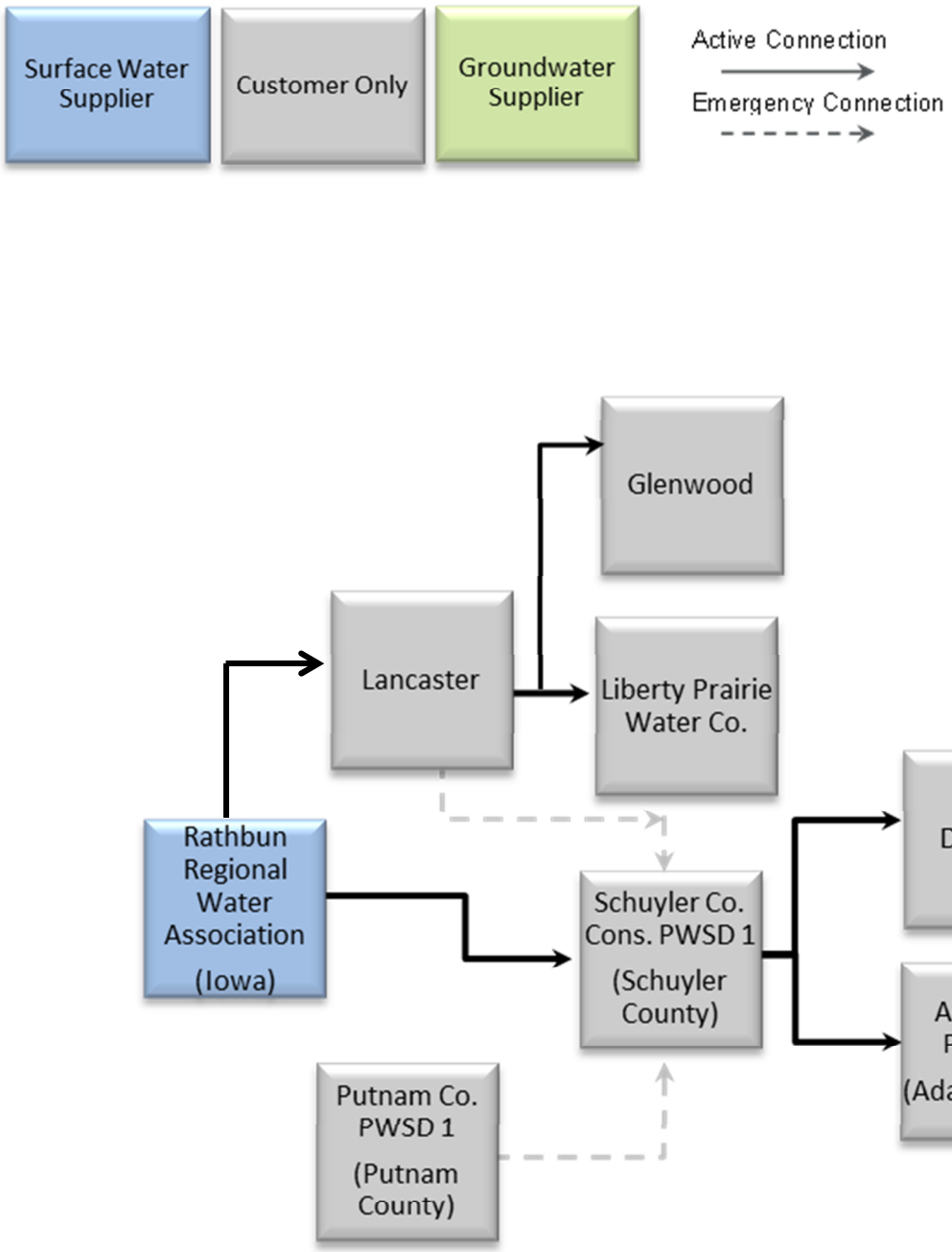


Figure 1-49 Schuyler County Water Suppliers and Customers

Table 1-17 Schuyler County – Water Supply Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Capacity (MGD)[2]
DOWNING MO2010224	207	335	0.03	0.07	0.05	SW Purchase	Purchase
GLENWOOD MO2010312	87	195	0.01	NR	0.01	SW Purchase	Purchase
LANCASTER MO2010450	383	728	NR	NR	NR	SW Purchase	Purchase
LIBERTY PRAIRIE WATER CO MO2070133	47	120	NR	NR	NR	SW Purchase	Purchase
SCHUYLER CO CONSOLIDATED PWSD 1 MO2024559	1,336	3,362	0.23	0.34	0.09	SW Purchase	Purchase
Totals	**2,060**	**4,740**	**0.27**	**0.41**	**0.15**		

NR = Not Reported

[1]MDNR Drinking Water Watch

[2]MDNR 2011 RESOP Analysis

Scotland County

Scotland County is located within the northeastern portion of the Study Area in north central Missouri (see Figure 1-50). There are two public water systems within Scotland County: Scotland Co. PWSD 1 and the City of Memphis. The City of Memphis is the only surface water supplier located within Scotland County. Scotland Cons. 1 purchases finished surface water from the City of Memphis and Rathbun Regional Water Association in Iowa.

Figure 1-51 illustrates the suppliers and customers in Scotland County. Table 1-18 presents the general water system information for each system within Scotland including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the two public water systems within Scotland serve a total population of 5,182.

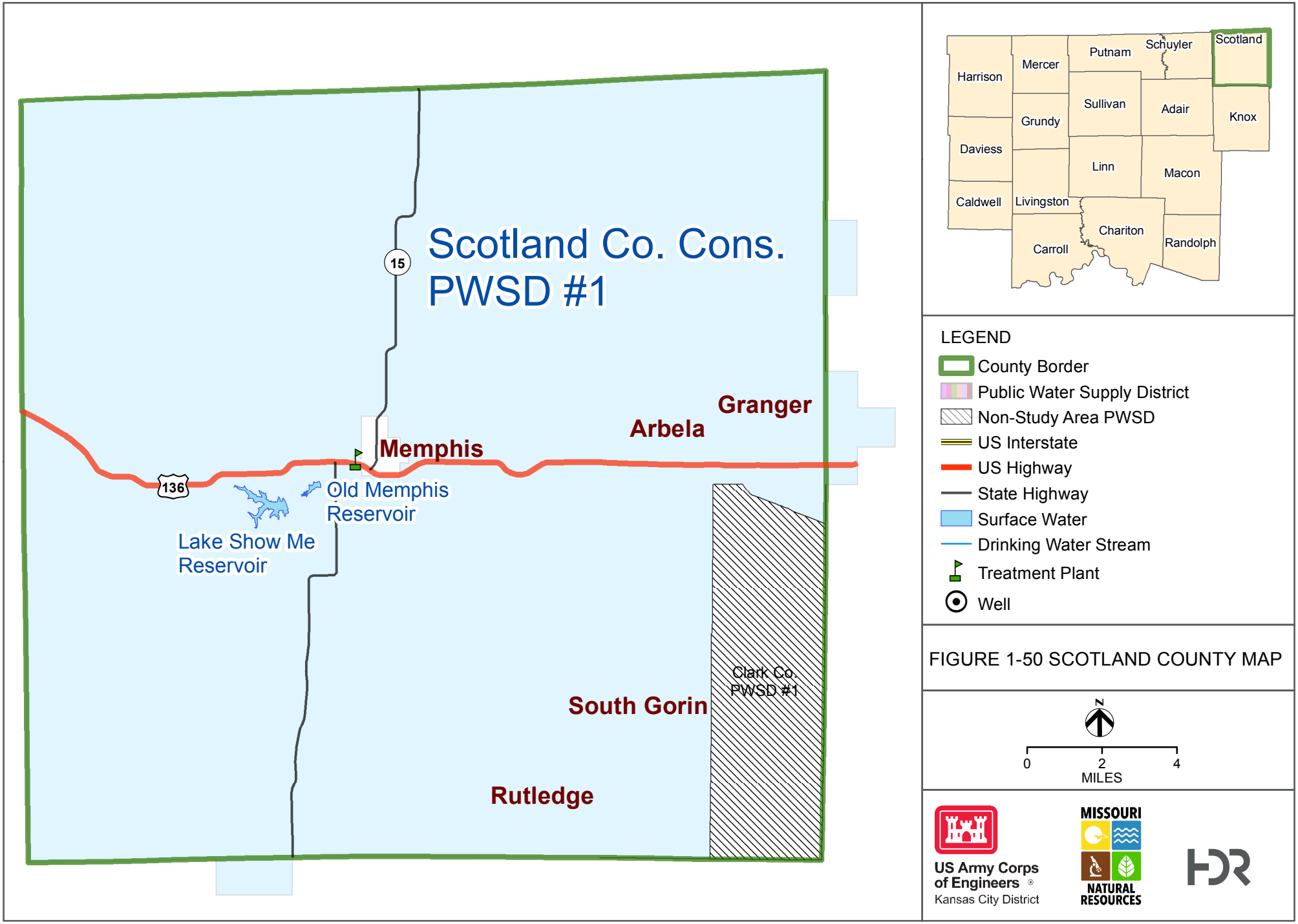
Current Groundwater Suppliers

Scotland County does not have any groundwater sources or any systems that purchase groundwater.

Current Surface Water Suppliers

The majority of Scotland County is located in the Fabius River watershed. The City of Memphis utilizes two lakes to convey finished surface water to the City. Lake Show Me Reservoir currently supplies Memphis with its total water demand while the Old Memphis Reservoir is used as a supplemental water supply. According to the 2011 WSS, the optimum yield for Lake Show Me is 0.780 MGD and 0.060 MGD for the Old Memphis Reservoir.

Figure 1-52 depicts the total annual demand verses the optimum yield for both Lake Show Me Reservoir and the Old Memphis Reservoir. As part of this study, the optimum yield determined in the 2011 WSS has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the demands projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source.


Scotland Co. Cons.
PWSD #1
15
136
Memphis
Granger
Arbela
Old Memphis
Reservoir
Lake Show Me
Reservoir
South Gorin
Rutledge
Clark Co.
PWSD #1
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Randolph
Carroll
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
FIGURE 1-50 SCOTLAND COUNTY MAP
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of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES
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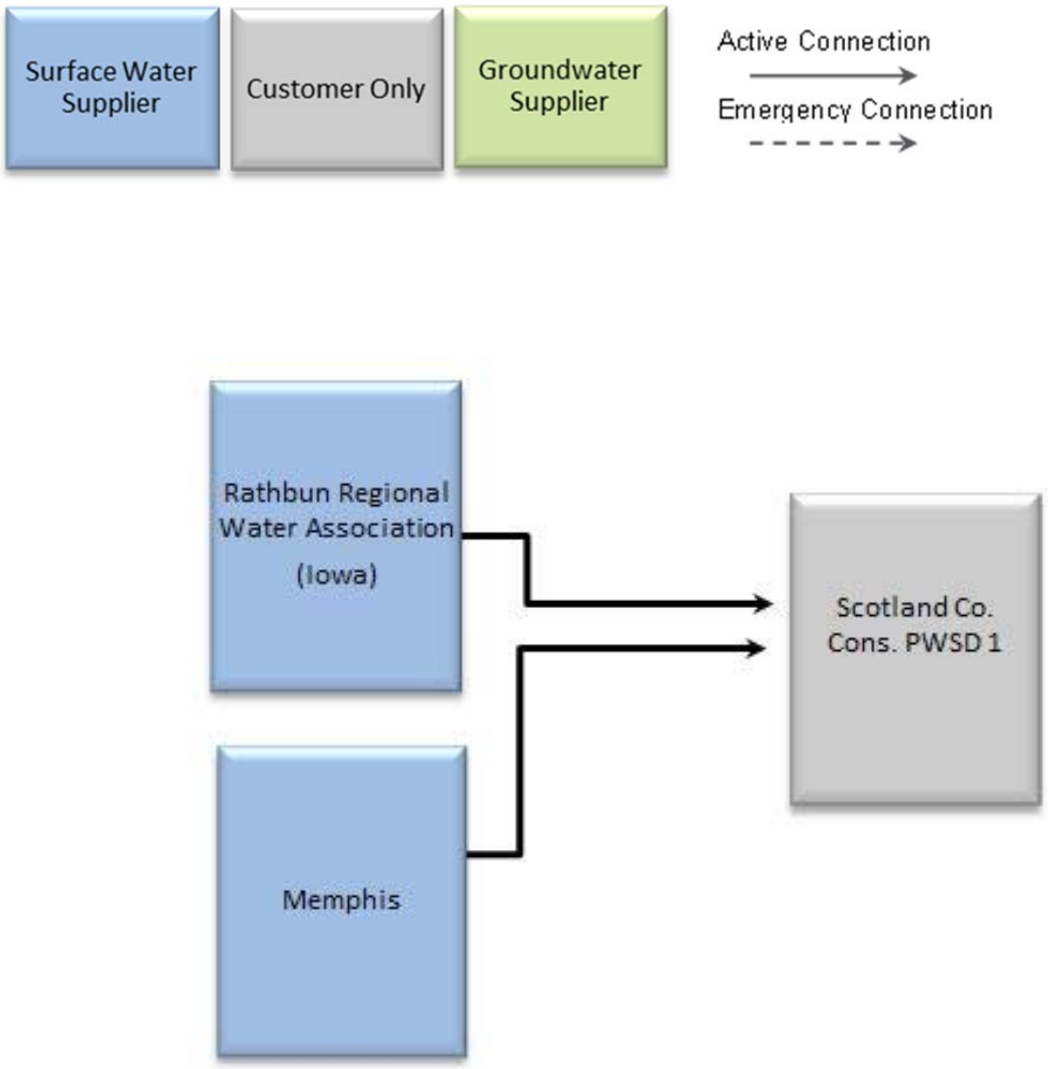


Figure 1-51 Scotland County Water Suppliers and Customers

Table 1-18 Scotland County – Water Supply Information

System/ID #	Connections[1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[2]	Source Name [2]	Source Capacity (MGD)[3]
MEMPHIS MO2010513	1,018	1,822	0.15	0.72	0.30	2 Lakes	Lake Show Me Old City Lake	0.88
SCOTLAND CO CONS PWSD 1 MO2024565	1337	3,360	0.29	0.27	0.30	SW Purchase		Purchase
Totals	**2,355**	**5,182**	**0.44**	**0.99**	**0.60**			

NR = Not Reported
[1]MDNR Drinking Water Watch
[2]MDNR 2011 RESOP Analysis

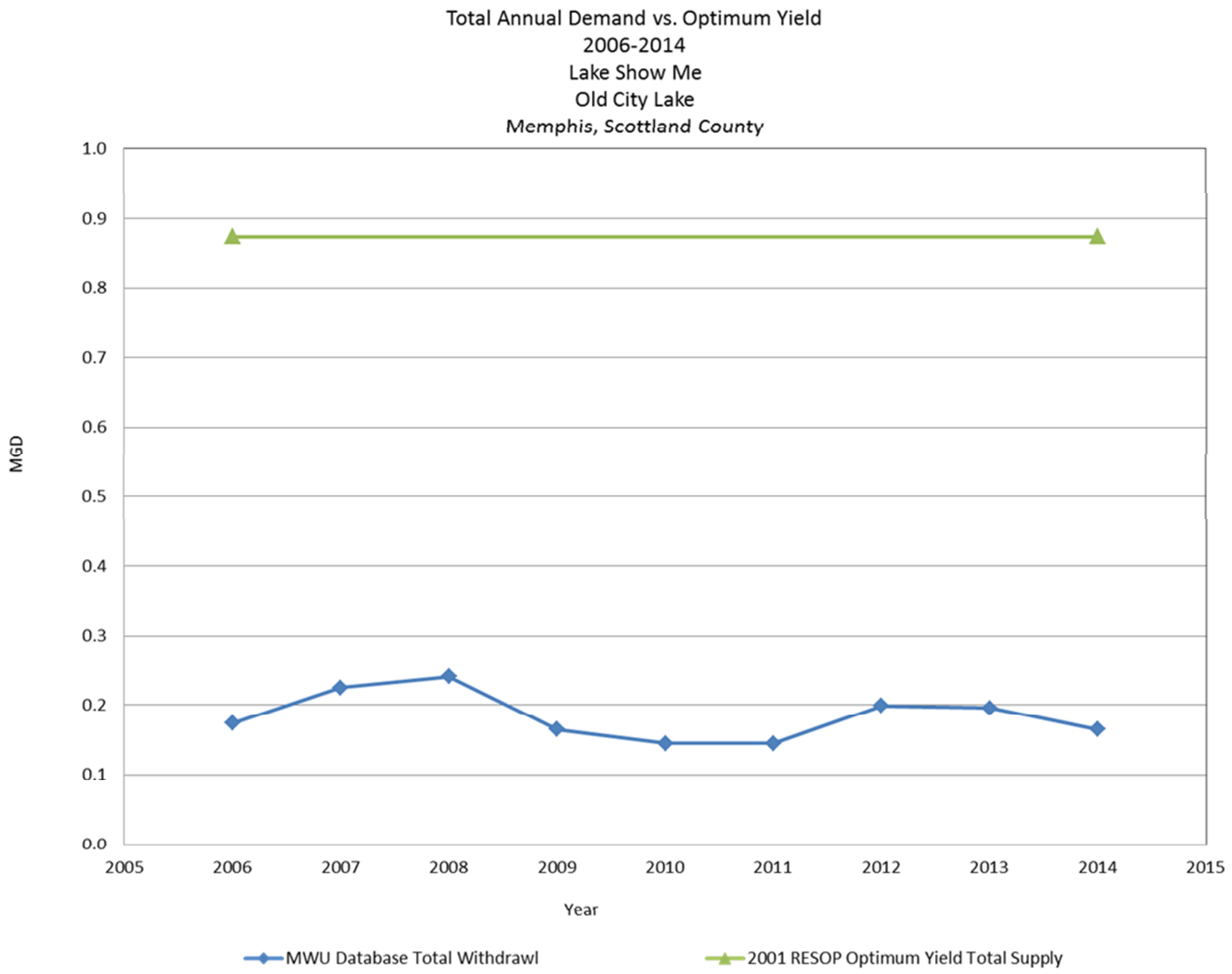


Figure 1-52 Demand Compared to 2001 Calculated Optimum Yield from Lake Show Me and Old City Lake

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

Sullivan County

Sullivan County is located within the north central portion of the Study Area in Missouri (see Figure 1-53). There are seven public water systems within Sullivan County: Sullivan Co. PWSD 1, North Central MO Regional Water Commission (NCMRWC), and the Cities of Green City, Green Castle, Humphreys, Milan, and Newtown. There is one private non-transient non-community (NTNC) water system within Sullivan County operated by Smithfield Farmland Corporation. Of the seven public water systems, only one is a surface water supplier (NCMRWC). The remaining six purchase finished surface water from within Sullivan County either directly from NCMRWC or via a consecutive connection. NCMRWC does have an emergency connection with the City of Trenton in Grundy County.

Figure 1-54 illustrates the supplier and customers in Sullivan County. Table 1-19 presents the general water system information for each system within Sullivan including the total number of connections, total population served, average daily flow, design capacity (or contracted capacity), total emergency capacity, water source, and source capacity. According to the MDNR DWW, the eight public water systems within Sullivan serve a total population of 8,739.

Of the seven public water systems, only one is a surface water supplier (NCMRWC). The remaining six purchase finished surface water from within Sullivan County either directly from NCMRWC or via a consecutive connection. NCMRWC does have an emergency connection with the City of Trenton in Grundy County.

Current Groundwater Suppliers

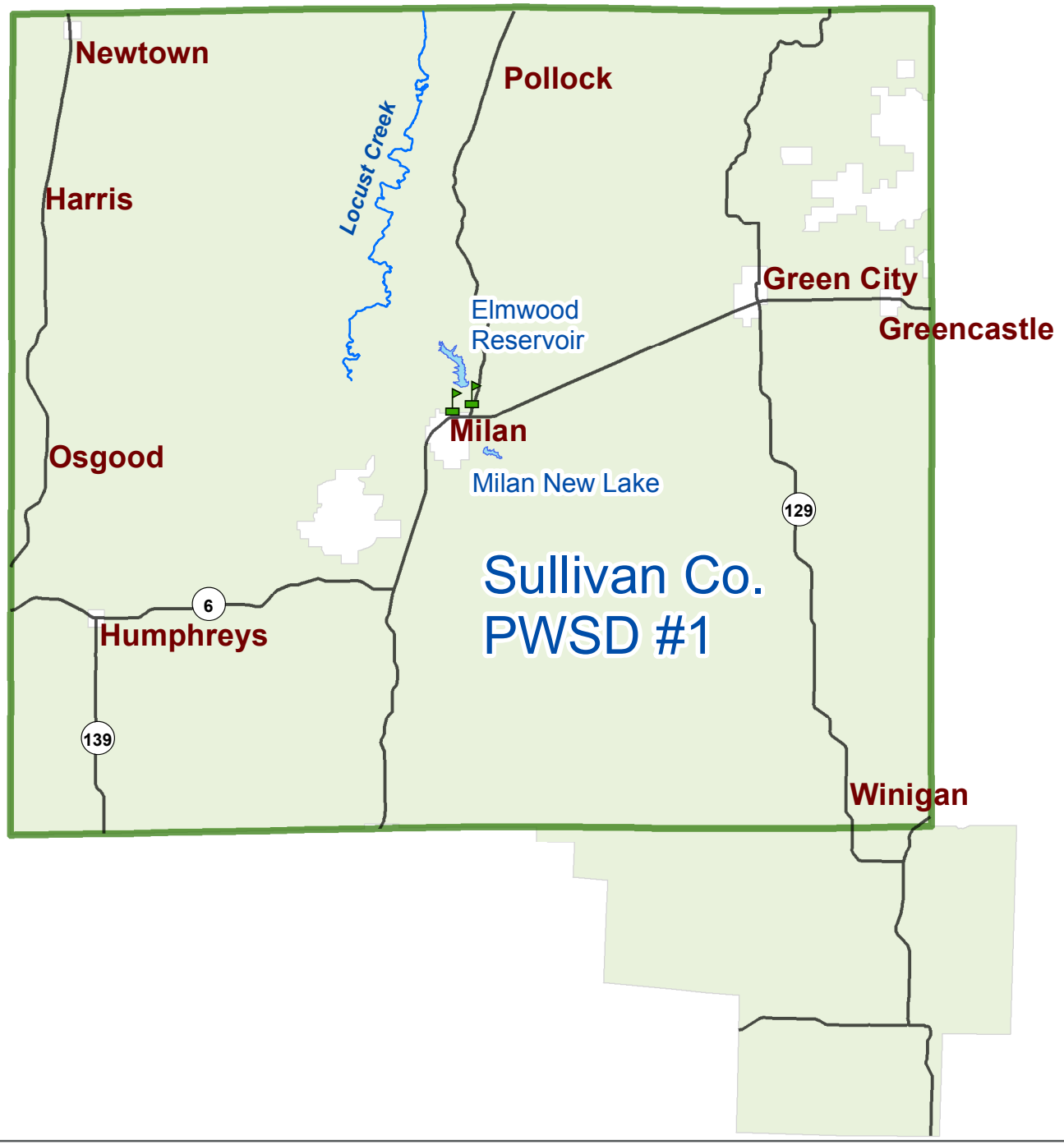
Sullivan County does not have any groundwater sources or systems that purchase groundwater.

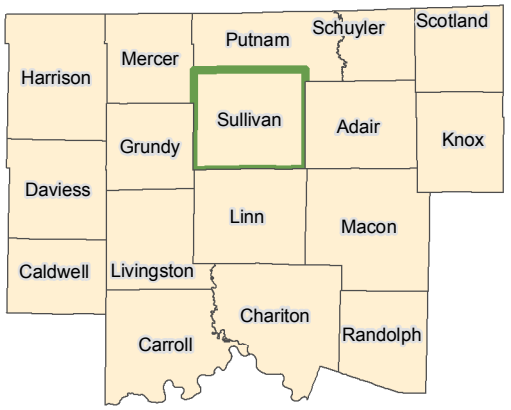
Current Surface Water Suppliers

In Sullivan County, the NCMRWC utilizes Elmwood Lake, Golf Course Lake, and Locust Creek for surface water supply. NCMRWC also has an emergency connection with Trenton Municipal Utilities.

The NCMRWC cannot meet current demand without pumping supplemental flow from Locust Creek into the Elmwood Reservoir. Smithfield Farmland Corp also draws from the Elmwood Reservoir to provide water to a poultry-processing plant and water for the Premium Standard Farms meat processing plant. The combined use from NCMRWC and Smithfield result in a total water demand of 1.65 MGD. According to the 2011 WSS, the optimum yield of the Elmwood and Golf Course Lakes is 0.937 MGD. Figure 1-55 depicts the total annual demand versus the optimum yield for the Elmwood and Golf Course Lakes and the optimum yield achieved by pumping Locust Creek. According to the 2015 NCMRWC Water System Source Improvement report, the Elmwood Lake demands stressed Locust Creek and Old City Lake to record low levels in spring 2013.

As part of this 2016 Study, the optimum yield determined in the 2011 WSS has been overlain with the more recent annual demands compiled as part of the Missouri's Major Water Users Database. However, the demands projected were not analyzed using RESOP, it is merely an aide to the reader to better understand the availability of the source.





LEGEND

- County Border
- Public Water Supply District
- Non-Study Area PWSD
- US Interstate
- US Highway
- State Highway
- Surface Water
- Drinking Water Stream
- Treatment Plant
- Well

FIGURE 1-53 SULLIVAN COUNTY MAP

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US Army Corps of Engineers
Kansas City District

MISSOURI NATURAL RESOURCES

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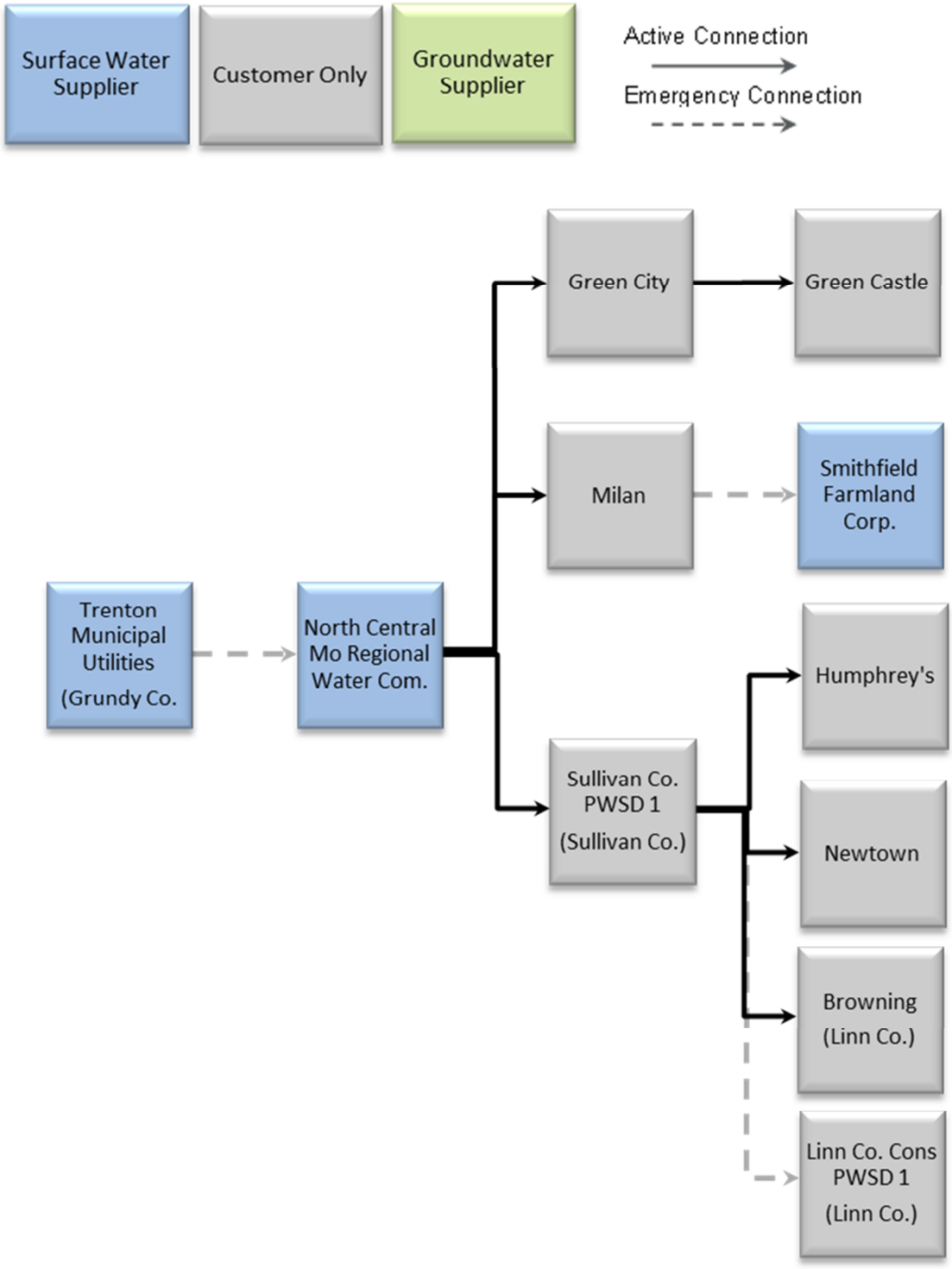


Figure 1-54 Sullivan County Water Suppliers and Customers

Table 1-19 Sullivan County – Water System Information

System/ID #	Connections [1]	Population[1]	ADF (MGD)[1]	Design Capacity/Contract (MGD)[1]	Total Emergency Capacity (MGD)[1]	Source[1],[3],[4]	Source Name [3]	Source Capacity (MGD)[3],[4]
GREEN CASTLE MO2010328	100	275	0.03	NR	0.03	SW Purchase		Purchase
GREEN CITY MO2010329	326	671	0.06	0.43	0.23	SW Purchase		Purchase
HUMPHREYS MO2010389	43	98	0.01	NR	0.01	SW Purchase		Purchase
MILAN MO2010523	809	1,960	0.16	0.20	0.78	SW Purchase		Purchase
NEWTOWN MO2010574	87	183	0.02	NR	0.02	SW Purchase		Purchase
NORTH CENTRAL MO REGIONAL WATER COM MO2021537	3	25	0.65	2.80	1.20	2 Lakes, 1 Creek	Elmwood Lake Golf Course Lake Locust Creek	1.09
SMITHFIELD FARMLAND CORP MO2181076	9	1,200 (NTNC)	0.32	0.40	NR	1 Lake	Elmwood Lake	NR
SULLIVAN CO PWSD 1 MO2024594	1,738	4,327	0.74	0.70	0.09	SW Purchase		Purchase
Totals	**3,115**	**7,539**	**1.99**	**4.53**	**2.35**			

NR = Not Reported NTNC = Non-Transient Non-Community

[1]MDNR Drinking Water Watch

[2]NCMRWC 2015 Preliminary Engineering Report and Feasibility Analyses for Water System Source Improvements

[3]MDNR 2011 RESOP Analysis

[4]MDNR 2007 Groundwater System Evaluation

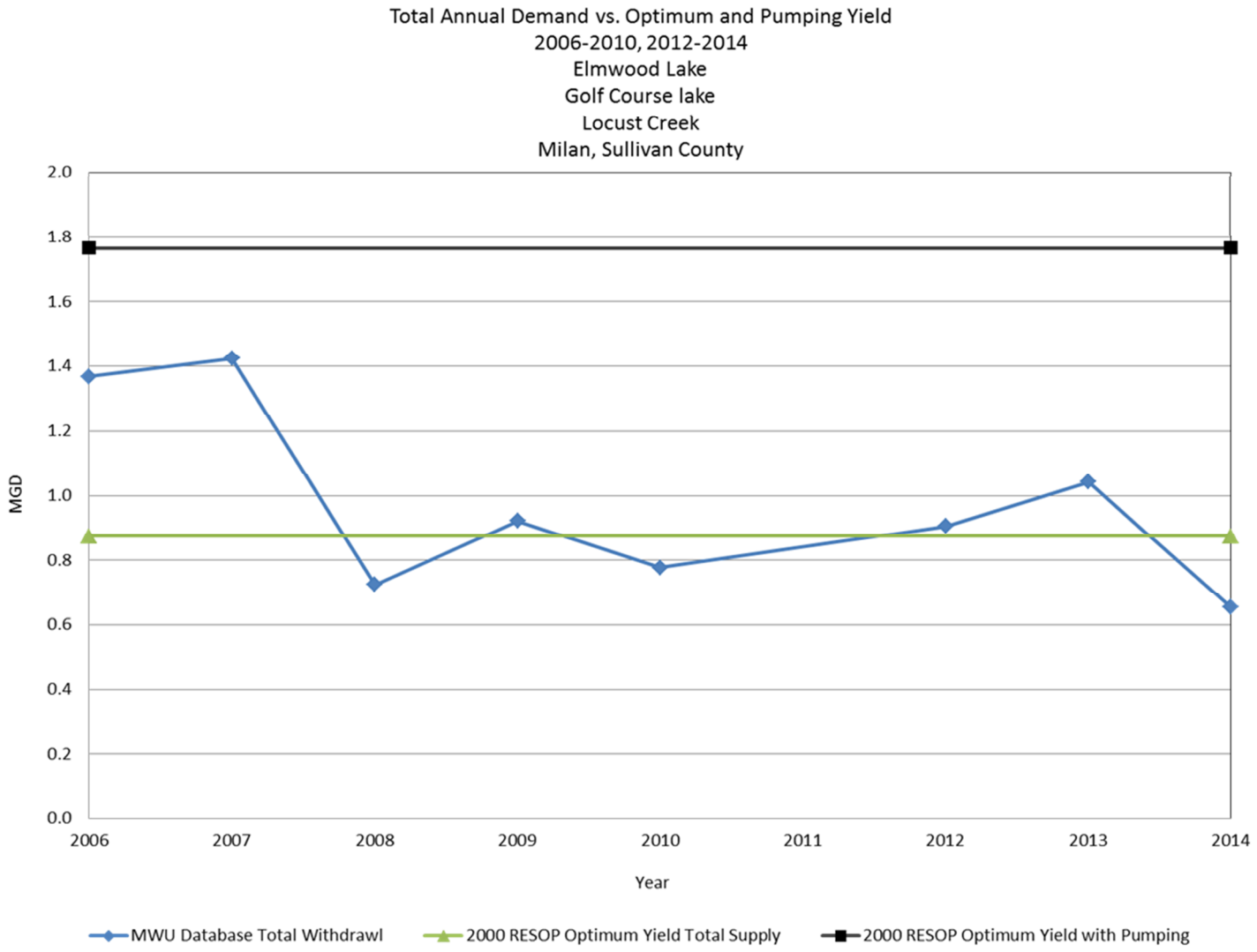


Figure 1-55 Demand Compared to 2000 Calculated Optimum Yield from Elmwood Lake, Golf Course Lake, and Locust Creek

Note: The demands projected above were not analyzed using RESOP. It is merely an aide to better understand the availability of the source.

1.5 Private Drinking Water Wells

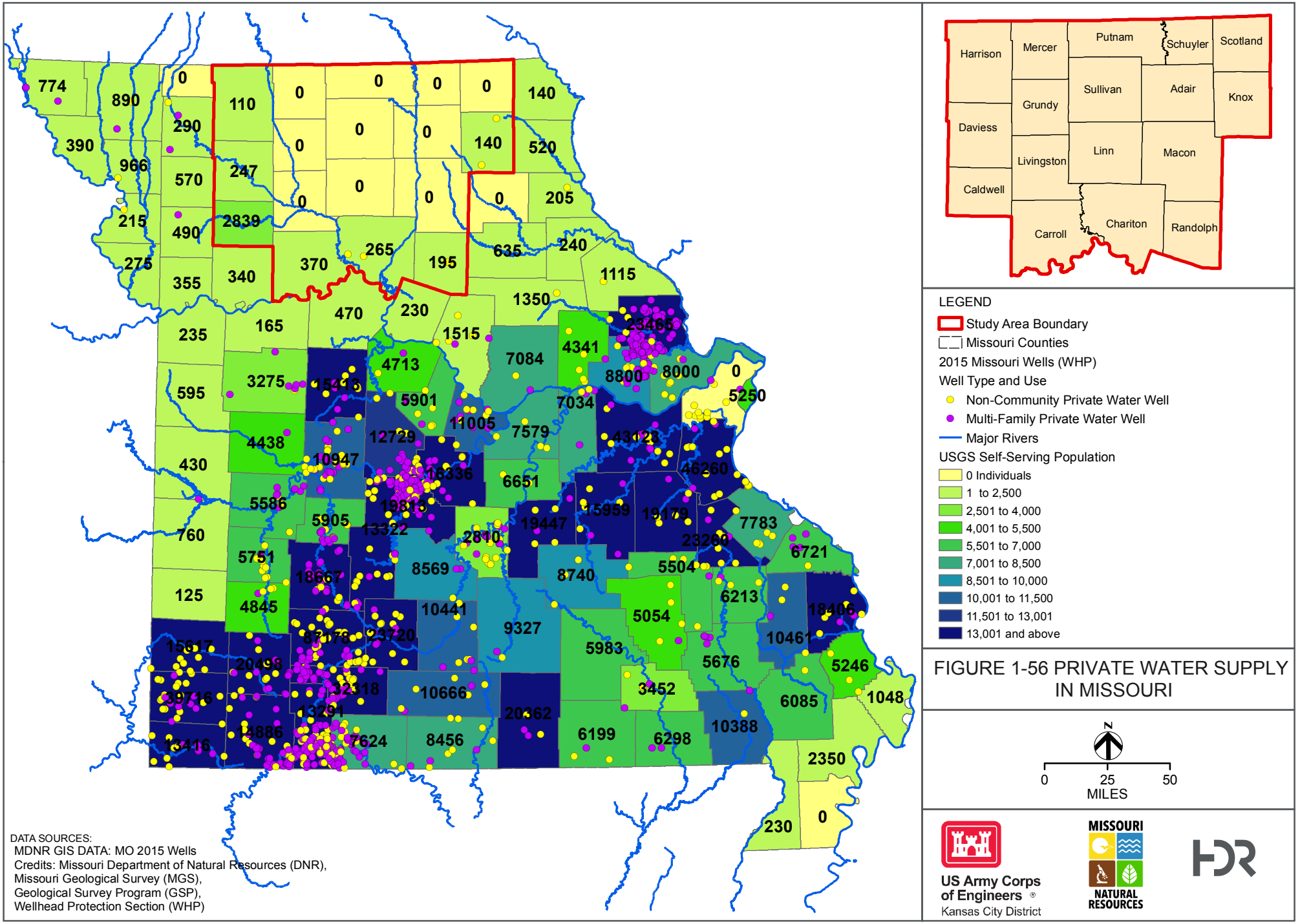
While the majority of the water users in Missouri rely on public water supply, private groundwater sources do exist and serve a portion of the population. USGS has published county-level water use estimates for the United States since 1950. According to the 2010 publication, approximately 883,000 people within the State of Missouri depend on domestic self-supplied water; a total of 14.7-percent of the total population in Missouri.

Private water supplies within Missouri are presented in Figure 1-56. According to MDNR, the number of private drinking wells in Missouri is unknown; however, the Missouri Water Well Drillers Act of 1985 created rules to enforce and establish well construction laws and standards aimed to protect Missouri's groundwater. MDNR implements this Act through The Wellhead Protection (WHP) Section, by regulating the construction of private domestic and multi-family groundwater wells and provides a database of the well information for wells drilled after July 1987. The WHP database includes 519 non-community water wells, 819 multi-family wells and 129,730 domestic private water wells for the State of Missouri.

According to the USGS estimates, 2-percent of the population (or 4,166 people) within the Study Area rely on a private water source and only 7 counties of the 17 have domestic self-supplied populations, see Table 1-20. Within the Study Area, the MDNR WHP database includes 6 non-community wells and 437 domestic private water wells. There are no multi-family wells listed within the WHP database in the Study Area.

Table 1-20 2010 Domestic Self-Supplied Groundwater Study Area Summary

COUNTY	Estimated Domestic, self-supplied population	Estimated Domestic, self-supplied groundwater withdrawals, MGD	Estimated Domestic, self-supplied per capita use, GPD
Caldwell	2,839	0.20	70
Carroll	370	0.03	81
Chariton	265	0.02	75
Daviess	247	0.02	81
Harrison	110	0.01	91
Knox	140	0.01	71
Randolph	195	0.01	51
Totals	4,166	0.30	72


Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Livingston
Linn
Macon
Caldwell
Carroll
Chariton
Randolph
LEGEND
Study Area Boundary
Missouri Counties
2015 Missouri Wells (WHP)
Well Type and Use
Non-Community Private Water Well
Multi-Family Private Water Well
Major Rivers
USGS Self-Serving Population
0 Individuals
1 to 2,500
2,501 to 4,000
4,001 to 5,500
5,501 to 7,000
7,001 to 8,500
8,501 to 10,000
10,001 to 11,500
11,501 to 13,001
13,001 and above
FIGURE 1-56 PRIVATE WATER SUPPLY IN MISSOURI
N
0
25
50
MILES
DATA SOURCES:
MDNR GIS DATA: MO 2015 Wells
Credits: Missouri Department of Natural Resources (DNR),
Missouri Geological Survey (MGS),
Geological Survey Program (GSP),
Wellhead Protection Section (WHP)
US Army Corps of Engineers
Kansas City District
MISSOURI NATURAL RESOURCES
HDR

Topic 2 Quality

In Missouri, the Safe Drinking Water Act is implemented by MDNR, which sets limits and monitors for 91 different chemical and microbiological contaminants in 2,722 public water supplies throughout the State. MDNR also monitors each public water supply to ensure it is operated by highly trained and certified staff.

The systems that provide potable drinking water are the focus of this report. As defined by MDNR, there are three types of public water systems:

1. Community systems supply water to the same population year-round and include towns, water districts, subdivisions, mobile home parks and residential facilities such as nursing homes or prisons.
2. Non-transient non-community are systems that regularly supply water to at least 25 of the same people at least six months per year, but not year round. Some examples include schools and factories.
3. Transient non-community are public water systems that provide water in a place such as a gas station or campground where people do not remain for long periods of time. These may be smaller systems are typically in rural areas where it is not feasible to hook up to a city or water district.

Construction, operation, monitoring, and other requirements, vary among these types of systems based on the type, size and source of water. Water testing at systems that are not public water systems, (such as homes served by private wells) is facilitated by local and county sanitarians and the Missouri Department of Health and Senior Services, rather than MDNR.

The quality of water is dependent on the source and conditions under which the water is obtained, as well as the treatment systems that make the water safe to drink. As discussed in Section 1.2, groundwater quality varies regionally throughout Missouri. However, unlike southern Missouri, the water located in the deep aquifers in northern Missouri is highly mineralized and generally non-potable. Deep bedrock formations contain groundwater with total dissolved solids (TDS) that range between 2,000 mg/L and 30,000 mg/L or more. Concentrations of TDS less that 1,000 mg/L are considered fresh water and palatable to humans. Concentrations above 1,000 mg/L are generally considered non-potable. Surface water quality may also be impacted greatly by an increase in seasonal rainfall. Substantial precipitation events have the potential to overwhelm water infrastructure such as sewer conveyance systems, water treatment plants and wastewater treatment plants with large volumes of water. A heavy rainfall can increase the amount of runoff into surface water, causing sediment, nutrients, pollutants, trash, animal waste and other material into the water supply, which may then be unusable, unsafe or in need of additional treatment.

MDNR provides public access to information on local water systems across the state on the MDNR Drinking Water Watch (DWW) database. Water quality issues and treatment processes for groundwater and surface water sources identified from the MDNR DWW database between the years 2005 and 2015 for groundwater and surface water are presented in Table 2-1 and Table 2-2, respectively.

The MDNR water system violation and inspection reports issued from 2005 through 2015 across the 17 county Study Area were reviewed. The issues on quality of treatment in the reports included:

- High percentage of water loss
- Maximum contaminant levels for disinfection byproducts were exceeded
- Inadequate maintenance for microbial threats within systems
- Maximum contaminant levels exceeded for a few constituents
- Need for routine reporting and monitoring processes
- Need for adequate operator staffing
- Additional treatment processes required (such as filtration)

2.1 Regional Groundwater Source Quality

Groundwater quality is highly dependent on the aquifer type for which it is derived from. In north central Missouri there are three available aquifers. A brief description of the general quality concerns and geologic setting of each aquifer is presented below:

- **Bedrock Aquifer** – Pennsylvanian-age bedrock underlies most of north central Missouri. Only the upper 100 to 150 feet potentially yields potable water. Deeper units contain progressively more mineralized groundwater. Groundwater in the shallower bedrock zones is marginal in quality, having total dissolved solids in the range of 800 mg/L to about 2,000 mg/L. The water can also contain excessive sulfate, chloride, iron, and manganese. Deeper bedrock formations contain groundwater with total dissolved solids that range between 2,000 mg/L and 30,000 mg/L or more.
- **Glacial Drift Aquifer** – Located above the Bedrock Aquifer, the water contained in the Pleistocene-age glacial drift aquifer tends to be better quality than that in the under lying bedrock. Total dissolved solids range between 400 and 1,500 mg/L. In some cases, the glacial drift may overlay preglacial valleys filled with pre-Pleistocene alluvial deposits. These valleys produce higher yields but water found in the valleys tends to be poorer quality. This is due to longer residence time, poor recharge potential, and local leakage of water from adjacent or deeper bedrock formations that contain highly mineralized water.
- **Recent Alluvium** – The Missouri River tributaries (Grand, Thompson, and Chariton Rivers) are known to have sufficient alluvial deposits to produce significant yields of water. The chemistry of the groundwater in the alluvial deposits is similar to the alluvium of the Missouri River. However, iron and manganese levels tend to be higher in the alluvium of the Missouri River tributaries, ranging between 0.4 mg/L to 18.0 mg/L for iron and 0.3 mg/L to 1.8 mg/L for manganese with the averages being 5.0 mg/L and 0.35 mg/L, respectively. Total dissolved solids range from 230 mg/L to approximately 850 mg/L.

The potential for groundwater contamination is high in large diameter, shallow wells located in the glacial drift aquifer or recent alluvium due to surface activities. The wells routinely contain bacteria and may also contain nitrate and agricultural chemicals. Pesticides were detected in several domestic wells

throughout Caldwell, Daviess, and Scotland counties in studies performed in 1991 and 1992. In addition, several wells also showed traces of nitrate and nitrite contamination.

As shown in Table 2-1, a majority of municipal groundwater suppliers have water quality issues. Many facilities reported violations for coliform, for total haloacetic acids, trihalomethanes, as well as the presence of hard water and lead. Many facilities require periodic acidification to maintain pumping capacity of production wells. Table 2-1 also outlines treatment processes used at each facility. The level and complexity of treatment is indicative of the quality of raw water.

As presented in Topic 1, groundwater aquifers of high yield, high recharge rates and low vulnerability to contamination are considered a precious commodity in northern Missouri. Of the limited groundwater sources found in northern Missouri, aquifers may have poor yield, recharge rates less than one inch per year, poor water quality, or an unfortunate combination. According to the Missouri SWP II, the potable groundwater aquifers in Missouri originated as, and are recharged by, local precipitation. Safe yield of an aquifer is dependent on the amount of water that can be drawn without producing an undesired result. Exceeding the safe yield of an aquifer can cause unnecessary drawdown of vulnerable aquifers and/or intrusion of lower quality water. During times of prolonged drought, with the possibility of increasing water demand, the declining aquifer levels and declining recharge rates may expose the stressed aquifers to additional contamination.

Table 2-1 Municipal Groundwater Supply Quality Issues and Treatment Processes within Study Area (2005 – 2015)

	Water Quality Issues																	Treatment Processes												
County	Ammonia	Carbon	Chlorine [1]	Chlorides	Chlorite	Coliform	Hard Water	Iron	Manganese	MTBE Contamination	Nitrates	Residual Chorine	Sulfates	Total Haloacetic Acid	Total Trihalomethanes	Turbidity	Lead and Copper Rule Violation	Routine Acidification	Aeration	Coagulation	Filtration	Flocculation	Fluoridation	Hypochlorination	Disinfection	Polyphosphaste Inhibitor	Lime-Soda Ash	Permanganate	pH Adjustment	Rapid Mix Sedimentation
Caldwell		X				X								X	X		X	X	X		X	X			X		X	X	X	X
Carroll			X			X											X		X	X	X	X	X	X	X		X		X	X
Chariton			X			X													X	X	X	X	X		X		X		X	X
Daviess						X	X	X										X	X		X		X	X	X		X			X
Harrison															X				X		X				X	X				X
Linn						X													X	X	X	X			X		X		X	
Livingston						X													X	X	X	X	X		X		X	X	X	X
Mercer			X																X		X				X		X		X	X

[1] Failure to maintain microbial treatment

2.2 Regional Surface Water Source Quality

The quality of surface water in north central Missouri is generally good (Vandike, 1995). The clay and silt content of the glacial till covering the landscape has a low permeability, and does not contribute appreciable amounts of groundwater to area streams. The soils are highly erodible, as a result, streams and rivers in the area tend to have low base flows and experience high runoff. Turbidity is also generally higher, especially after rain events. The water is generally a moderately mineralized calcium-magnesium-bicarbonate type, and total dissolved solids are typically below 500 mg/L. Sulfate and chloride are generally present at moderate levels, but are normally less than 150 mg/L. Runoff from agricultural area can contribute bacteria, nutrients, and pesticides to surface streams. Wastewater discharges from towns increase bacteria levels and also contribute nutrients to the stream. Sulfate, iron, and manganese contents can be well above public drinking water standards at times. Raw water quality issues can also occur, especially during periods of drought or flooding. Discharges from abandoned, unreclaimed coal mines in the Chariton River basin also adversely affect the quality of water in the receiving stream, especially during periods of low flow (Vandike, 1995).

Eutrophication in lakes that serve as public drinking water supply can give rise to several issues, including taste and odor problems, higher treatment costs, and potential health hazards. The last impact may come in the form of cyanotoxins or disinfection byproducts, notably total trihalomethanes (TTHMs). This is due to excess nutrients, including nitrogen and phosphorus, entering lakes from point and non-point sources within drainage basins. These may cause algal blooms, which are closely linked to algal toxins and high levels of organic carbon, which 0may be disinfection byproduct precursors.

Water quality issues identified in the Public Water Supply (PWS) Violations Database and treatment process used at each facility are presented by county in Table 2-2. The level and complexity of treatment is indicative of the quality of raw water; water that is of good quality does not require as much treatment. Most surface water treatment systems in north central Missouri require multiple steps of treatment to provide clean drinking water.

Table 2-2 Municipal Surface Water Supply Quality Issues and Treatment Processes within Study Area (2005 – 2015)

	Water Quality Issues										Treatment Processes													
County	Carbon	Chlorine Dioxide	Chlorite	Coliform	Free Residual Chlorine	Nitrate-Nitrite	Total Haloacetic Acids	Total Trihalomethanes	Turbidity	Lead and Copper Rule Violation	Activated Carbon	Chlorination	Chlorine Dioxide	Coagulation	Filtration	Flocculation	Fluoridation	Hypochlorination	Permanganate	pH Adjustment	Sedimentation	Lime - Soda Ash Addition	Rapid Mix	Sludge Treatment
Adair	X		X						X			X	X	X	X	X	X		X	X	X		X	
Caldwell	X	X					X	X	X	X	X	X	X	X	X					X	X		X	
Daviess							X	X			X	X		X	X			X			X		X	X
Grundy								X	X		X	X		X	X	X	X			X	X	X	X	
Harrison	X						X					X	X	X	X	X	X			X	X		X	
Linn	X						X	X			X	X		X	X	X	X		X	X	X	X	X	
Macon			X								X	X	X	X	X	X	X	X		X	X		X	
Putnam										X	X	X		X	X	X	X		X	X	X	X	X	
Randolph				X			X	X			X	X		X	X	X	X		X	X	X	X	X	
Scotland							X	X			X	X		X	X	X	X			X	X		X	
Sullivan									X		X	X	X	X	X	X			X	X	X		X	

2.3 Private Drinking Water Quality

The Safe Drinking Water Act, implemented by MDNR, requires monitoring and regulation of public water supplies. However, according to the USGS, approximately 14.7-percent of the population in Missouri relies on private sources. Private water sources can be ponds, cisterns, or shallow glacial drift wells; all of which maybe subject to surface water influence that is not regulated or monitored by MDNR or any Federal agency. The water quality testing for these private sources is performed by the Missouri Department of Health and Senior Services (MDHSS), only at the request of the landowner. According to the USGS, in a study of over 2,000 private drinking wells across the United States, 23-percent of those private wells had at least one contaminant at a level of potential health concern.

According to MDNR in northern Missouri, similar to public groundwater wells, private water supplies are obtained from glacial drift deposits from overlying limestone bedrock that is often too mineralized for drinking water purposes. Groundwater contamination risks due to the permeability of the soil and surface activities; such as agriculture, pose potential health risks. The major groundwater concern is the unfiltered transmission of contaminated surface runoff that travels through glacial drift directly to shallow aquifers. Sources of contamination might include septic tanks, agricultural activities (e.g. animal production) and other wastes (MDNR, 2012).

In 1994 the Centers for Disease Control and Prevention (CDC) conducted a survey and completed water quality testing from private water wells across nine Midwestern states including wells in northern Missouri. The study measured *e. coli*, nitrate, and atrazine concentrations in various well types. Well types that exhibited the largest number of contaminations included:

1. Shallow dug or bored wells
2. Wells with septic tanks in the vicinity
3. Wells in areas where pesticides were applied
4. Wells in the vicinity of manure or fertilizer applications within 100 feet of the well

Private water supply wells in northern Missouri were found to have a higher percentage of water samples containing *e. coli* and elevated nitrate levels compared to other areas sampled within the CDC report (CDC, 1994).

Topic 3 Regulatory Compliance Issues

This section provides a brief summary of regulatory issues that impact surface water and groundwater supplies. Regulatory issues discussed include Stage 1 and Stage 2 Disinfectants/Disinfection By-Product (D/DBP) rules, the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), the Groundwater Rule, the Lead and Copper Short-Term Revisions, Revised Total Coliform Rule, updated Minimum Design Standards for Missouri Community Water Systems, and Water Quality Standards.

3.1 Stage 1 and Stage 2 Disinfectants/Disinfection By-Product Rules

The Stage 1 D/DBP Rule applies to all community and non-transient non-community water systems that treat water with a chemical disinfectant for either primary or residual treatment. The rule sets maximum residual disinfectant levels for chlorine, chloramine, and chlorine dioxide, and tightens the maximum containment levels (MCLs) for disinfection by-products including:

- Total trihalomethanes (TTHM)
- Haloacetic acids (five) (HAA5)
- Chlorite
- Bromate

A system is in compliance when the running annual average of samples taken in the distribution system, computed quarterly, is less than or equal to the MCLs.

The Stage 2 DBP Rule published in the Federal Registrar in January 2006 and is a more stringent standard that builds upon Stage 1. Stage 2 made a significant change to the compliance calculation of Stage 1. The Rule became effective in Missouri on October 30, 2009. Stage 2 D/DBP applies to all community and non-transient non-community water systems that add or deliver water that is treated with a primary or residual disinfectant other than ultraviolet light. This includes any community and non-transient community systems that either chlorinate or buy and sell chlorinated water. The Stage 1 and Stage 2 rules are regulated throughout the whole distribution system and may be easier to attain and more cost-effective for a region-wide system than individual systems.

Under Stage 2 D/DBP, a system must be in compliance with a locational running annual average (LRAA). A LRAA requires that compliance be calculated for each monitoring location in the distribution system. Monitoring locations are determined through a distribution system evaluation that identifies locations with high disinfection by-product potential. This Rule also requires each system to determine if they have exceeded an operational evaluation level. A system that exceeds an operational evaluation level is required to review their operational practices and submit a report to MDNR which identifies actions that will mitigate future high DBP levels, particularly those that may jeopardize compliance with the disinfection by-product MCLs.

Most of the public water systems within the Study Area utilize chloramines for disinfection. Chloramines are a very stable and relatively long-lasting disinfectant in a distribution system. As an annual maintenance activity to optimize the water quality within the distribution system, the treatment plant will switch disinfection methods to free chlorine, usually during the spring months, for approximately 30 days or until the distribution system has been completely flushed. This practice is known as a “system

burnout" and is done to eliminate nitrification and remove any potential biofilm or bacteria within a distribution system. Once the system flushing is complete, the treatment plant will resume chloramine disinfection.

3.2 Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)

The LT2ESWTR applies to all public water systems that use surface water or ground water under the direct influence of surface water. It became effective in Missouri on October 30, 2009. LT2ESWTR requires systems to monitor for *cryptosporidium* (or for small systems, *e. coli*) to determine the treatment "bin". A bin is a treatment category based on their monitoring results. Systems in lowest bin have no additional treatment requirements. Systems in higher bins must provide additional treatment to further reduce *cryptosporidium* levels. Systems must select from different treatment and management options in a "microbial toolbox" to meet additional treatment requirements. Systems must also review the current level of microbial treatment before making significant changes in disinfection practices.

3.3 Groundwater Rule

The Groundwater Rule (GWR), published in the Federal Registrar in 2006, applies to all public water systems that use ground water, including consecutive systems. It also includes systems that mix surface and groundwater if the groundwater is added directly to the distribution system and provided to consumers without treatment equivalent to surface water treatment. In December 1, 2009 the GWR became effect in Missouri. The GWR establishes a risk-targeted approach to identify systems susceptible to fecal contamination including:

- periodic sanitary surveys of groundwater systems
- triggered source water monitoring
- corrective action if a significant deficiency is identified as a result of sanitary surveys or source water contamination
- compliance monitoring to demonstrate treatment effectiveness

If a corrective action is required, the public water system must implement one or more of the following correction actions:

- Correct all significant deficiencies
- Eliminate the source of contamination
- Provide an alternate source of water, or
- Provide treatment which reliably achieves 99.99 percent (4-log) inactivation or removal of viruses.

3.4 Lead and Copper Rule Short-Term Revisions

The purpose of the Lead and Copper Rule (LCR) is to protect public water system consumers from exposure to lead and copper in drinking water. It is applicable to systems classified as community water systems, non-transient non-community water systems, state primacy agencies, and local and tribal

governments. Originally published in 1991, revisions were implemented in 2007 that modified the following monitoring requirements:

- Systems are required to provide advanced notification and gain the approval of the primacy agency for intended changes in treatment or source water that could increase corrosion of lead.
- Systems are required to provide notification of tap water monitoring results for lead to owners and/or occupants of homes and buildings who consume water from taps that are part of the utility's sampling program.
- Utilities are required to reconsider previously "tested-out" lines when resuming lead service line replacement systems.
- Changes to the content, delivery method, and timeframes in which public notices and messages are delivered.
- Educational statements about lead in drinking water are to be included in all Consumer Confidence Reports.

High levels of lead and copper are rarely found in the source water that a water system treats and provides to its customers. The main sources of lead and copper in drinking water usually are plumbing materials made from copper, lead service lines and lead solder, and faucets containing brass or bronze internal parts, which may contain lead impurities. If the water provided by a water system is highly or even moderately corrosive, some of the lead and/or copper in the plumbing materials may be released into the drinking water in homes or buildings served by the water system.

A sampling program that measures lead and copper levels at customers' taps is an effective method for evaluating whether a system has corrosive water. Those water systems found to be providing corrosive water are required to install corrosion control treatment to lower the corrosiveness of the water, which should then result in lower lead and copper levels at customers' taps.

Many water systems have successfully employed corrosion control treatment to achieve compliance with the Lead and Copper Rule. However, some systems have difficulty in sufficiently reducing lead and copper leaching, and other systems may need to change water treatment approaches because of other regulatory issues or changes in water sources. In particular, groundwater systems with neutral pH values, high hardness, and high alkalinity may have difficulty meeting the copper action level.

Lead and copper entering drinking water from household plumbing can also be controlled by changing water quality characteristics. The water quality factors that have the greatest effect on lead and copper corrosion are pH, dissolved inorganic carbonate, orthophosphate concentration, alkalinity, and buffer intensity. Dissolved oxygen and/or chlorine residual are also important factors related to copper. There are many factors that effect the leaching of lead and copper, but cannot easily be altered by a water system, and have a lesser effect on corrosive water.

3.5 Revised Total Coliform Rule

The EPA promulgated revisions to the 1989 Total Coliform Rule in 2013 known as the Revised Total Coliform Rule (RTCR). The purpose of the Rule, which affects all public water systems, is to increase

public health protection by reducing potential pathways of entry for fecal contamination into distribution systems. The rule uses *e. coli* and total coliforms to initiate a "find and fix" approach to address problems that could potentially allow fecal contamination to enter the distribution system. System self-assessments will be required when certain total coliform or *e. coli* triggers are exceeded.

A Level 1 assessment can be conducted by system staff, and consists of a basic examination of the source water, treatment, distribution segment, and relevant operational practices. The purpose is to look at conditions that could have caused the total coliform-positive sample. Level 2 assessments are more comprehensive and must be performed by MDNR or an MDNR approved third party. The system must also comply with any expedited or additional actions required by MDNR in the case of an *e. coli* MCL violation. A system that incurs an *e. coli* MCL violation must conduct a Level 2 assessment and correct any sanitary defects found. A Level 2 assessment is also required if a system has triggered a second Level 1 assessment within a rolling 12-month period. There will no longer be an MCL violation for total coliform.

As the RTCR dictates, sanitary defects must be identified and corrective actions must be taken. The water system must maintain assessment forms and documentation of corrective actions for at least five years after completion of the assessment or corrective action. In addition, the Consumer Confidence Report is required to include information on Level 1 and Level 2 assessments and the total number of positive *e. coli* samples, if any.

In addition, the RTCR defines seasonal systems and sets monitoring requirements for these systems. At the beginning of each operating period, before serving water to the public, seasonal systems must conduct state-approved start-up procedures. This RTCR became effective on April 1, 2016.

3.6 Minimum Design Standards for Missouri Community Water Systems

Effective December 10, 2013, these standards apply to new community public water systems designed during the effective dates of the standard. The standard also applies to alterations made to existing community public water systems, although only the portion of the existing water system that is altered is subject to these standards. The standard is not an inspection tool to require facilities constructed with approvals issued under previous design standards to upgrade to new facilities. However, where deterioration of water quality, sanitation, safety, or performance requires corrective action, the alterations must meet or exceed these minimum design standards.

3.7 Water Quality Standards

The objectives of the Clean Water Act of 1972, along with its amendments, are to restore and maintain the chemical, physical, and biological integrity of the nation's waters. These regulations allow individual states to construct a framework for water quality standards providing there is no reduction in protection as compared to the federal standards.

Water quality standards provide a means by which attainment of water quality objectives can be measured. The objective is protection of designated uses though the application of narrative or numeric criteria. The level of protection given to a stream, lake, or river is dependent on the expected or

"designated use(s)," of that water. Classified waters in Missouri have been assigned a designated use. The effects of nutrients on designated water uses are complex and variable. Nutrients constitute an essential element of aquatic life, and are not generally toxic, with the exception of ammonia. However, in high concentrations, nutrients have been linked to drinking water-related concerns that include methemoglobinemia, disinfection by-products, cyanotoxins from cyanobacteria, and aesthetic impacts, such as taste and odor.

In 2009, Missouri adopted and received EPA approval for numeric nutrient criteria (Total Nitrogen, Total Phosphorus, and Chlorophyll-a) for a number of high quality reservoirs within the state. Missouri is currently developing nutrient criteria for the remainder of the state's reservoirs.

Topic 4 Reliability

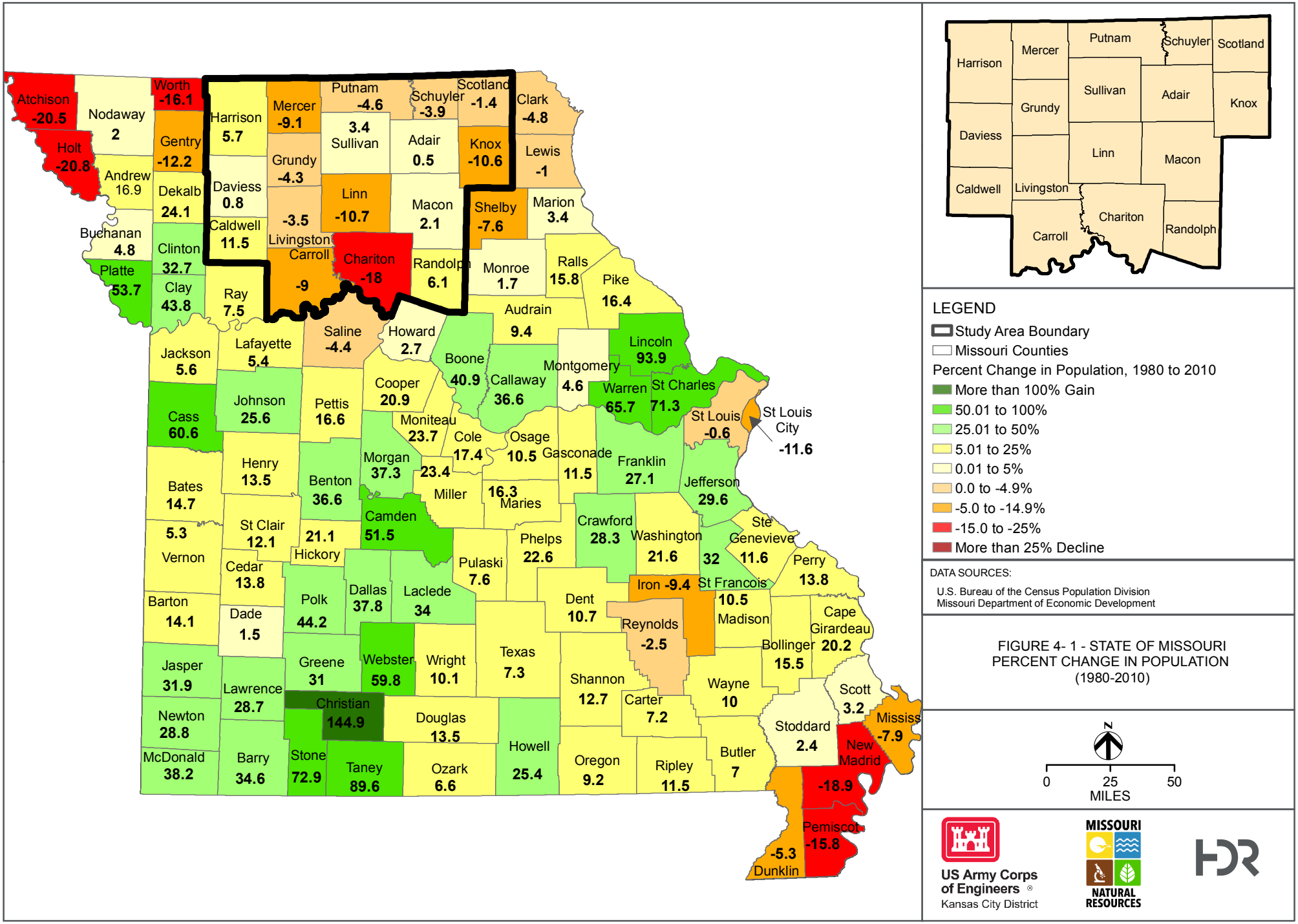
Determining the reliability of a water source is a highly, complex interdependent determination. The reliability of a water system, or more importantly its source, can involve financial viability, rate suitability, current and chronic enforcement actions, water loss, facility infrastructure needs and age, operation and maintenance practices, population trends, and potential impacts from major natural events.

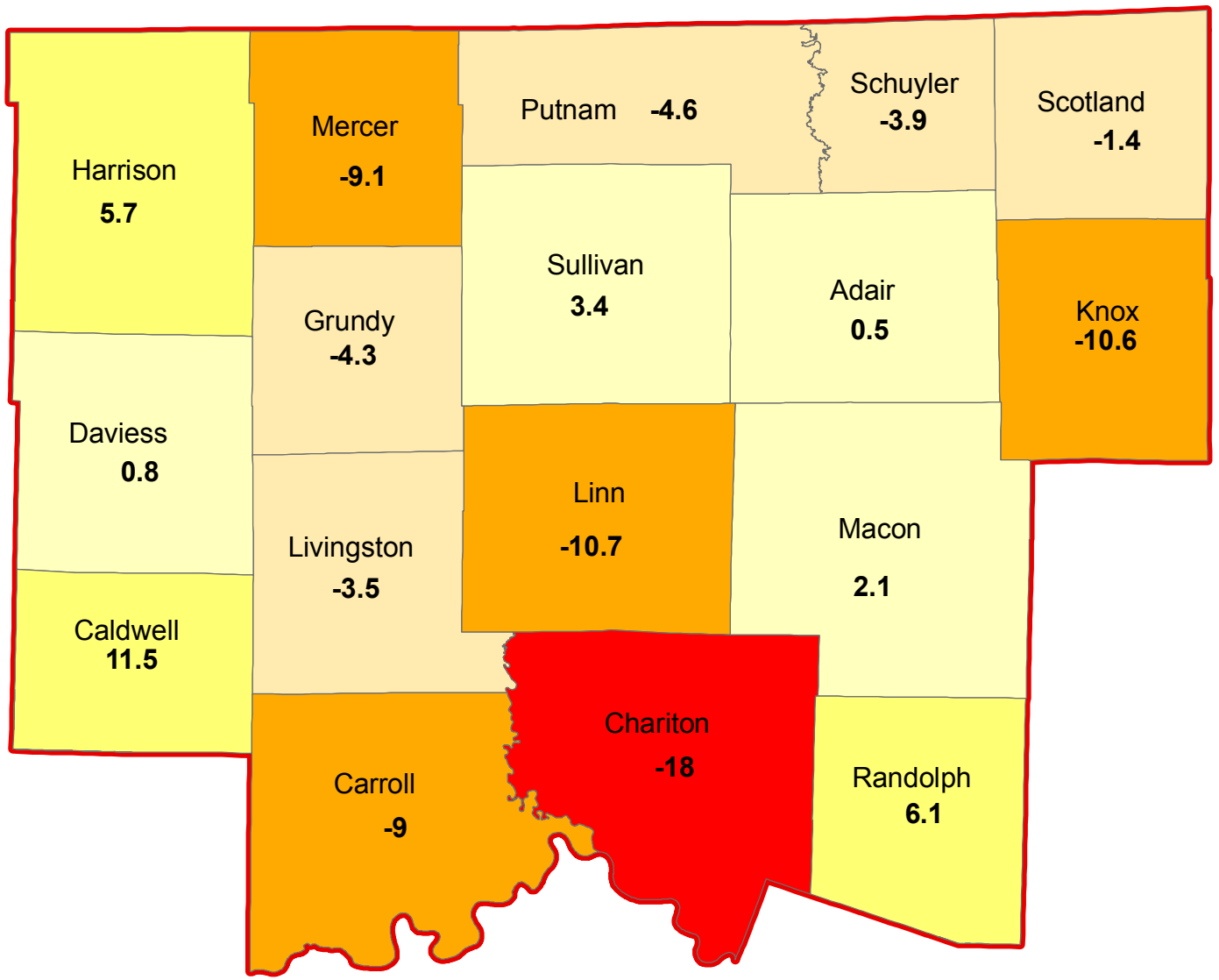
In an effort to project the reliability of water sources and the public water systems dependent on those sources within the Study Area, ten public water systems were selected for further investigation in the form of site visits and in-person discussions. Topic 4, as presented herein, focuses on those ten selected water systems in consideration that the issues affecting these selected systems will be indicative of the reliability issues facing the north central Missouri region, as a whole. While many issues throughout the region are common, it is not the intention of this Study to suggest that each system is facing the same challenges as the ten selected systems site visit conclusions may indicate. Rather, it is the intention of this Study to assist MDNR and the systems within the region to determine the need of future projects and to enable future planning efforts.

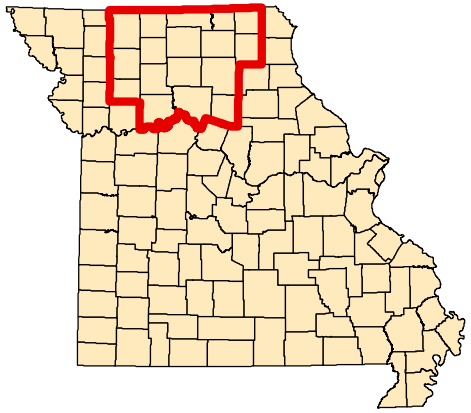
4.1 Regional Population Trends

Population census data from 1980 to 2010 was obtained and reviewed. Overall, the population for the state of Missouri increased 16.9-percent from 1980 to 2010. However, the population within the Study Area decreased slightly (by 1.5-percent) during the same timeframe. Figure 4-1 presents the state wide population in percent change between the years 1980 to 2010. Figure 4-2 presents the Study Area population percent change over the same period. The counties with the most significant population percent change are Caldwell (+11.5 percent), Chariton (-18 percent), Linn (-10.7 percent), Knox (-10.6 percent), Mercer (-9.1 percent), and Carroll (-9 percent).

Many conclusions may be drawn from the impacts of declining population but in terms of reliability it is difficult to ascertain if population decline is truly a positive or negative impact to water source reliability. It can be assumed that some excess capacity may be made available due to declining populations; however, this assumption only holds if the sources are well maintained and not impacted by pollution or sedimentation. Also, it could be assumed that a decline in a reliable water source may also be a potential factor in population decline. A decline in population may reflect a decline in workforce resulting in limited availability of registered operators to maintain these local systems. Declining populations may correlate to a reduction in water sales revenue that can drastically affect the funds to develop and maintain these water sources and water systems.


Atchison -20.5
Nodaway 2
Worth -16.1
Holt -20.8
Gentry -12.2
Andrew 16.9
Dekalb 24.1
Buchanan 4.8
Clinton 32.7
Platte 53.7
Clay 43.8
Ray 7.5
Harrison 5.7
Mercer -9.1
Putnam -4.6
Schuyler -3.9
Scotland -1.4
Clark -4.8
Grundy -4.3
3.4 Sullivan
Adair 0.5
Knox -10.6
Lewis -1
Daviess 0.8
Caldwell 11.5
-3.5
Linn -10.7
Macon 2.1
Shelby -7.6
Marion 3.4
Livingston
Carroll -9
Chariton -18
Randolph 6.1
Monroe 1.7
Ralls 15.8
Pike 16.4
Audrain 9.4
Saline -4.4
Howard 2.7
Lincoln 93.9
Jackson 5.6
Lafayette 5.4
Boone 40.9
Montgomery 4.6
Warren 65.7
St Charles 71.3
Cooper 20.9
Callaway 36.6
St Louis -0.6
St Louis City -11.6
Johnson 25.6
Pettis 16.6
Moniteau 23.7
Cass 60.6
Cole 17.4
Osage 10.5
Gasconade 11.5
Franklin 27.1
Jefferson 29.6
Henry 13.5
Morgan 37.3
23.4
Benton 36.6
Miller
16.3 Maries
Bates 14.7
Camden 51.5
Crawford 28.3
Washington 21.6
Ste Genevieve 11.6
32
5.3
St Clair 12.1
21.1
Hickory
Phelps 22.6
Perry 13.8
Vernon
Cedar 13.8
Pulaski 7.6
Iron -9.4
St Francois 10.5
Madison
Barton 14.1
Polk 44.2
Dallas 37.8
Laclede 34
Dade 1.5
Dent 10.7
Reynolds -2.5
Cape Girardeau 20.2
Bollinger 15.5
Jasper 31.9
Greene 31
Webster 59.8
Wright 10.1
Texas 7.3
Shannon 12.7
Carter 7.2
Wayne 10
Scott 3.2
Lawrence 28.7
Christian 144.9
Newton 28.8
Douglas 13.5
Howell 25.4
Oregon 9.2
Ripley 11.5
Butler 7
Stoddard 2.4
Mississ -7.9
McDonald 38.2
Barry 34.6
Stone 72.9
Taney 89.6
Ozark 6.6
New Madrid -18.9
Pemiscot -15.8
-5.3 Dunklin
Harrison
Mercer
Putnam
Schuyler
Scotland
Sullivan
Adair
Knox
Grundy
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Carroll
Randolph
LEGEND
Study Area Boundary
Missouri Counties
Percent Change in Population, 1980 to 2010
More than 100% Gain
50.01 to 100%
25.01 to 50%
5.01 to 25%
0.01 to 5%
0.0 to -4.9%
-5.0 to -14.9%
-15.0 to -25%
More than 25% Decline
DATA SOURCES:
U.S. Bureau of the Census Population Division
Missouri Department of Economic Development
FIGURE 4- 1 - STATE OF MISSOURI
PERCENT CHANGE IN POPULATION
(1980-2010)
N
0
25
50
MILES
US Army Corps of Engineers
Kansas City District
MISSOURI
NATURAL RESOURCES
HDR





LEGEND

- Study Area Boundary
- Missouri Counties

Percent Change in Population, 1980 to 2010

- More than 100% Gain
- 50.01 to 100%
- 25.01 to 50%
- 5.01 to 25%
- 0.01 to 5%
- 0.0 to -4.9%
- -5.0 to -14.9%
- -15.0 to -25%
- More than 25% Decline

DATA SOURCES:

U.S. Bureau of the Census Population Division
Missouri Deparment of Economic Development

FIGURE 4 -2 STUDY AREA
PERCENT POPULATION CHANGE
(1980-2010)

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4.2 Regional Rate Suitability

As defined by Missouri Department of Natural Resources 10 CSR 60-13.020, a disadvantaged community is defined as having a:

- Population of 3,300 or less based on the most recent decennial census;
- Median household income at or below 75-percent of the state average median household income on the most recent decennial census; and
- Water rate for 5,000 gallons that is at least 2-percent of the median household income of the applicant.

To determine rate suitability for the communities and public water supply districts, a comparison of the local median household incomes (MHI) and the monthly water rates were compiled. Community, county, and state MHI is available from the US Census Bureau American Community Survey 5-year Estimates. Figure 4-3 presents the county MHI compared to the average Missouri state MHI. Figure 4-3 illustrates that much of the Study Area has household incomes significantly below the state average.

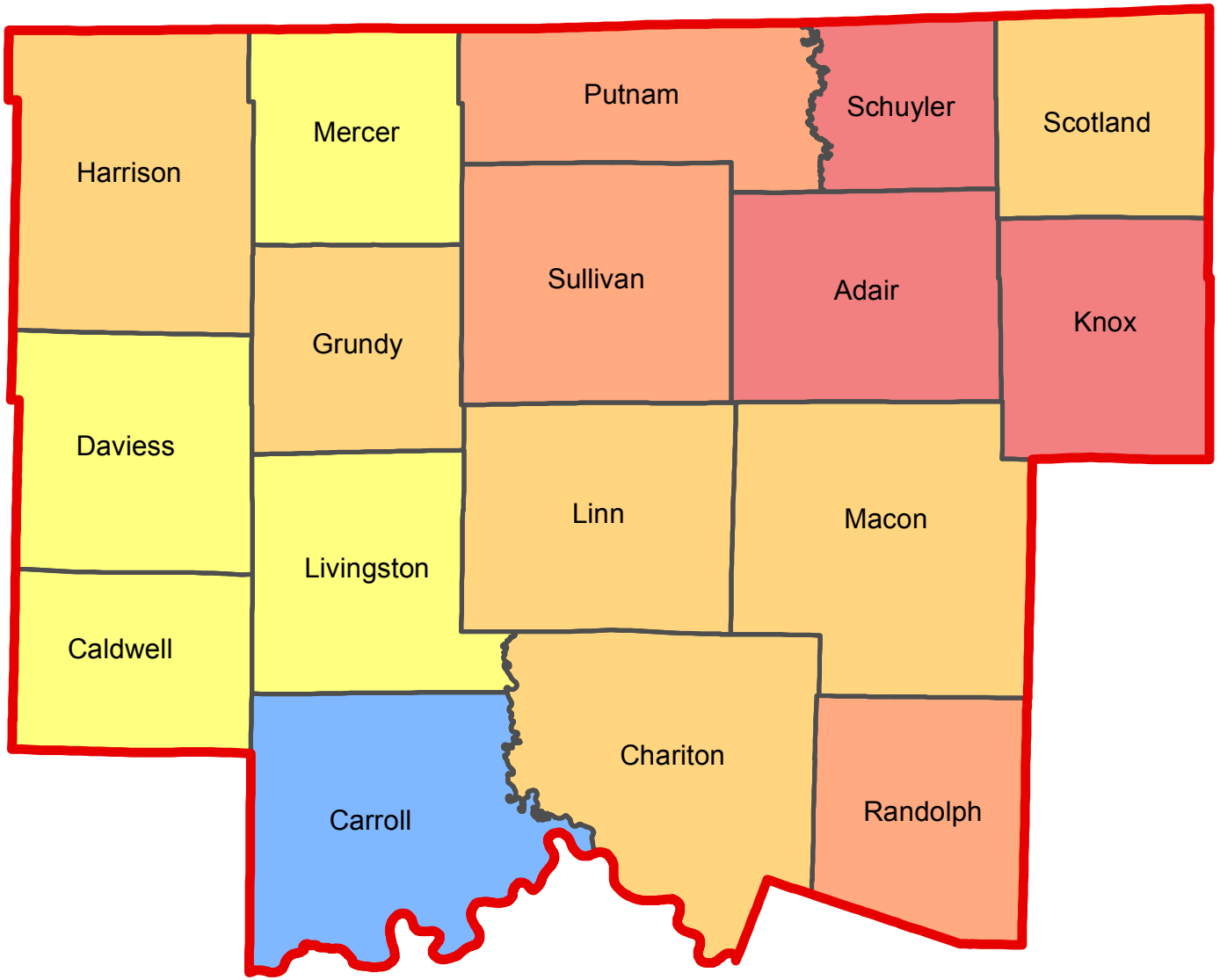
MHI for public water supply districts are not readily available since district boundaries sometimes fall across multiple counties and cover a broad area. MDNR staff provided guidance on methods for estimating the MHI for public water supply districts. The method utilized for this Study involved estimating the MHI per zip code within the PWSD boundaries. This was accomplished by using the Missouri Zip Code boundaries as provided by the University of Missouri's Geography Division and Geographic Resources Center (MSDIS). The MHI, as published by the US Census Bureau, was compiled for the individual zip code areas that fell within the public water supply district boundaries. The area of the zip codes and the MHI for that zip code were weighted with the total area of the PWSD to estimate the PWSD MHI. For example, zip code 64688 accounts for a total area of 11-percent within Linn Livingston PWSD 3. The zip code MHI was weighted as 11-percent of the total MHI for Linn Livingston PWSD 3. Each zip code within the PWSD boundary was weighted until 100-percent of the area was accounted.

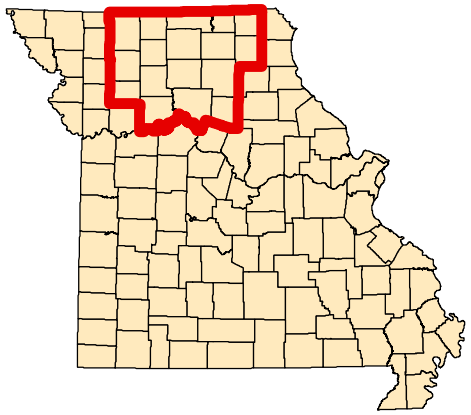
Once the MHI for the communities and PWSD were determined it was compared to the average state MHI of $47,350 as presented by the US Census Bureau. Service populations, local MHI as compared to average State MHI, and the percent of the water rate as compared to the local MHI were compiled for all water systems within the Study Area to determine which municipalities or PWSDs may be classified by MDNR as disadvantaged. Those identified as disadvantaged may have the opportunity to acquire state funding support in the form of Small Community Assistance Grants.

Figure 4-4 presents the community and PWSD annual water rates as a percent of Local MHI. The 17 communities that meet the definition of disadvantaged are indicated by a red dot with an *X*. These communities that are classified as disadvantaged are shown in Table 4-1. The rate suitability for the ten selected water systems is presented in Table 4-2.

There were no public water supply districts that met the definition of disadvantaged. Scotland Co. Cons. PWSD 1 has an annual rate above 2-percent of the local MHI; however, Scotland serves a population of

3,360 people, just over the service population limit defined for a disadvantaged community. It is important to note that 8 of the 31 rural districts have annual rates above 1.5-percent of the local MHI. This indicates that if water rates were to rise for these Districts they are at risk of becoming defined as disadvantaged by MDNR. However, similar to the disadvantaged communities above, these Districts may then have an opportunity to apply for state funding in the form of Small Community Assistance Grants.





LEGEND

Study Area Boundary

County Boundary

County MHI as a Percentage of State Average MHI

- 70 to 75%
- 75 to 80%
- 80 to 85%
- 85 to 90%
- 90 to 95%
- 95 to 100%

DATA SOURCES:

US Bureau of the Census Population Division

FIGURE 4-3 COUNTY MHI
AS A PERCENT OF STATE MHI
(STUDY AREA)

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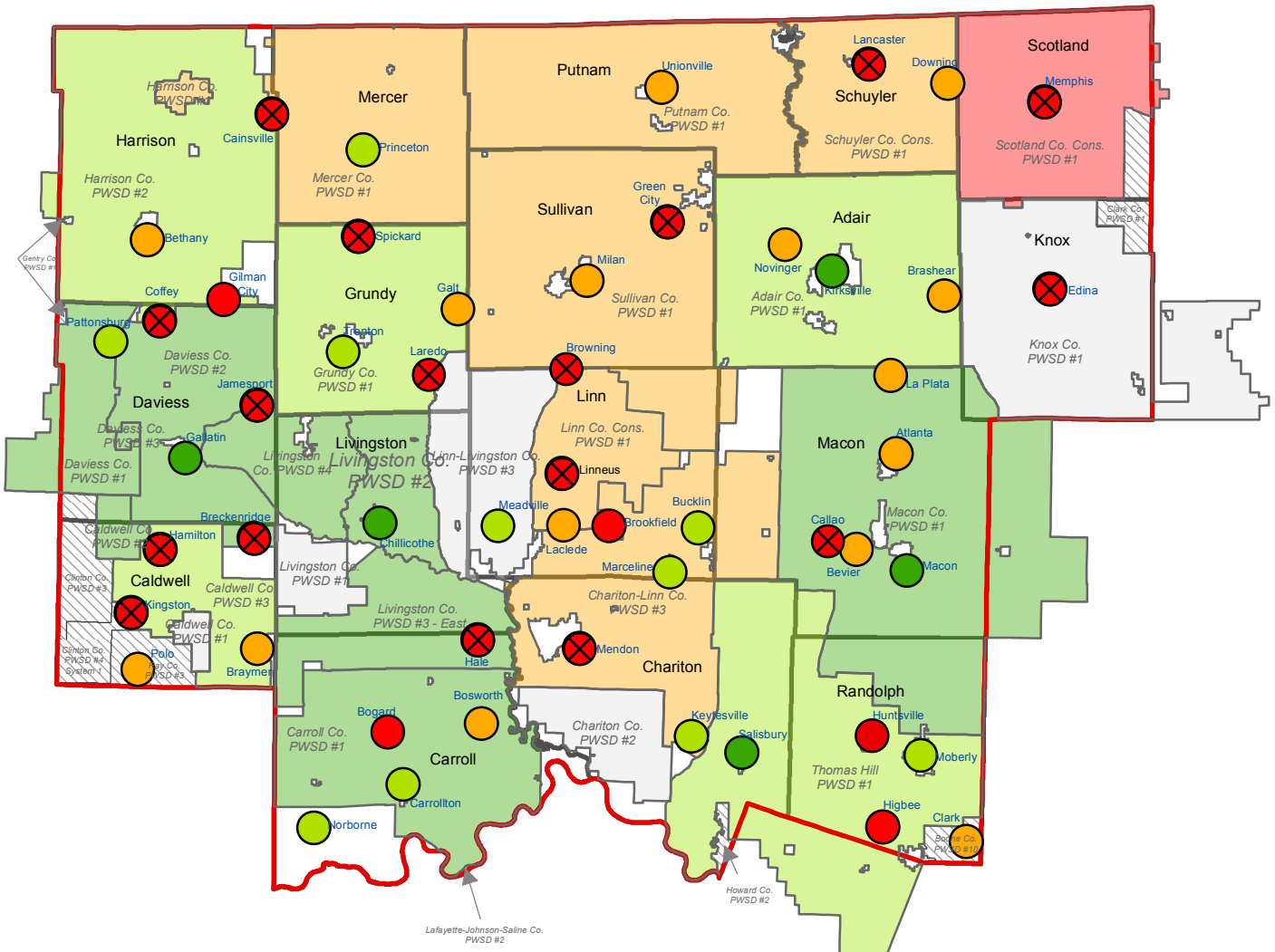

LEGEND

Annual User Rates as a Percent of Local MHI

- 0 - 1%
- 1 - 1.5%
- 1.5 - 2%
- Above 2%
- Disadvantaged Community

PWSD Annual User Rate as Percent of Local MHI

- Rate Not Available
- 0 - 1 %
- 1 - 1.5 %
- 1.5 - 2 %
- Above 2 %
- Study Area Boundary
- County Boundaries
- Non-Study Area PWSD

FIGURE 4-4 COMMUNITY WATER RATES AS PERCENT OF LOCAL MHI

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Table 4-1 Disadvantaged Communities within Study Area

County	System/ID #	Population[1]	Monthly Cost ($/5,000 gal)[2]	Median Household Income[3]	Percent of State Average MHI[3]	Annual Rates as percent of Local MHI
Caldwell	BRECKENRIDGE/MO1010099	454	$57.00	$28,958	61%	2.36%
	HAMILTON/ MO1010342	1,813	$55.30	$32,695	69%	2.03%
	KINGSTON/MO1010426	348	$60.00	$26,389	56%	2.73%
Carroll	HALE/MO2010338	480	$57.90	$28,750	61%	2.42%
Chariton	MENDON/MO2010514	207	$49.00	$27,188	57%	2.16%
Daviess	COFFEY/MO1010179	85	$69.00	$31,875	67%	2.60%
	JAMESPORT/MO1010406	524	$53.60	$30,272	64%	2.12%
Grundy	LAREDO/MO2010452	240	$85.00	$32,500	69%	3.14%
	SPICKARD/MO2010753	315	$45.00	$23,750	50%	2.27%
Harrison	CAINSVILLE/MO1010122	296	$47.00	$23,500	50%	2.40%
Knox	EDINA/MO2010238	1,153	$50.00	$24,420	52%	2.46%
Linn	BROWNING/MO2010108	265	$61.50	$23,958	51%	3.08%
	LINNEUS/MO2010472	278	$55.24	$30,729	65%	2.16%
Macon	CALLAO/MO2010125	311	$77.10	$31,250	66%	2.96%
Schuyler	LANCASTER/MO2010450	728	$57.50	$31,094	66%	2.22%
Scotland	MEMPHIS/MO2010513	1,822	$68.80	$33,306	70%	2.48%
Sullivan	GREEN CITY/MO2010329	671	$60.02	$31,413	66%	2.29%

[1]MDNR Drinking Water Watch
[2]2014 Public Utility Alliance Water & Wastewater Rate Survey
[3]2009-2013 American Community Survey 5-year Estimates
Notes: Disadvantaged Community as defined by Missouri Department of Natural Resources 10 CSR 60-13.020
Missouri State Average Median Household Income $47,350. U.S. Census Bureau

Table 4-2 - Selected Water Systems Rate Suitability

System	County	Population[1]	MHI[2]	Rate Monthly Cost ($/5,000 gal)[3]	Percent of State Average MHI	Annual Rates as percent of Local MHI
Adair Co. PWSD 1	Adair	7,500	$ 37,770	$48.60	80%	1.5%
Chariton-Linn Co. PWSD 3	Linn	5,913	$ 37,540	$50.00	79%	1.6%
Daviess Co. PWSD 1	Daviess	2,062	$ 46,603	$26.40	98%	0.7%
Grundy Co. PWSD 1	Grundy	3,710	$ 37,134	$41.00	78%	1.3%
Linn Co. Cons. PWSD 1	Linn	1,620	$ 36,255	$52.00	77%	1.7%
Putnam Co. PWSD 1	Putnam	2,997	$ 40,987	$66.25	87%	1.9%
Princeton	Mercer	1,166	$ 41,667	$51.74	88%	1.5%
Marceline	Linn	2,500	$ 32,440	$49.00	69%	1.8%
Hamilton[4]	Caldwell	1,813	$ 32,695	$56.84	69%	2.1%
Trenton Municipal Utilities	Grundy	6,001	$ 35,619	$31.63	75%	1.1%

[1] MDNR Drinking Water Watch
[2] Selected Systems Site Visits
[3] 2009-2013 American Community Survey 5-year Estimates
[4] Hamilton meets the definition of a disadvantage community.
Notes: Disadvantaged Community as defined by Missouri Department of Natural Resources 10 CSR 60-13.020
Missouri State Average Median Household Income $47,350.

4.3 Potential Regional Impacts from Major Natural Events

Water resources and regional characteristics, such as precipitation, are not evenly distributed throughout the state of Missouri. Northern Missouri has the lowest average rainfall, lowest groundwater recharge, and is often susceptible to both drought and flooding. Water reliability issues do not generally occur during normal conditions; instead these problems are increased during major climatic events such as flooding or drought. Such events may considerably affect economies and individual safety.

Drought

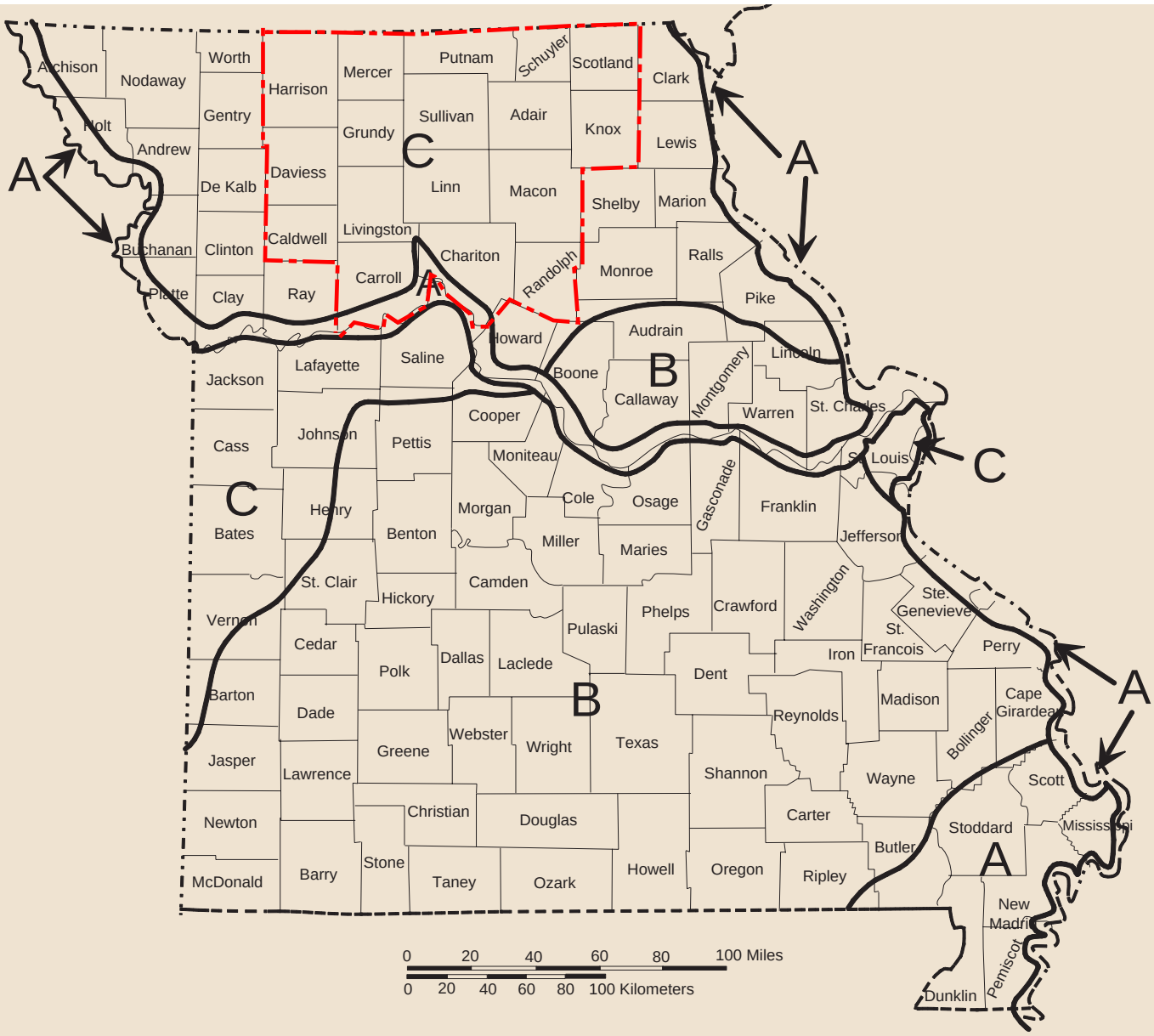
Drought is a hydrologic event that can occur at any time and any location. Droughts are often silent – slowly damaging crops and grasslands, and depleting surface water reservoirs. According to the 2002 Missouri Drought Plan, droughts are characterized by lack of precipitation to replenish and maintain normal seasonal levels of surface water and groundwater. Supply droughts are usually an act of nature while water usage droughts are man made.

Figure 4-5 illustrates the drought susceptibility for the State of Missouri according to the 2002 Missouri Drought Plan. The delineation of these regions is based on:

1. Historical drought occurrences in an area/region
2. Actual annual and seasonal rainfall amounts
3. Current and projected water demands and uses within an area
4. Sources of water available for use
5. Water reserves and accessibility to additional water supplies

The Study Area boundary is part of Region C, which is characterized as areas that are the most vulnerable to drought. Region C has severe surface and groundwater supply drought vulnerability. Surface water sources are especially susceptible during extended drought. These areas are designated by MDNR as Priority Drought Management Areas, and are to be given high priority relative to drought mitigation, and water supply regionalization activities.

MDNR staff noted that during the dry periods in 2012, there were segments of the Study Area that were affected by limited water for livestock facilities. During this period MDNR provided grants for drilling supplemental wells to provide a supplemental water source for livestock. Figure 4-6 depicts the number of cost share projects and the total cost share amounts provided per county.



Region A: Slight Susceptibility
Region B: Moderate Susceptibility
Region C: High Susceptibility

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DATA SOURCES:

Missouri Department of Natural Resources Topics in Water Use 1998

US Army Corps of Engineers
Kansas City District

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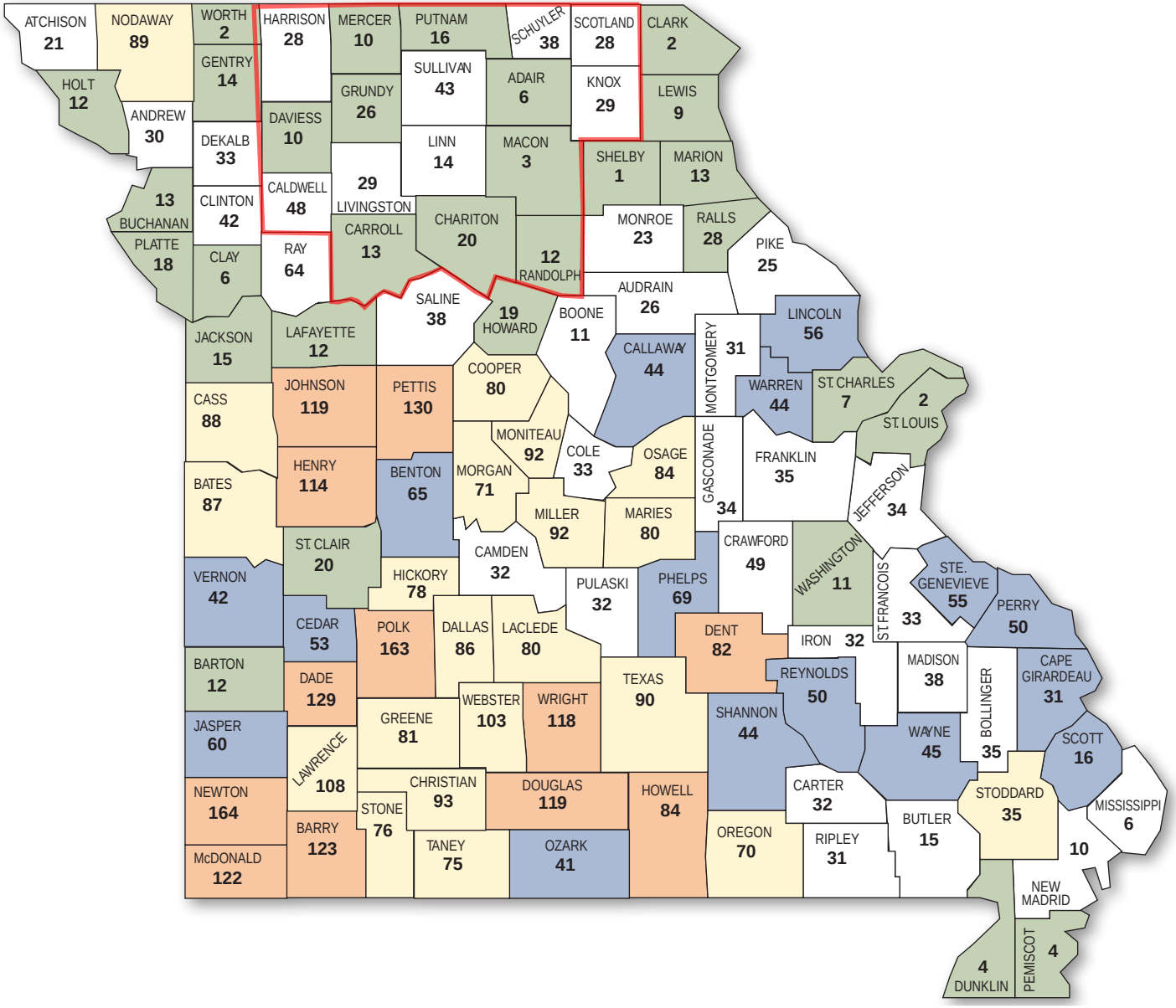
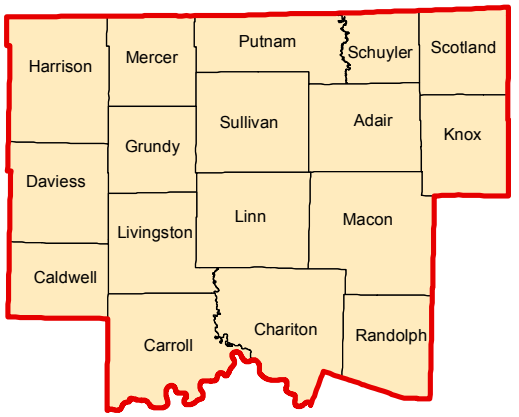
FIGURE 4-5 DROUGHT SUSCEPTIBILITY REGIONS OF MISSOURI





LEGEND

- Study Area Boundary
- Missouri Counties

Dollar amounts by county
(as of Dec. 31, 2012)

- $3,200 – 80,000
- $80,000.01 – 160,000
- $160,000.01 – 260,000
- $260,000.01 – 420,000
- > $420,000

DATA SOURCES:
The drought of 2012: Office of the Governor
Jeremiah W. (Jay) Nixon

FIGURE 4-6 EMERGENCY DROUGHT ASSISTANCE DOLLAR AMOUNTS APPROVED BY COUNTY

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Flooding

Flooding is simply defined as the condition when water leaves river banks and is usually the result of high runoff rates. According to the 1997 Missouri Hydrologic Extremes Report, several types of flooding can occur within Missouri: flash flooding, which is rapid and violent, or flooding on streams or rivers, which may develop over a period of days and affect large areas. Flash flooding and river flooding events have different impacts and require different mitigation techniques. The impacts of flooding include erosion and sedimentation to surface water supply reservoirs.

Historic accounts demonstrate that both floods and droughts have and will continue to occur. Planning is necessary when designing and selecting potential water supply sources. While droughts and floods are inevitable climatic features, proper planning and management of resources are necessary to reduce the impacts and societal vulnerability to such events.

4.4 Selected Public Water Systems

The list of selected public water systems was developed in collaboration with MDNR, USACE, HDR, and MRWA. These selected systems were chosen by MDNR based on source water reliability, state drinking water regulations compliance, and technical, managerial, and financial capacity. The selection was also based on systems purchasing water from out-of-state suppliers, consecutive suppliers purchasing from a supplier with a limited or stressed source, treatment plant capacity limitations, and distribution system limitations.

The ten selected public water systems are as follows:

1. Adair Co. PWSD 1
2. City of Hamilton (Caldwell County)
3. Daviess Co. PWSD 1
4. Grundy Co. PWSD 1
5. Trenton Municipal Utilities (Grundy County)
6. Chariton Linn Co. PWSD 3 (Linn County, Chariton County, Macon County)
7. City of Marceline (Linn County, Chariton County)
8. Linn Co. Cons. PWSD 1
9. City of Princeton (Mercer County)
10. Putnam Co. PWSD 1

These ten selected public water systems are located within 7 of the 17 counties within the Study Area: Adair, Caldwell, Chariton, Grundy, Linn, Mercer, and Putnam counties.

Each of the selected systems received a NCMO Water Supply Study Questionnaire prior to a site visit in an effort to provide the System staff an overview of the questions to be asked during the site visit (see Appendix B). The questionnaire topics covered infrastructure (i.e., source, treatment, and distribution); operations and maintenance; and financial background. The questionnaire included a request for copies of source water/well head protection plans, previous studies, wholesale water contracts, water rate

charts, recent audits, recent budgets, and the most recent Capital Improvement Plan or Supervised Plan. The site visits were completed between September and October of 2015.

The following subsections for each selected system present the information collected as part of the in-person interviews and site visits performed by HDR and MRWA. This includes information on the system's source, wholesale water contracts, distribution system, operations and maintenance, financial viability, and the primary concerns of the selected public water system (based on the staff that was interviewed).

4.4.1 Adair Co. PWSD 1

Adair Co. PWSD 1 is a public water supply district serving the entire rural area of Adair County. Adair 1 serves a population of nearly 7,500 people through approximately 3,000 active connections. Adair purchases 100 percent of its water supply from surface water suppliers. The average daily demand of the system is 640,000 gallons per day (GPD).

Source: At the time of the site visit, Adair 1 was purchasing nearly 99 percent of its supply from the City of Kirksville and the remaining 1 percent from the Schuyler Co Cons PWSD 1. MDNR staff had previously expressed concerns that the Kirksville WTP has reached its rated capacity. When questioned Adair operations staff expressed confidence in reliability of Kirksville as a supplier and did not express concerns of treatment capacity limitations at the WTP.

Adair 1 does have a master meter connection to Putnam 1 but are limiting purchase until Putnam's major water supplier (City of Unionville) completes the water treatment disinfection switch to chloramines.

Wholesale Purchase Contracts: The wholesale contract between Kirksville and Adair 1 provided at the time of the site visit has a 35 year term initiating in 1972 and expiring on 2007. Staff did not indicate if Adair and Kirksville are negotiating new contracts.

Adair 1 currently has wholesale water contracts for the sale of water with the cities of Brashear (expires 2017), Novinger (expires 2021), La Plata (expires 2042), and Macon Co. PWSD 1 (expires 2020).

Distribution System: Adair 1 utilizes several above ground storage tanks with a total combined storage capacity of nearly 550,000 gallons. The system is also comprised of several booster pump stations to convey water to storage and throughout the distribution system. The distribution system was first installed in 1972 and is comprised of 2- to 6-in PVC with some cast iron pipeline (CIP) under roadways and creek crossings.

A Fiber Optic Installation Project has been underway for one and a half years resulting in frequent water main breaks in the system. Distribution staff has had difficultly accurately marking the location of existing mains resulting in the increased frequency of main breaks due to the excavation and construction activities by the Fiber Optic team. Adair has approximately one break per month during the Fiber Installation Project. The greatest challenges as expressed by staff are their ability to locate PVC

pipe and the frequent creek washouts. FEMA is currently providing funding to repair 8 of the creek washouts.

Operations & Maintenance: In 2008, Adair 1 replaced over 3,000 residential meters with positive displacement Badger meters fit with radio read. Adair now hires a pilot to perform fly over and radio reads. Through these residential meters and the consecutive connections with public water systems Adair 1 has sold an estimated average annual volume of 210 million gallons of the estimated 232.2 million gallons purchased from 2010 to 2014. Over the same period, Adair 1 estimates an average annual water loss of 9 percent.

Adair 1 performs flushing annually as part of its formal flushing program, which coincides with the Kirksville system burnout, typically during the spring months.

There is not a formal meter change-out program or Asset Management Program in place. Although there is not backup power supply for critical infrastructure, each of the booster pump stations are configured with quick connects for portable generators to be brought on site during an emergency.

Financial: Adair 1 performs annual audits and adopts an annual budget. The last audit was performed on October 31, 2014. The District Board adopted the annual budget in October 2014. Adair 1 currently has outstanding debt in the form of Series 2004B Waterworks System Revenue Bonds. The debt for the water system is scheduled to be retired in 2025. Although Adair 1 has no formal Capital Improvement Plan in place, the District did complete a 5-year Owner Supervised Plan in 2001.

The average monthly water rate for 5,000 gallons (typical water usage for a family of 4) is $48.60 for Adair 1 residential customers. Rates were last raised on January 1st, 2015. Adair 1 carries approximately $9,000 of delinquent water bills on its books. There are 30 to 50 door hangers sent out each month for delinquent bills of which only about 3 to 5 are shutoff each month.

The District purchases wholesale water from the City of Kirksville at a rate of $4.13 per 1,000 gallons. The City of Kirksville increased rates for Adair 1 by approximately 10-percent in January 2015.

In August 2015, Adair supplied approximately 14,000 GPD to the City of Brashear, roughly 84,000 GPD to the City of La Plata, and just over 30,000 GPD to the City of Novinger. At the time of the site visit, the estimated water sold to Macon was not provided.

The rates charged by Adair 1 for wholesale supply are as follows:

- City of Brashear (Per revised rate schedule provided during site visit)
    - $4.34 per 1,000 gallons up to 15,000 gallons
    - $4.30 per 1,000 gallons for the next 735,000 gallons
    - $3.95 per 1,000 gallons for anything over 750,000 gallons
- City of La Plata (Per revised rate schedule provided during site visit)
    - $5.28 per 1,000 gallons for #40-3523
    - $4.71 per 1,000 gallons for #40-3989

- City of Novinger (Per revised rate schedule provided during site visit)
  - $4.62 per 1,000 gallons.
- City of Macon (Per revised rate schedule provided during site visit)
  - $4.75 per 1,000 gallons

It should be noted that the wholesale water rates have increased since the original wholesale contracts; however, the increases were not reflected in the contracts provided at the time of the site visit.

Primary Concerns: At the time of the site visit, Adair 1 operations staff expressed great interest in the improved ability to locate distribution pipelines in an effort to avoid main breaks. The superintendent explained that telephone companies receive federal funding for fiber optic installation; however, there is no federal funding to support or protect the distribution systems that may be greatly impacted during the fiber installation activities.

In addition, if the MDNR concerns of the Kirksville WTP capacity are realized, it is believed that the consecutive connection with Adair 1 will be the first to have its supply limited. Therefore, it is imperative for Adair 1 to expand its water portfolio. Adair 1 and the City of Kirksville are listed as associate members of the NCMRWC and have expressed interest in utilizing the future East Locust Creek Reservoir as a potential supply.

4.4.2 City of Hamilton

The City of Hamilton operates a municipal water supply system in northern Caldwell County. Hamilton serves a population of 1,800 people through 825 active connections. Hamilton is a surface water supplier with an average daily demand of 240,000 gpd.

Source and Treatment: The City of Hamilton utilizes Hamilton Lake Reservoir as its surface water supply, and supplements the reservoir by pumping from Marrow Bone Creek. The water quality issues at the source include turbidity, manganese, algae, and other issues created from surface runoff from the adjacent golf course on the north side of the reservoir. The Hamilton WTP has a rated capacity of 0.3 MGD and consists of sedimentation, filtration and disinfection. There have been no major upgrades to the plant since 1989, aside from basic plant maintenance, such as filter media and pump replacement. Staff explained there are no plans to switch to chloramines. As of October 1, 2015, the water and WWTP operations were being performed by an outside contractor, People Services.

Wholesale Purchase Contracts: On November 1, 2015, Hamilton initiated into a renewed wholesale contract for the sale of water to Caldwell 2 for a term of 5-years.

In addition to producing water, Hamilton purchases supplemental supply from Livingston 4 and, more recently, Daviess 2. In 2012, Hamilton renewed the water purchase contract with Livingston 4 with a 5 year term. The contract sets a 50,000 GPD minimum purchase and a 100,000 GPD maximum. The new permanent connection to Daviess 2, via a 3-mile 8-inch line, was completed on August 28, 2014. At the time of the visit, it was not indicated if a water purchase contract was in place between Hamilton and Daviess 2.

Distribution System: Hamilton utilizes several above ground storage tanks with a total combined storage capacity of nearly 500,000 gallons. The distribution system was first installed in the 1920's and is comprised of 2- to 6-in distribution pipelines and some 8-in transmission lines made of both PVC and CIP.

Figure 4-7 Calcium Carbonate Precipitate

The system has a Three Phase Water Main Replacement Project. Phase I is complete. Phase II is currently being bid and Phase III is anticipated for bid in 2017. In 2009 the system was experiencing 3 to 4 breaks per week. The Replacement Project has greatly reduced the number of system breaks. A sample of pipe removed during Phase I showing significant precipitation is depicted in Figure 4-7

According to City staff, Hamilton received a violation requiring public notification due to an exceedance of TTHMs within the distribution system believed to be the result of water age issues in the water storage tanks.

Operations & Maintenance: The system is comprised of 825 manual-read, positive displacement meters over 20-yrs old. It takes 3 operators nearly 1 week to read the meters. There is currently no meter change out program; meters are only changed as-needed.

Through these residential meters and the consecutive connections with public water systems, Hamilton has sold an estimated average annual volume of 59.2 million gallons. At the time of the visit, water produced at the Hamilton WTP or water purchased from Livingston 4 was not made available. However, City staff did provide an estimate of 6.3 million gallons purchased from Daviess 2 in a three month period between August and December of 2014.

The City currently reports approximately 20-percent water loss. The age of the meters and limited change out as described above, in addition to water main leaks are likely the cause of high water loss.

There is no formal Asset Management Program or flushing program in place for the City of Hamilton. There is also no backup power supply for critical infrastructure. Staff indicated that generators could be borrowed from Caldwell County.

Financial: The City of Hamilton performs annual audits and adopts an annual budget. The last audit was performed on July 1, 2014. The Board adopted the annual budget in 2015. Hamilton currently has outstanding debt in the form of revenue bonds and general obligation (GO) bonds. The debt for the water system is scheduled to be retired in 2024.

The average monthly water rate for 5,000 gallons is $55.30 for Hamilton residential customers. Rates were last raised on January 1, 2015. The City carries approximately $11,000 of delinquent water bills on

its books, none of which is written off at the end of the year. There are 20 to 25 customers with delinquent bills each month; some are disconnected and must pay a reconnection fee.

The City of Hamilton supplies approximately 30,000 GPD to Caldwell Co. PWSD 2 at a rate of $5.50 per 1,000 gallons. On November 1, 2015 a new contract took effect between Hamilton and Caldwell 2 establishing a revised rate of $6.50 per 1,000 gallons from November 2015 to November 2020.

Primary Concerns: The City expressed a great need for licensed distribution operators. Additionally, staff stressed that the greatest challenge are inefficiencies at the treatment plant. After Hamilton began purchasing approximately 20-percent of the supply from Daviess 2 there were no production and/or operation cost reductions at the Plant. In an effort to expand its water portfolio and improve reliability, Hamilton staff expressed interest in connecting to the proposed Little Otter Creek Reservoir in Caldwell County.

4.4.3 Daviess Co. PWSD 1

Daviess Co. PWSD 1 is a public water supply district serving a large portion of the rural area of Daviess County. Daviess 1 serves a population of nearly 2,100 people through approximately 860 active connections. Daviess purchases 100 percent of its water supply from a groundwater supplier. The average daily demand of the District is 150,000 gpd.

Source: Daviess 1 purchases all of its supply from the City of Pattonsburg. MDNR Drinking Water Watch indicates that Pattonsburg utilizes 5 active groundwater wells and a 300 gpm capacity WTP.

Wholesale Purchase Contracts: Daviess 1 sells water to the City of Altamont. Altamont purchases the water using residential water rates and is not treated as a wholesale customer.

At the time of the site visit, Pattonsburg and Daviess 1 were in the process of renegotiating the wholesale purchase contract which was set to expire in December 2015. The proposed contract from Pattonsburg established new wholesale rates that, according to Daviess 1 staff, would double over a 5-year period. The proposed contract also includes a minimum of 3.5 MG water purchased per month. Daviess 1 staff indicated that the contract negotiations were now being handled in mediation.

Distribution System: The existing distribution system was constructed in three phases in 1970, 1983, and 1985. The system is comprised of 2- to 4-in distribution lines made of PVC with glued joints and CIP at creek crossings. Some issues have been caused by air in the distribution system created by Pattonsburg's treatment plant maintenance and repair work. In 2006, approximately 12-miles of 8-in main to the Village of Winston were replaced.

Daviess 1 utilizes several above ground storage tanks with a total combined storage capacity of nearly 525,000 gallons. The 300,000 gallon Winston storage tank is filled by the 36,000 gallon Snider standpipe. This configuration creates a low pressure zone (roughly 30 psi) around the tank service area.

There is no formal Asset Management Program in place at Daviess 1.

Operations & Maintenance: The system is comprised of 853 manual-read, positive displacement meters approximately 11 to 12 years of age. The total active meters include the City of Altamont meter, the Winston school meter, and several farms. There is a meter change out program establishing 10-year change out goals. Through these residential meters, Daviess 1 has sold an estimated average annual volume of 48.13 million gallons of the estimated 61.6 million gallons purchased from 2010 to 2014. Daviess 1 estimates water loss as a percentage of water purchased versus water sold. Without accounting for flushing performed annually as part of the formal flushing program, Daviess 1 estimated water loss was approximately 16-percent in 2014.

Daviess 1 has a maintenance contract with Utility Services to support the District's two distribution operators with main flushing, tank cleaning, and main leak repair.

Financial: Daviess 1 performs annual audits and adopts an annual budget. The last audit was performed on May 16, 2015. The Board adopted the annual budget on January 15, 2015. Daviess 1 currently has outstanding debt in the form of lease to purchase agreements.

The average monthly water rate for 5,000 gallons is $26.40 for Daviess residential customers. Rates were last raised on May 10, 2013. There is currently a rate review underway precipitated by the threat of increase of rates from the City of Pattonsburg. The District does not carry delinquent water bills on its books. If a water bill is left unpaid the service is disconnected.

Primary Concerns: The staff stressed the greatest challenges for Daviess 1 are possible rate increases from its groundwater supplier and the high percentage of system water losses. At the time of the site visit, staff presented a recent article on the proposed Little Otter Creek Reservoir to be constructed in Caldwell County indicating an interest in this as a future potential source.

4.4.4 Grundy Co. PWSD 1

Grundy Co. PWSD 1 is a public water supply district serving the majority of the rural area in Grundy County. Grundy 1 serves a population of 3,700 people through approximately 1,500 active connections. Grundy purchases 100 percent of its water supply from a surface water supplier. The average daily demand of the District is 290,000 GPD.

Source: Grundy 1 purchases all of its water supply from Trenton Municipal Utilities (TMU). Grundy 1 staff explained that there has never been concern related to quantity but there are some concerns of the quality of supply from TMU. In 2015, Grundy received customer complaints for taste and odor.

Wholesale Purchase Contracts: The existing wholesale contract between TMU and Grundy 1 expires in 2017. Grundy 1 currently has wholesale water contracts with the cities of Spickard and Galt. There is no expiration indicated in either of the wholesale contracts.

Distribution System: Portions of the existing distribution system were first installed in 1969. The system is comprised of 2- to 6-in pipelines with a variety of materials: Schedule 20 PVC, Yelomine™ for creek crossings, and some CIP for service lines. Grundy 1 has begun to mount tracer wire with newly installed PVC.

Grundy 1 utilizes several above ground storage tanks with a total combined storage capacity of nearly 525,000 gallons. There have been some complaints about low pressures within the Koon Tower service area. Koon Tower (50,000 gal) could not be put into service for 5 years after its construction due to issues with water elevations.

Operations & Maintenance: The system is comprised of roughly 1,500 radio-read Neptune meters less than ten years old. Through these residential meters and the consecutive connections with public water systems, Grundy 1 has sold an estimated average annual volume of 89.3 million gallons of the estimated 126.3 million gallons purchased from 2010 to 2014. The estimated water loss in the system is nearly 30 percent based on volume sold versus volume purchased and not accounting for volume loss during system flushing.

The District staff explained the high water losses may likely be a result of meter issues including limited battery life, failed registers, and broken meter bodies of the Neptune meters. Meter issues result in need for re-reads; however, operators are resistant considering the widespread service area.

In 2013, the distribution system suffered from low chlorine residuals, which required flushing to pull up residuals. Additionally, pipe locating has been an issue and the system maps are limited.

The District does not currently have backup power supply for critical infrastructure. The District currently relies on generators provided by MRWA. The District did indicate that during past power outages Grundy Electric connected the District relatively quickly.

Financial: Grundy 1 performs annual audits and adopts an annual budget. The last audit was performed in 2014. The Board adopted the annual budget in 2015. The District does not currently have any outstanding debt.

The average monthly water rate for 5,000 gallons is $41.00 for Grundy residential customers. Rates were last raised on July 2014 as a result of a 2013 rate study. The District currently carries delinquent water bills on the District books with a total of about $2,600 written off each year. Courtesy letters are mailed out the 3rd week of the month for water accounts that have not yet submitted payment. The District posts approximately 10 to 20 door hangers per month for delinquent accounts, disconnecting approximately 4 per month due to non-payment.

TMU wholesale rates for Grundy 1 were increased by 18-percent in February 2014. Grundy 1 staff did indicate there has been billing questions raised related to TMU's reading of the Grundy 1 master meter. Therefore, Grundy 1 has also begun reading the master meter as well.

It should be noted that the community of Laredo received an annex for a separate water system within Grundy County. Laredo has the highest water rate in the Study Area at $85 per 5,000 gallons.

Primary Concerns: The District's major concerns involved the high rate of water losses resulting from bad meters or poor meter reading. Additionally, the need for tracer wire installation and updated GIS system maps were noted.

The District expressed confidence in the quantity of supply from Trenton; however, Grundy is listed as an associate member of NCMRWC with interest in utilizing the future East Locust Creek Reservoir.

4.4.5 Trenton Municipal Utilities

Trenton Municipal Utilities (TMU) operates a municipal water supply system in central Grundy County. TMU serves a population of over 6,000 people through 2,750 active connections. Trenton is a surface water supplier with an average daily demand of 2 MGD.

Source: Trenton utilizes the Thompson River as its surface water supply. Staff believes that the river base flow is fed by groundwater inflow. The TMU WTP has a rated capacity of 4.5 MGD but operates at an average daily flow of about 2 MGD. The plant was upgraded in 2014 including controls, chemical feed, VFDs and switch to chloramines. The raw water intake is limited to a specific river level. Intake issues at Thompson River are much improved during dry summer months when turbidity is improved. In the past, Trenton has had issues with taste and odor, algae growth and turbidity. High turbidity in the River can make pumping and treatment difficult at specific times throughout the year. In the winter months hardness typically reaches 300 mg/L.

TMU currently provides treated surface water to its residential users and a major industrial user, ConAgra. ConAgra uses approximately 700,000 to 800,000 GPD.

Wholesale Purchase Contracts: TMU currently has two wholesale water purchase contracts with Grundy 1 (expires 2017) and the NCMRWC (no contract expiration). The NCMRWC has an emergency connection to TMU. Trenton staff indicated that the NCMRWC is not currently utilizing any water from Trenton since the recent purchase of the Milan Plant by the Commission.

Distribution System: Pipe age throughout distribution system ranges from about 1886 to present. Material ranges from PVC, CIP, and some transite. Cast iron pipe that was installed in the 1950s is rapidly failing. There are 2 elevated finished water storage tanks located in the system with a total storage capacity of 1 million gallons. According to City staff, the hydraulics of the tanks has been impacted by ConAgra's change in daily use.

An 8-in transmission line from Trenton to Sullivan County was constructed and paid for by MDNR. The ownership for the transmission line has been transferred to the NCMRWC.

Operations & Maintenance: The system consists of mostly positive displacement meters fit with radio read and the average age of meters is 15 years. Meter replacement is made difficult for some residential meters as nearly 20 percent of meters are inside the customer homes. TMU has sold an annual volume of 557 million gallons of the estimated 618.7 million gallons produced in 2014. That same year TMU estimates an annual water loss of 7.8 percent.

Trenton has enacted main replacement and service line disconnections for abandoned homes. This has reduced water loss to below 8-percent and mainline breaks from 25 per month to less than 5 per month. There have been issues with non-working brass valves throughout the system, which comprise one-third of the total number of valves. The system had been out of compliance with TTHMs for 6 to 7 years prior

to switching to chloramines in September 2014. The system does not have a formal flushing program; however, a complete system flush was performed in 2012. TMU maintains two emergency generators as backup power supply for the critical system infrastructure (i.e., reservoir pumps and treatment plant)

Financial: Trenton performs annual audits and adopts an annual budget. The last audit was performed on April 30, 2014. The Board adopted the FY2015/2016 budget. Trenton currently has outstanding debt in the form of Certificate of Participation (COP) bonds. The debt for the water system is scheduled to be retired in 2038.

The average monthly water rate for 5,000 gallons is $31.63 for residential customers. Rates were last raised on May 1st, 2015. Less than $2,000 delinquent water bills are carried on system's books. Approximately $4,000 of delinquent water bills are written off each year, less than 0.2-percent.

TMU supplies approximately 300,000 to 400,000 GPD to Grundy 1 at a rate of $5.37 per 1,000 gallons.

Primary Concerns: It was the opinion of staff that the greatest O&M need was main replacement and tower renovation. At the time of the site visit, it was concluded the raw water storage reservoirs are in need of modification to enable the system to store water without short circuiting. Modifications to the system may also include installation of raw water intakes at higher river levels. These changes may enable TMU to utilize more flow from the Thompson River.

4.4.6 Chariton-Linn Co. PWSD 3

Chariton-Linn Co. PWSD 3 is a public water supply district serving portions of rural areas in the counties of Chariton, Linn and Macon. Chariton-Linn 3 serves a population of over 5,900 people through approximately 2,400 active connections. Chariton-Linn purchases 100-percent of its water supply from surface water suppliers. The average daily demand of the system is 400,000 GPD.

Source: Chariton-Linn purchases approximately 20-percent of its water supply from City of Brookfield and the remaining 80-percent from the City of Marceline. At the time of the site visit, Chariton-Linn staff expressed concern of the reliability of the Brookfield surface water supply. Brookfield and Marceline were both greatly impacted by the dry period in 2012. Brookfield's reservoir has a very poor watershed capture, possibly worsened by the construction of impoundments upstream of the reservoir. Staff indicated that the Brookfield supply requires a normal year of rain to supply normal demand.

Chariton-Linn is consistently purchasing more water from Marceline, most especially following Marceline's reservoir and system modifications. However, both Marceline and Brookfield had issues with DBPs in the fourth quarter of 2014; thereby, impacting Chariton-Linn's system compliance for TTHMs.

Wholesale Purchase Contracts: Chariton-Linn purchases water under wholesale contracts with the cities of Brookfield and Marceline. Additionally, Chariton-Linn has wholesale water contracts with the cities of Bucklin, Mendon, and Chariton Co. PWSD 1. Contracts and expiration dates of those contracts were not available at the time of the site visit. Chariton-Linn also maintains an emergency connection to Thomas Hill PWSD 1.

Distribution System: Chariton-Linn utilizes several water storage tanks throughout its system with a total combined storage capacity of roughly 515,000 gallons. Pipe age throughout distribution system ranges from 1968 to present with a range of diameters from 2- to 6-inch. Distribution material varies from PVC, "K-pipe" (i.e., small diameter black plastic pipe), transite, and cast iron and/or ductile iron pipe at creek crossings.

Operations & Maintenance: All 2,394 residential meters within the Chariton-Linn system were replaced in July 2014 with Bader E-series mini-mag meters. Prior to change out, the system was using a self-read method with an annual District audit. In 2014, the system reported nearly 21-percent water loss, following the complete meter change out in 2015, water loss was reduced to less than 9-percent.

Through these residential meters and the consecutive connections with public water systems the District has sold a total annual volume of 92.3 million gallons of the estimated 101 million gallons purchased in FY14/15. The District's fiscal year begins October 1st of each year. The annual volume presented does not include the total volume for the month of September 2015.

System flushing is performed in conjunction with burnouts performed within the Brookfield and Marceline systems. The District staff expressed concern about man power to flush entire system during these maintenance burnouts.

Financial: Chariton-Linn performs annual audits and adopts an annual budget. The District currently has outstanding debt and has expended its total bonding capacity. Chariton-Linn has a 5-year Capital Improvement Plan completed by Allstate Consultants.

The average monthly water rate for 5,000 gallons is $50.00 for Chariton-Linn residential customers. The District is currently carrying nearly $15,000 of delinquent water bills on the books. Approximately 6 to 7 meters are on the lock list each month.

Chariton-Linn sells wholesale water to the cities of Mendon, Bucklin, and Chariton 2 at a rate of $6 per 1,000 gallons. Chariton-Linn purchases wholesale water from Brookfield at a rate of $3.65 per 1,000 gallons and from Marceline at a rate of $2.95 per 1,000 gallons. There have been administrative issues with suppliers of Chariton-Linn. Specifically, in March 2015 Brookfield overbilled for water purchased by Chariton-Linn. Recently, Marceline discovered that a master meter for Chariton-Linn was recorded improperly (entered as a 7-digit meter instead of an 8-digit meter) resulting in a significant under billing.

Primary Concerns: At the time of the site visit, Chariton-Linn expressed great concern of the quality and availability from suppliers. Additionally, District staff indicated that increasing manpower for systems operations is a priority. Chariton-Linn has been listed as an immediate probable customer of the future East Locust Creek Reservoir in a recent report by Allstate Consultants.

4.4.7 City of Marceline

The City of Marceline operates a municipal water supply system in southeastern Linn County. Marceline serves a population of over 2,500 people through nearly 1,100 active connections. Marceline is a surface water supplier with an average daily demand of 500,000 GPD.

Source: Marceline utilizes 2 surface water reservoirs, New Marceline Lake and Old Marceline Lake, and supplements the reservoirs by pumping from the Mussel Fork Creek. In 2012 the creek was pumped dry. In 2014, upgrades to the spillway and pump house at the Old Marceline Lake were completed. Marceline has had challenges with chloramines causing BacT violations and nitrification in dead ends. Marceline staff expressed concerns about high TTHMs throughout northeast Missouri over the summer of 2015 and elected to sample the City's Plant effluent. The results of that sampling were not available at the time of the site visit.

Marceline staff expressed confidence in the design life and reliability of their surface water supply. However, MDNR staff has indicated that the surface water sources may not have enough capacity to serve Chariton-Linn in the future. There were also concerns raised by MDNR that the Old Lake may be heavily silted.

Wholesale Purchase Contracts: Chariton-Linn 3 is Marceline's only wholesale customer. The wholesale contract between the City and Chariton-Linn expires in 2027.

In 2012, City of Brookfield did approach Marceline expressing interest in a potential connection.

Distribution System: Marceline utilizes three water storage tanks with a total combined storage capacity of roughly 800,000 gallons. The distribution system pipe sizes range from 4 to 6-inches in diameter with 98 percent of the pipelines in the distribution system comprised of CIP with the remaining 2 percent comprised of PVC pipe. The oldest pipe in the system was installed in the 1890s. The system experiences approximately 18 mainline breaks per year mostly due to freezing ground.

Operations & Maintenance: The system is comprised of roughly 1,100 residential meters ranging in age from 10 to 20 years old. The majority meters are positive displacement manual reads. In June 2015, the City sold approximately 12.7 million gallons of the nearly 14.8 million gallons finished water produced at its WTP. Water loss is approximately 14 percent, likely caused by leaks from water mains and old meters.

The City has expended an estimated $25,000 per year for operations staff to read meters. The distribution staff is pushing for radio read meters but the Board has yet to approve a complete replacement. There are only 100 radio read meters on hand.

Financial: The City of Marceline performs annual audits and adopts an annual budget. The last audit was performed in 2014. The Board adopted the annual budget in October 2014. Marceline currently has outstanding debt in the form of revenue bonds. The debt for the water system is scheduled to retire in 2020.

The average monthly water rate for 5,000 gallons is $49.00 for the City's residential customers. The City sells wholesale water to the Chariton-Linn 3 at a rate of $2.95 per 1,000 gallons. Rates were last raised in 2008. Allstate Consultants is currently performing a rate survey for the City's water, wastewater and electric service.

At the time of the site visit, Marceline staff did not indicate how much, if any, delinquent residential water bills are carried on the system's books. However, staff did explain that there are 40 shutoff notices mailed to delinquent water accounts each month with approximately 12 to 15 shutoffs completed.

Marceline staff did confirm the master meter error which resulted in under billing Chariton-Linn 3.

Primary Concerns: The primary concerns expressed by City staff at the time of the site visit focused on aging infrastructure and need for replacement.

4.4.8 Linn Co. Cons. PWSD 1

Linn Co. Cons. PWSD 1 is a public water supply district serving a portion of the rural area in Linn County. Linn Cons. serves a population of over 1,600 people through approximately 550 active connections. Linn Cons. is a groundwater supplier with an average daily demand of 80,000 gpd.

Source: Linn Cons. 1 produces groundwater utilizing five groundwater wells. The source water quality issues include iron and hardness. The treatment plant was installed in 1998. There have been no upgrades to the plant since installation. A leak in the plant finished water pipe required Linn Cons 1 to purchase approximately 36,000 gallons from Sullivan Co. PWSD 1. Although Linn Cons. staff expressed confidence that the source is adequate, MDNR staff indicated that the groundwater supply may not be reliable for the foreseeable future.

Wholesale Purchase Contracts: Linn Cons. 1 has a newly installed two-way connection with Laclede. There is also an existing connection to Sullivan Co. PWSD 1. There have been discussions for installing a two-way connection to Sullivan. No wholesale purchase contracts were made available at the time of the site visit.

Distribution System: Linn Cons. utilizes three finished water standpipes within its system with a total combined storage capacity of nearly 150,000 gallons. The distribution system is approximately 30 to 45 years old. The system is comprised mostly of 2- to 6-in PVC. There is one remaining CIP creek crossing which was scheduled to be replaced in October 2015.

Operations staff indicated that a portion of the distribution system can reach pressures close to 110 psi. In 2015 there was a positive BacT result in one of the District's standpipes.

Operations & Maintenance: There are nearly 550 active residential positive displacement meters within the system approximately 15 to 20 years old. In addition to the active residential meters there are close to 200 meters that are currently installed but not active. All active meters are self-read. The staff performs annual meter read audits to validate self-reads. Meters are changed out only when the meter read reaches 750,000 gallons read. An example of a self billing meter book is presented in Figure 4-8.

Through these residential meters and the consecutive connections with public water systems, the District has sold an estimated average annual volume of 24 million gallons of the estimated 32.6 million gallons produced from 2010 to 2014. The estimated water loss in the system is nearly 26-percent based on volume sold versus volume purchased and not accounting for volume loss during system flushing.

Flushing is not performed often as there are not adequate loops in the distribution network. Additionally, operations staff is limited which makes operations, flushing, meter checks, and other maintenance difficult.

Financial: Linn Cons. staff indicated that the District performs annual audits and adopts an annual budget. The last audit was performed in 2013. The District Board adopted the annual budget in December 2014. The District does not currently have any outstanding debt. Although Linn Cons. 1 has no formal Capital Improvement Plan in place, the District did complete a 5-year Owner Supervised Plan in 2011.

The average monthly water rate for 5,000 gallons is $52.00 for Linn Cons. residential customers. Rates were last raised on June 1, 2015. There is no more than about $1,000 delinquent water bill carried on the system books. Staff usually performs no more than 3 shutoffs per month due to lack of payment.

According to District staff wholesale water users are charged at the production cost at a rate of $6.00 per 1,000 gallons.

Primary Concerns: District staff expressed concern for age of distribution system, man power required for flushing and valve exercising, tank turnover issues, and recent BacT results in system standpipes. These system concerns are compounded the limited confidence of MDNR in the future reliability of the groundwater supply utilized by Linn Co. Cons. PWSD 1.

REMINDER

READ YOUR METER EVERY MONTH ON THE 1ST

MAKE PAYMENT BY THE 10th OF THE MONTH

LATE PENALTY OF 10% IS APPLIED ON THE 11th

THESE ARE YOUR SELF-BILLING SUPPLIES FOR

CONSOLIDATED PUBLIC WATER SUPPLY DISTRICT No. 1
OF LINN COUNTY, MISSOURI
"Owned By Those We Serve"

Mail All Remittances To:

PUBLIC WATER SUPPLY DISTRICT No. 1
Box 111
Purdin, Missouri 64674
Phone: 244-7345

PLEASE REPORT PROMPTLY

Name _____

Account No. _____

FILL OUT STUB FOR YOUR REFERENCE NEXT MONTH.

Date _____

1. Present Meter Reading _____
2. Previous Meter Reading _____
3. Number of Gallons Used _____
4. Amount Due From Chart $_____
5. Add 10% Late Penalty After 10th $_____
6. Sub-Total $_____
7. Adjustment Notice $_____
8. Amount You Pay $_____

CONSOLIDATED PUBLIC WATER SUPPLY DISTRICT NO. 1 OF LINN COUNTY, MISSOURI
Box 111
Purdin, Missouri 64674

Payment cannot be properly credited to your account unless this bill is filled out, signed and submitted with your payment.

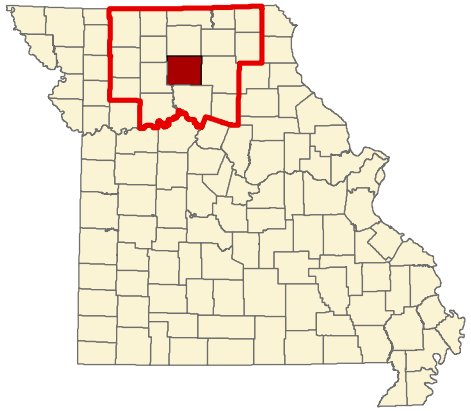
Name _____

Address _____

☐ Actual Reading
☐ Estimated Reading _____ Date

Account No. _____

1. Present Meter Reading _____
2. Previous Meter Reading _____
3. Number of Gallons Used _____
4. Amount Due From Chart $_____
5. Add 10% Late Penalty After 10th $_____
6. Sub-Total $_____
7. Adjustment Notice $_____
8. Amount You Pay $_____



DATA SOURCES:

SELECTED PUBLIC WATER SYSTEM SITE VISIT

FIGURE 4-8-LINN CO. CONS. PWSD 1
SELF REPORT METER BOOK

N

US Army Corps of Engineers ®
Kansas City District

MISSOURI NATURAL RESOURCES

HDR

4.4.9 City of Princeton

The city of Princeton is located in central Mercer County. Princeton serves a population of nearly 1,200 people through approximately 525 active connections. Princeton produces 100-percent of its water supply from seven active groundwater wells. The average daily production of the system is nearly 230,000 GPD.

Source: According to Princeton operations staff, three off the seven wells must operate a pump in order to meet average day demand. Two groundwater wells currently have iron bacteria issues. Precipitated iron must be removed once per year by pigging the raw water line from the well field. Each of the wellheads is fit with magnetic flow meters to monitoring water production but the meters have historically had issues.

The Princeton WTP has a design capacity of 360 gpm. The plant has not been upgraded in over 40 years, with the exception of SCADA and filter media change out. Aside from some necessary upgrades, staff expressed confidence in the treatment plant and source water capacity. Princeton is considering installing a tank mixer for storage at the treatment plant to combat high TTHMs results.

Wholesale Purchase Contracts: Princeton currently has wholesale contracts with the City of Mercer and Mercer Co. PWSD 1; both are set to expire in 2024. At the time of the site visit, Princeton staff explained that the City of Mercer was attempting to supply Mercer 1 as a wholesale customer. Mercer would purchase water from Princeton then sell to Mercer 1.

Distribution System: The Princeton distribution system was installed in 1975 and is composed primarily of DIP and PVC. The City staff indicated that there are issues with pipe age, small pipe diameters, and an inadequate number of valves throughout the system. The staff stressed that the distribution system is in need of priority main replacement.

Operations & Maintenance: The City of Princeton utilizes one system storage tank with a storage capacity of 500,000 gallons. There are approximately 526 active positive displacement meters throughout the Princeton distribution system with an average age of 5 years. A meter reader is employed by the City to perform meter reads. There is a meter change out program which aims to replace approximately 50 meters per year. Through these residential meters and the consecutive connections with public water systems the City has sold an estimated average annual volume of 47.5 million gallons of the estimated 54.2 million gallons produced from 2010 to 2014. The Princeton staff currently reports 18-percent water loss.

Financial: Princeton administrative staff indicated that an annual audit is not performed. The City does develop and adopt an annual budget. The last budget was adopted in May 2015. The City does not currently have any outstanding debt.

The average monthly water rate for 5,000 gallons is $51.74 for Princeton residential customers. Rates were last raised in May 2014. Princeton continually carries delinquent water bills on the books. Approximately 25 to 30 people are sent notices per month; only 1 or 2 are actually shut off.

The City sells wholesale water to the City of Mercer and Mercer Co. PWSD 1 at a rate of $5.65 per 1,000 gallons.

Primary Concerns: The City staff indicated that the primary concern involved losing Mercer 1 as a wholesale customer. Additionally, City staff indicated there were concerns with the accuracy of the residential meter reading.

4.4.10 Putnam Co. PWSD 1

Putnam Co. PWSD 1 is a public water supply district with a service area boundary comprised of Putnam County in its entirety. Putnam 1 serves a population of nearly 3,000 people through 1,540 active connections. Putnam 1 purchases 100-percent of its water supply from surface water suppliers. The average daily demand of the system is nearly 250,000 GPD.

Source: According to Putnam 1, the system purchases 50 percent of its supply from the City of Unionville. Putnam purchases the remaining 50-percent of its supply from Rathbun Regional Water Association based in Rathbun, Iowa. However, there are limitations on the volume of water that can be purchased from Rathbun.

Unionville has recently completed a WTP upgrade to convert the plant to chloramines. At the time of the site visit in September 2015, the chloramine conversion had not yet been initiated due to operational issues at the treatment plant. MDNR staff indicated during a follow-up meeting that Unionville system would be operational by the end of November. At the time of the site visit, Putnam staff indicated the Putnam 1 system and Unionville had both violated TTHMs for the most recent monitoring period but that Putnam 1 had received an MNDR waiver. However, DWW indicates that a formal notice of violation (NOV) was issued to Putnam 1 on November 18, 2015 for exceeding the MCL for TTHMs.

Wholesale Purchase Contracts: Putnam currently has water purchase contracts with Adair Co. PWSD 1 (expires 2022); Wildflower Community (expires 2038); Mercer Co. PWSD 1 (expires 2042); and Schuyler Co. PWSD 1 (expires 2024). At the time of the site visit only the Wildflower Community and Mercer 1 were utilizing the connections on a regular basis. Adair 1 had previously indicated an interest to Putnam staff in purchasing water regularly if the source water from Unionville is finally converted to chloramine disinfection.

Putnam 1 staff did express concern that the total water demand of the wholesale contracts may have overcommitted the sources that Putnam currently utilizes.

Distribution System: Putnam 1 utilizes three above ground storage tanks with a total combined storage capacity of 400,000 gallons. Each storage tank is affixed with a booster pump station to convey water to storage. There is an additional inline booster pump to convey water to the master meter at Mercer 1 for water that is purchased from that neighboring system. The Putnam 1 distribution system is comprised of 2- to 8-in PVC pipe ranging in age from 1978 to present. The system has issues with pipe age, small pipe sizes, and inadequate number of valves throughout the system.

As mentioned previously, Putnam has received violations for distribution system byproducts, more specifically TTHMs. Putnam 1 distribution staff indicated TTHM compliance is the greatest challenge for the distribution system, made even more important by the fact that the system purchases 100 percent of its water supply.

Operations & Maintenance: There are approximately 1,550 active positive displacement meters throughout the Putnam distribution system which are fit with radio read devices with an average age of 7 years. There is not a formal meter change-out program or Asset Management Program in place. Through these residential meters and the consecutive connections with public water systems Putnam 1 has sold an estimated 83.7 million gallons of the estimated 93 million gallons purchased for fiscal year 2014/2015. Putnam 1 calculates the water purchased versus water sold annually on the fiscal year beginning July 1.

Putnam 1 performs flushing annually as part of its formal flushing program, which coincides with the Rathbun system burnout during the spring months. Accounting for roughly 530,000 gallons of water used for system flushing, the system estimated water loss of approximately 9.54 percent for the FY14/15. The Putnam 1 system uses a portable three-phase 35 kilowatt backup power supply to power its critical infrastructure during emergencies.

The greatest need in terms of O&M as expressed by the System staff is lack of man power. Currently, the system is operated by two certified operators. The Superintendent explained that a part time operator to assist with reading meters and other labor would be extremely useful. However, Board approval of an additional position has not occurred. The system currently contracts labor activities, such as main leak repairs, to a contractor. However, response times have been longer since the contractor has reduced its team size.

Financial: Putnam 1 performs annual audits and develops an annual budget. The last audit was performed on October 16, 2014. The annual budget was updated on June 30, 2015. There is currently no formal Capital Improvement Plan in place.

Putnam 1 currently has outstanding debt in the form of revenue bonds. The debt for the water system is scheduled to be retired in July of 2028. The positive displacement meters throughout the system were funded using a lease to purchase agreement which had been paid off at the time of the site visit.

The average monthly water rate for 5,000 gallons is $66.25 for Putnam 1 customers. Putnam 1 carries roughly $6,000 of delinquent water bills on its books; writing off approximately $1,300 per year. The system is having difficulty collecting delinquent water bills from tenants. Currently, Putnam 1 does not go after landlords to collect.

The wholesale rates for Mercer 1, Adair 1, and Schuyler 1 are $3.78 per 1,000 gallons. The Wildflower Community pays a wholesale water rate of $3.98 per 1,000 gallons. According to Putnam 1 administrative staff, the residential and wholesale rates have not been reviewed or raised since November 2008.

Primary Concerns: As a water system which serves not only residential water connections but also wholesale water connections, Putnam 1 is in need of a reliable water source that is not limited on quantity or quality. In an effort to meet this need, Putnam 1 and Unionville expressed interest in joining the NCMRWC to utilize the potential future water supply from East Locust Creek Reservoir. However, MDNR staff indicated that Unionville ended negotiations with the Commission after expressing concerns about the potential price of water.

In terms of affordability, it is important for Putnam 1 to expand its water portfolio by utilizing more water suppliers. However, based on the existing median household income (MHI) of the Putnam 1 service area, residential water rates will quickly reach 2-percent of local MHI if the rates are increased above $68 per 5,000 gallons.

4.5 Regional Reliability

At the time of the site visits, every system expressed confidence in the reliability of their source; however, this is not likely realistic. Of the 99 systems within the Study Area, 13 systems, which had previously utilized their own supply, now purchase water. Of the 13 systems, 12 abandoned surface water sources and one abandoned a groundwater source.

The following list is a compilation of the issues identified during the site visits.

- Availability of licensed operators;
- Quality of treated water from suppliers;
- Water supply wholesale rate suitability;
- Ability to locate distribution system pipelines;
- Treatment plant inefficiencies;
- Water loss though leaking mains and meters or due to poor water accounting;
- Operational hardship caused by manual meter reads;
- Lack of Asset Management Programs; and
- Cost limitations for system improvements required to improve water supply utilization.

As mentioned previously, these issues may not directly align with those faced by every water system within the Study Area. However, when compared to those issues identified by the Missouri State Water Plan Phase 2 it is easy to conclude that these issues are common throughout the state.

The Missouri State Water Plan Phase 2 was completed by MDNR to identify and discuss water use problems and opportunities related to drinking water, agricultural, industrial, recreational, and environmental needs throughout five separate regions of the State: northwestern, northeastern, central, eastern and southern Missouri. The Phase 2 Report concluded with findings common to all five regions with noteworthy statewide implications. The findings are as follows:

- Changing land use practices, urban sprawl, and contaminants from runoff, threatens water supplies, which in-turn impact water demand and water use.
- Drinking water supply and delivery infrastructure is not only stressed from age but also from capacity and supply limitations.

- Water supply quality or quantity threats exist in every watershed. Left unchecked, these threats can negatively impact drinking water supplies, agricultural water use, recreation, tourism, fish and wildlife, and business and industrial water uses.
- Problems associated with surface water are more noticeable than problems associated with groundwater; therefore, they are identified more readily and more often.

The Study Area falls within the northwestern and northeastern regions of Phase 2. The northwestern region encompasses Harrison, Daviess, and Caldwell counties. The northeastern region encompasses the remaining 14 counties of the Study Area. The Phase 2 findings for these regions are presented below.

Northeastern Region: This region is primarily rural, with findings reflecting those concerns. Findings for this region include: concerns with lack of planning and high costs of developing, expanding, maintaining, and replacing water supply sources and delivery systems; unclear water use rights; aging water supply sources and infrastructure; changing use demands stemming from population trend changes; and system stress in meeting water demands during periods of drought and industrial growth. Other significant concerns involve water quality and the environment; including water and land impacts associated with confined animal feeding operations, industrial and residential growth, stream channelization, sedimentation, stream bank erosion, and loss of vegetated riparian corridors.

Northwestern Region: This is a diverse water use region, ranging from large tracts of rural, agriculture areas to populous metropolitan and suburban areas. Identified concerns include: aging infrastructure and water supply impoundments, lack of both water supply and public water system coordination (especially during drought); contamination of water supplies by chemicals, human and animal waste; urban sprawl and land use management; and channelization, sedimentation and stream degradation.

Six of the selected water systems have been designated as part of this Study for possible connection to a conceptual regional transmission system supplied by two of the regions future potential sources: Little Otter Creek Reservoir (Caldwell County) and East Locust Creek Reservoir (Sullivan County). The systems were selected based on need of reliable water source or source redundancy and proximity to the future potential sources. These systems include Putnam Co. PWSD 1, Adair Co. PWSD 1, Trenton Municipal Utilities, Linn Co. Cons. PWSD 1, the City of Marceline, and Daviess Co. PWSD 1. The City of Hamilton has already been identified in previous Little Otter Creek studies as a potential future customer. Therefore, alignment and costs of connection for Hamilton will not be discussed in this study. The conceptual regional distribution system is presented in further detail in Topic 5.

Topic 5 Conceptual Distribution System

From the information gathered in Topics 1 and 4, six of the selected water systems may have limited ability to supply water. Therefore, conceptual water transmission line alignments and conceptual costs were identified for those selected water systems within the Study Area. The conceptual alignments could provide these systems with the potential to supply water to their customers in the event their existing sources are no longer available, are limited from the impacts of major natural events (as noted in section 4.3), or other reasons that would limit the ability to supply water.

The conceptual alignments identified are listed and described in the sub-sections below. These conceptual alignments assume that the proposed East Locust Creek Reservoir and Little Otter Creek Reservoir will be constructed and that they will have adequate capacity to supply the needs for these water supply systems. From the reports and information reviewed for these two reservoir projects, we have assumed that the City of Milan would connect to the East Locust Creek Reservoir and that the City of Hamilton would connect to the Little Otter Creek Reservoir, and they would have pipeline and pumping capacity in place to accommodate additional suppliers.

Available water use data from MDNR's Drinking Water Watch was utilized to evaluate and determine approximate pipe sizes. Existing road maps and elevation profiles were utilized to estimate the length of the pipeline and the number of booster pump stations that may be needed. For purposes of this Study, we assumed that each alignment would utilize public right-of-way along existing roads to keep easement acquisition costs to a minimum. The conceptual construction costs for the water transmission lines were estimated and are based on other similar water transmission lines of comparable size. Each cost estimate includes the estimated construction costs, as well as contingency (25-percent), estimated engineering costs (both design and construction engineering, at 20-percent), as well as construction contractor's overhead, general conditions, and insurance costs (20-percent). The cost estimates presented are an opinion of probable cost at a conceptual level and are intended to be used in support of future planning by MDNR only. The detail for each cost estimate is provided in more detail in Appendix C.

Conceptual alignment to supply Putnam Co. PWSD 1

Putnam Co. PWSD 1 purchases its water supply from either the City of Unionville or Rathbun Regional Water Association in Iowa. The City of Unionville gets its water supply from Lake Mahoney, with an emergency connection from Lake Thunderhead. Lake Thunderhead is a privately owned lake and is not designated as a water supply reservoir; however it has the capabilities of providing some emergency water supply. As demonstrated in Topic 1, there are periods when the Unionville demands may exceed the optimum yield from Lake Mahoney. In addition, based on the site visit conducted with Putnam Co. PWSD1, there are limitations on the volume of water that they can purchase from Rathbun Regional Water Association. For these reasons, a conceptual alignment from the East Locust Creek Reservoir to Putnam Co. PWSD 1 was evaluated.

This conceptual pipeline would be an 8-inch, approximately 21 mile long with one booster pump station to supply approximately 0.47 MGD of water to Putnam Co. PWSD 1 (see Figure 5-1). The pipeline would

run north along Missouri Highway 5 between the Milan WTP and the Putnam Co. PWSD 1 system. For purposes of this Study, we assumed the connection would be near the storage tank in Unionville. Although this alignment was evaluated for Putnam Co. PWSD 1, this water main could also be of benefit to the City of Unionville. This alignment was estimated to cost approximately $11.6 Million.

Conceptual alignment to supply Adair Co. PWSD 1

Adair Co. PWSD 1 purchases its water supply from the City of Kirksville. They also have the ability to supplement their water supply by purchasing water from Putnam Co. PWSD 1 or from Schuyler Co. Cons. PWSD 1. However, at the time of our site visit, Adair Co. PWSD 1 noted that the majority of the water they purchase is from the City of Kirksville. They have not purchased water in the recent past from Putnam Co. PWSD 1 and the amount they purchase from Schuyler Co. Cons. PWSD 1 is minimal. The City of Kirksville gets its water supply from two separate lakes. As demonstrated in Topic 1, the optimum yield from these lakes is adequate to supply the demand for the City of Kirksville. MDNR staff have previously expressed concerns that the City of Kirksville's WTP has reached its rated capacity and during periods of high demand, they may not have the ability to supply Adair Co. PWSD 1. For this reason, a conceptual alignment from the East Locust Creek Reservoir to Adair Co. PWSD 1 was evaluated.

This conceptual pipeline would be a 12-inch, approximately 23 mile long with one booster pump station to supply approximately 1.07 MGD of water to Adair Co. PWSD 1 (see Figure 5-2). The pipeline would run east along Missouri Highways Y, J, and 6 between the Milan WTP and the Adair Co. PWSD 1 system. For purposes of this Study, we assumed the connection would be to the storage tank west of Novinger. This alignment was estimated to cost approximately $18.7 Million.

Conceptual alignment to supply Linn Co. PWSD 1 and City of Marceline

Linn Co. PWSD 1 gets its water supply from five (5) groundwater wells and then they treat the groundwater at their WTP. At the time of our site visit, Linn Co. PWSD 1 expressed confidence in their groundwater source, however, MDNR staff indicated that the groundwater supply may not be reliable for the foreseeable future.

The City of Marceline gets its water supply from two (2) surface water reservoirs and supplements the reservoirs by pumping from the Mussel Fork Creek. The City of Marceline provides treated water to Chariton-Linn Co. PWSD 3. At the time of our site visit, it was noted that in 2012, the creek was pumped dry. Also at the time of our site visit, Marceline staff expressed confidence in the reliability of the surface water supply, however, MDNR staff indicated that the surface water sources may not have enough capacity to serve Chariton-Linn Co. PWSD 3 in the future. Chariton-Linn Co. PWSD 3 also purchases water from the City of Brookfield.

As demonstrated in Topic 1, there are periods when the City of Marceline's and the City of Brookfield's demands may exceed the optimum yield from those surface water supplies. For these reasons, a conceptual alignment from the East Locust Creek Reservoir to Linn Co. PWSD 1 and the City of Marceline was evaluated. Although this alignment was evaluated for Linn Co. Cons PWSD 1 and the City of

Marceline, this water main could also be of benefit to the City of Brookfield, the City of Laclede, and the City of Linneus.

This conceptual pipeline would be a 24-inch, approximately 19 mile long with one booster pump station to supply a total of approximately 3.90 MGD of water (0.2 MGD to Linn Co. Cons PWSD 1, 0.07 MGD to the City of Laclede, 0.22 MGD to the City of Linneus, 1.25 MGD to the City of Brookfield, and 2.16 MGD to the City of Marceline). A 20-inch, approximately 31-mile long, pipe with one additional booster pump station was identified to continue the pipeline from Linn Co. Cons. PWSD 1 to the City of Marceline (see Figure 5-3). The pipeline would run south from the Milan WTP along Missouri Highway 5 to the existing WTP for Linn Co. Cons. PWSD 1 near Purdin. The pipeline would then continue south along Missouri Highway 5 to US Highway 36, then run east along US Highway 36 to Brookfield, and then south along Missouri Highway 5. For purposes of this Study it was assumed the connection would be to the storage tank for the City of Marceline's system. This overall alignment was estimated to cost approximately $60.7 Million.

Conceptual alignment to supply Daviess Co. PWSD 1

Daviess Co. PWSD 1 purchases its water supply from the City of Pattonsburg and then supplies water to Altamont. The City of Pattonsburg utilizes five (5) groundwater wells for its supply and then treats the water at their WTP. At the time of our site visit, Daviess Co. PWSD 1 and the City of Pattonsburg were in the process of renegotiating the terms of their wholesale contract, which was set to expire in December 2015. According to Daviess Co. PWSD 1 staff, the proposed new wholesale rate would double over a 5-year period. For this reason, a conceptual alignment from the Little Otter Creek Reservoir (via the City of Hamilton) to Daviess Co. PWSD 1 was evaluated. Although this alignment was evaluated for Daviess Co. PWSD 1, this water main could also be of benefit to the City of Gallatin as well as Daviess Co. PWSD 2.

This conceptual pipeline would be a 12-inch, approximately 11 mile long with one booster pump station to supply a total of approximately 0.93 MGD of water (0.11 MGD to Daviess Co. PWSD 2, 0.72 MGD to the City of Gallatin, and 0.10 MGD to Daviess Co. PWSD 1). A 4-inch, approximately 10-mile long, pipeline with one booster pump station between Daviess Co. PWSD 2 and Daviess Co. PWSD 1 was also identified to supply approximately 0.1 MGD to Daviess Co. PWSD 1 (see Figure 5-4). The pipeline would run north from Hamilton along Missouri Highway 13 to the Daviess Co. PWSD 2 system. For purposes of this Study, we assumed the connection would be at the storage tank in Gallatin. The pipeline alignment would continue west along Missouri Highway 6 to the Daviess Co. PWSD 1 system. For purposes of this Study, we assumed the connection would be at the storage tank in Altamont. This overall alignment was estimated to cost approximately $14.4 Million.

Conceptual alignment to supply Trenton Municipal Utilities

Trenton Municipal Utilities (TMU) gets its water supply from the Thompson River and then they treat the water at their WTP. TMU then sells water to Grundy Co. PWSD 1, who then sells water to both Galt and Spickard. As demonstrated in Topic 1, the minimum in-stream flow requirements for the Thompson River is 9 cfs (5.81 MGD), and the average TMU demand was 2.69 cfs (1.74 MGD). So, the minimum flow

in the Thompson River would need to be 11.69 cfs (7.56 MGD) to meet TMUs average demands. As part of this study, the mean daily flow determined in the 2011 WSS was overlain with the 7Q10 requirement and more recent average demands from Missouri's Major Water Users Database. From this evaluation, a flow deficit for the Thompson River was noted for the 1-percent chance (1 year in 100) of non-exceedance flows. In addition, according to the 2011 WSS HYSEP analysis, during the drought of record, there were five (5), 30 day periods that the flow in the Thompson River was not adequate to allow for pumping. For these reasons, a conceptual alignment from the East Locust Creek Reservoir to TMU was evaluated.

This conceptual pipeline would be a 16-inch, approximately 32 miles long with one booster pump station to supply a total of 1.74 MGD of water to TMU (see Figure 5-5). The pipeline would run south from the Milan WTP along Missouri Highway 5 and then west along Missouri Highway 6. For purposes of this Study it was assumed the connection would be near the current interconnection located along Highway 6, just east of Trenton. This overall alignment was estimated to cost approximately $28.8 Million.

Overall Conceptual alignments

Figure 5-6 provides an overall view of the above described conceptual alignments within the Study Area.

Putnam

Putnam Co.
PWSD #1

Sullivan

Sullivan Co.
PWSD #1

Lake Thunderhead

Unionville Reservoir

Unionville

East Locust Creek Reservoir

Elmwood Reservoir

Milan Lake (new)

Green City

WTP

139

136

5

129

6

149

LEGEND

- Conceptual Alignment
- Approximate Location of Proposed Reservoir
- Consecutive Connection (Active)
- Consecutive Connection (Emergency)
- Intake (Active)
- Intake (Emergency)
- Treatment Plant
- Public Wells
- Well
- Storage Tank
- City
- US Interstate
- US Highway
- State Highway
- County Road
- Study Area PWSD
- County Boundaries

FIGURE 5-1
MILAN (EAST LOCUST CREEK RESERVOIR)
TO PUTNAM CO. PWSD 1
CONCEPTUAL ALIGNMENT

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0 1.5 3
MILES

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Kansas City District

MISSOURI NATURAL RESOURCES

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Sullivan

Adair

East Locust Creek Reservoir

Green City

Elmwood Reservoir

Milan Lake (new)

Milan

Novinger

Adair Co. PWSD #1

5

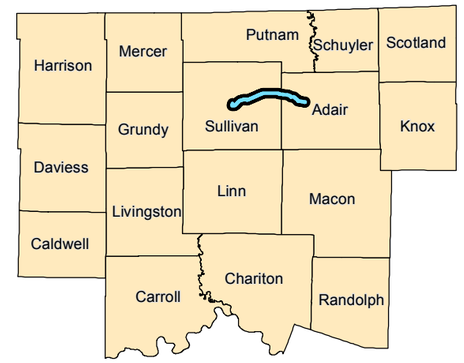
6

129

149

11

WTP



LEGEND

- Conceptual Alignment
- Approximate Location of Proposed Reservoir
- Consecutive Connection (Active)
- Consecutive Connection (Emergency)
- Intake (Active)
- Intake (Emergency)
- Treatment Plant
- Public Wells
- Well
- Storage Tank
- City
- US Interstates
- US Highways
- State Highways
- County Road
- Study Area PWSD
- County Boundaries

FIGURE 5-2 MILAN
(EAST LOCUST CREEK RESERVOIR)
TO ADAIR CO. PWSD 1
CONCEPTUAL ALIGNMENT

N

0 1 2
MILES

US Army Corps of Engineers ®
Kansas City District

MISSOURI NATURAL RESOURCES

HDR

East Locust Creek Reservoir
Elmwood Reservoir
Milan Lake (new)
Milan
Green City
Sullivan
Adair
Hazel Creek Lake
Novinger
Kirksville
Forest Lake
Adair Co. PWSD #1
Galt
Laredo
Browning
Purdin
Linneus
Linn
Linn Co. Cons. PWSD #1
Linn-Livingston Co. PWSD #3
Livingston Co. PWSD #2
Meadville
Laclede
Brookfield
Brookfield Lake
Bucklin
Bucklin Lake
Marceline
Marceline Lake
Marceline Lake (New)
Chariton-Linn Co. PWSD #3
Macon
Callao
Bevie
Harrison
Mercer
Putnam
Schuyler
Scotland
Sullivan
Adair
Knox
Grundy
Daviess
Linn
Macon
Livingston
Caldwell
Carroll
Chariton
Randolph
LEGEND
Conceptual Alignment
Approximate Location of Proposed Reservoir
Consecutive Connection (Active)
Consecutive Connection (Emergency)
Intake (Active)
Intake (Emergency)
Treatment Plant
Public Well
Well
Storage Tank
City
US Interstates
US Highways
State Highways
County Road
Study Area PWSD
County Boundaries
FIGURE 5 - 3
MILAN (EAST LOCUST CREEK RESERVOIR)
TO LINN. CO. PWSD 1
TO MARCELINE
CONCEPTUAL ALIGNMENT
0 2.5 5
MILES
US Army Corps of Engineers
Kansas City District
MISSOURI NATURAL RESOURCES
HDR
TE: 4/15/2016

Daviess Co. PWSD #3

Lake Viking

WTP

Daviess Co. PWSD #2

Jamesport

Livingston Co. PWSD #4

Altamont

Gallatin

Daviess Co. PWSD #1

Marrowbone Creek

Daviess County

Caldwell Co. PWSD #2

Caldwell Co. PWSD #3

Hamilton Lake

Hamilton

Breckenridge Lake

Breckenridge

Little Otter Creek Reservoir

Caldwell County

Clinton Co.

6

69

35

13

36

190

ARD - DATE: 4/15/2016

LEGEND

- Conceptual Alignment
- Approximate Location of Proposed Reservoir
- Consecutive Connection (Active)
- Consecutive Connection (Emergency)
- Intake (Emergency)
- Intake (Active)
- WTP Treatment Plant
- Public Wells
- Well
- Storage Tank
- City
- US Interstate
- US Highway
- State Highway
- County Road
- Non-Study Area PWSD
- Study Area PWSD
- County Boundaries

FIGURE 5-4 HAMILTON
(LITTER OTTER CREEK RESERVOIR)
TO DAVIESS CO. PWSD 2 (AT GALLATIN)
TO DAVIESS CO. PWSD 1 (AT ALTAMONT)
CONCEPTUAL ALIGNMENT

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MILES

US Army Corps of Engineers
Kansas City District

MISSOURI NATURAL RESOURCES

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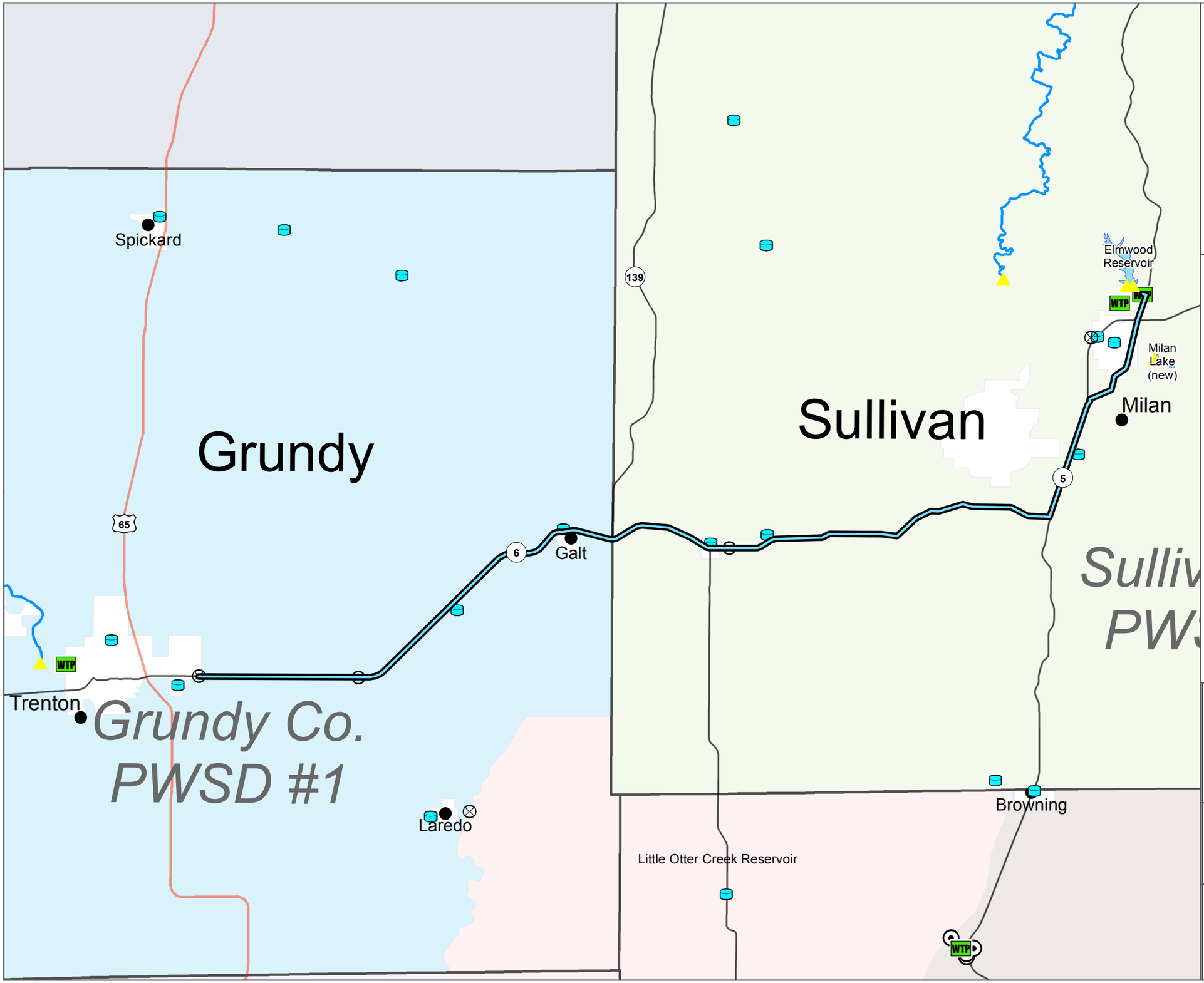

LEGEND

- Conceptual Alignment
- Approximate Location of Proposed Reservoir
- Consecutive Connection (Active)
- Consecutive Connection (Emergency)
- Intake (Emergency)
- Intake (Active)
- Treatment Plant
- Public Wells
- Well
- Storage Tank
- City
- US Interstate
- US Highway
- State Highway
- County Road
- Non-Study Area PWSD
- Study Area PWSD
- County Boundaries

FIGURE 5-5 TRENTON MUNICIPAL UTILITIES TO MILAN

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MILES

US Army Corps of Engineers
Kansas City District

MISSOURI NATURAL RESOURCES

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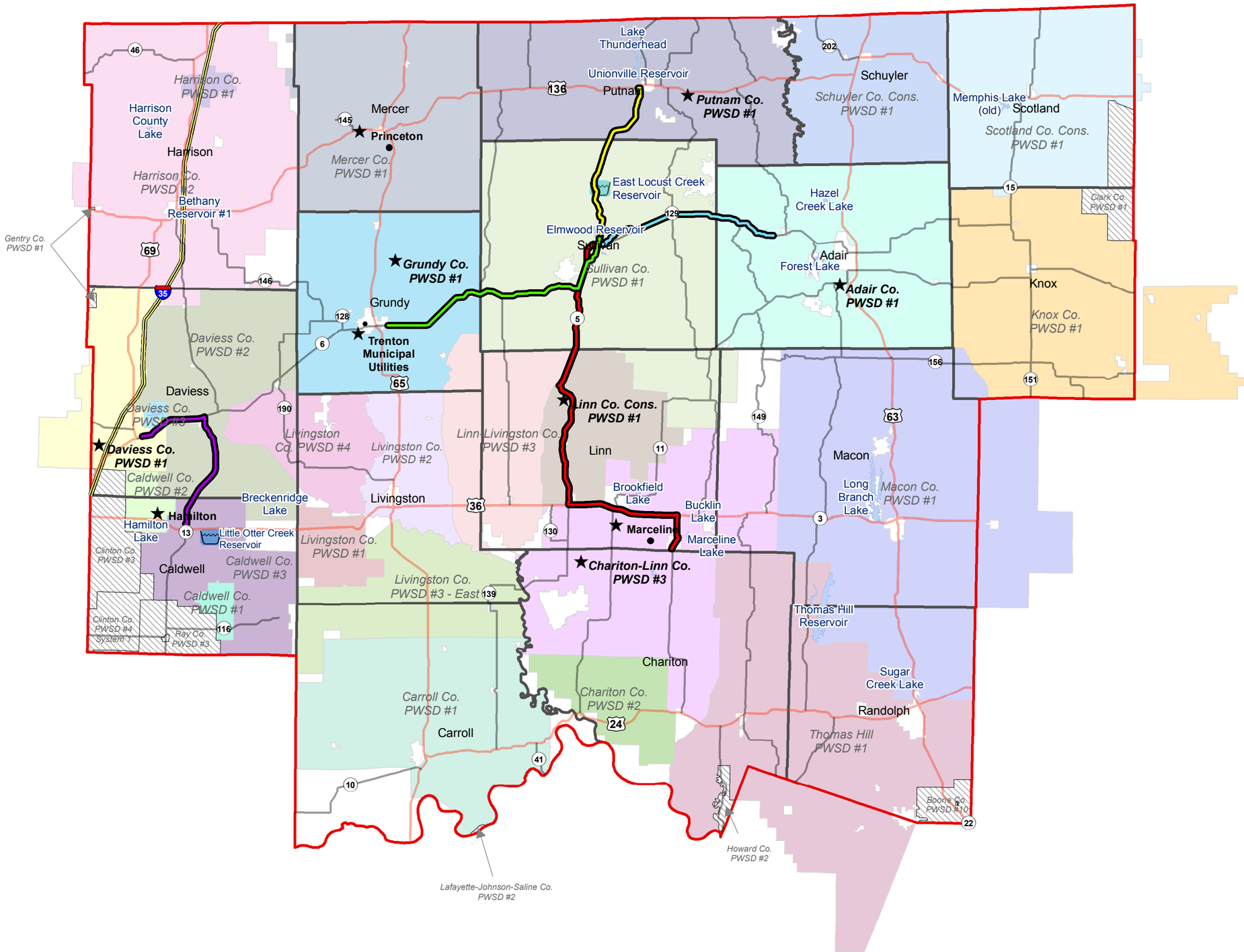

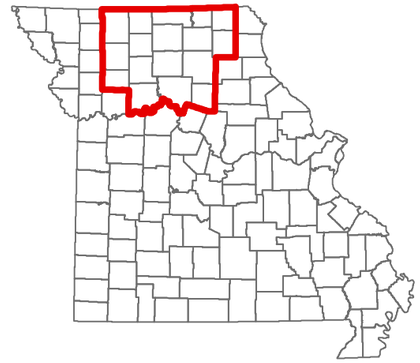

LEGEND

- County Boundary
- Study Area Boundary
- Study Area PWSD
- Non-Study Area PWSD
- City
- Priority Water System
- Approximate Location of Proposed Reservoir
- State Highway
- US Highway
- US Interstate

Conceptual Alignments

- Milan to Adair Co. PWSD 1
- Hamilton to Daviess Co. PWSD 1 to PWSD 2
- Milan to Linn Co. Cons. PWSD 1 to Marceline
- Milian to Putnam Co. PWSD 1
- Trenton Municipal Utilities to Milan

FIGURE 5-6 STUDY AREA CONCEPTUAL ALIGNMENT

N

0 10 20
MILES

US Army Corps of Engineers
Kansas City District

MISSOURI NATURAL RESOURCES

HDR

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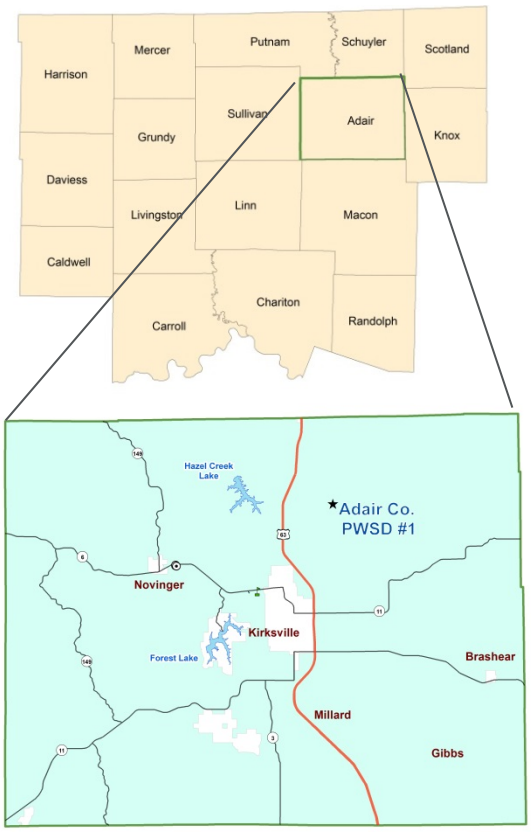
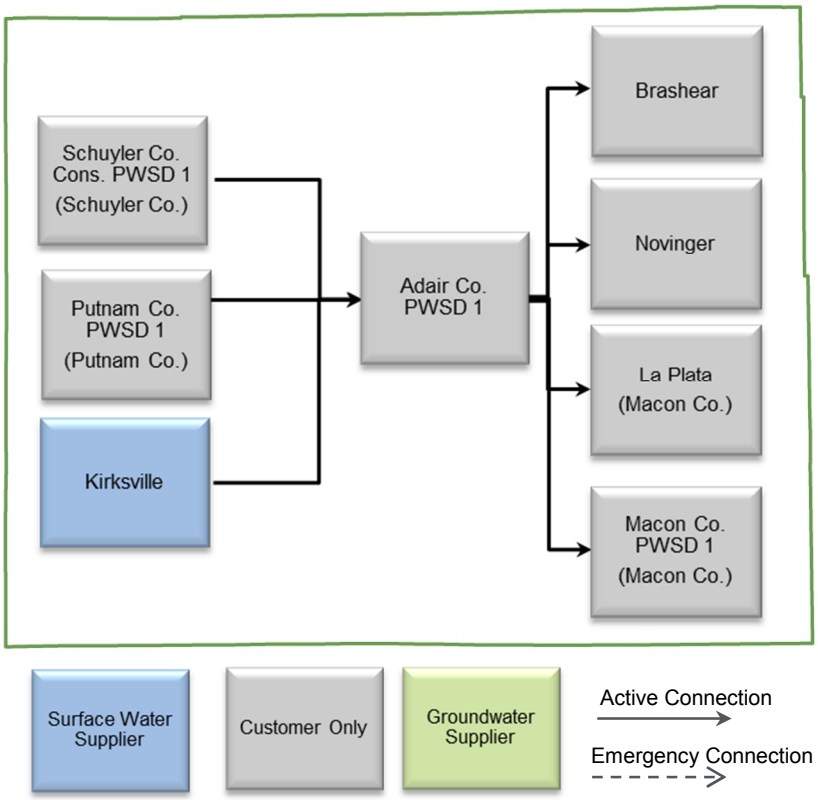
Appendix A Issue Statements





Water Supply Summary: *Adair County*

Within Adair County there are four public water systems serving a population of 25,642: Adair Co. PWSD 1 and the cities of Kirksville, Brashear, and Novinger. Of the four public water systems, one is a surface water supplier (Kirksville) and the remaining three are all purchasers of that surface water. One system, Adair Co. PWSD 1, supplements by purchasing surface water from two systems outside of Adair County.

Availability

- The City of Kirksville supplies surface water from two sources: Forest Lake and Hazel Creek Lake.
- Adair County does not have any groundwater sources or have any systems that purchase from groundwater suppliers.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
Forest and Hazel Creek Lake	City of Kirksville/MO2010429	Surface Water	5.48	6.00	2.9

[(1)]MDNR RESOP Analysis 2011
[(2)]MDNR 2015

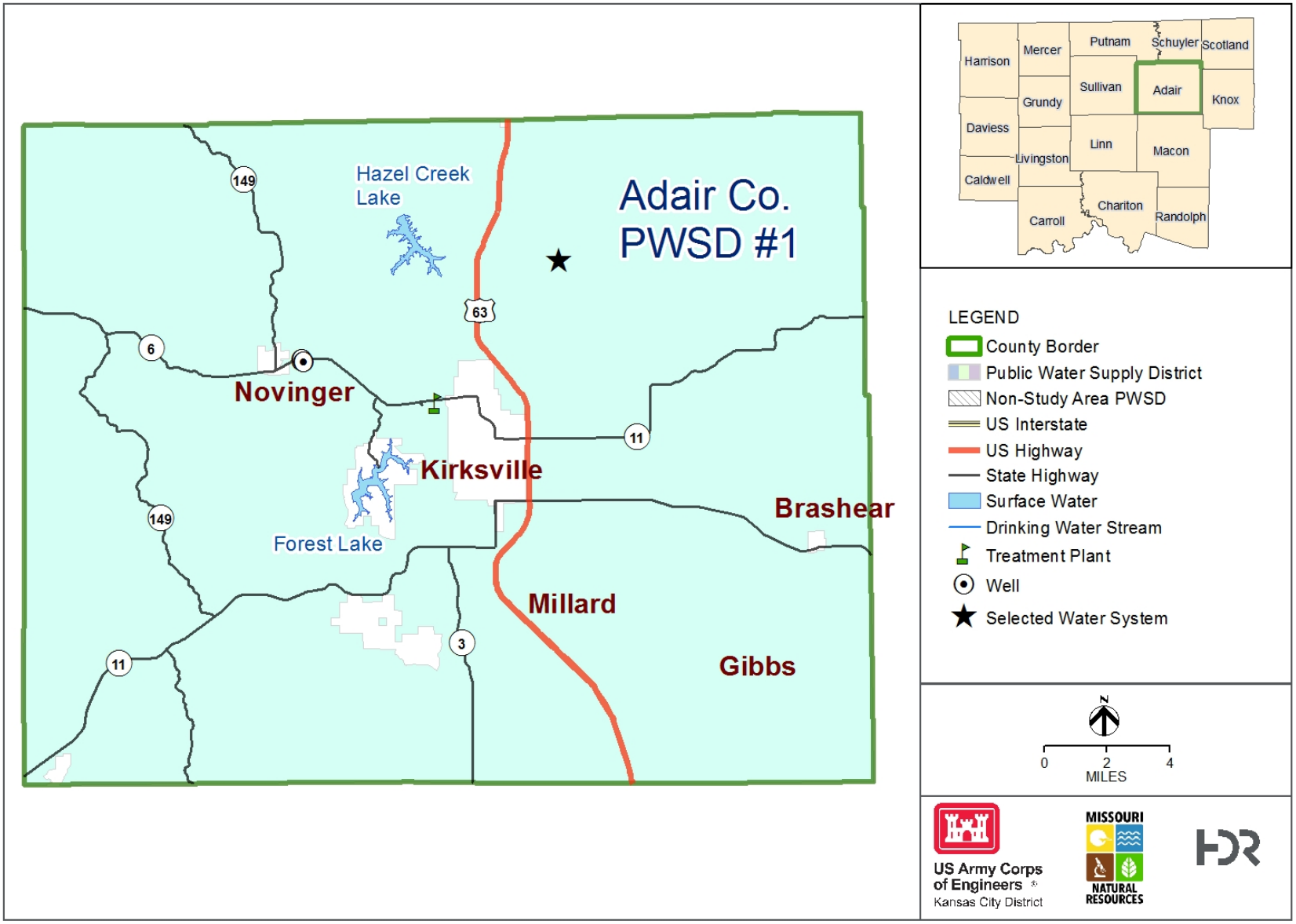
Reliability

- Adair County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- According to MDNR analysis, Forest and Hazel Creek Reservoirs demonstrate that Kirksville's demand will be met for the foreseeable future.

- Adair Co. PWSD 1 purchases nearly 99 percent of its supply from the City of Kirksville. According to MDNR, Kirksville WTP has reached its rated capacity and this may cause Kirksville to limit supply to Adair 1.
- Due to fiber optic installations in the area, Adair 1 has experienced water main breaks in the distribution system resulting in unnecessary water loss.

Quality

- The surface water treatment for Forest and Hazel Creek Lakes includes filtration, sedimentation, and disinfection.
- Historical water quality issues within the County include disinfection byproduct DBP compliance violations.


Adair Co.
PWSD #1
Hazel Creek
Lake
Forest Lake
Novinger
Kirksville
Brashear
Millard
Gibbs
149
63
6
11
149
3
11
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Livingston
Caldwell
Carroll
Chariton
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
Selected Water System
N
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US Army Corps
of Engineers
Kansas City District
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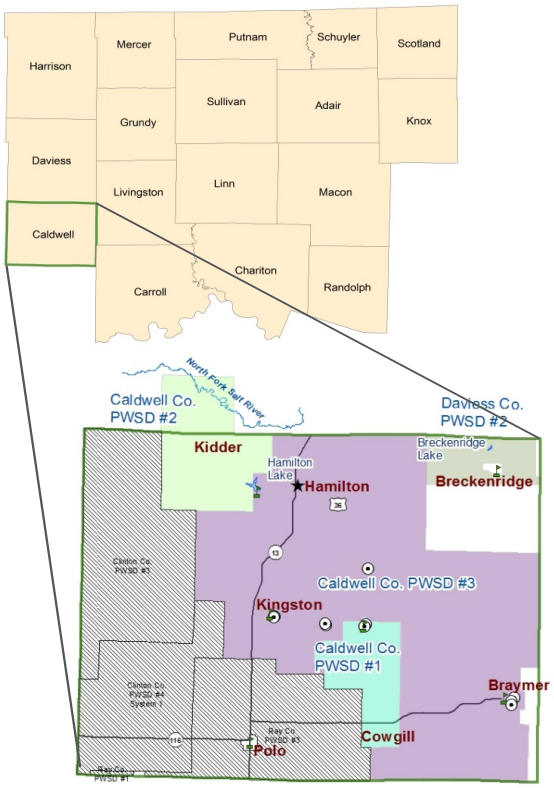
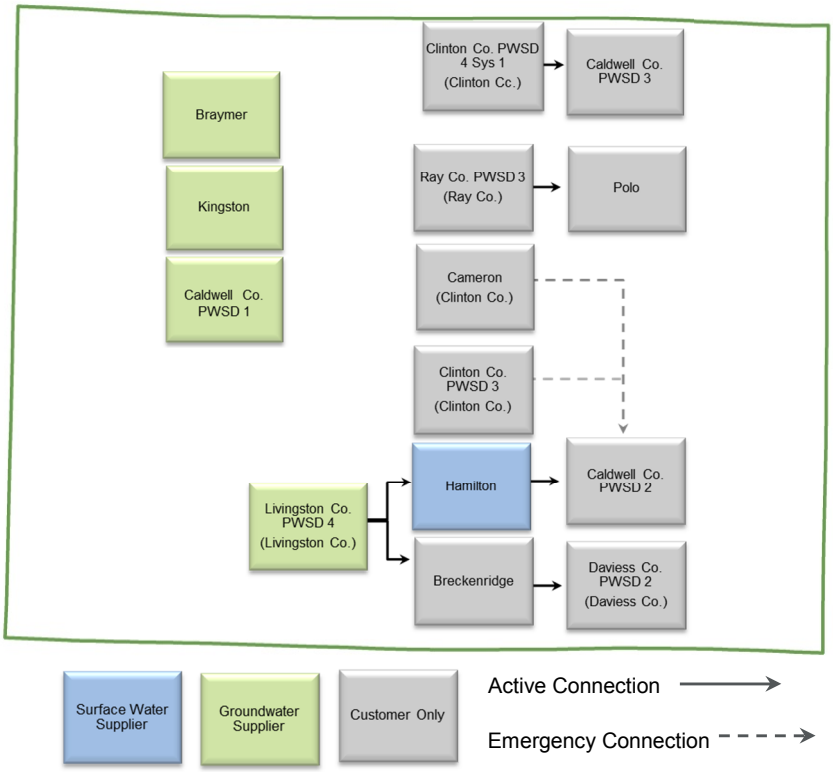




Water Supply Summary: *Caldwell County*

There are eight public water systems that serve a total population of 6,328 within Caldwell County: Caldwell Co. PWSD 1, 2, and 3, the cities of Braymer, Breckenridge, Hamilton, Kingston, and Polo. Of the eight public water systems, one is a surface water supplier (Hamilton) and three are groundwater suppliers. The remaining systems purchase water supply from other sources.

Availability

- Little Otter Creek Reservoir is a proposed 1.2 MGD capacity surface water source to be constructed within the County.
- Hamilton Lake is the primary source for the City of Hamilton with supplemental supply pumped from Marrowbone Creek.
- The City of Braymer, Caldwell Co. PWSD 1, and Kingston utilize shallow gravel walled wells to supply groundwater to their customers.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
**Little Otter Creek	-	Surface Water	1.2	-	-
Hamilton Lake	City of HAMILTON/ MO1010342	Surface Water	0.19	0.576	0.26
Breckenridge Lake	KINGSTON/MO1010426	Surface Water Ground Water	0.52	0.144	0.059
City of Braymer	BRAYMER/MO1010098	Ground Water	0.115	0.144	0.059
Caldwell County PWSD 1	CALDWELL CO PWSD 1 /MO1024078	Ground Water	0.0688	0.038	0.03
City of Kingston	KINGSTON /MO1010426	Ground Water	0.237	0.072	0.033
Totals			2.33	0.974	0.441

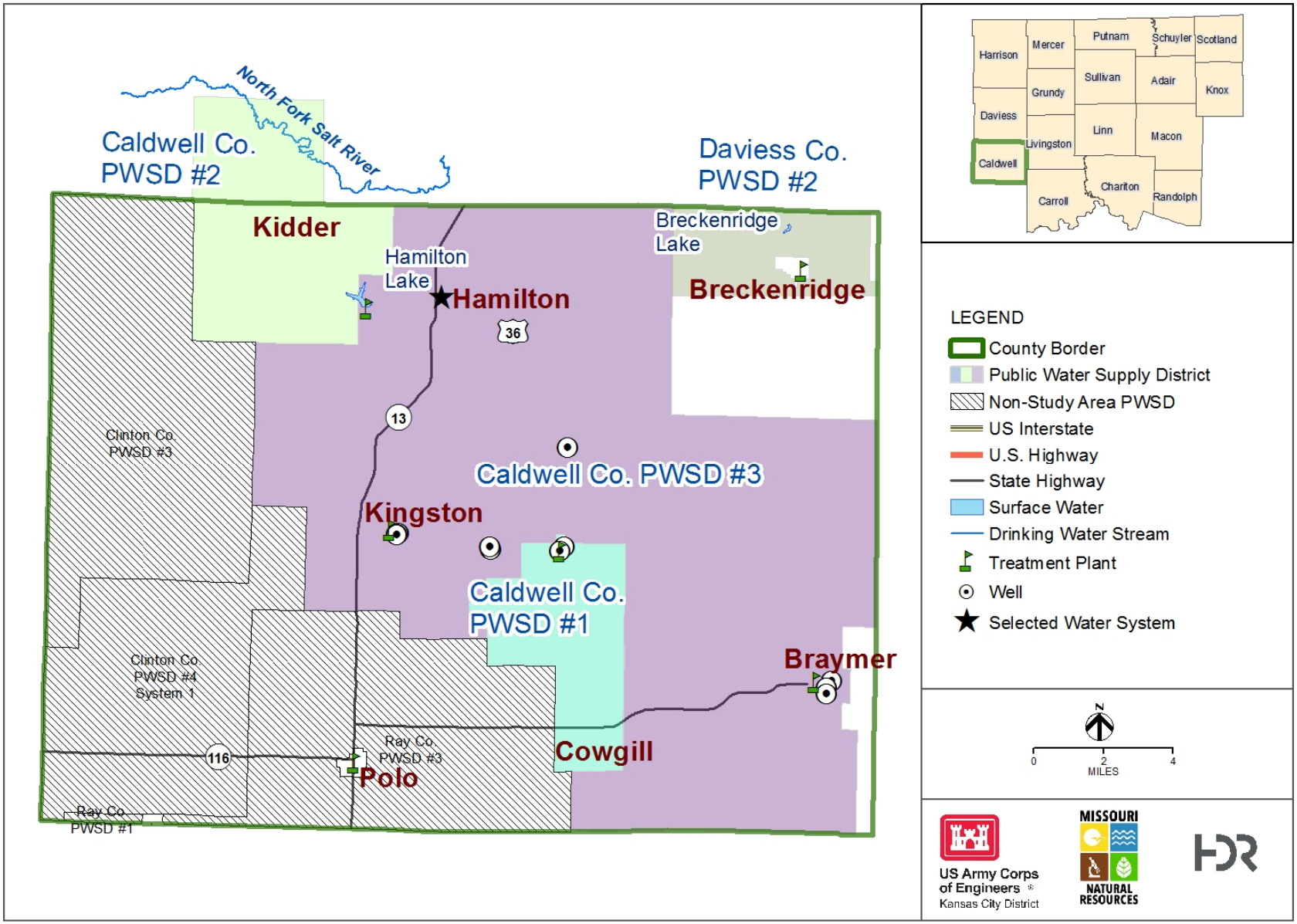
[(1)]MDNR RESOP Analysis 2011
[(2)]MDNR 2015
**Future potential source

Reliability

- Caldwell County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- Little Otter Creek Reservoir is proposed as a future surface water source to supply public water systems within Caldwell County.
- Hamilton Lake may not meet demands during periods of extended drought. Additionally, its water treatment plant has had no major improvements to the plant since 1989; aside from typical plant maintenance such as filter media and pump replacement.
- The City of Braymer and Caldwell Co. PWSD 1 respective groundwater treatment plants may be in need of upgrades or replacement.
- The City of Polo historically relied on groundwater wells to supply its system. However, for unknown reasons the wells have been abandoned. Polo now purchases groundwater via a consecutive connection in Ray County.

Quality

- Hamilton surface water treatment includes filtration, sedimentation, and disinfection. Limited quality in the Reservoir during periods of extended drought can make treatment more difficult.
- Groundwater in the region is hard, and commonly high in iron and manganese. Wells require routine acidification to maintain production capacity.
- Ground water treatment within Caldwell County includes filtration, sedimentation, disinfection and softening.
- Water quality issues include disinfection byproduct (DBP) compliance violations.


North Fork Salt River
Caldwell Co.
PWSD #2
Daviess Co.
PWSD #2
Kidder
Hamilton
Lake
Hamilton
Breckenridge
Lake
Breckenridge
36
13
Clinton Co.
PWSD #3
Caldwell Co. PWSD #3
Kingston
Caldwell Co.
PWSD #1
Braymer
Clinton Co.
PWSD #4
System 1
Ray Co.
PWSD #3
Cowgill
116
Polo
Ray Co.
PWSD #1
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Livingston
Linn
Macon
Caldwell
Carroll
Chariton
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
U.S. Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
Selected Water System
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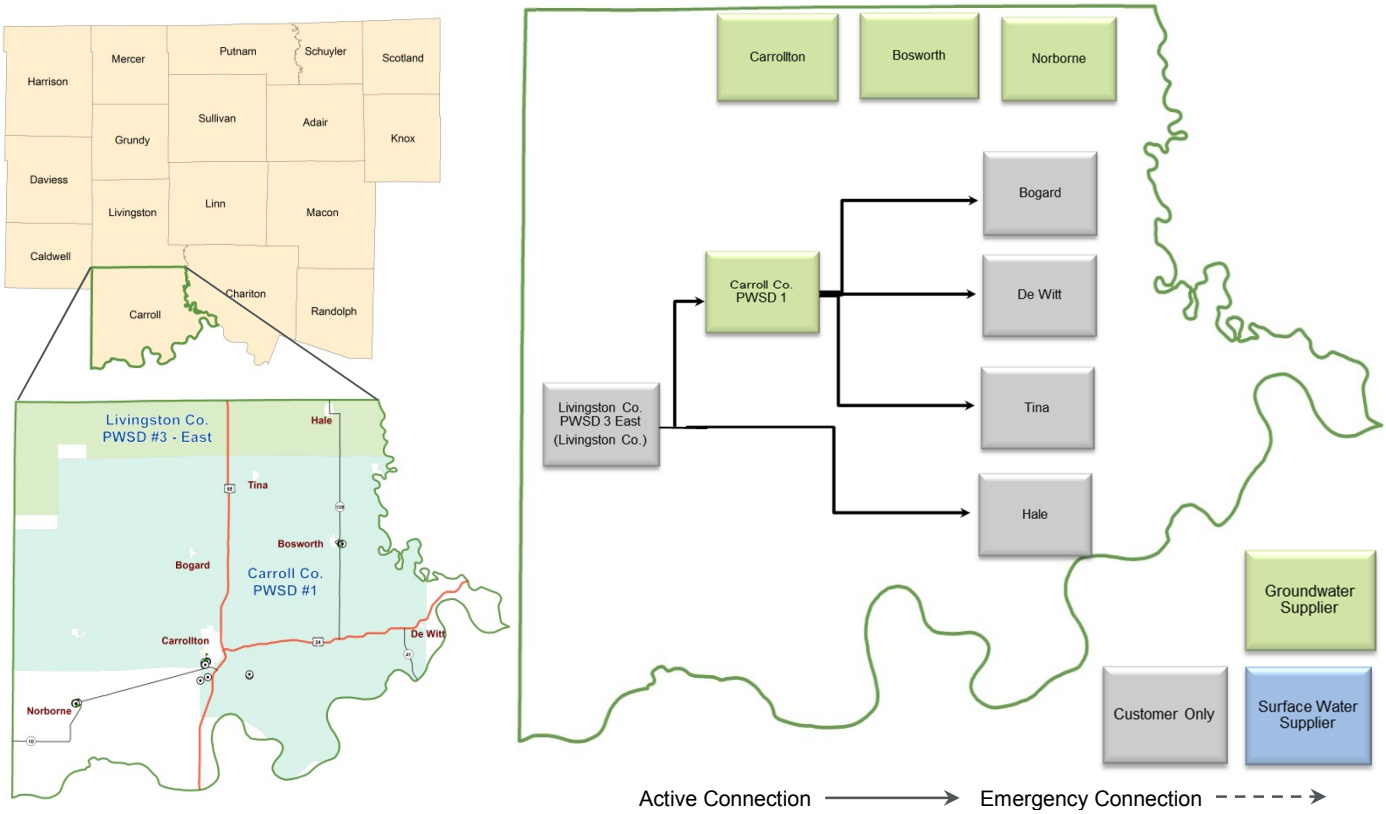
MILES
US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES



Water Supply Summary: *Carroll County*

Within Carroll County there are eight public water systems that serve a total population of 8,312: the cities of Bogard, Bosworth, Carrollton, De Witt, Hale, Norborne, Tina, and Carroll Co. PWSD 1. Of the eight public water systems, there are four groundwater suppliers. Carroll Co. PWSD 1, supplies groundwater to three water systems within the county and supplements its groundwater supply by purchasing groundwater from Livingston Co. PWSD 3. The remaining system purchases its entire supply from Livingston 3.

Availability

- The cities of Carrollton, Bosworth, and Norborne each meet municipality needs with groundwater supply.
- Carroll Co. PWSD 1 supplies groundwater to the cites of Bogard, De Witt, and Tina.
- Carroll County does not have any surface water suppliers or customers.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
City of Bosworth	Bosworth MO2010091	Groundwater	NR	0.086	0.02
Carroll Co PWSD 1	Carroll County PWSD 1 MO2024105	Groundwater	NR	0.73	0.20
City of Carrollton	Carrollton MO2010140	Groundwater	NR	2.40	0.60
City of Norborne	Norborne MO2010578	Groundwater	NR	0.36	0.06
Totals			NR	3.58	0.88

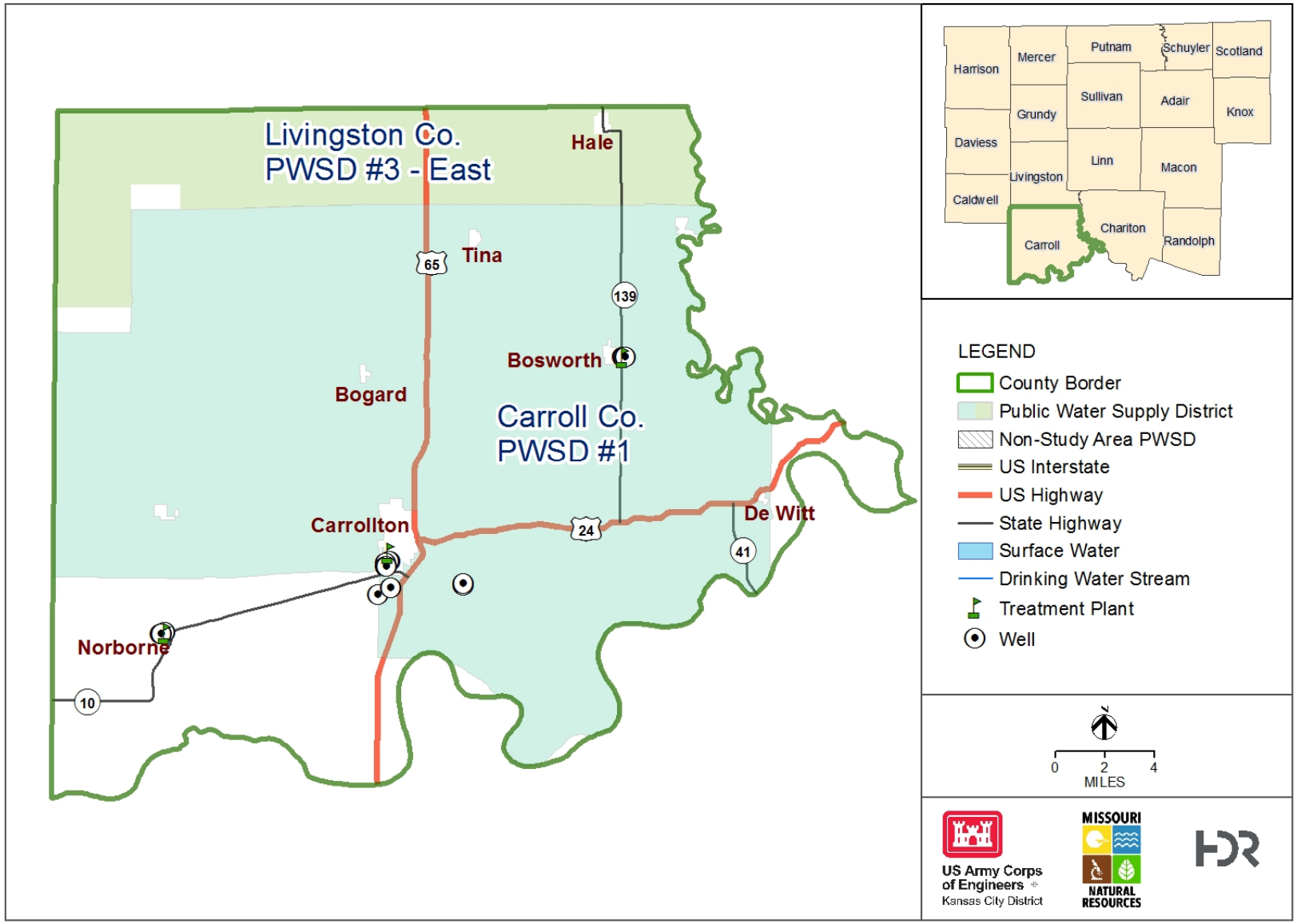
[(1)]MDNR RESOP Analysis 2011
[(2)]MDNR 2015

Reliability

- Carroll County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.

Quality

- Groundwater treatment processes include filtration, sedimentation, disinfection, and water softening.
- Historically, groundwater quality issues include disinfection byproduct (DBP) violations.


Livingston Co.
PWSD #3 - East
Hale
Tina
65
139
Bosworth
Bogard
Carroll Co.
PWSD #1
Carrollton
24
De Witt
41
Norborne
10
Harrison
Mercer
Putnam
Schuyler
Scotland
Sullivan
Adair
Grundy
Knox
Daviess
Livingston
Linn
Macon
Caldwell
Carroll
Chariton
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
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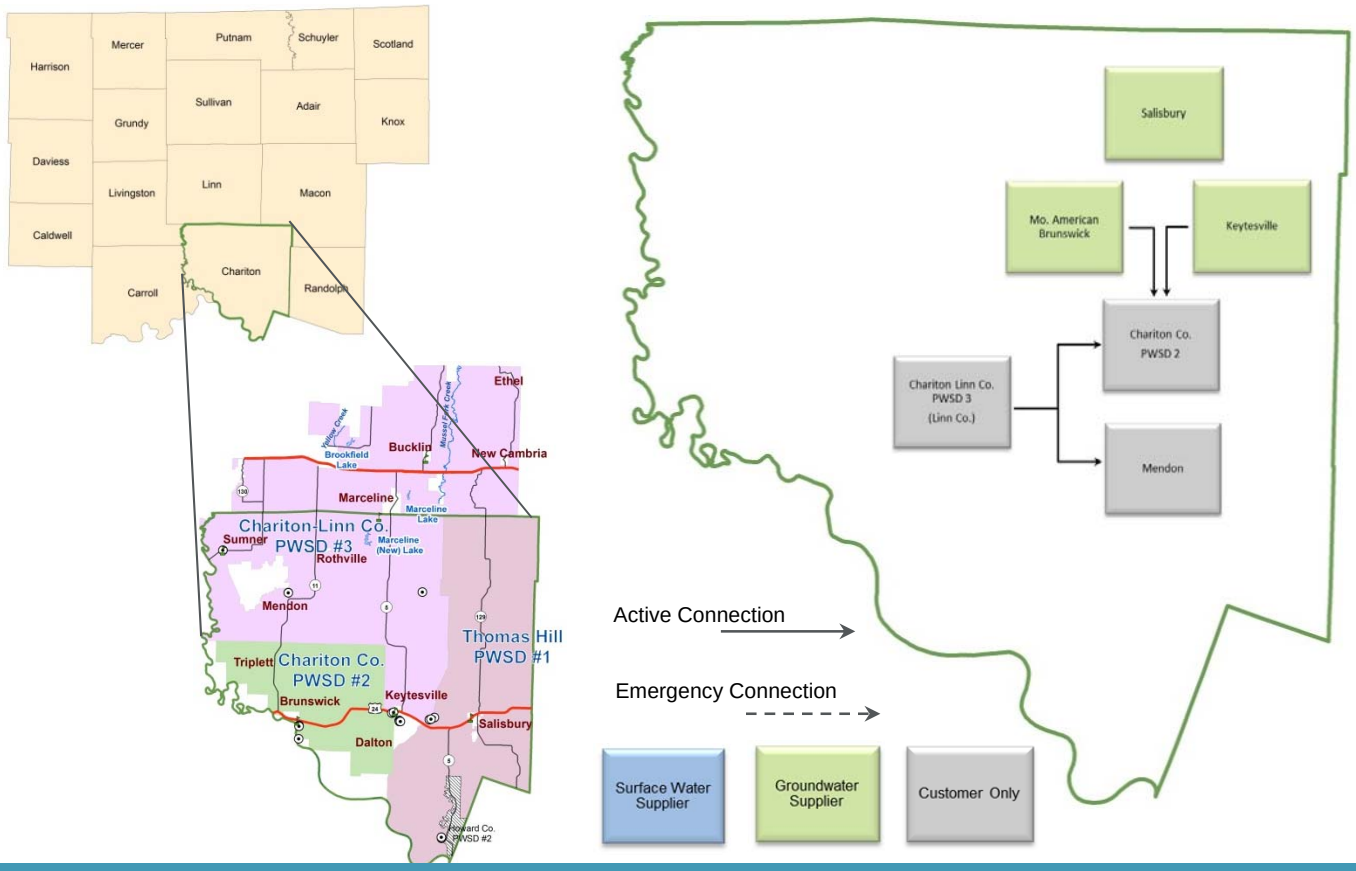
2
4
MILES
US Army Corps of Engineers
Kansas City District
MISSOURI
NATURAL RESOURCES



Water Supply Summary: *Chariton County*

Within Chariton County there are five water systems serving a total population of 4,213: the cities of Keytesville, Mendon, and Salisbury, and Chariton Co. PWSD 2, and a private system, Mo American Brunswick. Of the five public water systems, three are groundwater suppliers and the remaining two purchase surface water. One system, Chariton Co. PWSD 2, which purchases surface water from the City of Keytesville, supplements this supply by purchasing surface water from a system in Linn County.

Availability

- The cities of Keytesville, Salisbury and Missouri American Brunswick in Chariton County have groundwater sources.
- Chariton County does not have any surface water sources that provide drinking water; however, Chariton Co. PWSD 2 and the City of Mendon purchase surface water from Chariton Linn Co. PWSD 3 in Linn County.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[1]**	**Treatment Capacity (MGD)[2]**	**Average Daily Use (MGD)[2]**
City of Keytesville	Keytesville/MO2010420	Groundwater	0.17	0.17	0.05
City of Brunswick	MO American Brunswick / MO2010109	Groundwater	0.4	0.4	0.84
City of Salisbury	Salisbury/MO2010722	Groundwater	0.5	0.5	0.20
Totals			1.07	1.07	1.09

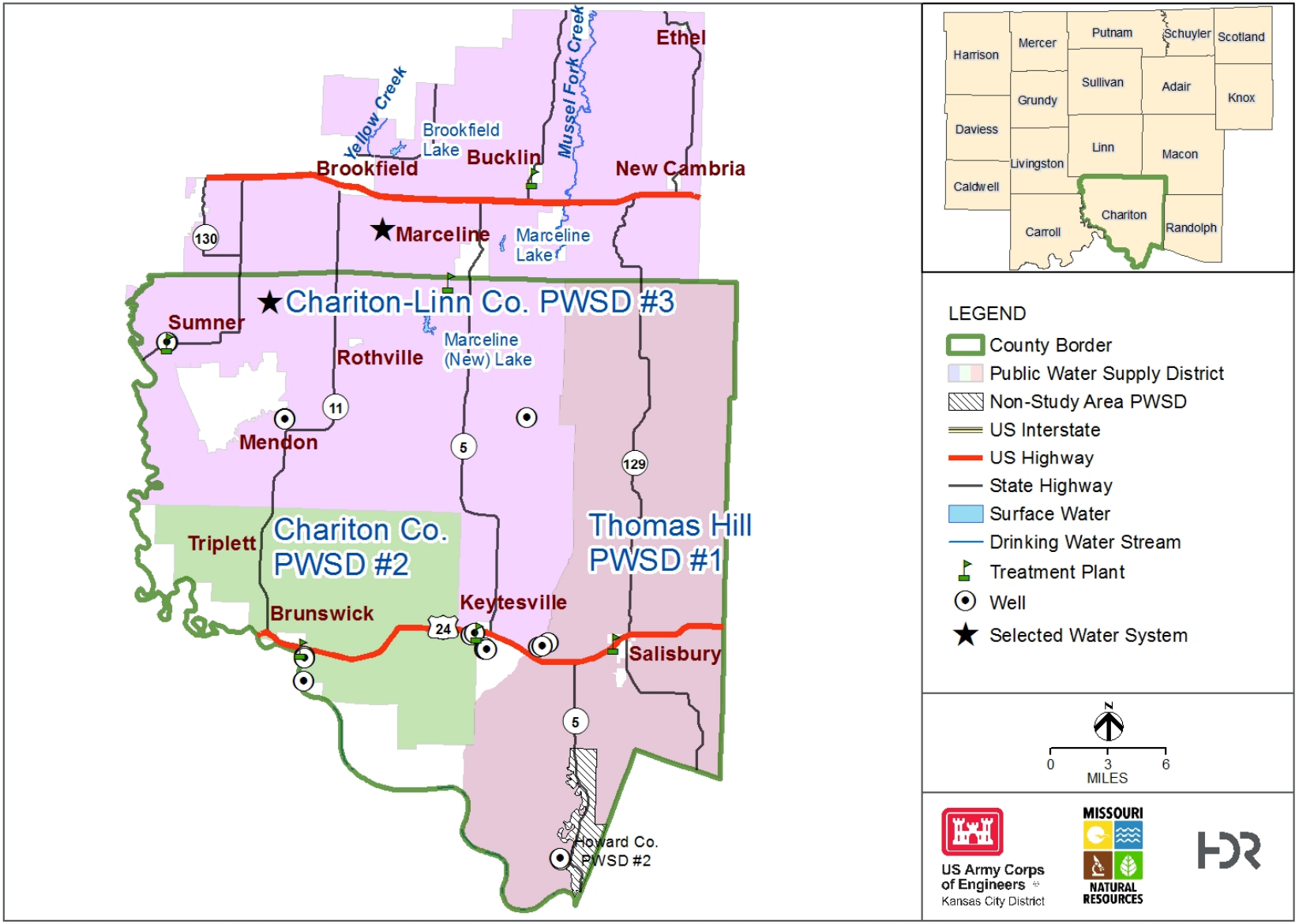
[1]MDNR RESOP Analysis 2011
[2]MDNR 2015

Reliability

- Chariton County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- According to MDNR Drinking Water Watch Database, Mo. American Brunswick has treatment plant capacity that can accommodate only half of the average daily flow.
- Chariton Co. and Mendon receive surface water from a consecutive connection with Chariton Linn Co. PWSD 3. Chariton Linn purchases surface water from Brookfield and Marceline. Both cities' reservoirs were greatly impacted by the dry year in 2012.

Quality

- Groundwater treatment processes include filtration, sedimentation, disinfection, and softening.
- Groundwater quality issues include disinfection byproduct (DBP) compliance violations.


Ethel
Yellow Creek
Brookfield Lake
Mussel Fork Creek
Brookfield
Bucklin
New Cambria
130
Marceline
Marceline Lake
Chariton-Linn Co. PWSD #3
Sumner
Rothville
Marceline (New) Lake
11
Mendon
5
129
Triplett
Chariton Co. PWSD #2
Thomas Hill PWSD #1
Brunswick
Keytesville
24
Salisbury
5
Howard Co. PWSD #2
Harrison
Mercer
Putnam
Schuyler
Scotland
Sullivan
Adair
Knox
Grundy
Daviess
Linn
Macon
Livingston
Caldwell
Chariton
Carroll
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
Selected Water System
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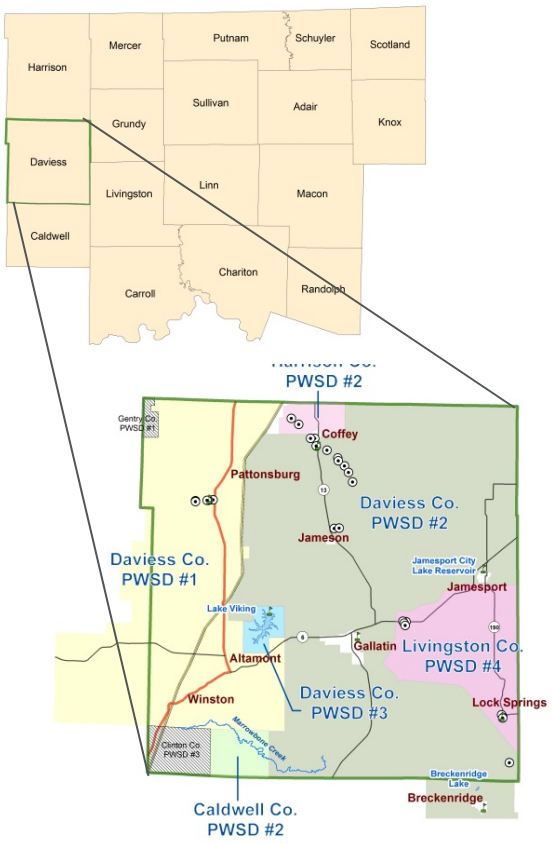
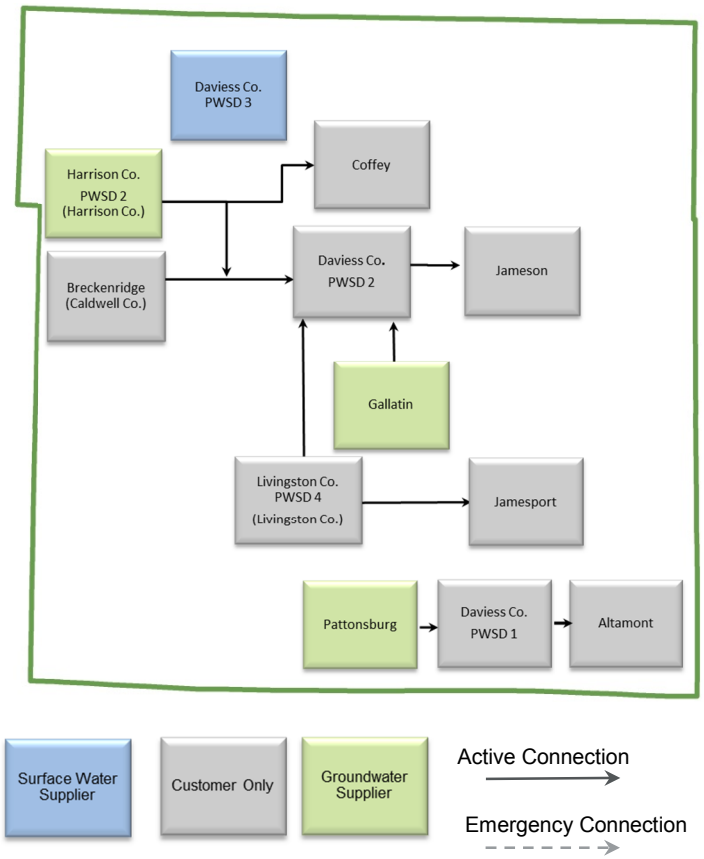
MILES
US Army Corps of Engineers
Kansas City District
MISSOURI
NATURAL RESOURCES





Water Supply Summary: *Daviess County*

There are nine public water systems serving a total population of 8,218: Daviess Co. PWSD 1, 2 and 3 and the cities of Altamont, Coffey, Gallatin, Jameson, Jamesport, and Pattonsburg. Of the nine public water systems, one is a surface water supplier (Daviess Co. PWSD 3) and two are groundwater suppliers. The remaining six public water supply systems either purchase from these sources or from outside of the County.

Availability

- The Cities of Gallatin and Pattonsburg both are supplied by shallow gravel walled wells. The City of Gallatin currently supplies groundwater to Daviess Co. PWSD 2. Pattonsburg currently supplies groundwater to Daviess Co. PWSD 1
- Lake Viking is a private reservoir supplying a community subdivision system which is operated by Daviess Co. PWSD 3.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[1]**	**Treatment Capacity (MGD)[2]**	**Average Daily Use (MGD)[2]**
City of Gallatin	Gallatin / MO1010299	Groundwater	NR	0.72	0.38
Daviess County PWSD 3-Lake Viking	Daviess County PWSD #3 / MO1036130	Surface Water	2.46	0.20	0.05
City of Pattonsburg	Pattonsburg / MO1010632	Groundwater	1.01	0.43	0.25
Totals			3.47	1.35	0.68

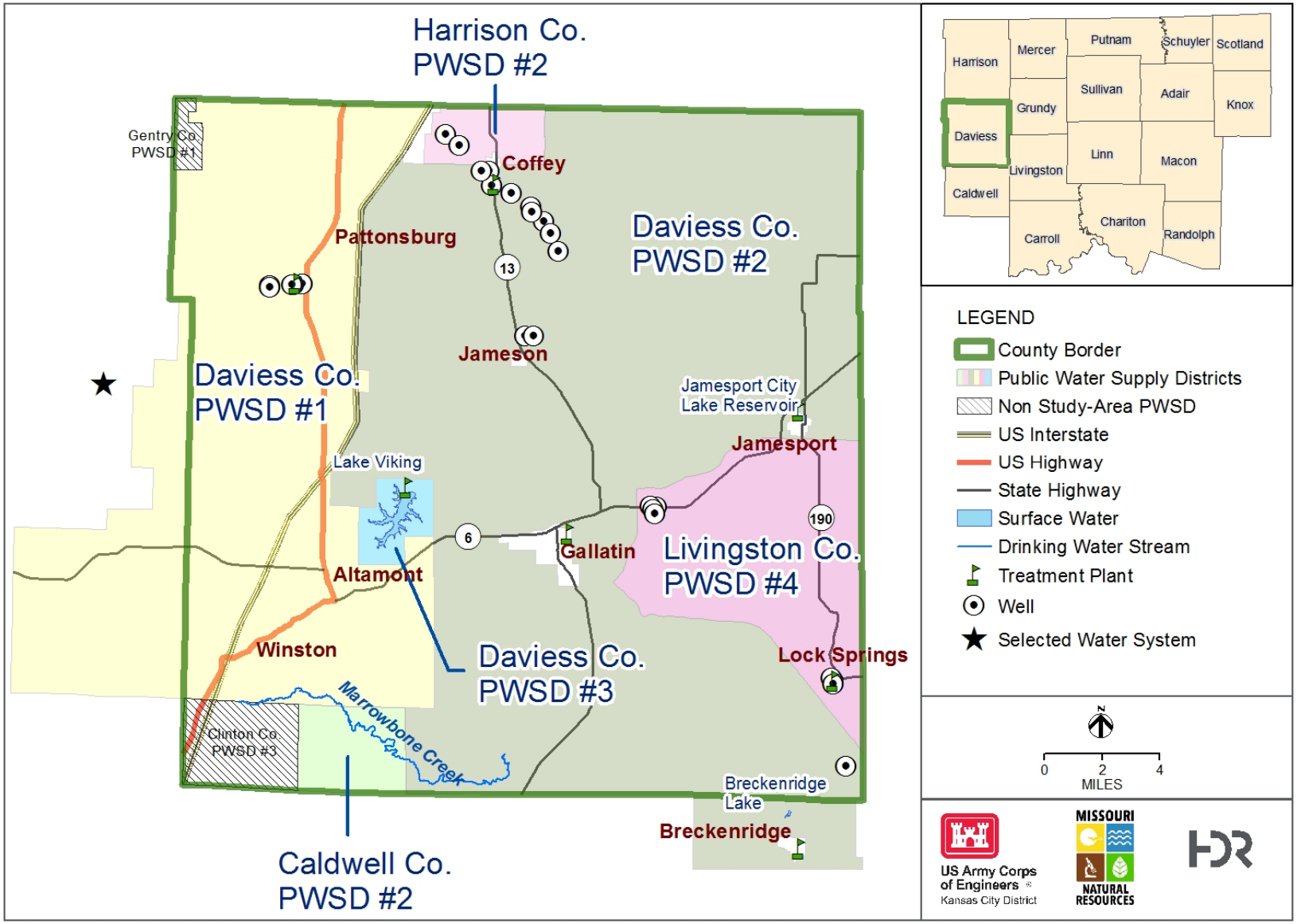
[1]MDNR RESOP Analysis 2011
[2]MDNR 2015

Reliability

- Daviess County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- According to MDNR, the Gallatin treatment plant may require improvements to meet current demand.
- Historically, the City of Pattonsburg has had to abandon wells due to low production.
- The only surface water source in Daviess is a privately owned reservoir. According to the RESOP Analysis, Lake Viking has optimum yield of 2.46 MGD, of which only 0.05 MGD is required to serve the community subdivision.

Quality

- Ground water treatment within Caldwell County includes filtration, sedimentation, disinfection and softening.
- Water quality issues include disinfection byproduct (DBP) violations.


Harrison Co.
PWSD #2
Gentry Co.
PWSD #1
Coffey
Pattonsburg
Daviess Co.
PWSD #2
13
Jameson
Daviess Co.
PWSD #1
Jamesport City
Lake Reservoir
Jamesport
Lake Viking
190
6
Gallatin
Livingston Co.
PWSD #4
Altamont
Winston
Daviess Co.
PWSD #3
Lock Springs
Marrowbone Creek
Clinton Co.
PWSD #3
Breckenridge
Lake
Breckenridge
Caldwell Co.
PWSD #2
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Livingston
Linn
Macon
Caldwell
Carroll
Chariton
Randolph
LEGEND
County Border
Public Water Supply Districts
Non Study-Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
Selected Water System
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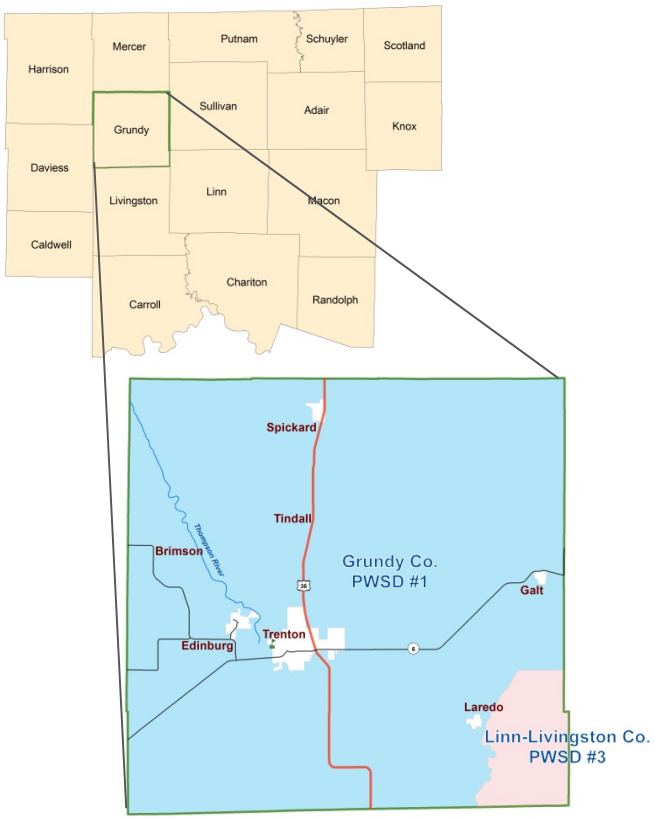
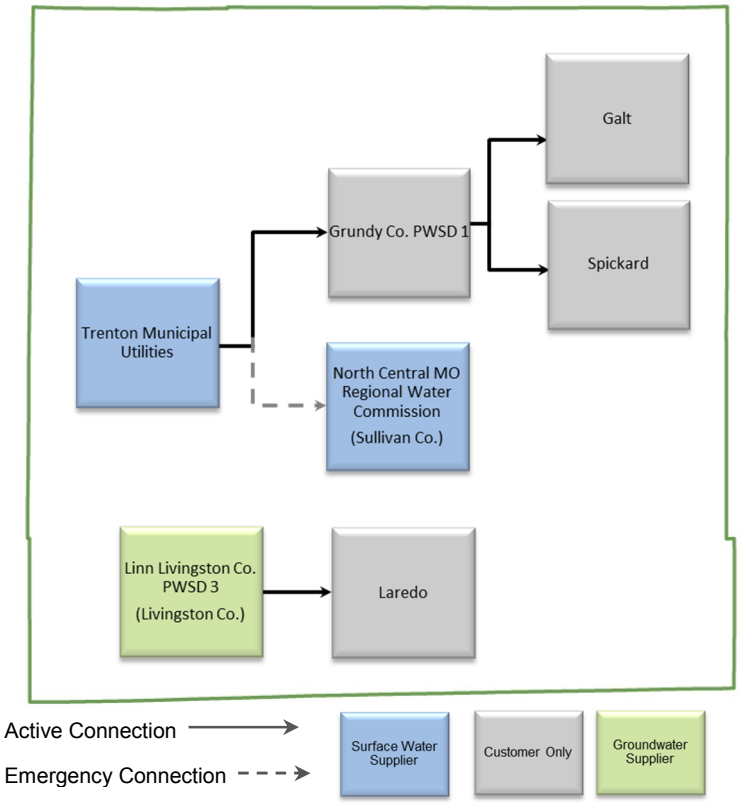
MILES
US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES





Water Supply Summary: *Grundy County*

There are five public water systems that serve a total population of 10,519: Grundy Co. PWSD 1, and the cities of Trenton, Galt, Laredo, and Spickard. Of the five public water systems, one is a surface water supplier (Trenton) and the remaining four are purchasers of either surface water or groundwater. One system, Laredo, purchases groundwater from a system outside of Grundy County.

Availability

- Trenton Municipal Utilities (TMU) utilizes two raw water storage reservoirs filled by the Thompson River.
- TMU supplies finished surface water to its municipal customers and to Grundy Co. PWSD 1.
- Grundy County does not have any groundwater sources that provide drinking water.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Firm Yield (MGD)**	**Treatment Capacity (MGD)[(1)]**	**Average Daily Use (MGD)[(1)]**
City of Trenton-Thompson Stream	Trenton Municipal Utilities / MO2010796	Surface Water	Variable*	4.5	1.74

[(1)] MDNR 2015

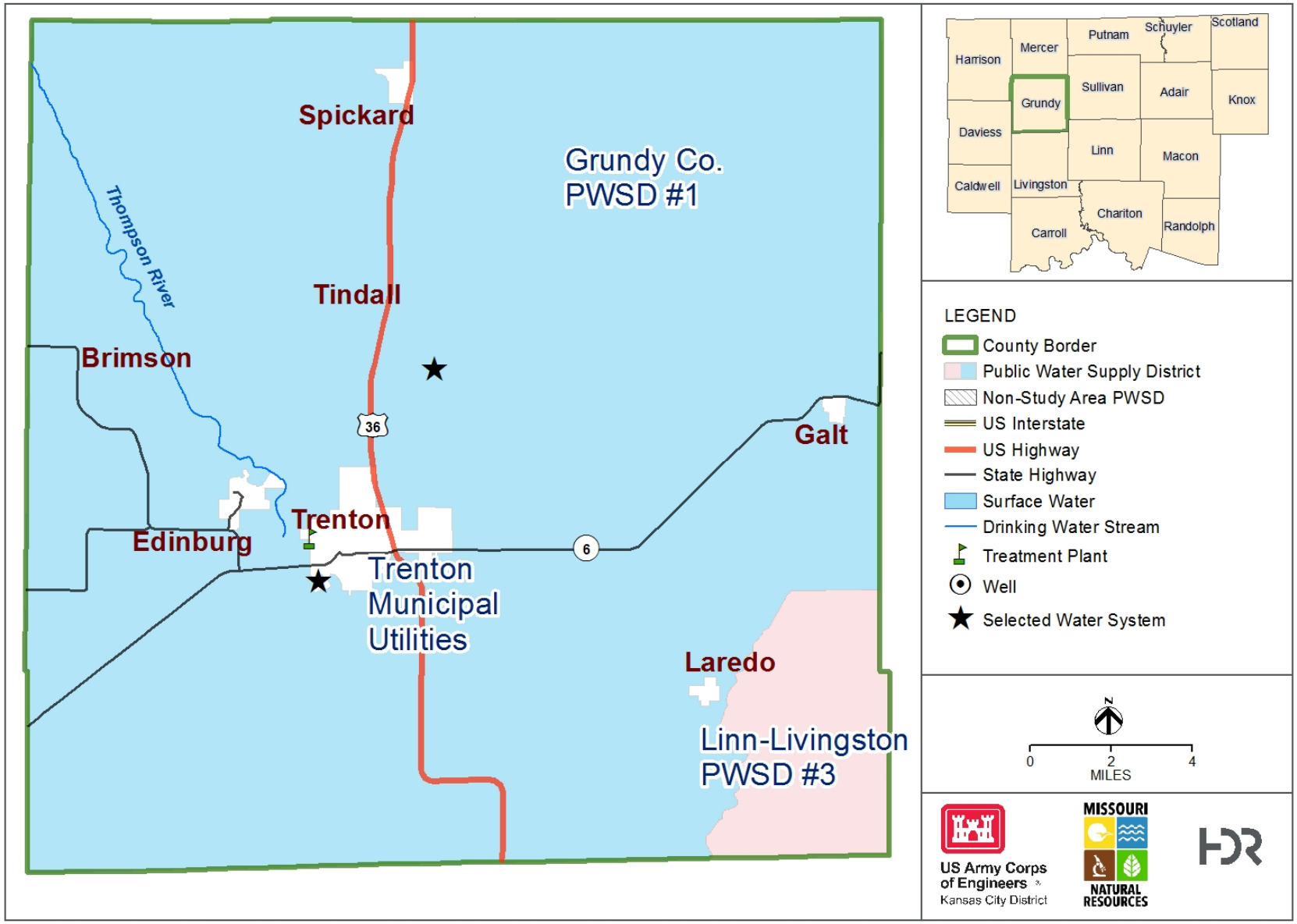
* According to 2011 WSS, the Thompson River discharge should exceed 9 cfs (5.81 MGD) prior to diverting water.

Reliability

- Grundy County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- During the drought of record there were periods that flow in the Thompson River was not adequate to meet demand; however, storage in the reservoirs was sufficient to meet Trenton Municipal Utilities' demands during these periods.

Quality

- Surface water treatment process includes filtration, sedimentation, disinfection, pH adjustment and softening.
- Historical water quality issues within the County include disinfection byproduct DBP compliance violations.


Spickard
Grundy Co.
PWSD #1
Thompson River
Tindall
Brimson
36
Galt
Trenton
Edinburg
6
Trenton
Municipal
Utilities
Laredo
Linn-Livingston
PWSD #3
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Carroll
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
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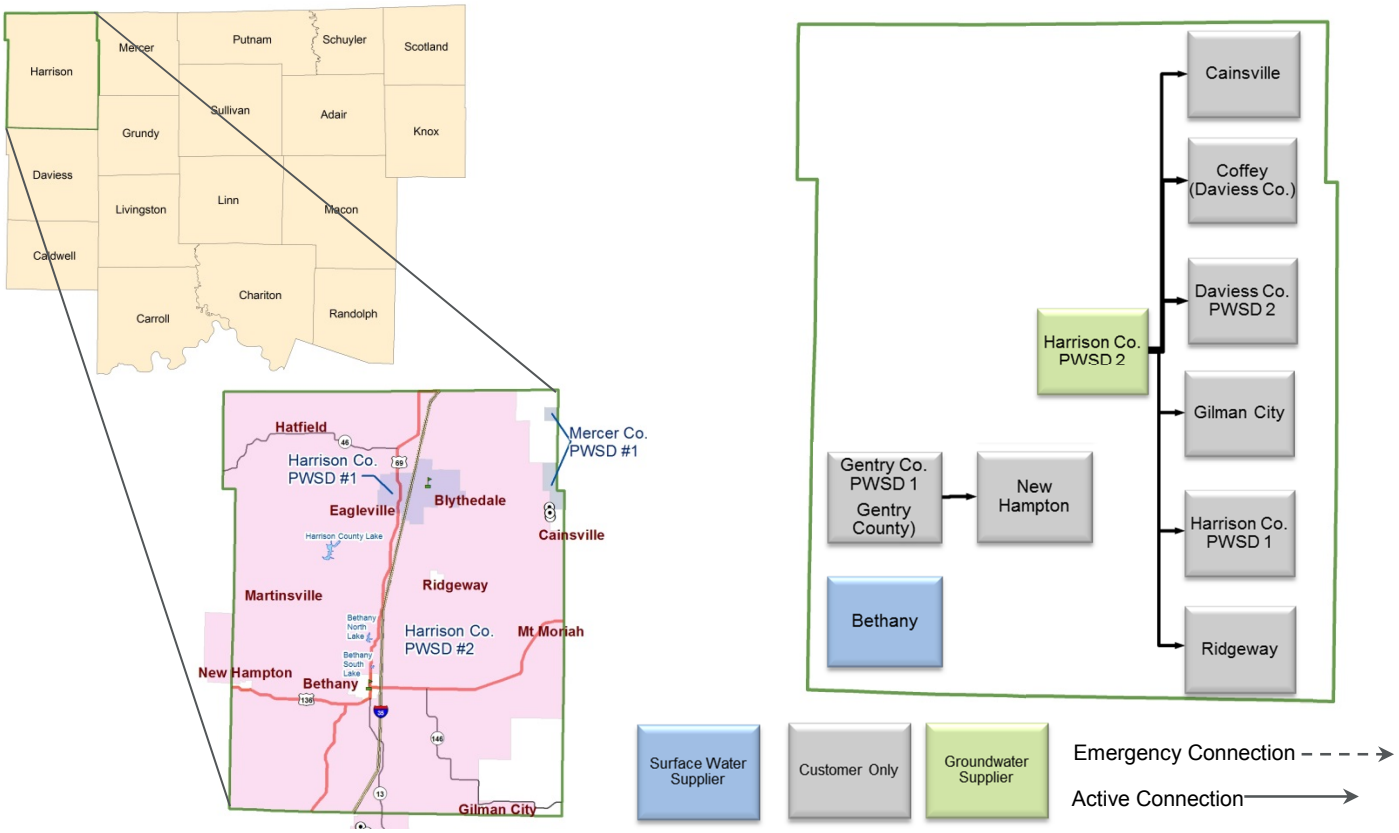
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES



Water Supply Summary: *Harrison County*

Within Harrison County there are seven public water systems serving a total population of 8,220: Harrison Co. PWSD 1, 2 and the cities of Bethany, Cainsville, Gilman City, New Hampton, and Ridgeway. Of the seven public water systems, one is a surface water supplier (Bethany), one is a groundwater supplier (Harrison 2), and the remaining five purchase groundwater.

Availability

- Bethany supplies surface water from three reservoirs: Harrison County Lake, Bethany North Lake, and Bethany South Lake.
- Harrison Co. PWSD 2 supplies groundwater to six systems: Cainsville, Ridgeway, Gilman City, Harrison Co. PWSD 1, Coffey (Daviess County), and Daviess Co. PWSD 2

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
City of Bethany Harrison County Lake and Bethany Lakes	Bethany / MO1010068	Surface Water	0.816	1.44	0.365
Harrison County PWSD 2	Harrison County PWSD 2 / MO1024242	Groundwater	NR	0.40	0.45
Totals			0.816	1.84	0.815

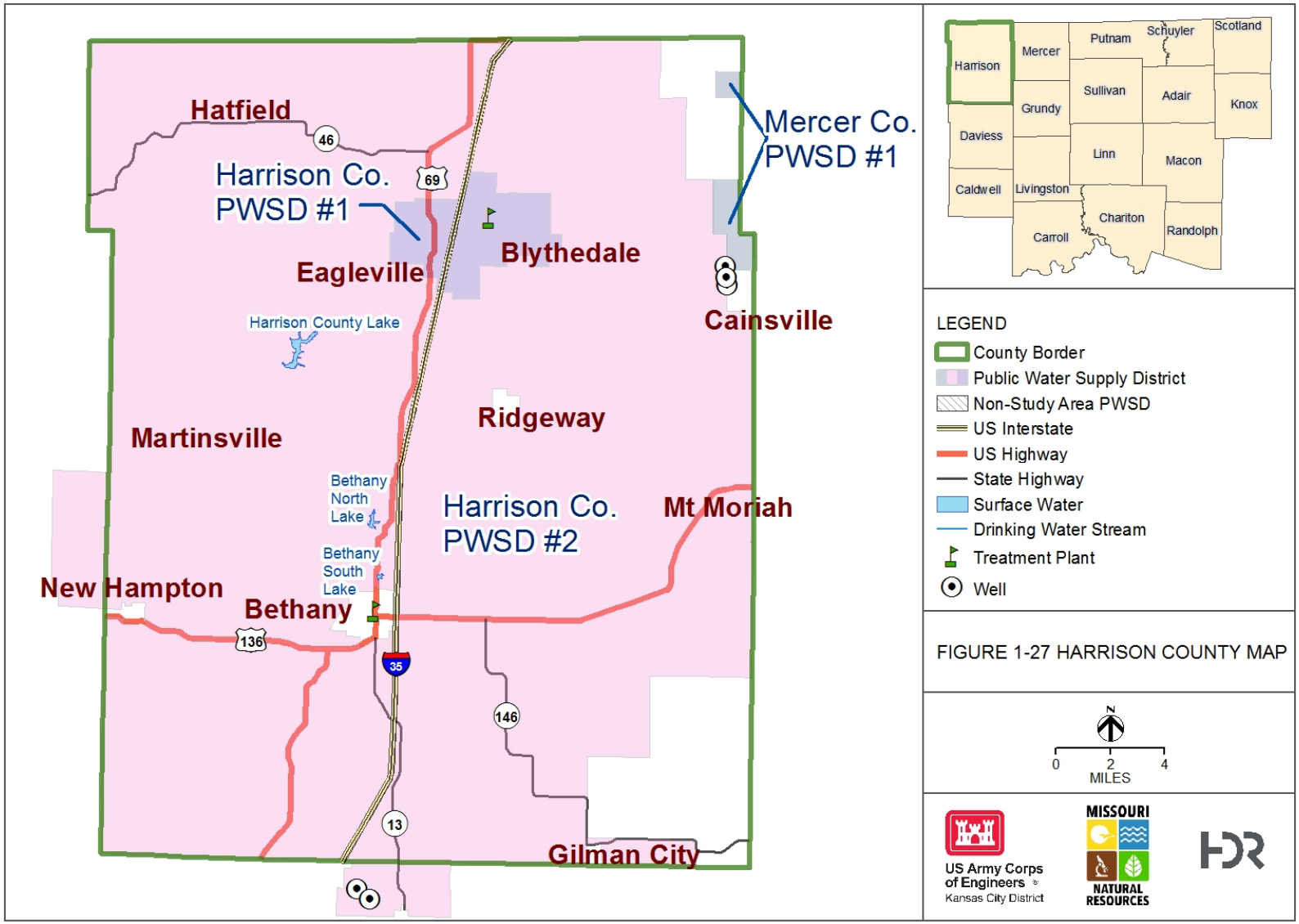
[(1)]MDNR RESOP Analysis 2011
[(2)]MDNR 2015

Reliability

- Harrison County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- The MDNR RESOP Analysis concluded that West Big Fork Lake meets current demands during the drought of record.
- The Harrison Co. PWSD 2 groundwater levels have steadily decreased since construction and there are concerns with low aquifer levels. MDNR considers the wells and treatment plant insufficient for the District to expand supply as a regional water supplier.

Quality

- Surface water treatment process includes filtration, sedimentation, pH adjustment, and disinfection.
- Groundwater in the region is commonly high in iron and manganese. Wells require routine acidification to maintain production capacity.
- Ground water treatment processes include filtration, sedimentation, and disinfection.
- Historical water quality issues within the County include disinfection byproduct DBP compliance violations.


Hatfield
46
Harrison Co.
PWSD #1
69
Eagleville
Blythedale
Mercer Co.
PWSD #1
Cainsville
Harrison County Lake
Martinsville
Ridgeway
Bethany
North
Lake
Harrison Co.
PWSD #2
Mt Moriah
Bethany
South
Lake
New Hampton
Bethany
136
35
146
13
Gilman City
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Randolph
Carroll
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
FIGURE 1-27 HARRISON COUNTY MAP
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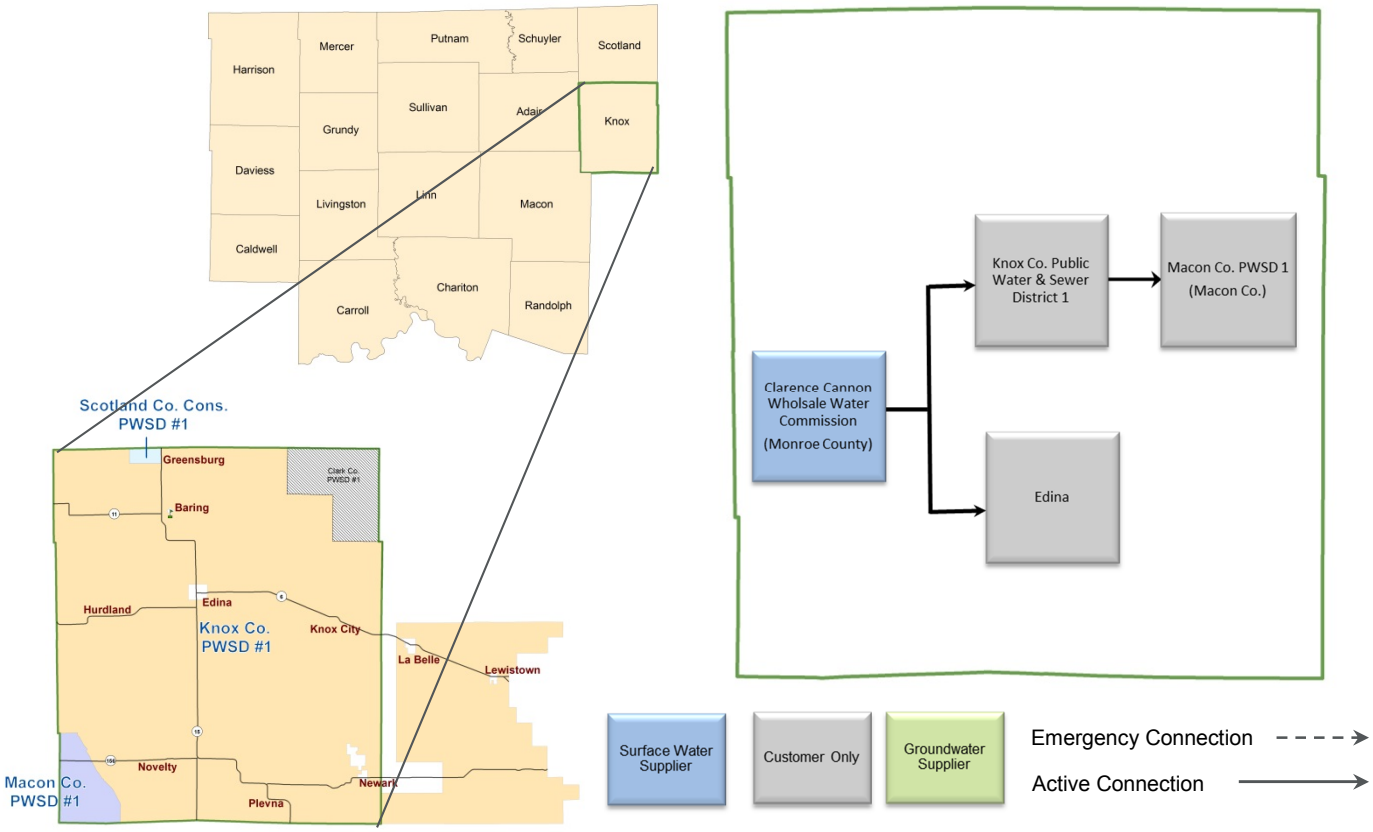
MILES
US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES



Water Supply Summary: *Knox County*

Within Knox County there are two public water systems serving a total population of 5,451: Knox Co. PWSD 1 and the City of Edina. Neither of the water systems in Knox County have water sources. Both systems purchase finished surface water from Mark Twain Lake by the Clarence Cannon Wholesale Water Company.

Availability

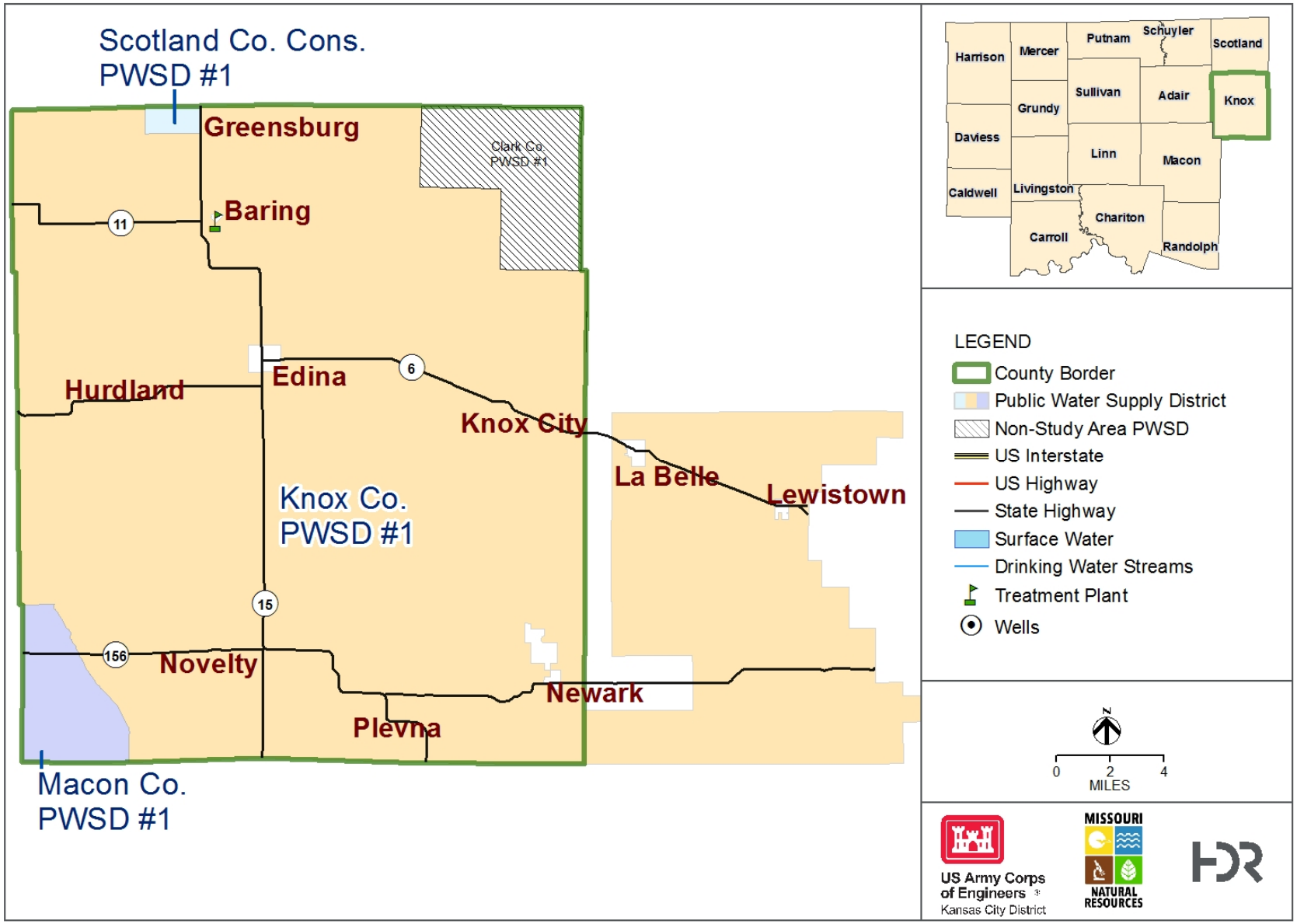
- Knox County does not have any groundwater sources or systems that purchase groundwater.
- Knox County does not have any surface water sources that provide drinking water. Clarence Cannon Wholesale Water Commission (CCWWC) currently supplies both Knox 1 and Edina with finished surface water from Mark Twain Lake.

Reliability

- The reliability of CCWWC in Monroe County was not part of this Study.

Quality

- The water quality of CCWWC in Monroe County was not part of this Study.


Scotland Co. Cons.
PWSD #1
Greensburg
Clark Co.
PWSD #1
Baring
11
Hurdland
Edina
6
Knox City
La Belle
Lewistown
Knox Co.
PWSD #1
15
156
Novelty
Newark
Plevna
Macon Co.
PWSD #1
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Carroll
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Streams
Treatment Plant
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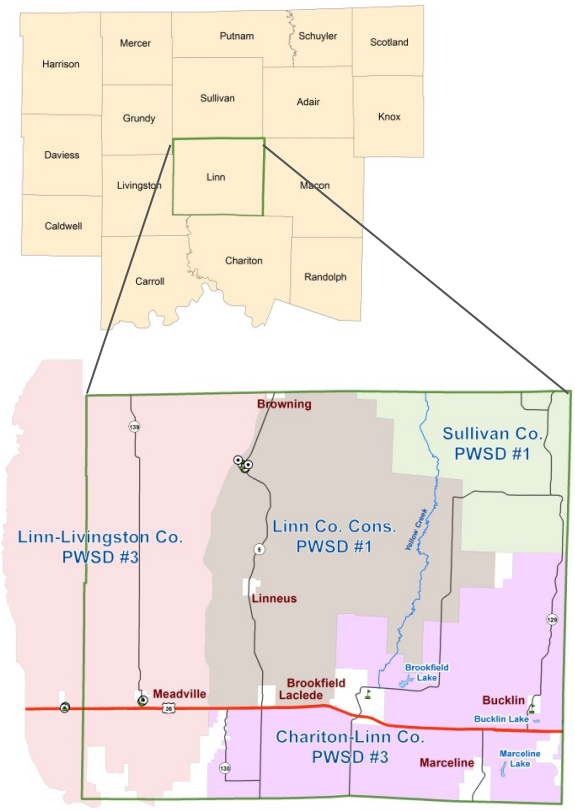
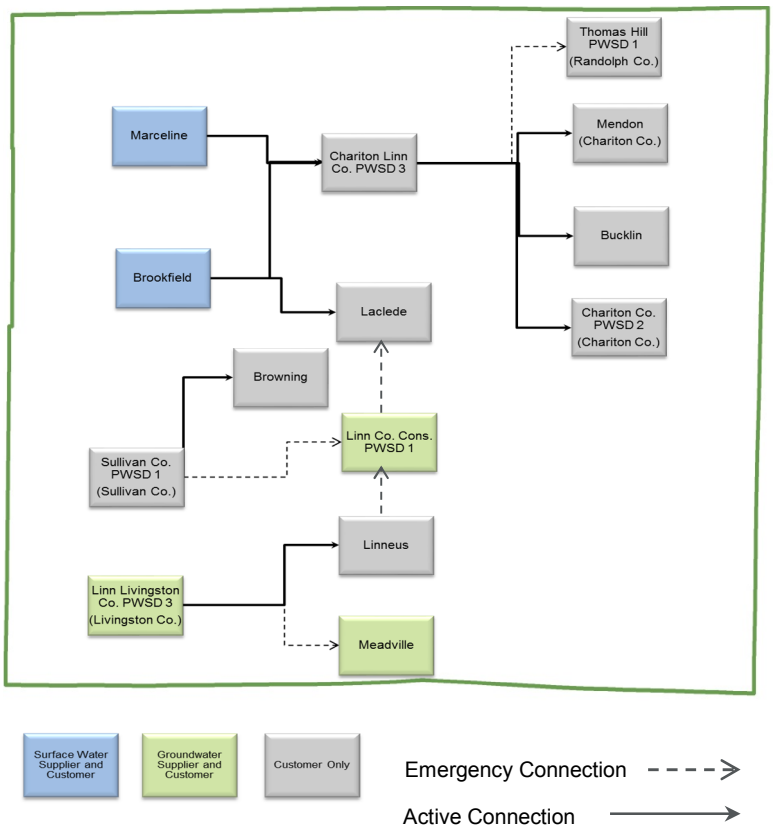
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES





Water Supply Summary: *Linn County*

Within Linn County there are nine public water systems serving a total population of 16,380: Chariton Linn Co. PWSD 3, Linn Co. PWSD 1, and the cities of Brookfield, Browning, Bucklin, Laclede, Linneus, Marceline, and Meadville. Of the nine public water systems, two are surface water suppliers (Marceline and Brookfield) and two are groundwater suppliers (Meadville and Linn Cons. 1). Three of the systems purchase finished surface water either from a Linn County surface water supplier or through a consecutive connection of the supplier. The remaining two systems purchase groundwater from outside of Linn County.

Availability

- The City of Meadville and Linn Co. Cons PWSD 1 have groundwater suppliers.
- Brookfield supplies surface water from Brookfield Lake.
- Marceline supplies surface water from Marceline Reservoirs Old and New.
- Brookfield and Marceline provide finished surface water for their respective municipalities and also to Chariton-Linn PWSD 3. Brookfield also supplies the Laclede system.
- The City of Bucklin uses Bucklin Lake as an emergency surface water supply.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
City of Brookfield-City Lake and stream	Brookfield / MO2010105	Surface Water	0.207*	1.25	0.671
City of Marceline-City Lakes	Marceline / MO2010497	Surface Water	0.472	2.16	0.448
Linn County Cons PWSD 1	Linn County Cons PWSD 1 / MO2024346	Groundwater	-	0.12	0.09
Meadville	Meadville / MO2010512	Groundwater	-	0.07	0.03
Totals			0.679	2.56	1.24

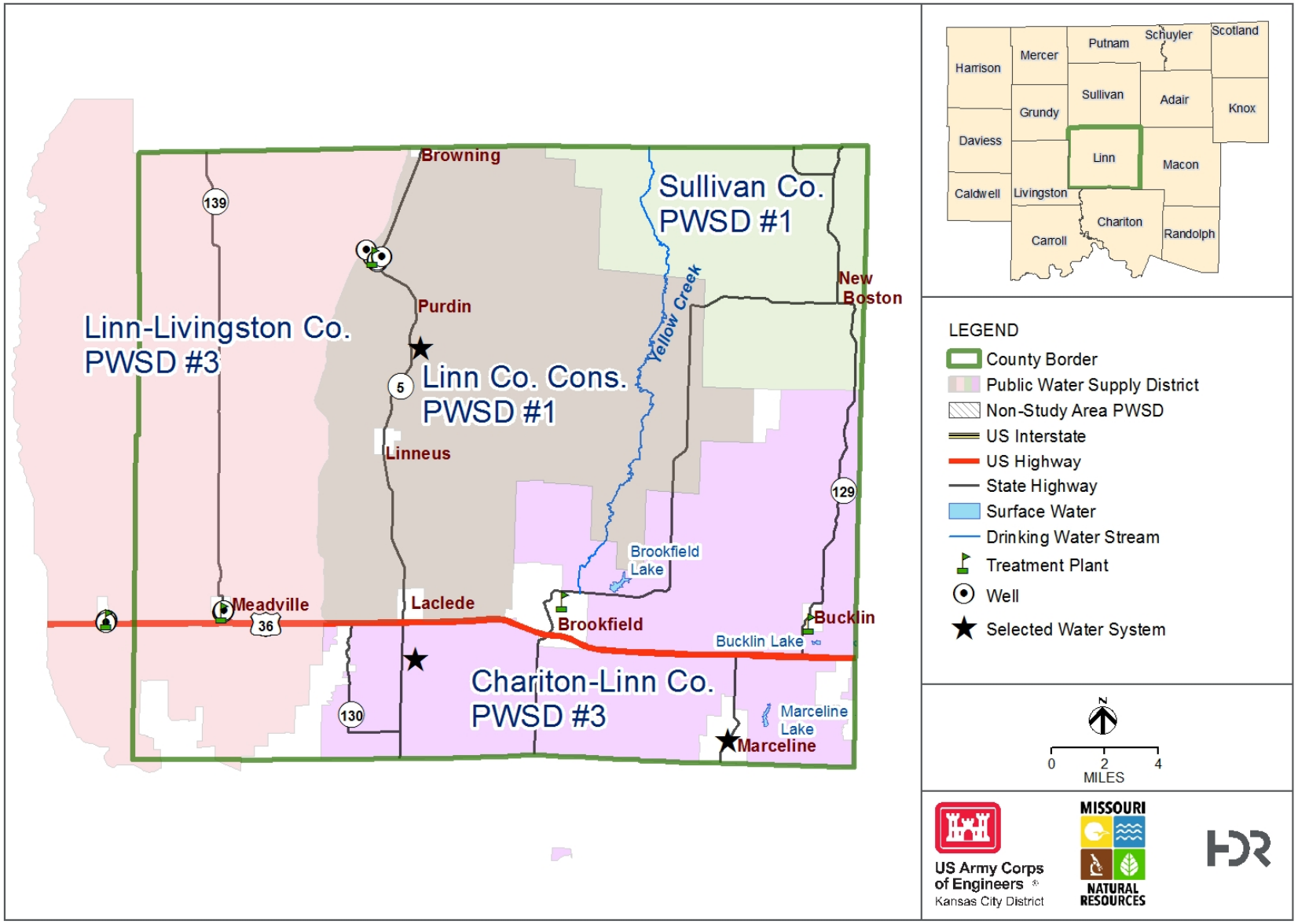
[(1)]MDNR RESOP Analysis 2011
[(2)]MDNR 2015
*Lake only

Reliability

- Linn County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- At times Brookfield Lake alone is not able to meet the community's demand; supplemental supply must be pumped from the West Yellow Creek.
- According to the MDNR RESOP Analysis New Marceline Reservoir is capable of meeting Marceline's water demand; however, the reservoir would be at risk of not meeting the demand during an extended drought event.
- Marceline utilizes Mussel Fork Creek for supplemental supply; in 2012 the Creek was pumped dry.
- The emergency source of Bucklin Lake is not capable of meeting the Bucklin's water supply demands.

Quality

- The surface water treatment processes for Linn County include filtration, sedimentation, disinfection, softening and pH adjustment.
- The groundwater treatment processes for Linn County includes aeration, sedimentation, disinfection, softening and pH adjustment.
- Historical water quality issues within the County include disinfection byproduct DBP compliance violations.
- Groundwater suppliers have historically reported water quality violations for Total Coliform.


Browning
Sullivan Co.
PWSD #1
New
Boston
Purdin
Linn-Livingston Co.
PWSD #3
Linn Co. Cons.
PWSD #1
Yellow Creek
Linneus
139
5
129
Brookfield
Lake
Meadville
36
Laclede
Brookfield
Bucklin
Bucklin Lake
Chariton-Linn Co.
PWSD #3
130
Marceline
Lake
Marceline
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Randolph
Carroll
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
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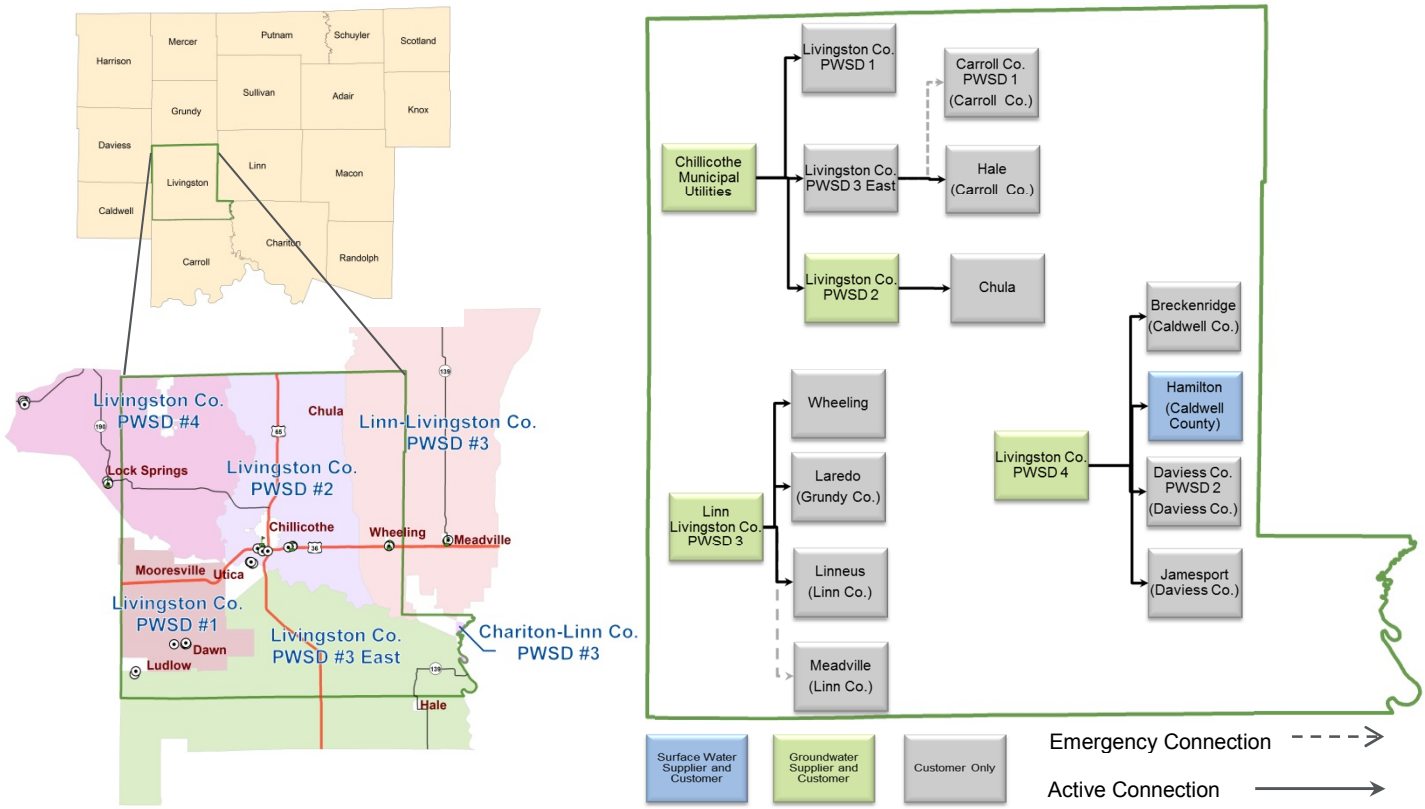
MILES
US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES



Water Supply Summary: *Livingston County*

Within Livingston County there are eight public water systems serving a total population of 18,274: Chillicothe Municipal Utilities, Linn Livingston Co. PWSD 3, Livingston Co. PWSD 1, 2, 3 East, 4 and the cities of Chula and Wheeling. Of the eight public water systems, four are groundwater suppliers and the remaining four purchase drinking water from these suppliers.

Availability

- Four systems supply groundwater: Chillicothe Municipal Utilities, Livingston Co. PWSD 2, Livingston Co. PWSD 4, and Linn Livingston Co. PWSD 3.

Water Statistics

Location Name	Source Name and ID	Supply Type	Optimum Yield (MGD)[1]	Treatment Capacity (MGD)[2]	Average Daily Use (MGD)[2]
City of Chillicothe	Chillicothe Municipal Utilities MO2010162	Groundwater	NR	4.5	1.3
-	Linn Livingston County PWSD 3 MO2024350	Groundwater	NR	0.36	0.17
-	Livingston County PWSD 2 MO2024353	Groundwater	NR	0.432	0.10
-	Livingston County PWSD 4 MO2024355	Groundwater	NR	0.288	0.11
Totals			NR	5.58	1.68

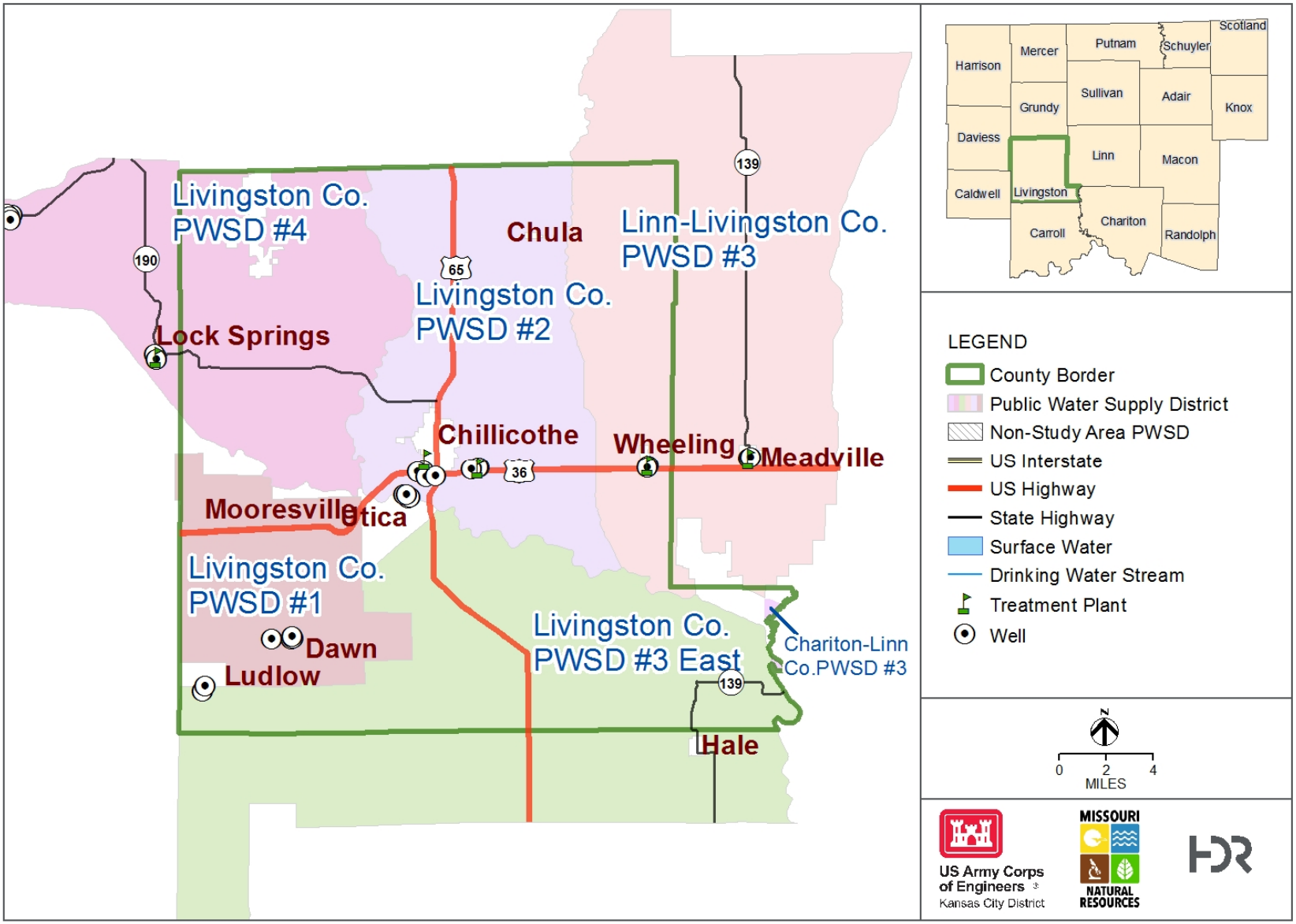
[1] MDNR RESOP Analysis 2011
[2] MDNR 2015

Reliability

- Livingston County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- According to MDNR, Livingston 4 has the groundwater source capacity to potentially serve as a regional supplier. However, Livingston 4 treatment plant has recently been expanded and has already reached capacity. The plant would need to be expanded for the District to provide groundwater regionally.

Quality

- Groundwater treatment plants within Livingston County include aeration, rapid mix sedimentation, disinfection, pH adjustment, and water softening.
- Groundwater suppliers have historically reported water quality violations for Total Coliform.


Livingston Co.
PWSD #4
Chula
Linn-Livingston Co.
PWSD #3
Livingston Co.
PWSD #2
Lock Springs
Chillicothe
Wheeling
Meadville
Mooresville
Utica
Livingston Co.
PWSD #1
Dawn
Ludlow
Livingston Co.
PWSD #3 East
Chariton-Linn
Co.PWSD #3
Hale
190
65
139
36
139
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Carroll
Chariton
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
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Treatment Plant
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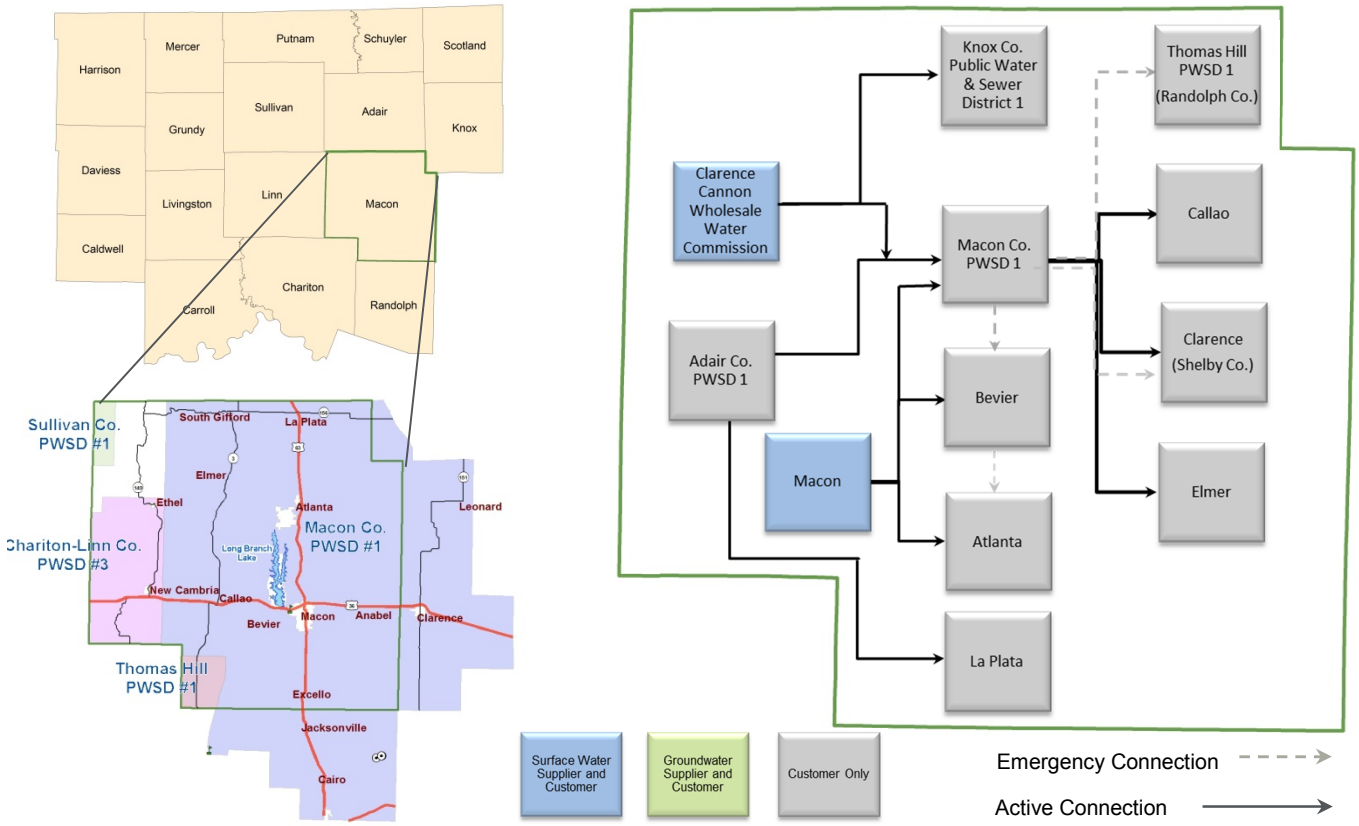
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES



Water Supply Summary: *Macon County*

Within Macon County there are seven public water systems serving a total population of 20,034: Macon Co. PWSD 1, and the cities of Macon, Bevier, Callao, Elmer, and La Plata. Of the seven public water systems, one system is surface water supplier, two systems purchase drinking water from this supplier and the remaining four systems purchases finished surface water from a supplier outside of Macon County.

Availability

- The City of Macon is the only surface water supplier in Macon County using Long Branch Reservoir to supply the cities of Bevier, Atlanta and the Macon PWSD 1. Long Branch Reservoir has potentially 24,000 acre-feet of storage and future efforts may be required to determine if additional water supply maybe available.
- The remaining systems purchase surface water from Adair County PWSD 1 and Clarence Cannon Wholesale Water Commission in Monroe County.
- Macon County does not have any groundwater sources or systems that purchase groundwater.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
City of Macon-Long Branch Reservoir	Macon / MO2010487	Surface Water	NR	4.32	2.5

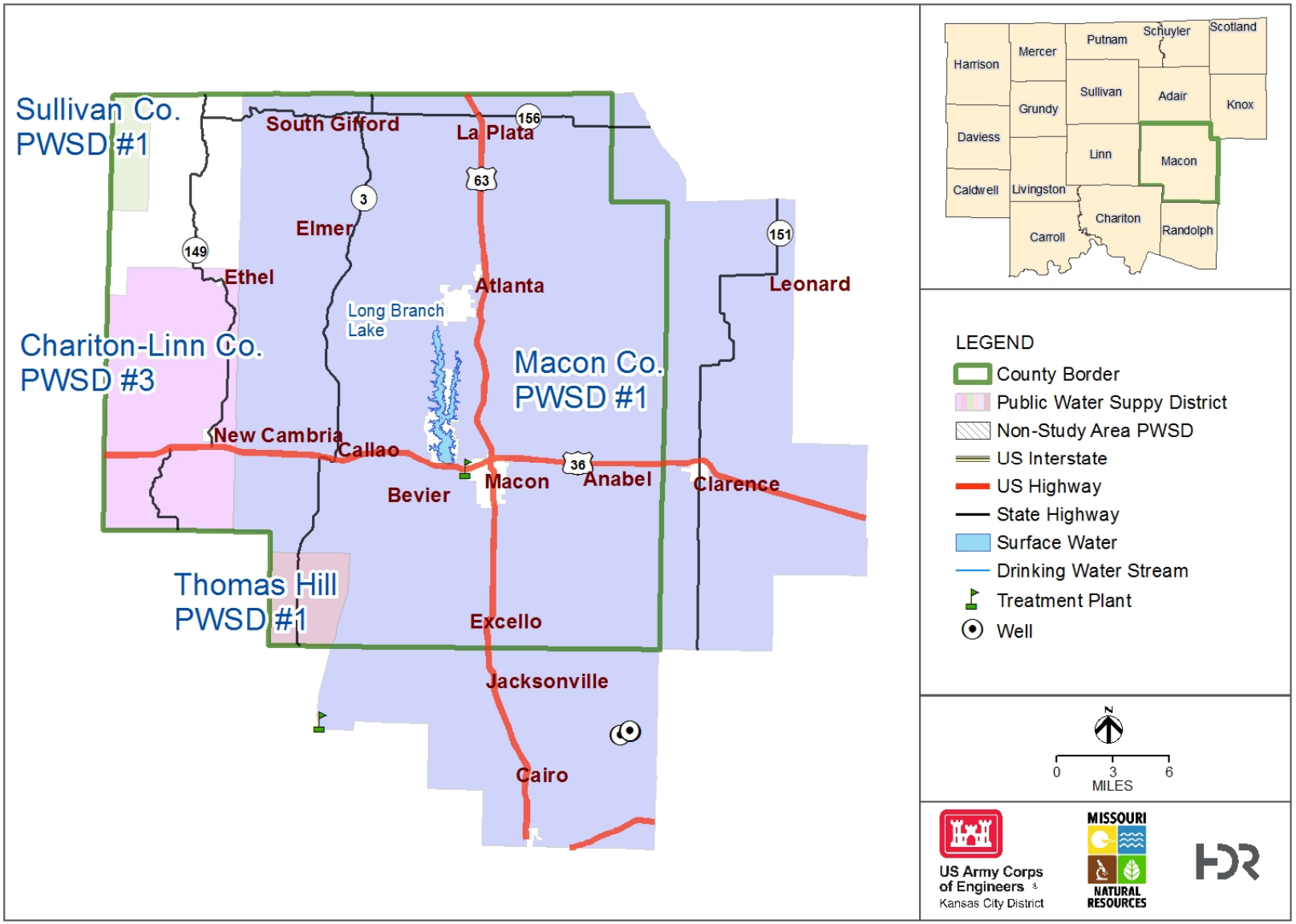
[(1)]MDNR RESOP analysis 2011
[(2)]MDNR 2015

Reliability

- Macon County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- According to the MDNR State Water Plan Volume I, water releases from the Long Branch Reservoir can have downstream effects on the water supply of East Fork Little Chariton River and, subsequently, the City of Moberly and the Sugar Creek Reservoir.

Quality

- The City of Macon surface water treatment plant includes rapid mix sedimentation, filtration, and disinfection.
- Historical water quality issues within the County include disinfection byproduct (DBP) compliance violations.


Sullivan Co.
PWSD #1
Chariton-Linn Co.
PWSD #3
Thomas Hill
PWSD #1
Macon Co.
PWSD #1
South Gifford
La Plata
Elmer
Ethel
Atlanta
Long Branch
Lake
Leonard
New Cambria
Callao
Bevier
Macon
Anabel
Clarence
Excello
Jacksonville
Cairo
156
63
3
149
151
36
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Carroll
Randolph
LEGEND
County Border
Public Water Suppy District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
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MILES
US Army Corps
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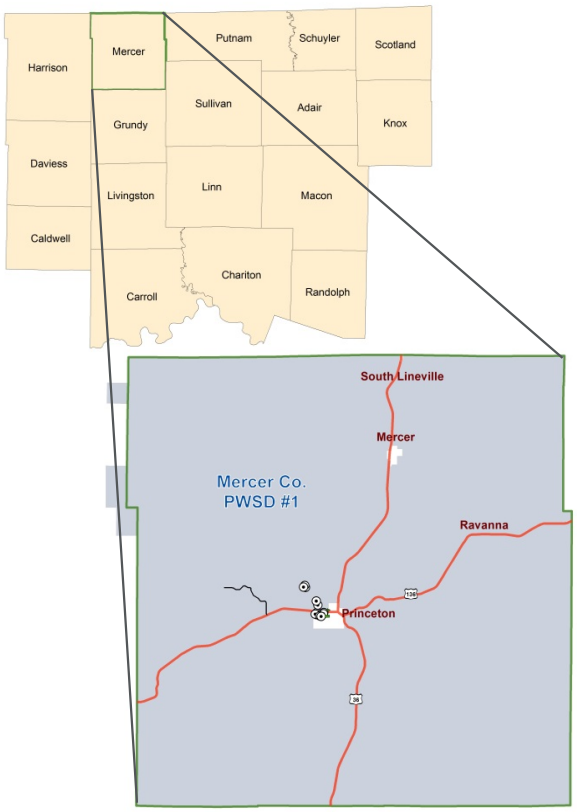
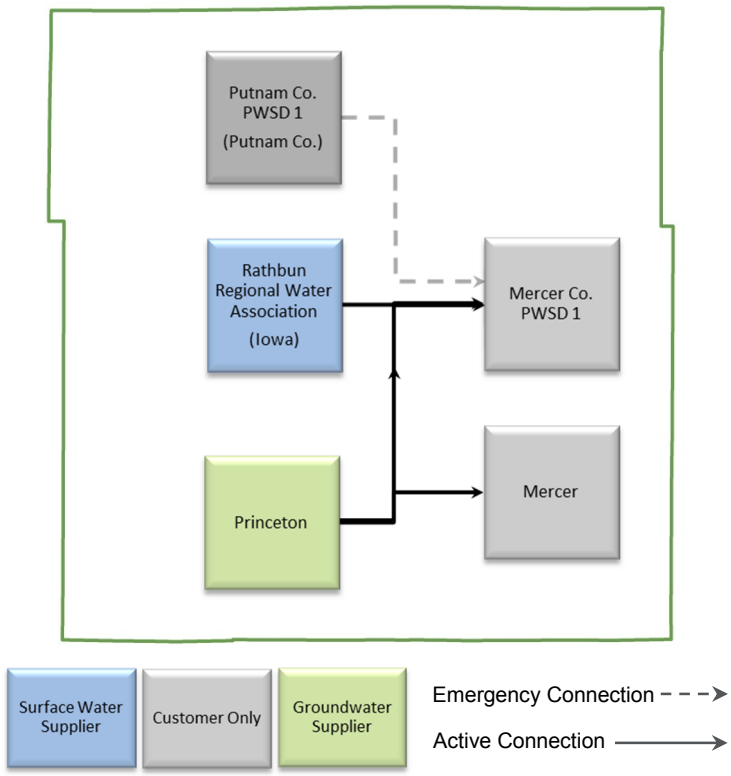
Kansas City District
MISSOURI
NATURAL
RESOURCES





Water Supply Summary: *Mercer County*

Within Mercer County there are three public water systems serving a total population of 4,679: Mercer Co. PWSD 1 and the cities of Mercer and Princeton. Of the three public water systems, one is a groundwater supplier (Princeton) and the remaining two purchase the finished groundwater supplied by this system.

Availability

- The City of Princeton is the only groundwater supplier within Mercer County.
- Mercer Co. PWSD 1 purchases from Rathbun Regional Water Association in Iowa and Putnam Co. PWSD 1 in Putnam County.
- Mercer County does not have any surface water sources or systems which purchase surface water.

Water Statistics

Location Name	Source Name and ID	Supply Type	Optimum Yield (MGD)[1]	Treatment Capacity (MGD)[2]	Average Daily Use (MGD)[2]
City of Princeton	Princeton MO2010664	Groundwater	NR	0.5184	0.14

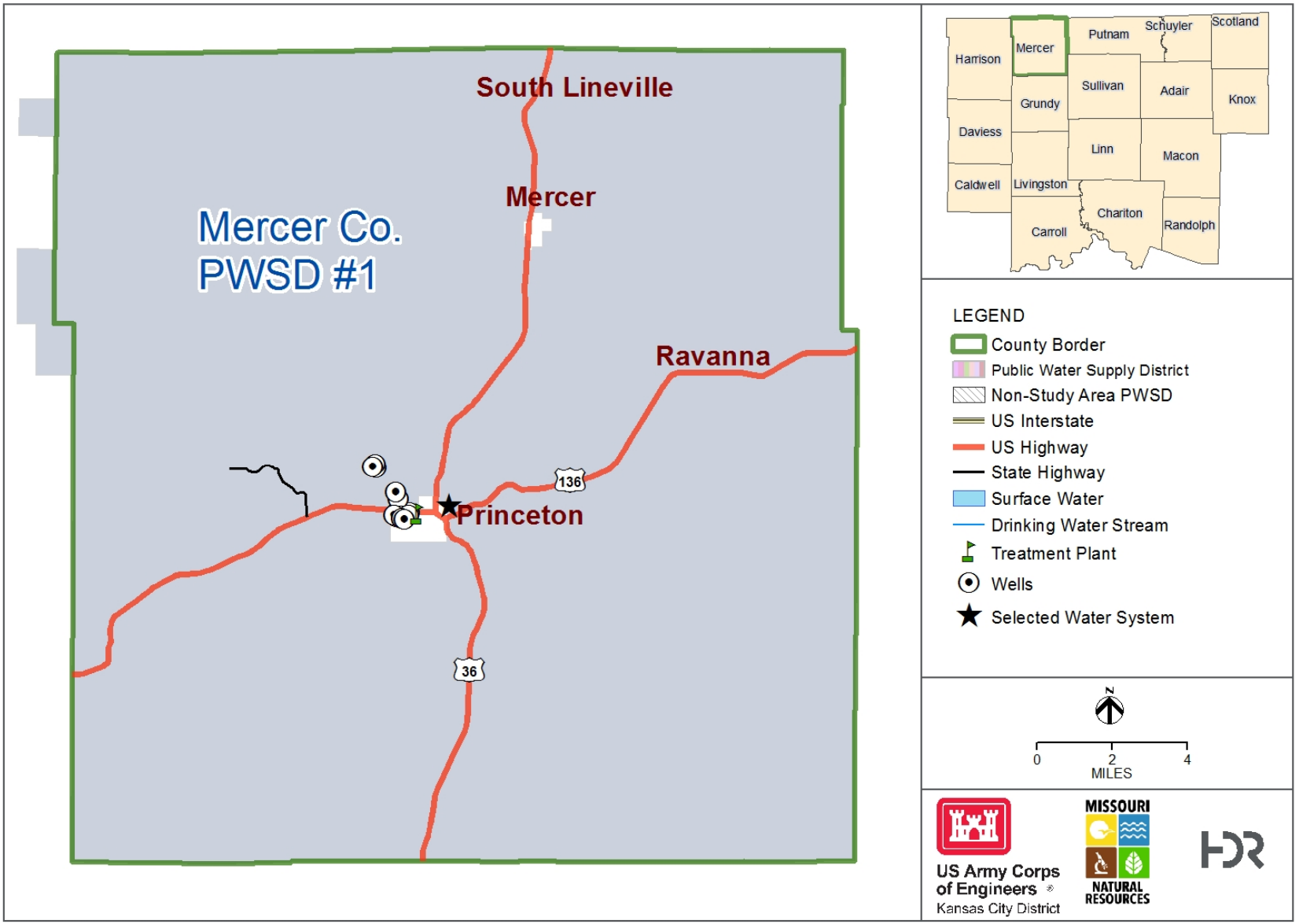
[1] MDNR RESOP Analysis 2011
[2] MDNR 2015

Reliability

- Mercer County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- Princeton must pump from three of its seven wells in order to meet average day demand.
- Princeton's water treatment plant has not been updated since installation in 1975.

Quality

- Princeton has two wells infected with iron bacteria. Iron removal maintenance is required once per year.
- Groundwater treatment includes aeration, filtration, rapid mix sedimentation, pH adjustment, disinfection, and water softening using Lime Soda Ash.


South Lineville
Mercer
Mercer Co.
PWSD #1
Ravanna
136
Princeton
36
Harrison
Mercer
Putnam
Schuyler
Scotland
Sullivan
Adair
Knox
Grundy
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Randolph
Carroll
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Wells
Selected Water System
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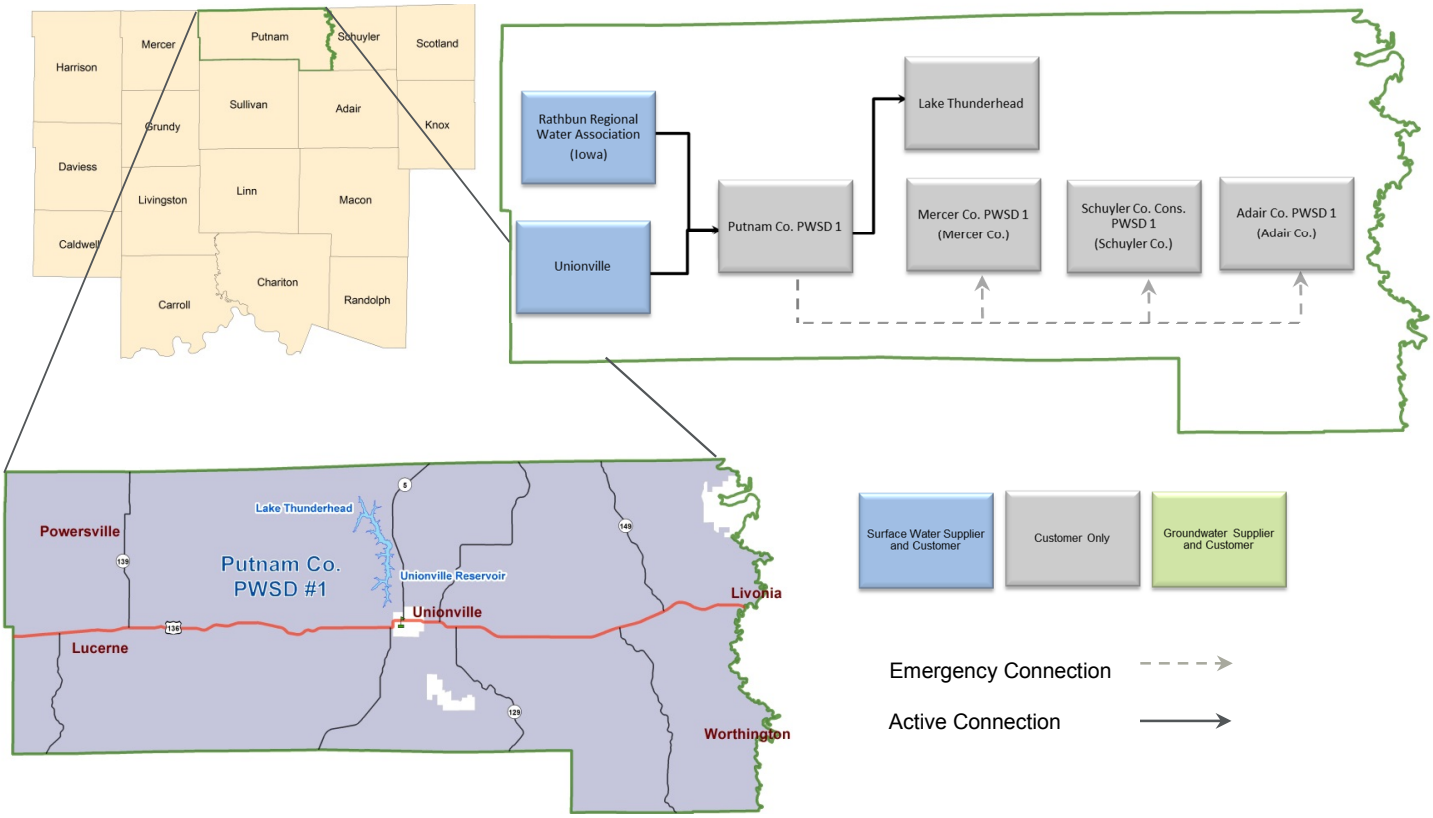
MILES
US Army Corps of Engineers
Kansas City District
MISSOURI
NATURAL RESOURCES



Water Supply Summary: *Putnam County*

Within Putnam County there are three public water systems serving a total population of 5,497: Putnam Co. PWSD 1, Lake Thunderhead, and the City of Unionville. Of the three public water systems, one is a surface water supplier (Unionville). The remaining two purchase the finished surface water supplied by this system and additional supply from Rathbun Regional Water Association in Iowa.

Availability

- Putnam County has two surface water sources, Lake Mahoney and Lake Thunderhead.
- Lake Mahoney supplies surface water to the City of Unionville. Unionville supplies approximately 50 percent of the water supply for Putnam Co. PWSD 1. Putnam Co. PWSD 1 purchases the remainder of its water supply from Rathbun Regional Water Association in Iowa.
- Lake Thunderhead is a privately owned lake and is not designed as a water supply reservoir.
- Putnam County does not have any groundwater sources or purchasers of groundwater.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
City of Unionville	Lake Mahoney MO2010804	Surface Water	0.283	1.512	0.25
-	Lake Thunderhead MO2036165	Surface Water	3.361	NR	0.02
Total			3.644	1.512	0.27

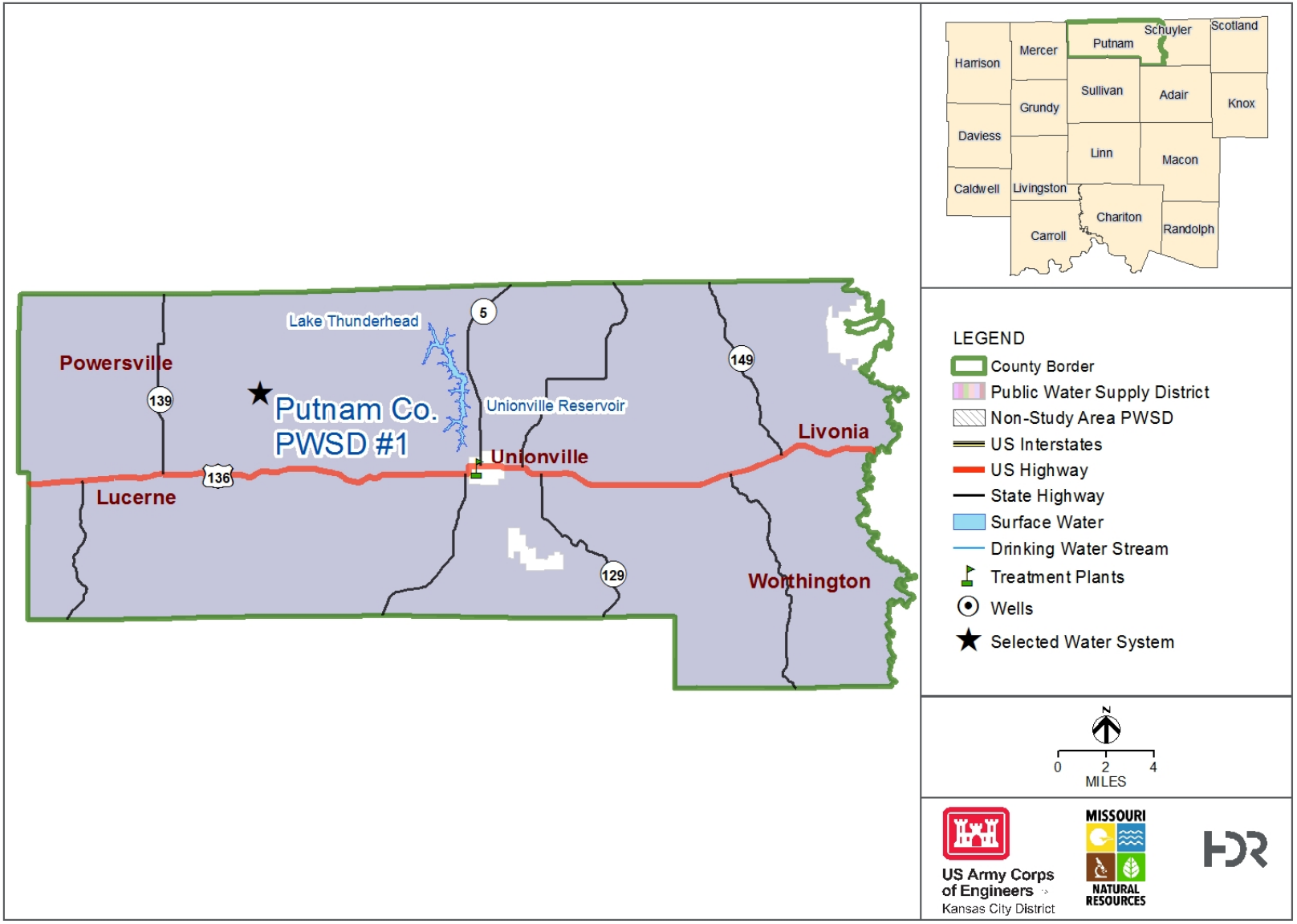
[(1)]MDNR RESOP Analysis 2011
[(2)]MDNR 2015

Reliability

- Putnam County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- According to the MDNR RESOP Analysis, Lake Mahoney is at risk of not meeting the community's demand for water during times of drought.
- Lake Thunderhead is a privately owned lake and has the capabilities of providing supplemental water supply during periods of extreme droughts.

Quality

- Surface water treatment includes filtration, sedimentation, disinfection, and softening.
- Water quality issues include disinfection byproduct (DBP) compliance violations.


Lake Thunderhead
Powersville
Putnam Co.
PWSD #1
Unionville Reservoir
Unionville
Livonia
Lucerne
Worthington
5
139
136
149
129
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Carroll
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
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US Highway
State Highway
Surface Water
Drinking Water Stream
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Wells
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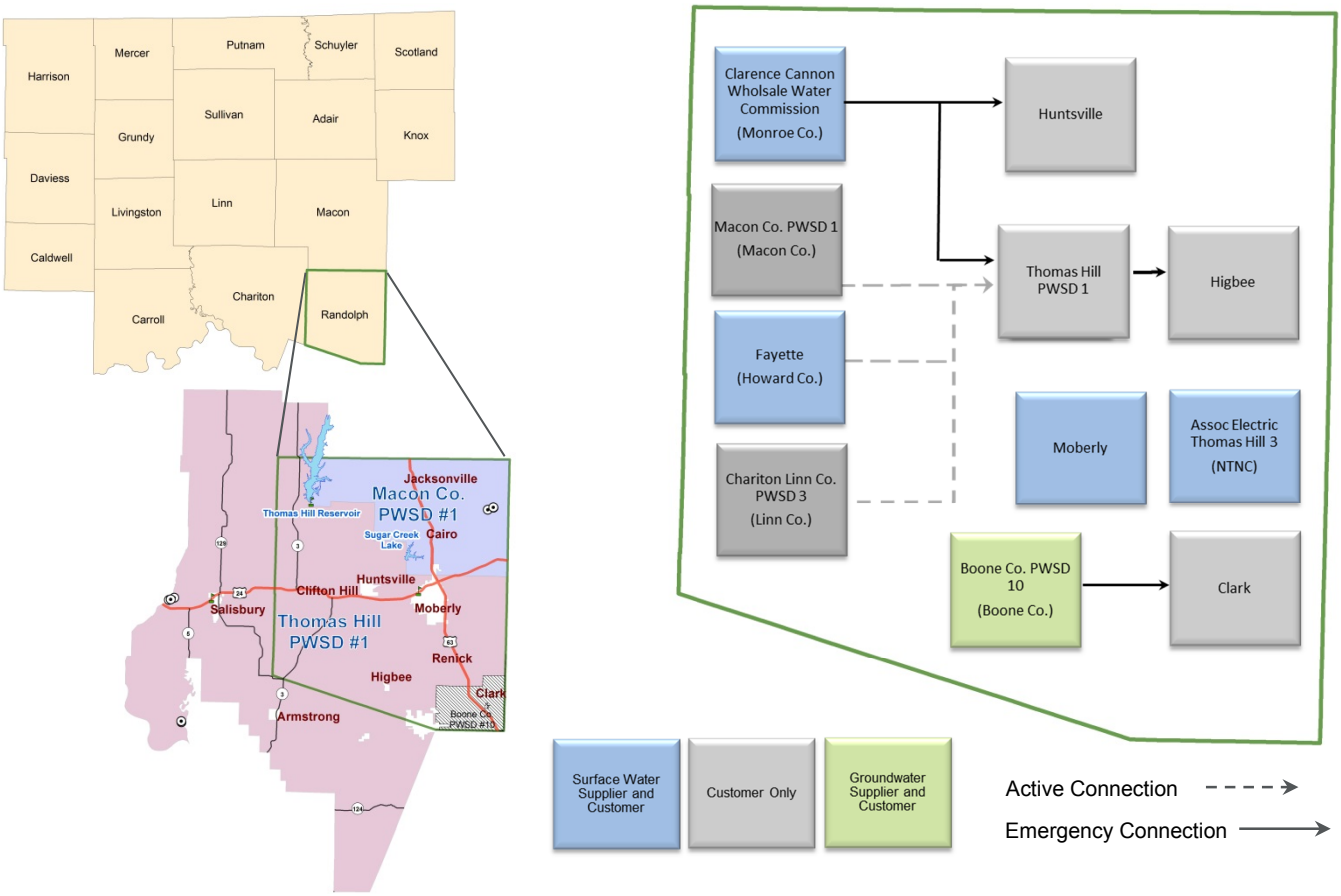
US Army Corps of Engineers
Kansas City District
MISSOURI
NATURAL RESOURCES



Water Supply Summary: *Randolph County*

Within Randolph County there are five public water systems serving a total population of 26,307: Thomas Hill Co. PWSD 1 and the cities of Clark, Higbee, Huntsville, and Moberly. Of the five public water systems, only one is a surface water supplier (Moberly). The remaining purchase finished surface water and groundwater supplied from outside the County.

Availability

- Sugar Creek Reservoir supplies the City of Moberly with supplemental supply provided by East Fork Chariton River.
- Thomas Hill Lake is a private reservoir that supplies surface water only to the non-transient non-community system operated by Associated Electric.
- Randolph County does not have any groundwater sources that supply drinking water but the City of Clark purchases groundwater from Boone Co. PWSD 10 in Boone County.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
City of Clifton Hill-Thomas Hill Lake	Assoc Electric Thomas Hill 3 / MO2182290	Surface Water	NR	1.51	1.00
City of Moberly-Sugar Creek Lake	Moberly / MO2010533	Surface Water	1.01	5.00	0.42
Totals			1.01	6.51	1.42

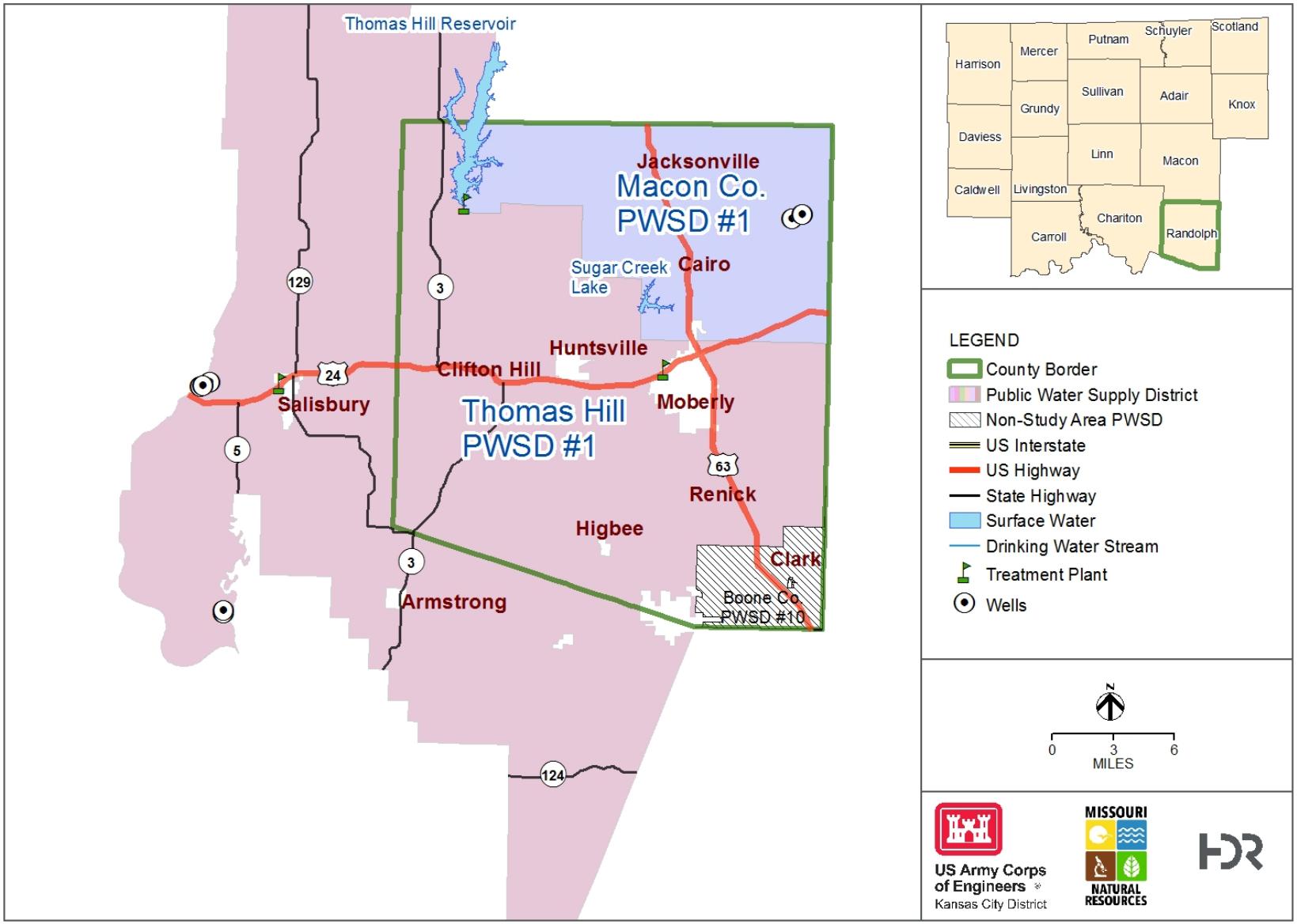
[(1)]MDNR RESOP Analysis 2011
[(2)]MDNR 2015

Reliability

- Randolph County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- According to the 2011 WSS, Sugar Creek Reservoir is unable to meet normal demand. The optimum yield from the lake without supplemental water supply is 1.2 MGD. The RESOP concludes that the optimum yield of Sugar Creek can be increased to 1.54 MGD if water is diverted from the East Fork Chariton River into Sugar Creek Reservoir. If flow from the East Fork Chariton River is insufficient, water can be purchased and released from Long Branch Reservoir at Macon.

Quality

- Surface water treatment for Randolph County includes rapid mix sedimentation, disinfection, pH adjustment, and water softening.
- Historical water quality issues within the County include disinfection byproduct (DBP) compliance violations.


Thomas Hill Reservoir
Jacksonville
Macon Co.
PWSD #1
Sugar Creek
Lake
Cairo
Huntsville
Clifton Hill
Salisbury
Thomas Hill
PWSD #1
Moberly
Renick
Higbee
Clark
Armstrong
Boone Co
PWSD #10
129
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24
5
63
124
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
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Knox
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LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
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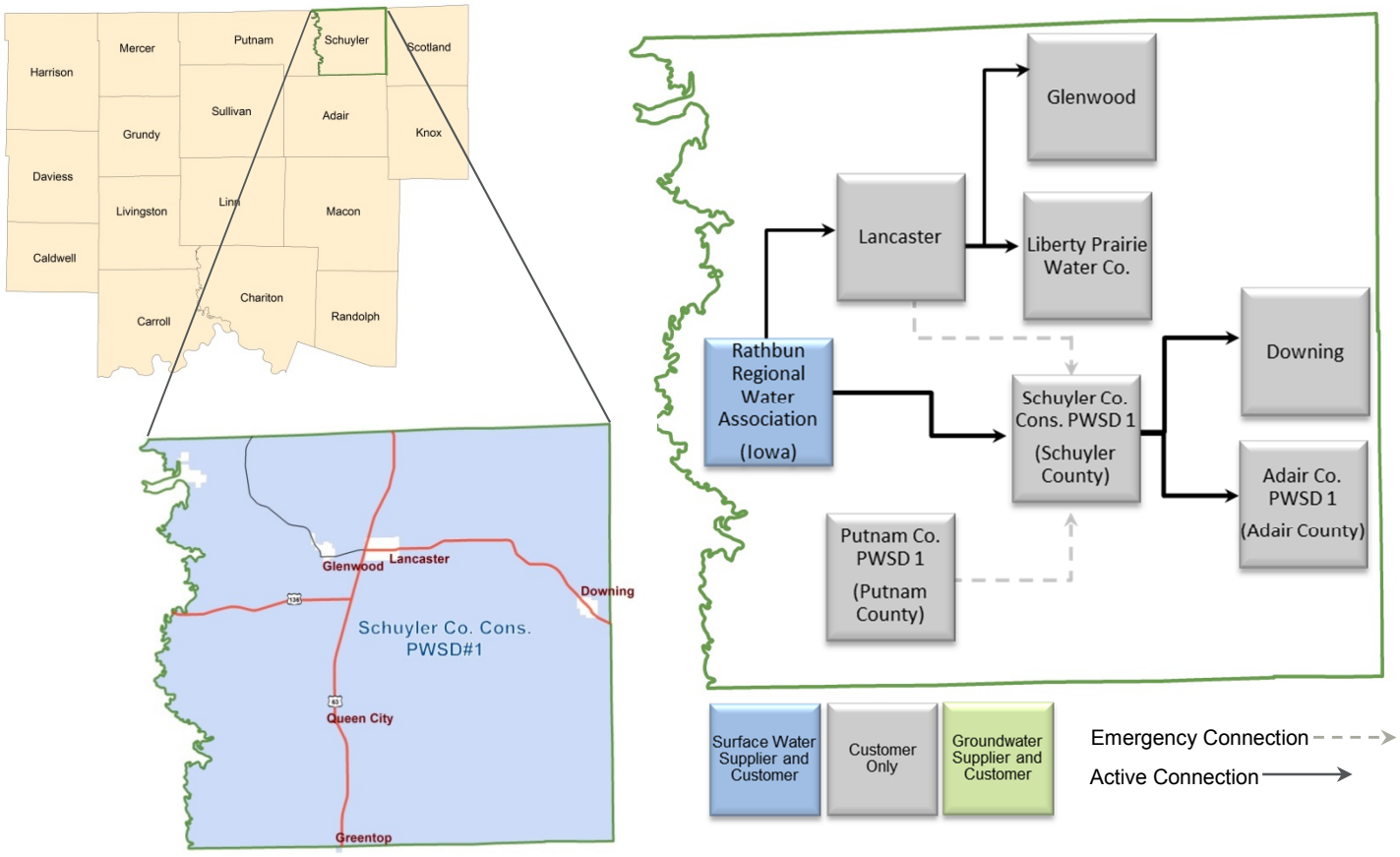
US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES



Water Supply Summary: *Schuyler County*

Within Schuyler County there are five public water systems serving a total population of 4,740: Schuyler Co. PWSD 1, Liberty Prairie Water Co. and the cities of Downing, Glenwood, and Lancaster. Schuyler County does not have any groundwater or surface water supplies. All five systems purchase potable drinking water from Rathbun Regional Water Association in Iowa.

Availability

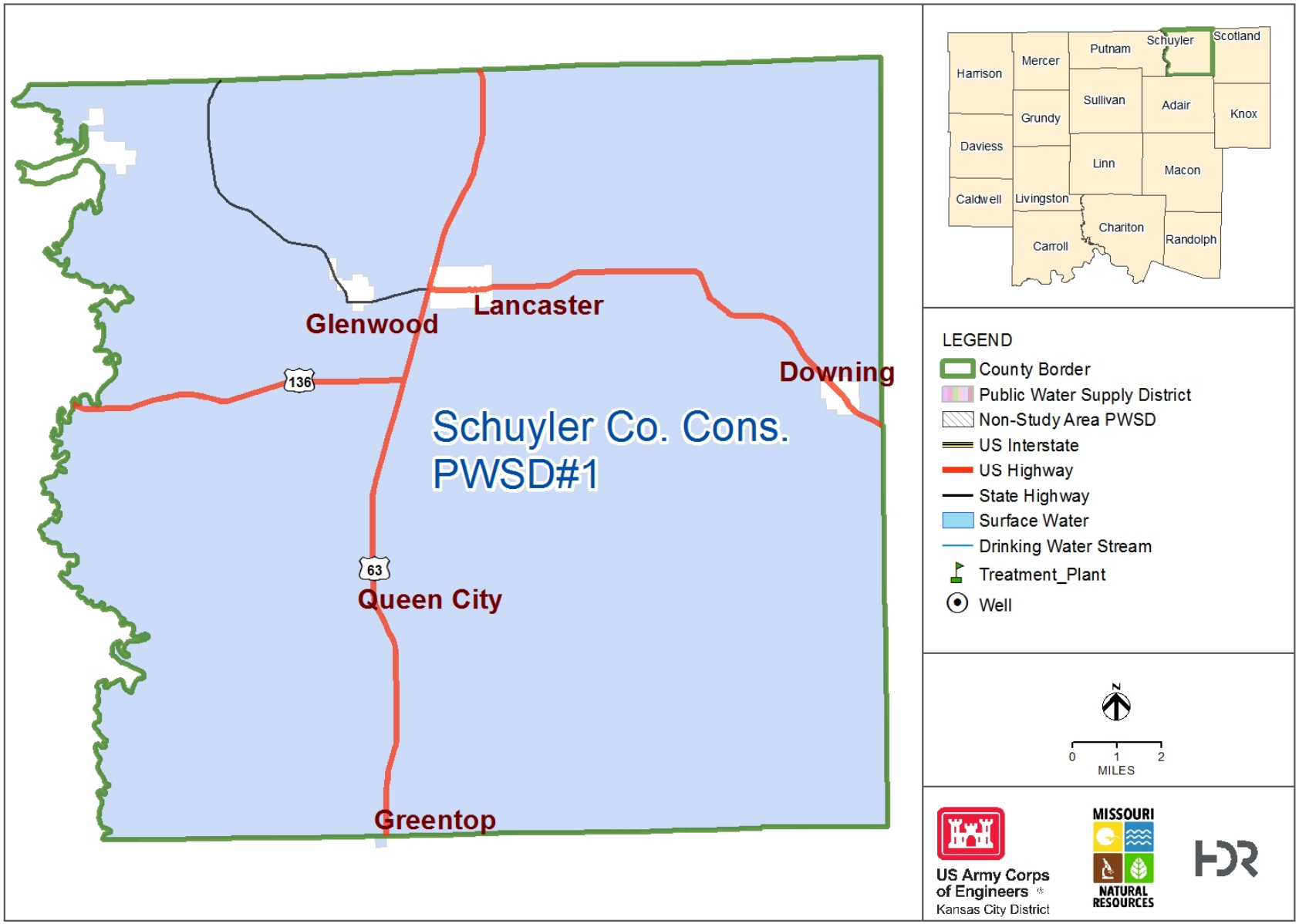
- All water systems within Schuyler County purchase finished surface water from Rathbun Regional Water Association in Iowa.
- Schuyler County does not have any groundwater sources or any systems which purchase groundwater.

Reliability

- The reliability of Rathbun Regional Water Association in Iowa was not part of this Study.

Quality

- The water quality of Rathbun Regional Water Association in Iowa was not part of this Study.


Glenwood
Lancaster
Downing
136
Schuyler Co. Cons.
PWSD#1
63
Queen City
Greentop
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
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Non-Study Area PWSD
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State Highway
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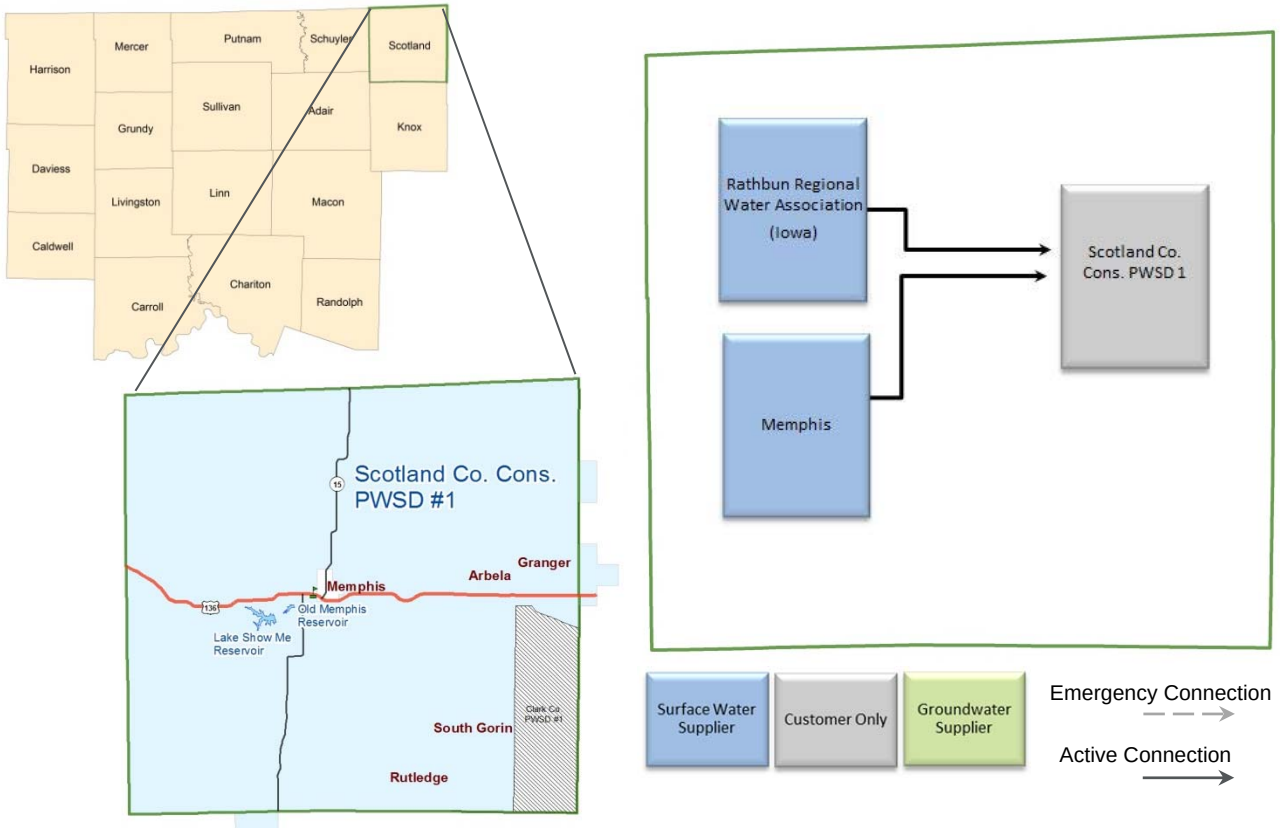
RESOURCES



Water Supply Summary: *Scotland County*

Within Scotland County there are two public water systems serving a total population of 5,182: Scotland Co. PWSD 1 and the City of Memphis. The City of Memphis is the only surface water supplier located within Scotland County. Scotland Cons. 1 purchases finished surface water from the City of Memphis and Rathbun Regional Water Association in Iowa.

Availability

- The City of Memphis utilizes Lake Show Me Reservoir to supply its municipal customers with finished surface water. Old Memphis Reservoir is available for supplemental supply.
- Scotland County does not have any groundwater sources or any systems that purchase groundwater.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[(1)]**	**Treatment Capacity (MGD)[(2)]**	**Average Daily Use (MGD)[(2)]**
City of Memphis – Lake Show Me and Old Memphis Reservoir	Memphis/MO2010513	Surface Water	0.875	0.72	0.42

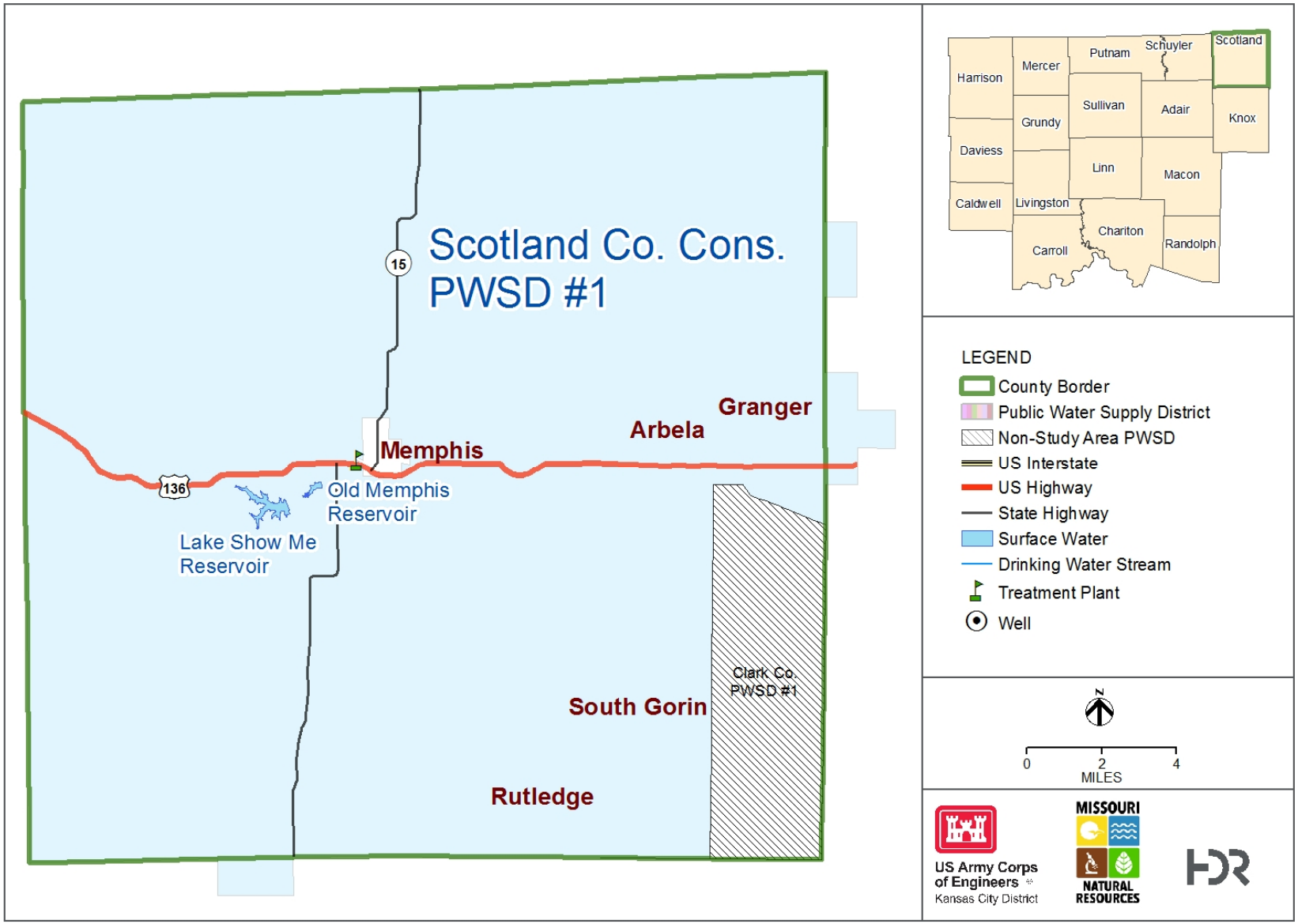
[(1)]MDNR RESOP Analysis 2011
[(2)]MDNR 2015

Reliability

- Scotland County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- According to the 2011 WSS, the optimum yield for Lake Show Me is 0.780 MGD, well above its average daily demand of 0.42 MGD.

Quality

- The Memphis surface water treatment plant includes rapid mix sedimentation, disinfection, and pH adjustment.
- Historical water quality issues within the County include disinfection byproduct (DBP) compliance violations.


Scotland Co. Cons.
PWSD #1
15
136
Memphis
Granger
Arbela
Old Memphis
Reservoir
Lake Show Me
Reservoir
South Gorin
Rutledge
Clark Co.
PWSD #1
Harrison
Mercer
Putnam
Schuyler
Scotland
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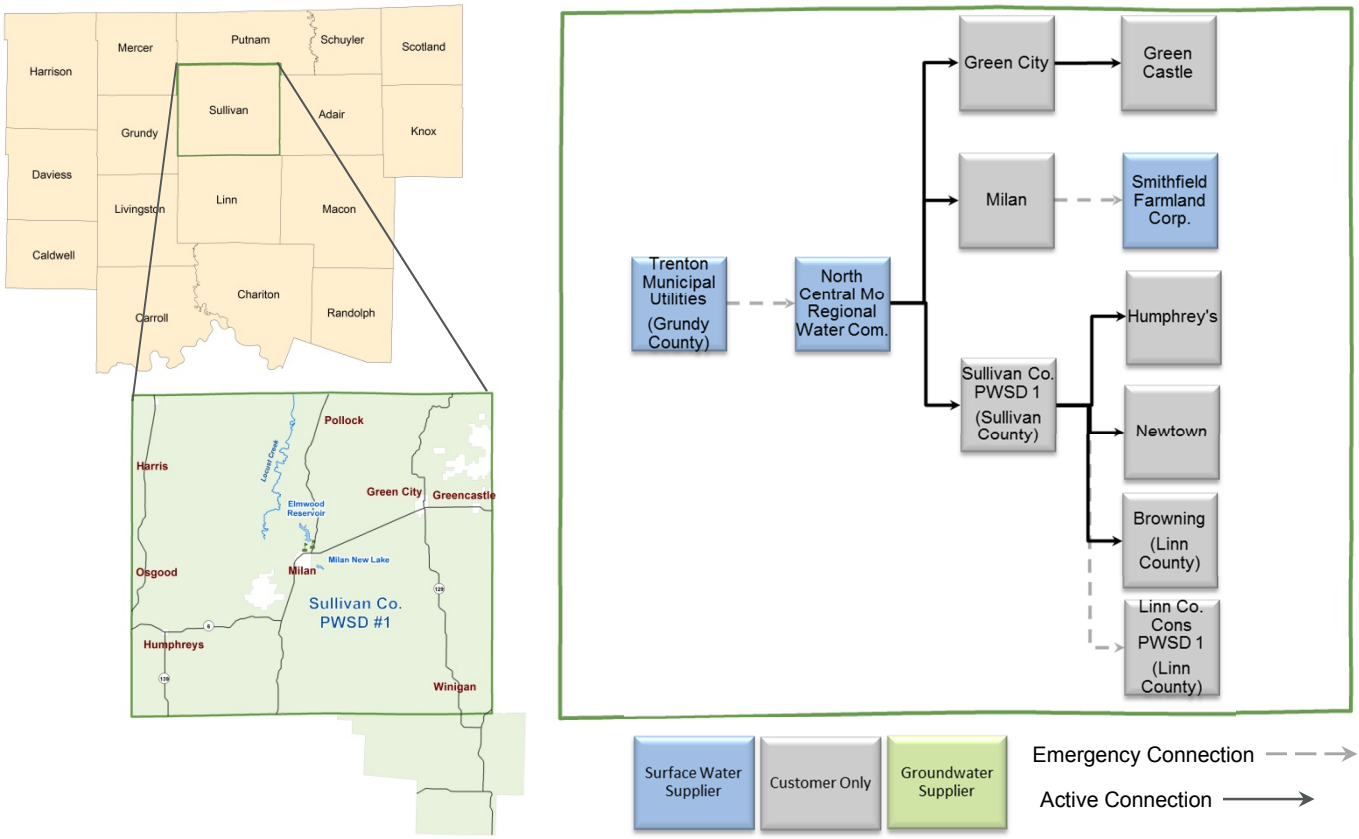
Kansas City District
MISSOURI
NATURAL
RESOURCES



Water Supply Summary: *Sullivan County*

Within Sullivan County there are seven public water systems serving a total population of 8,739: Sullivan Co. PWSD 1, North Central MO Regional Water Company (NCMRWC), and the cities of Green City, Green Castle, Humphreys, Milan, and Newtown. Of the seven public water systems, only one is a surface water supplier (NCMRWC). The remaining six purchase finished surface water from within Sullivan County either directly from NCMRWC or via a consecutive connection.

Availability

- East Locust Creek Reservoir is a proposed 7 MGD capacity surface water source to be constructed within the County and to be operated by the North Central Missouri Regional Water Commission (NCMRWC).
- NCMRWC currently utilizes Elmwood Lake, Golf Course Lake, and Locust Creek for surface water supply and also has an emergency connection with Trenton Municipal Utilities.
- Sullivan County does not have any groundwater sources or systems that purchase groundwater.

Water Statistics					
Location Name	**Source Name and ID**	**Supply Type**	**Optimum Yield (MGD)[1]**	**Treatment Capacity (MGD)[2]**	**Average Daily Use (MGD)[2]**
**East Locust Creek Reservoir	North Central Missouri Regional Water Com	Surface Water	7.0	–	–
Elmwood Lake, Golf Course Lake, Locust Creek	North Central Missouri Regional Water Com MO2021537	Surface Water	0.937	2.80	0.65
Smithfield Farmland Corp Elmwood Lake	Smithfield Farmland Corp MO2181076	Surface Water	–	0.40	0.32
Totals			7.937	3.20	0.97

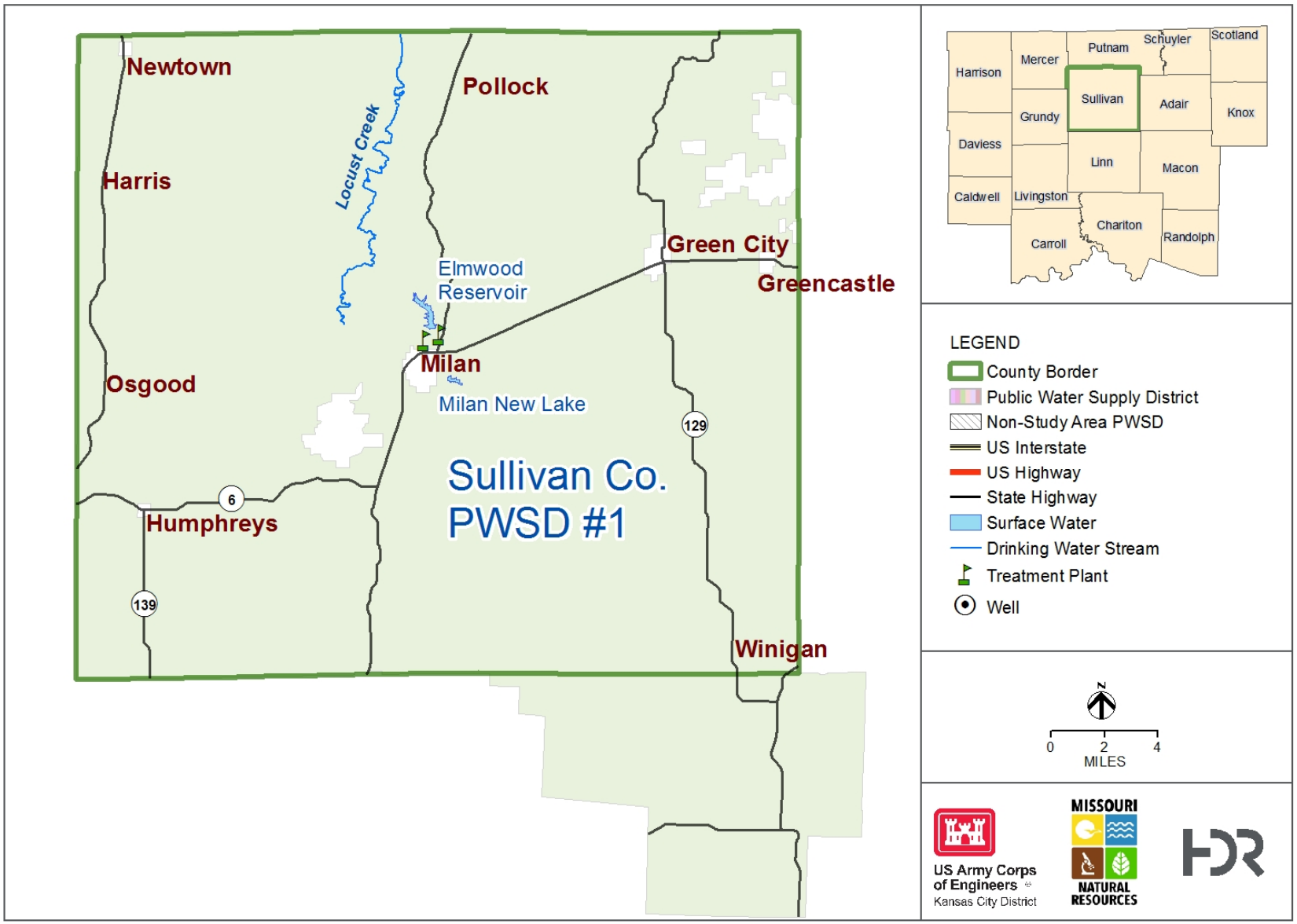
[1]MDNR RESOP Analysis 2011
[2]MDNR 2015
**Future potential source

Reliability

- Sullivan County is within the region of Missouri in which groundwater and surface water supply is severely vulnerable to drought.
- East Locust Creek Reservoir is proposed as a future surface water source to supply public water systems within Sullivan County and adjacent Counties.
- According to MDNR RESOP, the NCMRWC cannot meet current demand without pumping supplemental flow from Locust Creek into the Elmwood Reservoir.
- Smithfield Farmland Corp also draws from the Elmwood Reservoir to provide water to a poultry-processing plant and water for the Premium Standard Farms meat processing plant.

Quality

- Surface water treatment includes filtration, sedimentation, and disinfection.
- Historical water quality issues are unknown for the North Central Missouri Regional Water Commission.


Newtown
Pollock
Harris
Locust Creek
Green City
Elmwood
Reservoir
Greencastle
Milan
Osgood
Milan New Lake
129
Sullivan Co.
PWSD #1
6
Humphreys
139
Winigan
Harrison
Mercer
Putnam
Schuyler
Scotland
Grundy
Sullivan
Adair
Knox
Daviess
Linn
Macon
Caldwell
Livingston
Chariton
Carroll
Randolph
LEGEND
County Border
Public Water Supply District
Non-Study Area PWSD
US Interstate
US Highway
State Highway
Surface Water
Drinking Water Stream
Treatment Plant
Well
N
0
2
4
MILES
US Army Corps
of Engineers
Kansas City District
MISSOURI
NATURAL
RESOURCES

Appendix B Selected Water System Sample Questionnaire

NORTH CENTRAL MISSOURI
WATER SUPPLY STUDY QUESTIONNAIRE

MEETING DATE:_____ **SYSTEM NAME:**_____

SYSTEM ID: MO_____

PERSON(S) PARTICIPATING:_____

SYSTEM PHONE NUMBER:_____ **SYSTEM EMAIL:**_____

Study Goals/Objective: HDR Engineering and MRWA have been retained to perform a Study investigating water supplies and water systems in a 17-county area of North Central Missouri. The goals of the Study are to evaluate key water systems in the Study area and to assess water supply availability, reliability, and current conditions. The evaluation of the water systems will result in useful information enabling future planning and the determination of the need for water projects, including identification of state and/or federal funding assistance.

INFRASTRUCTURE:

Source:

1. What is/are the system's water source(s)?_____

_____

2. What is/are the water source(s) estimated yield? (gpd, gpm, etc.)_____

_____

3. What type of water quality issues does the source have?

_____

_____

a. Is there any recent water quality data available for the water source(s)?_____

_____

4. What do you feel is the remaining design life expectancy of the water source(s)?_____

_____

5. Does the system have a Source Water Protection/Wellhead Protection Plan in place? _____

a. If yes, please provide a copy of the Plan or briefly describe the Plan:_____

_____

Treatment:

6. What type of treatment facility does the system operate? _____

_____

a. Age of the treatment facility?_____

b. Treatment facility capacity (gpd)? _____

c. Average daily flow for the system? _____

d. Date of last major upgrade? _____ What was done? _____

_____

e. What do you feel are the future treatment needs for the system? _____

_____

f. Have there been any previous studies completed to address these needs?_____

_____

g. What are the estimated costs for future treatment needs? _____

7. What are the current and/or future treatment challenges facing the system?

___DBP's ___TOC removal ___ Turbidity ___Pest/Herb removal

___ Bacteriological issues ___Iron/Mn removal ___Other:_____

Distribution:

8. What is the age of the distribution system? _____

9. Describe the type, age and capacity of the system's storage facility or facilities.

_____

_____

10. Does the system have issues/problems with the following?

___low pressures ___frequent waterline breaks ___ excessive water loss (over 10%)

___ aging waterlines ___ inadequate/non-working valves ___ inadequate storage

___other_____

11. In your opinion, what are the greatest needs/challenges facing the system's distribution system?

_____

_____

_____

12. In your opinion, what are the upcoming regulatory requirements that may provide the greatest needs / challenges to your system?

_____

_____

Level of Service (Purchasers Only):

13. From whom does the system purchase water? _____

14. Are there any issues with water quality supplied by the wholesaler?_____

If yes, explain:_____

_____

15. Are there any issues with delivery pressure, delivery flow, etc. from the supplier? _____

If yes, explain:_____

_____

_____

16. Are there any administrative issues with the supplier (correct billing, timely billing, addressing issues, following contract requirements, etc.)?_____

If yes, explain:_____

_____

17. Is the supplier dependable in terms of providing adequate, non-interruptible supply? _____

If no, explain:_____

_____

18. In your opinion, what are the primary concerns, strengths or weaknesses of your current wholesale supplier(s)?_____

_____

_____

OPERATIONS & MAINTENANCE:

1. Total gallons pumped/purchased for the past 5 years?

2014 gallons _____

2013 gallons _____

2012 gallons _____

2011 gallons _____

2010 gallons _____

2. Total gallons sold for the past 5 years?

2014 gallons _____

2013 gallons _____

2012 gallons _____

2011 gallons _____

2010 gallons _____

3. Does the system have a chief operator certified at the required certification level of the system? _____

4. Does the system have an Asset Management Program in place?_____

5. Does the utility have a formal flushing program in place?_____

6. What is the average age of the water meters in the system? _____

7. What types of meters are in place (positive displacement, electronic, other)?

_____

_____

8. Does the system have a meter change out program? _____

9. What is the approximate percentage of annual water loss in your system? And, in simple terms, how is that amount identified? _____

_____

10. Does the system have backup power supply for critical infrastructure? _____

If yes, describe:_____

11. How many people are employed by the water system?

_____ certified operators

_____ other operators/laborers, etc

_____ administrative (clerk, billing, etc)

12. In your opinion, what are the greatest needs/challenges facing the system in terms of operations and maintenance?

_____

_____

_____

_____

FINANCIAL:

1. How many customer accounts and active meters does the system serve? (5 year history)

	Customer Accounts	Active Meters
2014		
2013		
2012		
2011		
2010		

2. What is the approximate dollar amount of delinquent water bills that is carried on the system's books? _____

3. Approximately how many dollars of delinquent water bills are written off each year?

_____

4. Does the water system have any outstanding debt?

a. If yes, what is the principal amount still owed? _____

b. What type and amount of debt (revenue bonds, lease/purchase, GO Bonds, etc)?

_____

_____

5. When is the debt scheduled to be retired? _____

6. What are the system's water rates - both residential and wholesale? _____

_____

_____

7. When were water rates last reviewed/raised? _____

8. Does the system have wholesale customers? _____

a. If yes, who are the customers and what are the rough daily or monthly volumes of water delivered?_____

_____

9. What limitations, if any, are included in the wholesale contracts?

_____ maximum daily gallon limits ____maximum annual gallon limits

____minimum pay/gallons ____ take or pay provisions

____ delivery pressure limits ____ability to serve during times of limited supply

____other

10. What are the reasons for such limits? _____

_____

_____

11. When do the wholesale contract(s) expire? _____

_____

12. Does the system have an annual audit performed? _____

a. Date of last audit:)_____

13. Does the system develop and adopt an annual budget? _____

a. Date last budget was adopted/modified:_____

14. Does the system have a formal Capital Improvement Plan in place?_____

a. If yes, how many years does it cover?_____

15. In your opinion, would the customers support passage of a bond issue in order to fund future system needs? _____

a. Why or why not? _____

_____

_____

REQUESTED DOCUMENTS:

As part of this study, copies of the following documents/information are requested, if available:

___Source water/wellhead protection plans

___Previous studies on future system needs, including cost estimates

___Wholesale water contracts with purchasers

___Residential and wholesale water rate charts

___Most recent audit report

___Most recent budget

___Copy of the most recent Capital Improvement Plan or 5 Year Supervised Plan

___ Total gallons of water pumped/purchased and total gallons sold for the past 5 years

Appendix C Regional Conceptual Distribution System – Opinion of Probable Cost

North Central Missouri Water Supply Study
Cost Estimates for Water Transmission Mains
Milan to Putnam County

Item	Description	Unit	Quantity	Unit Price	Extension
	General Costs				
1	Mobilization (~3%)	LS	1	$215,000	$215,000
	Water Main Costs				
2	8" PVC Water Main	LF	110,880	$50	$5,544,000
3	8" Butterfly Valve	EA	37	$3,200	$118,400
4	Road Crossing Steel Casing Bore & Jack	LF	100	$110	$11,000
5	Combo Air/Vacuum Release Valves	EA	8	$4,000	$32,000
6	Connection to Existing Mains	EA	2	$10,000	$20,000
	Pump Station / Ground Storage Costs				
7	Booster Pump Station	EA	1	$300,000	$300,000
8	Generator for Booster Pump Station	EA	1	$60,000	$60,000
9	Site Work/Seeding/Fencing	LS	1	$60,000	$60,000
10	Electrical for Pump Station	LS	1	$75,000	$75,000
11	0.5 MG Gallon Pre-stressed Concrete Tank	LS	1	$600,000	$600,000
	Subtotal - Direct Capital Costs				$7,035,400
	Engineering / Design / Surveying (20%)				$1,407,080
	Contingency (25%)				$1,758,850
	Contractor Overhead / General Conditions / Bonds & Insurance (20%)				$1,407,080
	Total Estimated Project Costs				$11,608,410

Notes:

1. Does not include costs for any rock excavation
2. Does not include costs for any environmental permitting or issues (soil contamination, etc)
3. Does not include any easement acquisition costs
4. Does not include costs for property acquisition

North Central Missouri Water Supply Study
Cost Estimates for Water Transmission Mains
Milan to Adair County

Item	Description	Unit	Quantity	Unit Price	Extension
	General Costs				
1	Mobilization (~3%)	LS	1	$330,000	$330,000
	Water Main Costs				
2	12" PVC Water Main	LF	121,440	$75	$9,108,000
3	12" Butterfly Valve	EA	40	$4,000	$160,000
4	Road Crossing Steel Casing Bore & Jack	LF	100	$125	$12,500
5	Combo Air/Vacuum Release Valves	EA	12	$5,000	$60,000
6	Connection to Existing Mains	EA	2	$10,000	$20,000
	Pump Station / Ground Storage Costs				
7	Booster Pump Station	EA	1	$400,000	$400,000
8	Generator for Booster Pump Station	EA	1	$75,000	$75,000
9	Site Work/Seeding/Fencing	LS	1	$80,000	$80,000
10	Electrical for Pump Station	LS	1	$100,000	$100,000
11	1 MG Gallon Pre-stressed Concrete Tank	LS	1	$1,000,000	$1,000,000
	Subtotal - Direct Capital Costs				$11,345,500
	Engineering / Design / Surveying (20%)				$2,269,100
	Contingency (25%)				$2,836,375
	Contractor Overhead / General Conditions / Bonds & Insurance (20%)				$2,269,100
	Total Estimated Project Costs				$18,720,075

Notes:

1. Does not include costs for any rock excavation
2. Does not include costs for any environmental permitting or issues (soil contamination, etc)
3. Does not include any easement acquisition costs
4. Does not include costs for property acquisition

North Central Missouri Water Supply Study
Cost Estimates for Water Transmission Mains
Milan to Marceline

Item	Description	Unit	Quantity	Unit Price	Extension
	General Costs				
1	Mobilization (~2%)	LS	1	$750,000	$750,000
	Water Main Costs				
2	24" DIP Water Main	LF	100,320	$115	$11,536,800
3	24" Butterfly Valve	EA	33	$7,000	$231,000
4	20" DIP Water Main	LF	163,680	$100	$16,368,000
5	20" Butterfly Valve	EA	54	$6,000	$324,000
6	Road Crossing Steel Casing Bore & Jack	LF	600	$150	$90,000
7	Combo Air/Vacuum Release Valves - 24"	EA	4	$8,000	$32,000
8	Combo Air/Vacuum Release Valves - 20"	EA	8	$7,000	$56,000
9	Connection to Existing Mains	EA	4	$25,000	$100,000
	Pump Station / Ground Storage Costs				
10	Booster Pump Station	EA	1	$1,200,000	$1,200,000
11	Generator for Booster Pump Station	EA	1	$80,000	$80,000
12	Site Work/Seeding/Fencing	LS	1	$240,000	$240,000
13	Electrical for Pump Station	LS	1	$300,000	$300,000
14	2.0 MG Gallon Pre-stressed Concrete Tank	LS	1	$2,000,000	$2,000,000
15	Booster Pump Station	EA	1	$1,000,000	$1,000,000
16	Generator for Booster Pump Station	EA	1	$75,000	$75,000
17	Site Work/Seeding/Fencing	LS	1	$200,000	$200,000
18	Electrical for Pump Station	LS	1	$250,000	$250,000
19	2.0 MG Gallon Pre-stressed Concrete Tank	LS	1	$2,000,000	$2,000,000
	Subtotal - Direct Capital Costs				$36,832,800
	Engineering / Design / Surveying (20%)				$7,366,560
	Contingency (25%)				$9,208,200
	Contractor Overhead / General Conditions / Bonds & Insurance (20%)				$7,366,560
	Total Estimated Project Costs				$60,774,120

Notes:

1. Does not include costs for any rock excavation
2. Does not include costs for any environmental permitting or issues (soil contamination, etc)
3. Does not include any easement acquisition costs
4. Does not include costs for property acquisition

North Central Missouri Water Supply Study
Cost Estimates for Water Transmission Mains
Hamilton to Davies 1

Item	Description	Unit	Quantity	Unit Price	Extension
	General Costs				
1	Mobilization (~3%)	LS	1	$265,000	$265,000
	Water Main Costs				
2	12" PVC Water Main	LF	58,080	$75	$4,356,000
3	12" Butterfly Valve	EA	19	$4,000	$76,000
4	4" PVC Water Main	LF	52,800	$35	$1,848,000
5	4" Butterfly Valve	EA	17	$2,500	$42,500
6	Road Crossing Steel Casing Bore & Jack	LF	200	$125	$25,000
7	Combo Air/Vacuum Release Valves - 12"	EA	3	$5,000	$15,000
8	Combo Air/Vacuum Release Valves - 4"	EA	5	$3,000	$15,000
9	Connection to Existing Mains	EA	4	$10,000	$40,000
	Pump Station / Ground Storage Costs				
10	Booster Pump Station	EA	1	$350,000	$350,000
11	Generator for Booster Pump Station	EA	1	$50,000	$50,000
12	Site Work/Seeding/Fencing	LS	1	$70,000	$70,000
13	Electrical for Pump Station	LS	1	$87,500	$87,500
14	1 MG Gallon Pre-stressed Concrete Tank	LS	1	$1,000,000	$1,000,000
15	Booster Pump Station	EA	1	$200,000	$200,000
16	Generator for Booster Pump Station	EA	1	$40,000	$40,000
17	Site Work/Seeding/Fencing	LS	1	$40,000	$40,000
18	Electrical for Pump Station	LS	1	$50,000	$50,000
19	100K Pre-stressed Concrete Tank	LS	1	$200,000	$200,000
	Subtotal - Direct Capital Costs				$8,770,000
	Engineering / Design / Surveying (20%)				$1,754,000
	Contingency (25%)				$2,192,500
	Contractor Overhead / General Conditions / Bonds & Insurance (20%)				$1,754,000
	Total Estimated Project Costs				$14,470,500

Notes:

1. Does not include costs for any rock excavation
2. Does not include costs for any environmental permitting or issues (soil contamination, etc)
3. Does not include any easement acquisition costs
4. Does not include costs for property acquisition

North Central Missouri Water Supply Study
Cost Estimates for Water Transmission Mains
Milan to Trenton Municipal Utilities

Item	Description	Unit	Quantity	Unit Price	Extension
	General Costs				
1	Mobilization (~3%)	LS	1	$525,000	$525,000
	Water Main Costs				
2	16" DIP Water Main	LF	168,960	$85	$14,361,600
3	16" Butterfly Valve	EA	56	$4,000	$224,000
4	Road Crossing Steel Casing Bore & Jack	LF	200	$150	$30,000
5	Creek Crossings Steel Casing Bore & Jack	LF	200	$150	$30,000
6	Combo Air/Vacuum Release Valves	EA	8	$5,500	$44,000
7	Connection to Existing Mains	EA	2	$15,000	$30,000
	Pump Station / Ground Storage Costs				
8	Booster Pump Station	EA	1	$800,000	$800,000
9	Generator for Booster Pump Station	EA	1	$65,000	$65,000
10	Site Work/Seeding/Fencing	LS	1	$160,000	$160,000
11	Electrical for Pump Station	LS	1	$200,000	$200,000
12	1 MG Gallon Pre-stressed Concrete Tank	LS	1	$1,000,000	$1,000,000
	Subtotal - Direct Capital Costs				$17,469,600
	Engineering / Design / Surveying (20%)				$3,493,920
	Contingency (25%)				$4,367,400
	Contractor Overhead / General Conditions / Bonds & Insurance (20%)				$3,493,920
	Total Estimated Project Costs				$28,824,840

Notes:

1. Does not include costs for any rock excavation
2. Does not include costs for any environmental permitting or issues (soil contamination, etc)
3. Does not include any easement acquisition costs
4. Does not include costs for property acquisition