Memorandum

To: *Gail Melgren, Executive Director, Tri-State Water Resources Coalition*

From: *Donie Grimsley, CDM Smith*

Date: *October 4, 2016 (Current as of July 13, 2016)*

Subject: *Southwest Missouri Water Resource Study: Summary of Phases*

INTRODUCTION

This document is a summary of the previous phases of study related to the Stockton reallocation study and the alternatives analysis for Table Rock and Pomme de Terre Lakes. The objective of this summary is to provide clarity on the purpose and findings of each phase of study. Figure 1 illustrates the study phases and reflects the respective refinement of quantities of water to be requested of the U.S. Army Corps of Engineers (Corps) reservoir(s), with the main focus on Stockton Lake since that was funded for a reallocation study in Fiscal Year 2014. Aside from the reallocation study, the three phases of study have been funded in partnership with the Corps Planning Assistance to States (PAS) program and Missouri Department of Natural Resources (MDNR) as the sponsor.

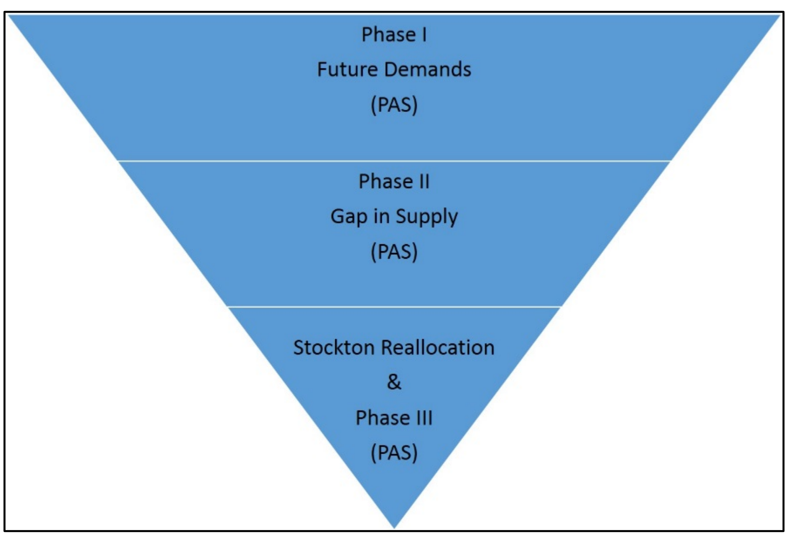

Figure 1: Southwest Missouri Water Resource Study Phases

Table 1 presents the refinement of the quantities of supply needed to meet future demands in the forecast year 2060 particularly during drought periods.

Table 1: Summary and Description of Study Phases

Study Phase	Description	Quantities in 2060	Notes
Phase I* (PAS) 2012	Additional water demands for Southwest Missouri	125 mgd	All water use sectors. Medium growth scenario for population and employment. No conservation measures.
Phase II** (PAS) 2014	Gap in water supply availability to meet projected domestic demands	Scenario 3 83 mgd Scenario 4 146 mgd Scenario 5 107 mgd (2016)	Drought scenarios, reflecting greatest gap in the month of August. Water use sectors represent public supply, self-supply residential, and non-residential (agriculture not included in gap). Scenario 4 applies additional restrictions on groundwater withdrawals. Scenario 5 decreases sub-region 2 groundwater availability assumptions to 2006 known withdrawals based on Tri-State Coalition comments
Stockton Lake & Pomme de Terre Reallocation***	Preliminary reallocation request	Scenario 3 33 mgd Scenario 4 87 mgd Scenario 5 53 mgd (2016)	Drought scenarios, converting the daily gap of each month to the average annual daily gap from Phase II, forecast year 2060. Scenario 4 applies additional restrictions on groundwater withdrawals. Scenario 5 decreases sub-region 2 groundwater availability assumptions to 2006 known withdrawals based on Tri-State Coalition comments
Phase III (PAS) 2015 – Table Rock Lake	Alternative distribution (Not a reallocation study)	--	Facilities assessment to treat and convey water throughout Southwest Missouri.

*Phase I quantities shown are highlighted in Table 2 for reference
**Phase II quantities shown are highlighted in Table 3 for reference
***Phase III quantities are highlighted in Table 6 for reference; Pomme de Terre is in the initial assessment phase
Note – Scenario 5 was developed in 2016 and was not part of the original Phase II and Phase III Studies

Scenarios 3, 4, and 5 are drought scenarios. Phase II, Scenario 3 reflects continued rate of groundwater use whereas Scenario 4 restricts future groundwater withdrawals to meet future demands. Thus in 2060, Scenario 4 reflects a greater need beyond that of the projected additional demand of the Phase I study. Scenario 5 models the same assumptions as Scenario 3, but with the 2006 drought year known groundwater withdrawals for Greene County and vicinity[1] based on concerns by Tri-State Water Resources Coalition of high groundwater availability assumptions in sub-region 2 under Scenario 3.

[1] USGS. 2010. Groundwater-Flow Model and Effects of Projected Groundwater Use in the Ozark Plateaus Aquifer System In the Vicinity of Greene County, Missouri – 1907-1930. Available at: http://pubs.usgs.gov/sir/2010/5227/pdf/SIR2010-5227.pdf

Phase II monthly quantities are then averaged across the year for consideration of reallocation quantities as shown for Stockton and Pomme de Terre lakes above and derived in Tables 4 and 5.

The following discussions summarize the previous phases to provide clarity of the process in defining the future supply need.

FUTURE WATER DEMANDS (Phase I)

The water demands for the 16-county region of Southwest Missouri were forecast for three growth scenarios: high, medium, and low based upon population and employment projections. The estimated additional regional water demand in 2060 under the medium growth scenario compared to the 2010 baseline demand is 125 million gallons per day (mgd,), a nearly 40 percent increase, as shown in Table 2. In addition, two domestic use conservation programs reflecting locally successful measures were applied to the domestic demands. Under conservation scenario I, water demand projections for future forecast years are 1 to 3 percent lower than baseline future projections annually based on moderate conservation activities. Under a more restrictive conservation scenario II, water demands are projected to be 4 to 7 percent lower than baseline future projections annually, as shown in Figure 2.

Table 2: Projected Demands with Conservation Scenarios (MGD)

	Baseline Demands			Conservation Scenario I			Conservation Scenario II		
	Growth Scenario								
Year	High	Medium	Low	High	Medium	Low	High	Medium	Low
2010	339	339	339	339	339	339	339	339	339
2060	584	464	388	569	454	382	544	437	371
Total Increase in Demand	245	125	49	230	115	42	204	98	32

*Variation in 2010 baseline demands between growth scenarios is due to the methodology used to determine future agricultural demands from a 2007 baseline.

Highlighted quantities are summarized in Table 1.

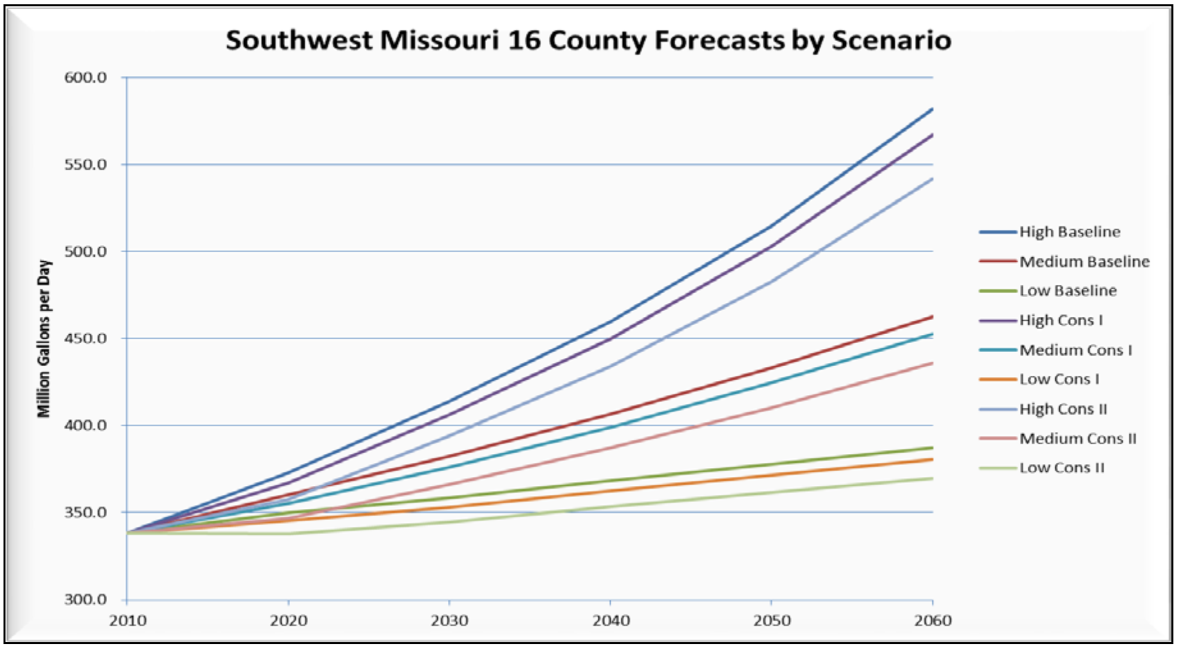

Figure 2: Southwest Missouri Water Resource Study Phase I, Conservation Scenarios (MGD)

SUPPLY AVAILABILITY AND GAP EVALUATION (Phase II)

To address surface water and groundwater availability in both normal (i.e., Scenarios 1 and 2) and drought (i.e., Scenarios 3, 4, and 5) conditions, the following five management scenarios were applied in the gap analysis:

- **Scenario 1.** Scenario 1 combines normal weather surface water flows and withdrawals with U.S. Geological Survey (USGS) groundwater models representing current rate of growth with continual groundwater declines.
- **Scenario 2.** Scenario 2 combines normal weather surface water flows and withdrawals with an estimated sustainable groundwater management option (fully saturated Ozark Aquifer – reduced groundwater withdrawals).
- **Scenario 3.** Scenario 3 combines drought condition surface water flows and withdrawals with USGS groundwater models representing current rate of growth with continual declines.
- **Scenario 4.** Scenario 4 combines drought condition surface water flows and withdrawals with an estimated sustainable groundwater management option (fully saturated Ozark Aquifer – reduced groundwater withdrawals).
- **Scenario 5.** Scenario 5 was created in June 2016 following concerns from Tri-State Water Resources Coalition of high groundwater availability in sub-region 2 under Scenario 3. This scenario combines drought surface water flows and withdrawals with adjusted USGS groundwater models representing current rate of growth with continual declines.

There is currently not a groundwater policy in Missouri that would limit groundwater withdrawals as reflected in Scenario 4. Drought is the controlling factor for future supply gap.

Where surface water and groundwater supplies do not meet future forecasted demands (i.e., public supply for this evaluation), the term “gap” is used to identify the deficit. For the gap analysis, water demands reflected the use sectors of public supply, self-supplied residential, and self-supplied industrial not including agriculture.

As shown in Table 3, as a region under normal weather conditions (Scenarios 1 and 2), there is sufficient available surface water without any additional supplies (e.g., future reallocation) to supplement localized declining groundwater. However, there is not sufficient available source water without additional supplies during drought (scenarios 3, 4, and 5). Additionally, the infrastructure to capture, store, treat, and deliver this water is not in place currently to meet the impending demands particularly during severe drought (scenarios 3, 4, and 5).

Table 3: Gap Evaluation - Regional Summary (MGD)

	Scenario 1											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2020	-	-	-	-	-	-	-	-	-	-	-	-
2030	-	-	-	-	-	-	-	-	-	-	-	-
2040	-	-	-	-	-	-	-	-	-	-	-	-
2050	-	-	-	-	-	-	-	-	-	-	-	-
2060	-	-	-	-	-	-	-	-	-	-	-	-
	Scenario 2											
2020	-	-	-	-	-	-	-	-	-	-	-	-
2030	-	-	-	-	-	-	-	-	-	-	-	-
2040	-	-	-	-	-	-	-	-	-	-	-	-
2050	-	-	-	-	-	-	-	20	20	-	-	-
2060	-	-	-	-	-	-	-	49	49	9	-	-
	Scenario 3											
2020	-	-	-	-	-	-	-	-	-	-	-	-
2030	-	-	-	-	-	-	-	3	6	-	-	-
2040	-	-	-	-	-	-	3	27	29	-	-	-
2050	-	-	-	-	-	-	28	54	54	8	1	-
2060	4	9	14	20	-	25	55	83	82	31	23	11
	Scenario 4											
2020	-	-	4	7	-	1	24	45	48	13	11	1
2030	10	13	19	23	-	19	44	66	69	30	26	16
2040	27	31	37	41	-	40	66	90	92	49	44	34
2050	46	51	56	61	-	63	91	117	117	71	64	53
2060	67	72	77	83	-	88	118	146	145	94	86	74
	Scenario 5											
2020	-	-	-	-	-	-	-	6	9	-	-	-
2030	-	-	-	-	-	-	5	27	30	-	-	-
2040	-	-	-	2	-	1	27	51	53	10	5	-
2050	7	12	17	22	-	24	52	78	78	32	25	14
2060	28	33	38	44	-	49	79	107	106	75	47	35

Highlighted quantities are summarized in Table 1.

In an effort to accurately reflect the unique differences in demands and sources of supply, as well as to align with past Tri-State Water Resources Coalition and USGS study boundaries, the 16-county region was subdivided into four sub-regions. A map of the sub-regions is shown in Figure 3.

The counties within each of the sub-regions are as follows:

- **Sub-region 1.** Barry, Barton, Jasper, McDonald, and Newton counties
- **Sub-region 2.** Christian, Greene, Lawrence, Polk, and Stone counties
- **Sub-region 3.** Taney County
- **Sub-region 4.** Cedar, Dade, Hickory, St. Clair, and Vernon counties

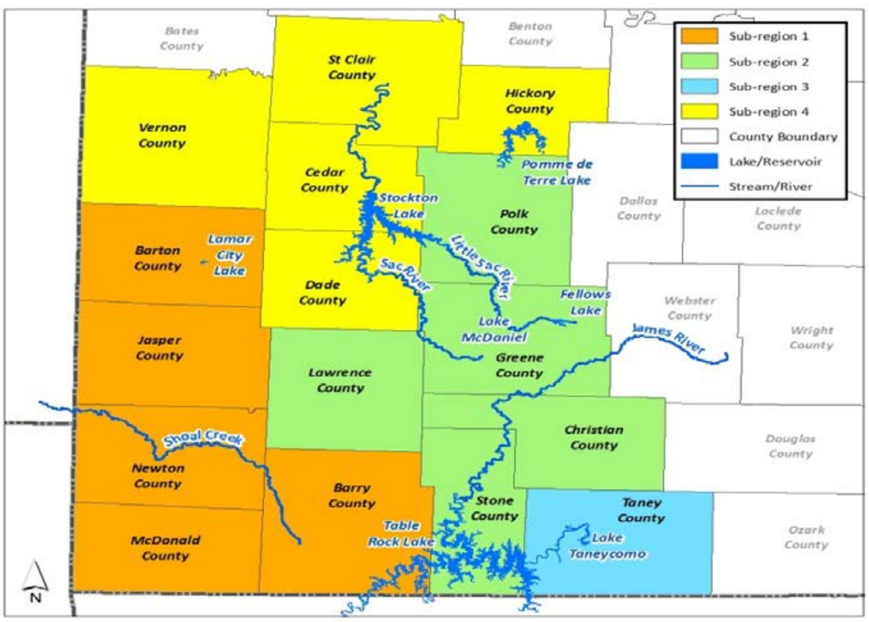

Figure 3: Sub-regions of Southwest Missouri for the Purpose of Gap Analysis

The sub-region gap evaluations allowed a comparison of forecasted demands by county to the supply availability, particularly groundwater, as modeled by USGS for sub-regions 1 and 2. These comparisons include the water use sectors of public supply, self-supplied residential, and self-supplied industrial (as applied by USGS studies). There was little to no gap in supply projected for sub-regions 3 and 4; thus, greater emphasis was placed on the gap projected for sub-regions 1 and 2. The groundwater withdrawal assumptions for sub-regions 1 and 2 for the three drought scenarios 3, 4, and 5 are as follows:

- **Sub-region 1**
  - **Scenario 3** applies a groundwater threshold of 27 mgd.
  - **Scenario 4** applies the Wittman Hydro Planning Associates (WHPA) study "best fit" yield of 8 mgd believing this amount is the most likely sustainable scenario without increasing the cone of depression and furthering the unconfined reaches of the Ozark Aquifer.

- **Scenario 5** maintains the Scenario 3 groundwater threshold of 27 mgd. Scenario 5 was not adjusted for sub-region 1, as there were no stakeholder concerns with the assumed groundwater and surface water maximum withdrawals. Groundwater withdrawals were determined from published studies within the sub-regional area of analysis and surface water withdrawals were based on USGS reported Shoal Creek flows during average and drought years.

- **Sub-region 2**
  - **Scenario 3** applies a groundwater threshold of 56 mgd.
  - **Scenario 4** applies a groundwater threshold of 16 MGD to allow aquifer recharge.
  - **Scenario 5** applies the USGS study 2006 withdrawal amount held constant at 32 mgd.

Thus, the lower groundwater withdrawal threshold of Scenario 4 increases the amount needed to be met by surface water during drought and thus, increases the gap in surface water supply over that of Scenarios 3 and 5.

The most immediate need identified was in sub-region 1, where during an extended drought (i.e., Scenarios 3, 4, and 5) there is neither sufficient flow nor storage in Shoal Creek to meet base flow requirements and sub-regional demands. This was observed during the drought of 2012, and based on drought of record conditions, the gap in supply and demand is estimated to be 19 mgd in August of 2020 and could potentially grow to over 50 mgd in August of 2060. Gaps in supply are also projected in sub-region 2 under extended drought conditions (i.e., Scenarios 3, 4, and 5) and may occur in the summer months as early as 2020. Tables 4 and 5 reflect these respective sub-regional gaps during drought.

REALLOCATION CALCULATION (Stockton Reallocation Study & Phase III)

One of the supply alternatives for the 16-county region is a reallocation for water supply from Stockton Lake. Springfield City Utilities has an existing 50,000 acre-feet (30 mgd) allocation from Stockton Lake. For the purposes of a reallocation request, per the example provided by City Utilities reallocation from Stockton, the average annual daily gap by forecast year was calculated by weighting the monthly gap by the number of days in each month as shown in the following equation:

$$\boldsymbol{Average\ Annual\ Daily\ Gap} = (W_{Jan} * D_{Jan} + W_{Feb} * D_{Feb} \ldots + W_{Dec} * D_{Dec})/365$$

Where: *W = Average Daily Gap, by Month*
D = Number of Days in each month

For example, as shown in Table 4 (below), in Sub-region 1, Scenario 3 in 2060 the following calculation was completed:

Average Annual Daily Gap =
*[(21*31)+(20*28)+(24*31)+(26*30)+(0*31)+(17*30)+(44*31)+(54*31)+(47*30)+(30*31)+(24*30)+(20*31)]/365 = 27*

The results of this calculation are shown in the red highlighted columns of Tables 4 and 5. Table 6 is a summary of average daily gap by forecast year for both sub-regions 1 and 2 reflecting Scenarios 3, 4, and 5 defined above.

Table 4: Sub-region 1. Average Daily Gap by Forecast Year (MGD)

Sub-Region 1	Scenario 3												MGD
Forecast Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2020	-	-	-	-	-	-	10	19	12	0	-	-	3
2030	-	-	0	2	-	-	15	24	17	5	1	-	5
2040	5	4	7	9	-	-	24	33	26	12	8	4	11
2050	13	12	15	17	-	7	33	43	36	20	16	11	19
2060	21	20	24	26	-	17	44	54	47	30	24	20	27

Sub-Region 1	Scenario 4												MGD
Forecast Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2020	13	12	15	17	-	4	29	38	30	19	15	11	17
2030	17	16	19	21	-	9	34	43	36	24	20	16	21
2040	24	23	26	28	-	17	43	52	45	31	27	23	28
2050	32	31	34	36	-	26	52	62	55	39	35	30	36
2060	40	39	43	45	-	36	63	73	66	49	43	39	45

	Scenario 5												MGD
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2020	-	-	-	-	-	-	10	19	12	0	-	-	3
2030	-	-	0	2	-	-	15	24	17	5	1	-	5
2040	5	4	7	9	-	-	24	33	26	12	8	4	11
2050	13	12	15	17	-	7	33	43	36	20	16	11	19
2060	21	20	24	26	-	17	44	54	47	30	24	20	27

Table 5: Sub-region 2. Average Daily Gap by Forecast Year (MGD)

Sub-Region 2	Scenario 3												MGD
Forecast Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2020	-	-	-	-	-	-	-	-	-	-	-	-	-
2030	-	-	-	-	-	-	-	-	-	-	-	-	-
2040	-	-	-	-	-	-	-	-	4	-	-	-	0.3
2050	-	-	-	-	-	-	-	9	17	-	-	-	2.2
2060	-	-	-	-	-	5	7	24	33	-	-	-	5.8

Sub-Region 2	Scenario 4												MGD
Forecast Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2020	-	-	-	-	-	-	-	7	18	-	-	-	2
2030	-	-	1	2	4	8	8	21	31	6	7	1	7
2040	4	9	11	12	14	20	20	34	44	16	16	11	18
2050	15	20	21	23	26	32	33	49	57	28	27	21	29
2060	26	32	33	35	38	45	47	64	73	40	39	32	42

	Scenario 5												MGD
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2020	-	-	-	-	-	-	-	-	2	-	-	-	0
2030	-	-	-	-	-	-	-	5	15	-	-	-	2
2040	-	-	-	-	-	4	4	18	28	-	-	-	4
2050	-	4	5	7	10	16	17	33	41	12	11	5	13
2060	10	16	17	19	22	29	31	48	57	24	23	16	26

Table 6: Sub-regions 1 and 2. Average Daily Gap by Forecast Year (MGD)

	Sub-Region 1			Sub-Region 2			Total		
Year	Scenario 3	Scenario 4	Scenario 5*	Scenario 3	Scenario 4	Scenario 5	Scenario 3	Scenario 4	Scenario 5
2020	3	17	3	-	2	0	3	19	4
2030	5	21	5	-	7	2	5	28	7
2040	11	28	11	0	18	4	11	46	16
2050	19	36	19	2	29	13	21	65	32
2060	27	45	27	6	42	26	33	87	53

Highlighted quantities are summarized in Table 1.

A summary of all phases of study is shown in Table 1 of the Introduction.

Next Steps

In addition to Stockton Lake, other Corps reservoirs may be considered for reallocations including Pomme de Terre Lake and Table Rock Lake. The Corps will explore whether one or a combination of Corps reservoirs are needed to meet the future supply gap. The future supply gap can be evaluated and reviewed as new data may become available and other potential reallocations are considered to insure the future supply gap is adequate to cover the needs of Southwest Missouri. The study team may incorporate a contingency on the gap to include risk and uncertainty and compare results with stakeholder projections. Current considerations and evaluations are of the various constraints on the reallocation request(s) that include, but are not limited to authorized purpose(s), environmental impacts and costs. Other alternatives such as a new reservoir and groundwater well fields are also being considered at this time. The entire Stockton reallocation study process is expected to be completed by the end of 2018.