# MEMORANDUM

**TO:** SRBA

**FROM:** Jon Albright and Spencer Schnier

**SUBJECT:** Revised Patman and Nichols Yield Modeling

**DATE:** October 20, 2015

**PROJECT:** Sulphur River Basin Feasibility Study
SBG15119

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## Introduction

This portion of the Sulphur Basin Feasibility Study was designed to refine the combinations of the proposed Marvin Nichols Reservoir and Lake Wright Patman Reallocation that meet a supply goal of 604,000 acre-feet per year. The supply goal of 604,000 acre-feet per year includes 584,000 acre-feet per year for the Dallas-Fort Worth Metroplex and 20,000 acre-feet per year for in-basin needs. The supply goals were set by the Joint Committee for Program Development (JCPD), which provides input to the Feasibility Study and are based on needs established for Region C water providers in the State Water Planning process and estimates of future water supply needs within the Sulphur River Basin developed by SRBA as part of the USACE Feasibility study. This yield target reflects estimated actual future water supply gaps and is unrelated to the 80/20 project share reflected in the current Advanced Funding Agreement.

Based on previous modeling, it had been determined that the supply goal could be met using a combination of the small and medium versions of Marvin Nichols Reservoir and Lake Patman reallocation (between 296.5 and 313.5 feet at Nichols and between 232.5 and 242.5 feet at Patman). However, it was determined in this study that the supply goal could not be met by projects of this size. The factors that lead to this determination are discussed in this memorandum. At the maximum elevations for each project (313.5 feet at Nichols and 242.5 feet at Patman), the yield is only 458,722 acre-feet per year, which is more than 145,000 acre-feet per year short of the supply goal. As a result, larger versions of these projects were considered that did meet the supply goals.

The modeling used in this study is different than previous yield analyses performed as part of the Feasibility Study. Previous yields were based on the Texas Commission on Environmental Quality's Sulphur Basin Water Availability Model (Sulphur WAM). In this study, we used a RiverWare model (USACE Model) developed by the U.S. Army Corps of Engineers, modified to mimic the priority assumptions used in the Sulphur WAM. The hydrology used in the Sulphur WAM ends in 1996 and does not include recent droughts which have

significantly impacted the firm yields of the proposed projects. The USACE Model has hydrology through 2014, which includes the recent drought. In addition to the extended hydrology, the USACE Model was also modified to include environmental flow releases using the Lyons method. Previous Feasibility Study modeling did not explicitly model environmental flow releases – instead, environmental flows were assumed to reduce project yields by 10 to 20 percent. The USACE Model also has a minimum release of 96 cfs from May through October with a 10 cfs release during the remainder of the year. This is based on current operation of Lake Patman. Previous studies only assumed a constant 10 cfs release from the reservoir.

The main body of this memorandum presents a summary of the results. Attachment 1 contains more detailed information regarding the modeling approach used in this study, and Attachment 2 has more information on the results of the modeling.

# Results

Table 1 and Figure 1 show the combinations of Marvin Nichols Reservoir and Lake Wright Patman reallocation that meet the 604,000 acre-feet per year supply goal. These yields have the following assumptions:

- The yields represents “new” supplies and do not include the 180,000 acre-feet per year water right held by Texarkana in Lake Wright Patman.
- Priority releases from upstream reservoirs and Marvin Nichols for the existing Lake Wright Patman water right. Marvin Nichols does not, however, make priority releases for the new storage and diversions associated with the Patman reallocation.
- Environmental flow releases based on the Lyons method.
- A 96 cfs release from Lake Wright Patman from May to October, with a 10 cfs release at other times of the year.

Using these assumptions, with Marvin Nichols at elevation 328 feet (the largest version of Nichols), the minimum reallocation elevation for Lake Wright Patman that meets the supply goal is 241.5 feet. At the largest version of Patman reallocation (elevation 252.5 feet), the minimum conservation elevation for Marvin Nichols required to meet the demand goal is around 315 feet. More information on project yields may be found in Attachment 2.

**Table 1: Combinations of Wright Patman Reallocation and the Proposed Marvin Nichols Reservoir that Meet Supply Goal**

| **Patman Reallocation Elevation** (feet) | **Nichols Elevation** (feet) |
|---|---|
| 252.5 | 314.8 |
| 250.5 | 318.1 |
| 249.0 | 319.8 |
| 247.5 | 321.6 |
| 246.0 | 323.3 |
| 244.5 | 324.2 |
| 242.5 | 326.4 |
| 241.5 | 328.0 |

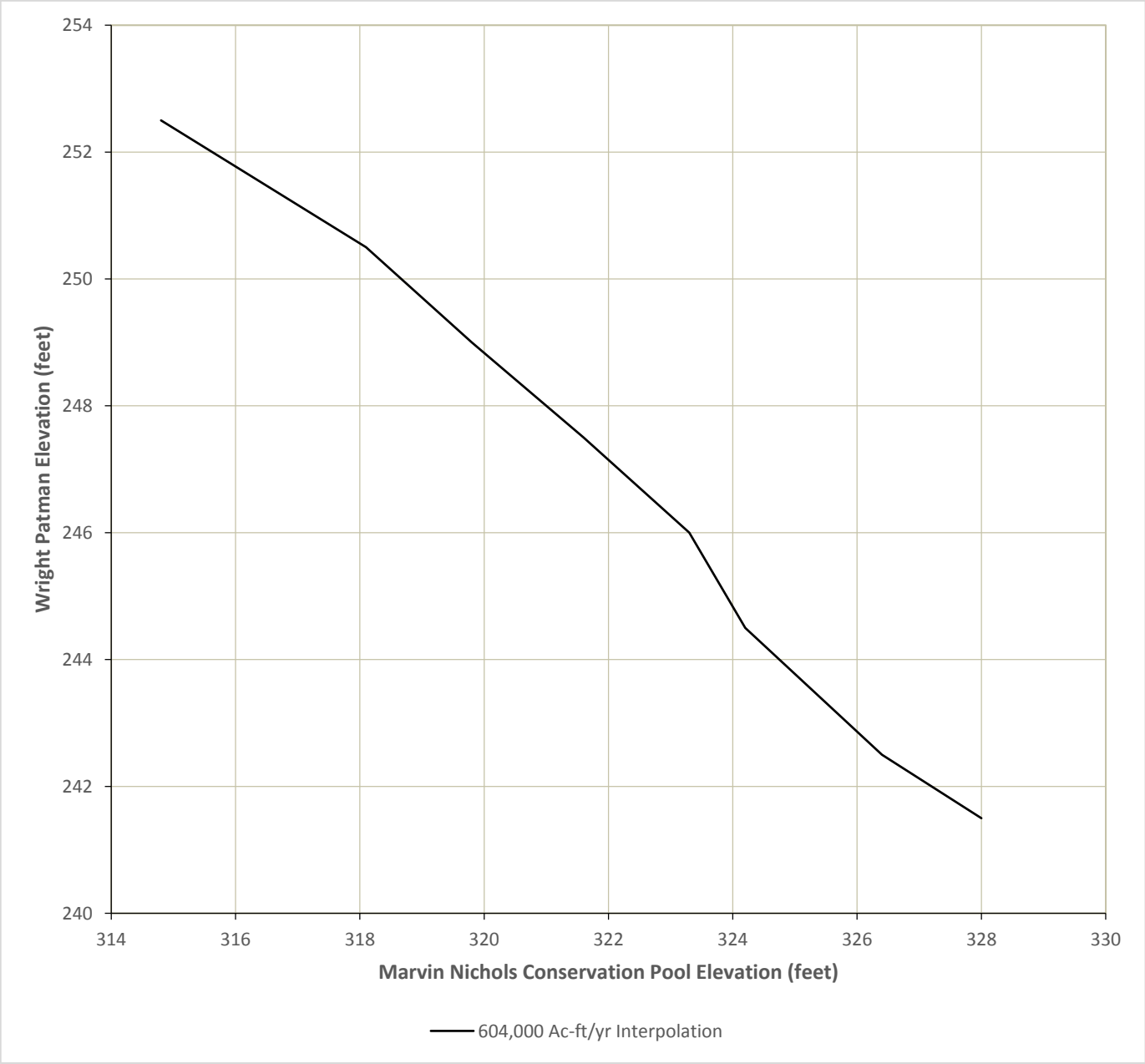


**Figure 1: Combinations of Wright Patman Reallocation and the Proposed Marvin Nichols Reservoir that Meet Supply Goal**

# Impact of Assumptions on Yields

The yields in this study are substantially less than the yields that were determined in previous studies. In order to determine the source of the changes, we performed a forensic analysis turning on and off various modeling assumptions in order to quantify the sources of the changes. Although some of the difference in yield is due to different modeling platforms (the Sulphur WAM vs the USACE RiverWare Model), the most significant differences are:

- The new drought of record, which was not included in the previous modeling. The new drought reduces yields by about 210,000 acre-feet per year.
- The application of environmental flows, which were not explicitly modeled in previous studies. The impact of environmental flows on yield was assumed to be between 10 and 20 percent. Environmental flows reduce the yield by about 105,000 acre-feet per year.
- Differences in current Patman release policies. Previous studies assumed a constant 10 cfs release, which is incorporated into the USACE contract with the City of Texarkana. The current modeling has an additional 86 cfs release for the months of May through October, which is based on current USACE policy incorporated into the USACE Model. The additional May through October release of 86 cfs reduces yields by about 30,000 acre-feet per year.

The blue bars in Figure 2 show the annual inflows into Lake Wright Patman. A four-point moving average has been added to show trends in the data. Note that the years with the lowest consecutive inflows occur between 2003 and 2006, corresponding to an apparent new drought of record for the reservoir. The next lowest years are between 2011 and 2014. These two periods are much lower than any other four-year period, including the drought of the 1950s. Figure 3 shows the modeled storage trace for Marvin Nichols Reservoir assuming a maximum elevation of 313.5 feet. The worst drought in this simulation begins in April 2003 with a minimum storage at the end of 2006. The reservoir is also very low in the 2013-2014 time frame. Note that there is almost 300,000 acre-feet of water in storage at the lowest point in the 1950s drought and over 240,000 acre-feet of water in storage in the late 1970s drought. These two graphs indicate the severity of the two recent droughts, which are much worse than previous record droughts.

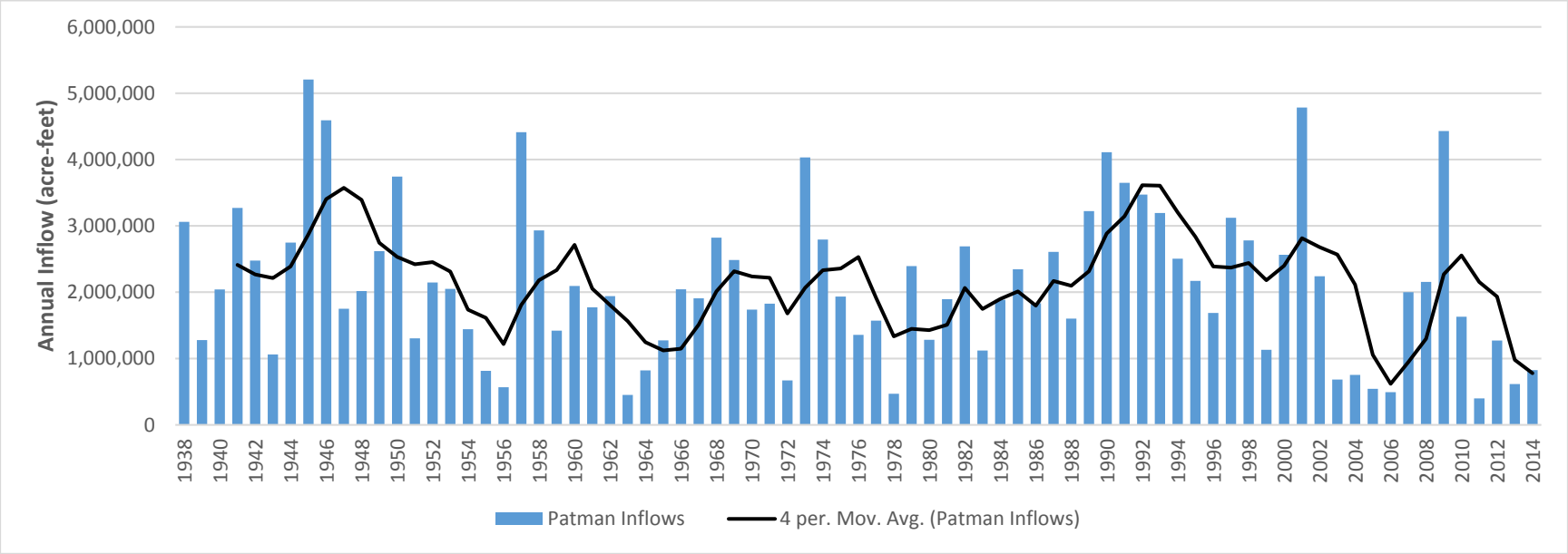


**Figure 2: Annual Modeled Inflows for Lake Wright Patman**

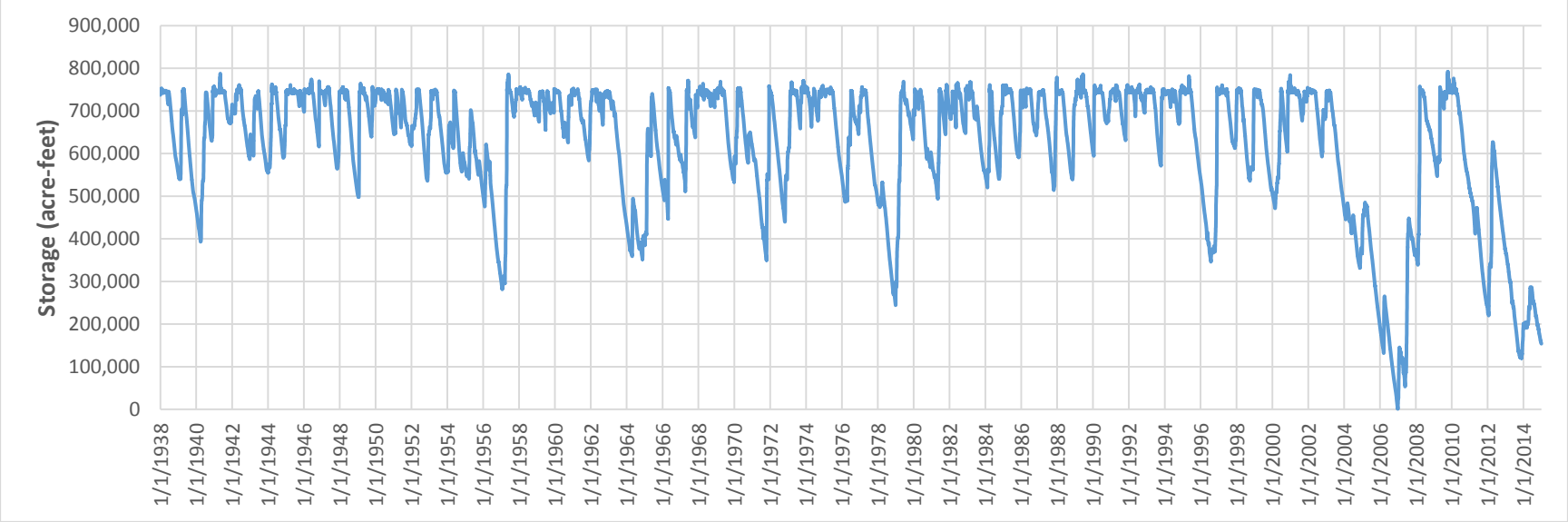


**Figure 3: Storage Trace for Marvin Nichols Reservoir – Elevation 313.5 feet**

The apparent new drought of record has the most significant impact on yield. This impact is a reflection of real-world conditions and should be explicitly considered in the plan selection process. The other impacts, environmental flows and Patman release policies, are potentially open to negotiation and the impacts could possibly be reduced. We examined three factors that could potentially be modified to reduce impacts on yields:

- Operating the two reservoirs as a system by not passing water from Marvin Nichols for Lake Patman's senior water right. This assumption increases yields between 4,000 and 15,000 acre-feet per year, depending on assumptions. The larger increase in yield occurs when the Patman reallocation is small and Nichols is large.

- Using only a 10 cfs constant release from Lake Patman instead of increasing the release to 96 cfs from May to October. This assumption increases yields by about 30,000 acre-feet per year.

- Using an alternative Lyons method environmental release from Lake Patman. (The environmental release is only applied to the portions of the supply from Lake Patman associated with the reallocation). Previous work had based the environmental release on historical outflows from the reservoir. The Lyons environmental releases based on historical outflows reserve up to 547,775 acre-feet per year. If the inflows into the reservoir are used instead, the Lyons releases are substantially less, reserving up to 329,956 acre-feet per year. This change increases the yield of the two reservoirs by about 20,000 acre-feet per year.

Combined these three assumptions could increase yields by up to 70,000 acre-feet per year. However this is not sufficient to make up the deficit of 145,000 acre-feet per year with the two medium sized projects (Nichols at 313.5 feet and Patman at 242.5 feet). With all of these changes applied, the minimum elevation for reallocation at Lake Patman is 237.5 feet, assuming that Nichols is at its maximum elevation (328 feet). More information on project yields may be found in Attachment 2.

# Summary and Conclusions

- The apparent new drought of record in the Sulphur Basin has substantially reduced the firm yields of the proposed Marvin Nichols Reservoir and Lake Wright Patman reallocation. The reduction in yield indicates that these two projects need to be built at larger than anticipated capacities in order to meet the supply goal of 604,000 acre-feet per year from the two projects.

- Table 1 shows the configurations of Lake Wright Patman reallocation and Marvin Nichols Reservoir that meet the supply goals of 604,000 acre-feet per year. Using the assumptions originally developed for this study, the smallest Lake Patman reallocation that meets the supply goal is 241.5 feet. This assumes that Marvin Nichols is built at its maximum capacity of 328 feet.

- Significant changes to the modeling assumptions regarding Lake Patman environmental flows and release policies could reduce the maximum elevation needed for Patman reallocation. Additional studies may be needed to examine the implications of reduced Patman release policies.

# Attachment 1 Modeling Approach

The model used in this study to determine combined firm yields of Lake Wright Patman reallocation and the proposed Marvin Nichols Reservoir was developed with the following assumptions:

- Historical hydrology through 2014 so that the impact of recent droughts on yield can be determined
- Releases from upstream reservoirs (Ralph Hall, Chapman and Marvin Nichols) for the senior portions of Lake Patman's water right
- Marvin Nichols modeled at a priority that is senior to the reallocation of Lake Patman (i.e. Marvin Nichols passes water to Patman's senior right but not to the new diversion and storage rights associated with the reallocation)
- Environmental flows for the new water rights (Nichols and the Patman reallocation)

These modeling assumptions can be turned on and off to determine the impact of each assumption on yield. Each of these assumptions is discussed in more detail below.

The primary model used for the current study is an updated RiverWare model developed by the Fort Worth District of the U.S. Army Corps of Engineers (USACE), referred to in this memorandum as the USACE RiverWare Model. This model was delivered to SBG on March 6, 2015. The model contained two major updates:

1) Extended the hydrology through 12/31/2014
2) Removed precipitation on the reservoir surface from the inflows into reservoirs

SBG then made two additional modifications to the USACE RiverWare Model:

1) Inclusion of the priority operations of the reservoirs
2) Inclusion of environmental flow requirements previously determined for these reservoirs using the Lyons method

In addition to the USACE RiverWare Model, this study used data from three other models:

1. The FNI Sulphur Water Availability Model (FNI Sulphur WAM), developed in previous studies
2. A condensed version of the FNI Sulphur WAM that includes only the features in the USACE RiverWare Model and
3. The SBG SB WRAP Model, which is similar to the condensed FNI Sulphur WAM but uses hydrology from the USACE RiverWare Model.

Each of these models and how they were used are described in more detail below.

Although the FNI Sulphur WAM would be an appropriate model to use to determine available yield under Texas water law, it was not used for the following reasons:

- The hydrology for the WAM is only available through 1996 and therefore does not include recent drought-of-record conditions. Hydrology for the WAM could not be updated in the time frame required by the current study.
- The WAM uses a monthly time step while the USACE RiverWare Model uses a daily time step. The USACE prefers a daily time step for environmental and other evaluations.
- The WAM does not include flood operation of USACE reservoirs, which is important in determining the yield of Lake Patman. Lake Patman can have a very short critical drought period, and the amount of water in flood storage at the beginning of the drought has an impact on the yield of the reservoir.

## Description of Parent Models: USACE RiverWare Model and FNI WAM

RiverWare is a generalized river-reservoir modeling system developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado, Boulder. The USACE RiverWare Model was developed by the U.S. Army Corps of Engineers (USACE) Fort Worth District and includes the Sulphur River Basin, the Cypress Basin and the main stem of the Red River from the Red River at Fulton gage (USGS 07341500) to the Red River at Shreveport gage (USGS 07348500). The model is based on a larger model of the Red River Basin that was developed primarily to simulate flood control operations. Figure 1-1 shows the Sulphur Basin portion of the USACE RiverWare Model. Reservoirs in the model include Lake Ralph Hall, Lake Chapman (labeled as Cooper), the proposed Marvin Nichols reservoir (labeled MCN1a), and Lake Patman. The round circles are control points that correspond either to USGS stream gages or locations of proposed projects.

The Sulphur River Basin Water Availability Model (WAM) was developed by the Texas Commission on Environmental Quality (TCEQ) primarily to evaluate water rights applications. The model is an application of the Water Rights Analysis Package (WRAP), developed by Dr. Ralph Wurbs of Texas A&M University. The TCEQ WAM was subsequently modified by Freese and Nichols for the Sulphur River Basin Feasibility Study (FNI WAM).

Both the USACE RiverWare Model and the FNI WAM have been verified and used in previous phases of the Feasibility Study. More information on the models can be found in the August 26, 2014 *Technical Memorandum on Hydrologic Yields*.

## Revised USACE Hydrology

Tables 1-1, 1-3, 1-5 and 1-7 are monthly and annual summaries of the new inflows included in the USACE RiverWare model. (Other tables in this section include the portion of the flows that is passed for downstream senior water rights, which is discussed later in this document.) The hydrology of the USACE RiverWare Model used in the Hydrologic Yield study included precipitation on the reservoir surface as part of the inflow into reservoirs. This assumption is fine for studies that use existing storage. However, as described in the Hydrologic Yields memorandum, this approach underestimates the yield available from the reallocation of Lake Wright Patman due to the signifiant increase in surface area associated with the reallocation. To address this issue, the USACE revised the inflows for all reservoirs.

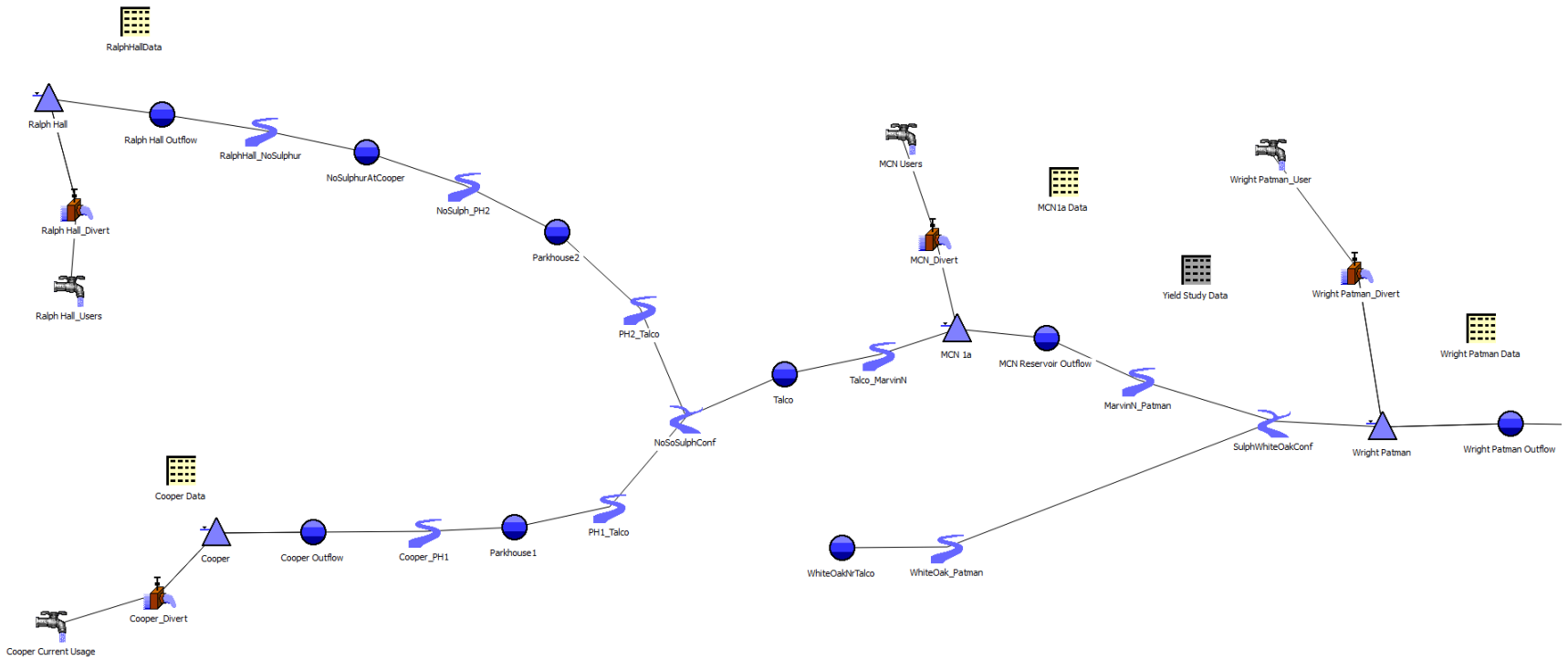


**Figure 1-1: Sulphur River Basin Portion of the USACE RiverWare Model**

**Table 1-1: Monthly Lake Ralph Hall Inflow**
(Values in acre-feet per month)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1938 | 40,201 | 20,249 | 4,170 | 28,110 | 348 | 5,257 | 261 | 157 | 38 | 2 | 207 | 20 | 99,020 |
| 1939 | 1,231 | 11,295 | 10,554 | 16,919 | 454 | 678 | 261 | 2 | 0 | 0 | 0 | 34 | 41,428 |
| 1940 | 12 | 429 | 415 | 11,354 | 10,308 | 10,524 | 9,454 | 40 | 153 | 17 | 7,368 | 17,707 | 67,781 |
| 1941 | 8,386 | 6,118 | 13,849 | 10,110 | 30,489 | 19,024 | 6,724 | 609 | 200 | 976 | 2,576 | 5,845 | 104,906 |
| 1942 | 930 | 2,418 | 6,456 | 39,296 | 18,578 | 7,133 | 273 | 118 | 494 | 53 | 534 | 1,966 | 78,249 |
| 1943 | 4,660 | 694 | 10,785 | 4,717 | 831 | 8,862 | 318 | 26 | 48 | 343 | 205 | 935 | 32,424 |
| 1944 | 2,935 | 7,223 | 21,007 | 6,938 | 29,688 | 7,683 | 105 | 94 | 845 | 20 | 2,156 | 8,344 | 87,038 |
| 1945 | 12,316 | 17,844 | 46,380 | 45,889 | 4,023 | 20,581 | 4,619 | 307 | 114 | 13,603 | 1,112 | 201 | 166,989 |
| 1946 | 16,012 | 28,572 | 6,488 | 7,720 | 28,582 | 17,184 | 295 | 227 | 387 | 88 | 27,895 | 11,043 | 144,493 |
| 1947 | 4,220 | 551 | 7,147 | 8,649 | 15,260 | 608 | 32 | 65 | 199 | 25 | 2,904 | 16,364 | 56,024 |
| 1948 | 9,711 | 12,318 | 13,669 | 2,490 | 22,923 | 985 | 444 | 153 | 20 | 27 | 70 | 92 | 62,902 |
| 1949 | 14,046 | 16,048 | 14,339 | 5,701 | 6,896 | 2,186 | 484 | 257 | 201 | 2,494 | 28 | 1,291 | 63,971 |
| 1950 | 26,666 | 30,475 | 532 | 969 | 23,929 | 1,416 | 7,457 | 817 | 12,639 | 126 | 37 | 60 | 105,123 |
| 1951 | 107 | 11,589 | 303 | 900 | 2,706 | 37,960 | 752 | 13 | 132 | 1,244 | 217 | 26 | 55,949 |
| 1952 | 91 | 89 | 3,435 | 26,355 | 4,390 | 1,344 | 11 | 0 | 0 | 0 | 3,815 | 1,582 | 41,112 |
| 1953 | 1,228 | 213 | 6,057 | 24,730 | 8,359 | 15 | 3,686 | 534 | 197 | 193 | 1,652 | 4,605 | 51,469 |
| 1954 | 6,981 | 3,683 | 101 | 2,838 | 19,379 | 1,545 | 0 | 0 | 3 | 12,826 | 1,164 | 204 | 48,724 |
| 1955 | 541 | 2,413 | 7,921 | 6,267 | 1,904 | 253 | 2,678 | 665 | 264 | 667 | 0 | 0 | 23,573 |
| 1956 | 120 | 14,482 | 231 | 967 | 5,943 | 170 | 0 | 0 | 0 | 9 | 800 | 138 | 22,860 |
| 1957 | 386 | 943 | 7,486 | 53,361 | 54,171 | 18,801 | 180 | 1,424 | 7,103 | 2,020 | 30,950 | 2,977 | 179,802 |
| 1958 | 7,638 | 560 | 12,648 | 20,933 | 25,907 | 12,409 | 748 | 28 | 164 | 20 | 120 | 126 | 81,301 |
| 1959 | 92 | 652 | 928 | 80 | 133 | 9,816 | 13,133 | 1,518 | 1,456 | 3,984 | 1,726 | 15,103 | 48,621 |
| 1960 | 9,863 | 5,412 | 5,154 | 820 | 2,665 | 6,570 | 2,142 | 2,053 | 4,139 | 8,835 | 229 | 32,984 | 80,866 |
| 1961 | 6,695 | 3,873 | 14,151 | 1,790 | 1,298 | 597 | 440 | 79 | 993 | 11 | 2,828 | 6,650 | 39,405 |
| 1962 | 5,178 | 2,163 | 3,708 | 4,913 | 1,032 | 12,393 | 1,097 | 96 | 10,927 | 5,418 | 18,056 | 875 | 65,856 |
| 1963 | 2,309 | 194 | 1,736 | 3,216 | 531 | 104 | 890 | 8 | 0 | 0 | 1 | 9 | 8,998 |
| 1964 | 4 | 62 | 3,969 | 7,328 | 5,303 | 5,850 | 9 | 8 | 6,905 | 35 | 6,947 | 713 | 37,133 |
| 1965 | 3,653 | 20,833 | 1,237 | 318 | 12,771 | 497 | 5 | 17 | 1,735 | 2 | 67 | 17 | 41,152 |
| 1966 | 32 | 2,690 | 199 | 66,420 | 8,414 | 201 | 25 | 1,850 | 1,710 | 581 | 27 | 266 | 82,415 |
| 1967 | 87 | 183 | 1,702 | 20,489 | 25,452 | 4,631 | 1,121 | 35 | 7,289 | 6,591 | 1,027 | 11,480 | 80,087 |
| 1968 | 6,351 | 4,800 | 27,819 | 13,832 | 20,136 | 18,837 | 8,763 | 775 | 10,984 | 2,298 | 7,296 | 8,768 | 130,659 |
| 1969 | 16,288 | 7,820 | 13,309 | 3,187 | 29,515 | 1,056 | 39 | 13 | 19 | 2,315 | 136 | 8,184 | 81,881 |
| 1970 | 1,121 | 21,831 | 19,926 | 15,391 | 1,903 | 171 | 5 | 0 | 4,350 | 9,347 | 3,032 | 988 | 78,065 |
| 1971 | 820 | 2,559 | 1,228 | 266 | 864 | 27 | 962 | 3,636 | 828 | 40,587 | 1,532 | 24,901 | 78,210 |
| 1972 | 1,283 | 365 | 394 | 65 | 55 | 114 | 18 | 128 | 5 | 6,322 | 6,683 | 2,267 | 17,699 |
| 1973 | 5,949 | 7,373 | 18,743 | 17,034 | 3,570 | 6,269 | 233 | 67 | 12,868 | 28,074 | 19,579 | 6,411 | 126,170 |
| 1974 | 7,375 | 1,006 | 553 | 6,170 | 3,879 | 18,356 | 37 | 147 | 8,739 | 11,323 | 17,670 | 5,757 | 81,012 |
| 1975 | 6,278 | 22,623 | 6,405 | 5,175 | 12,708 | 11,944 | 1,328 | 55 | 43 | 3 | 15 | 40 | 66,617 |
| 1976 | 19 | 17 | 1,100 | 4,017 | 2,649 | 11,270 | 19,841 | 252 | 300 | 3,061 | 352 | 3,229 | 46,107 |
| 1977 | 2,518 | 6,842 | 15,999 | 4,779 | 245 | 1,144 | 27 | 59 | 5 | 2 | 743 | 214 | 32,577 |
| 1978 | 641 | 4,116 | 3,041 | 526 | 1,420 | 2,527 | 0 | 0 | 0 | 0 | 5,528 | 5,322 | 23,121 |
| 1979 | 10,177 | 8,460 | 16,730 | 3,336 | 15,428 | 5,269 | 1,407 | 1,758 | 47 | 331 | 121 | 4,224 | 67,288 |
| 1980 | 1,800 | 3,088 | 249 | 469 | 2,763 | 21 | 0 | 0 | 6,882 | 1,007 | 100 | 4,554 | 20,933 |
| 1981 | 135 | 259 | 4,238 | 684 | 8,402 | 28,300 | 1,119 | 40 | 955 | 32,005 | 11,996 | 496 | 88,629 |
| 1982 | 2,778 | 5,727 | 2,753 | 3,970 | 56,000 | 9,493 | 3,141 | 637 | 122 | 210 | 2,490 | 7,202 | 94,523 |
| 1983 | 718 | 19,636 | 9,513 | 634 | 3,004 | 1,837 | 5,564 | 13 | 26 | 79 | 347 | 155 | 41,526 |
| 1984 | 247 | 12,000 | 12,379 | 3,437 | 9,018 | 53 | 1 | 0 | 0 | 3,975 | 3,866 | 13,659 | 58,635 |
| 1985 | 4,569 | 6,013 | 19,182 | 10,850 | 12,009 | 2,201 | 216 | 1 | 0 | 2,927 | 9,911 | 6,905 | 74,784 |
| 1986 | 242 | 7,719 | 647 | 10,219 | 6,878 | 8,293 | 2,897 | 0 | 1,313 | 2,658 | 18,713 | 5,782 | 65,361 |
| 1987 | 6,559 | 10,853 | 11,459 | 190 | 2,265 | 1,207 | 2,222 | 99 | 11,735 | 5,163 | 24,661 | 22,673 | 99,086 |
| 1988 | 5,794 | 4,835 | 6,940 | 4,182 | 134 | 6 | 1,230 | 5 | 357 | 943 | 3,581 | 3,111 | 31,118 |
| 1989 | 4,410 | 24,834 | 12,354 | 1,979 | 20,198 | 39,444 | 9,515 | 401 | 1,781 | 43 | 38 | 99 | 115,096 |
| 1990 | 11,616 | 17,773 | 22,788 | 14,476 | 31,718 | 5,259 | 274 | 235 | 154 | 3,783 | 3,376 | 4,077 | 115,529 |
| 1991 | 16,362 | 4,881 | 2,936 | 15,630 | 4,268 | 6,093 | 74 | 315 | 428 | 21,998 | 5,234 | 34,743 | 112,962 |
| 1992 | 14,025 | 5,824 | 17,101 | 1,102 | 13,685 | 20,370 | 5,054 | 1,277 | 125 | 18 | 808 | 10,785 | 90,174 |
| 1993 | 4,684 | 21,366 | 11,940 | 10,337 | 4,617 | 2,731 | 31 | 3 | 18 | 17,248 | 6,336 | 19,257 | 98,568 |
| 1994 | 690 | 5,950 | 16,115 | 5,142 | 23,083 | 4,854 | 11,351 | 1,325 | 240 | 2,092 | 22,876 | 9,843 | 103,561 |

**Table 1-1 (continued)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 8,489 | 740 | 9,167 | 10,618 | 30,462 | 3,038 | 388 | 11 | 1,182 | 37 | 104 | 85 | 64,321 |
| 1996 | 692 | 83 | 362 | 333 | 961 | 2,129 | 1,126 | 2,914 | 500 | 4,470 | 25,284 | 4,623 | 43,477 |
| 1997 | 947 | 24,800 | 10,821 | 16,160 | 470 | 2,719 | 51 | 77 | 3 | 1,020 | 547 | 15,712 | 73,327 |
| 1998 | 22,290 | 6,893 | 15,504 | 959 | 138 | 23 | 0 | 0 | 3,005 | 6,397 | 9,987 | 25,820 | 91,016 |
| 1999 | 13,955 | 2,568 | 3,524 | 3,967 | 3,692 | 1,825 | 284 | 0 | 44 | 0 | 211 | 5,042 | 35,112 |
| 2000 | 223 | 1,202 | 6,798 | 3,764 | 12,797 | 16,701 | 684 | 0 | 0 | 32 | 26,346 | 23,700 | 92,247 |
| 2001 | 13,843 | 43,123 | 24,215 | 3,997 | 3,465 | 602 | 104 | 3,753 | 3,737 | 7,014 | 2,170 | 38,504 | 144,527 |
| 2002 | 17,482 | 13,652 | 38,602 | 17,060 | 5,407 | 108 | 1,017 | 1,947 | 802 | 32,560 | 2,906 | 16,687 | 148,230 |
| 2003 | 3,079 | 12,199 | 3,797 | 142 | 2,513 | 5,593 | 177 | 23 | 511 | 24 | 730 | 117 | 28,905 |
| 2004 | 2,832 | 8,395 | 4,764 | 949 | 1,586 | 3,574 | 297 | 13 | 5 | 236 | 16,103 | 4,809 | 43,563 |
| 2005 | 25,442 | 5,966 | 4,486 | 2,576 | 100 | 7 | 6 | 0 | 0 | 0 | 0 | 0 | 38,583 |
| 2006 | 5 | 398 | 15,250 | 290 | 3 | 0 | 0 | 0 | 0 | 344 | 480 | 3,945 | 20,715 |
| 2007 | 17,564 | 110 | 1,230 | 5,381 | 14,602 | 29,678 | 34,782 | 1,226 | 1,717 | 5,955 | 215 | 5,541 | 118,001 |
| 2008 | 271 | 10,462 | 54,754 | 8,080 | 327 | 1,579 | 5 | 1 | 10 | 5 | 12 | 29 | 75,535 |
| 2009 | 47 | 38 | 3,116 | 13,703 | 32,908 | 26 | 789 | 1,586 | 10,829 | 52,847 | 5,310 | 8,545 | 129,744 |
| 2010 | 16,558 | 20,223 | 10,365 | 634 | 700 | 229 | 145 | 0 | 669 | 89 | 440 | 538 | 50,590 |
| 2011 | 407 | 723 | 104 | 3,971 | 12,687 | 93 | 2 | 0 | 0 | 0 | 9 | 1,879 | 19,875 |
| 2012 | 14,989 | 2,362 | 22,334 | 1,247 | 776 | 402 | 192 | 27 | 0 | 0 | 0 | 16 | 42,345 |
| 2013 | 768 | 543 | 959 | 689 | 5,177 | 2,748 | 42 | 1 | 0 | 76 | 647 | 3,499 | 15,149 |
| 2014 | 262 | 110 | 695 | 765 | 11,198 | 512 | 881 | 323 | 3,506 | 3,912 | 161 | 1,969 | 24,294 |
| Min | 4 | 17 | 101 | 65 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8,998 |
| Max | 40,201 | 43,123 | 54,754 | 66,420 | 56,000 | 39,444 | 34,782 | 3,753 | 12,868 | 52,847 | 30,950 | 38,504 | 179,802 |
| Median | 3,079 | 5,412 | 6,488 | 4,182 | 5,177 | 2,527 | 297 | 65 | 201 | 581 | 1,112 | 3,945 | 66,617 |

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**Table 1-2: Monthly Lake Ralph Hall Passage for Lake Wright Patman Senior Right**
(Values in acre-feet per month)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1938 | 0 | 0 | 0 | 0 | 348 | 0 | 261 | 157 | 38 | 2 | 0 | 20 | 826 |
| 1939 | 0 | 0 | 0 | 0 | 454 | 678 | 261 | 2 | 0 | 0 | 0 | 34 | 1,429 |
| 1940 | 12 | 429 | 415 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 873 |
| 1941 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1942 | 0 | 0 | 0 | 0 | 0 | 0 | 273 | 0 | 0 | 0 | 0 | 0 | 273 |
| 1943 | 0 | 0 | 0 | 0 | 831 | 0 | 318 | 26 | 48 | 0 | 0 | 0 | 1,223 |
| 1944 | 0 | 0 | 0 | 0 | 0 | 0 | 105 | 94 | 0 | 20 | 0 | 0 | 219 |
| 1945 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1946 | 0 | 0 | 0 | 0 | 0 | 0 | 295 | 227 | 0 | 0 | 0 | 0 | 522 |
| 1947 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 65 | 199 | 0 | 0 | 0 | 296 |
| 1948 | 0 | 0 | 0 | 0 | 0 | 0 | 444 | 153 | 20 | 0 | 0 | 92 | 709 |
| 1949 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1950 | 0 | 0 | 0 | 969 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 1,029 |
| 1951 | 0 | 0 | 0 | 900 | 2,706 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,606 |
| 1952 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 11 |
| 1953 | 0 | 0 | 0 | 0 | 0 | 15 | 3,604 | 104 | 0 | 0 | 0 | 0 | 3,722 |
| 1954 | 0 | 0 | 0 | 2,838 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2,841 |
| 1955 | 0 | 0 | 0 | 0 | 1,904 | 253 | 2,678 | 665 | 0 | 0 | 0 | 0 | 5,500 |
| 1956 | 120 | 0 | 0 | 967 | 5,943 | 170 | 0 | 0 | 0 | 9 | 800 | 138 | 8,147 |
| 1957 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1958 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1959 | 0 | 0 | 0 | 0 | 133 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 133 |
| 1960 | 0 | 0 | 0 | 820 | 2,665 | 6,570 | 0 | 0 | 0 | 0 | 0 | 0 | 10,055 |
| 1961 | 0 | 0 | 0 | 0 | 1,298 | 597 | 0 | 0 | 0 | 0 | 0 | 0 | 1,895 |
| 1962 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 96 | 0 | 0 | 0 | 0 | 96 |
| 1963 | 0 | 194 | 0 | 3,216 | 531 | 104 | 890 | 8 | 0 | 0 | 1 | 9 | 4,953 |
| 1964 | 4 | 62 | 0 | 0 | 0 | 0 | 9 | 8 | 0 | 0 | 0 | 0 | 83 |
| 1965 | 0 | 0 | 0 | 318 | 0 | 0 | 5 | 17 | 1,735 | 2 | 67 | 17 | 2,161 |
| 1966 | 32 | 0 | 199 | 0 | 0 | 201 | 25 | 1,850 | 0 | 0 | 0 | 0 | 2,307 |
| 1967 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 0 | 0 | 0 | 0 | 35 |
| 1968 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1969 | 0 | 0 | 0 | 0 | 0 | 0 | 39 | 13 | 19 | 2,315 | 0 | 0 | 2,386 |
| 1970 | 0 | 0 | 0 | 0 | 0 | 171 | 5 | 0 | 4,350 | 0 | 0 | 0 | 4,526 |
| 1971 | 0 | 0 | 0 | 266 | 864 | 27 | 962 | 3,636 | 828 | 0 | 0 | 0 | 6,583 |
| 1972 | 0 | 0 | 394 | 65 | 55 | 114 | 18 | 128 | 5 | 6,322 | 0 | 0 | 7,101 |
| 1973 | 0 | 0 | 0 | 0 | 0 | 0 | 233 | 67 | 0 | 0 | 0 | 0 | 300 |
| 1974 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 147 | 0 | 0 | 0 | 0 | 184 |
| 1975 | 0 | 0 | 0 | 0 | 0 | 0 | 1,328 | 55 | 0 | 3 | 15 | 40 | 1,441 |
| 1976 | 19 | 17 | 0 | 0 | 0 | 0 | 0 | 252 | 0 | 0 | 0 | 0 | 288 |
| 1977 | 0 | 0 | 0 | 0 | 245 | 1,144 | 27 | 59 | 5 | 2 | 0 | 0 | 1,482 |
| 1978 | 0 | 0 | 0 | 526 | 1,420 | 2,527 | 0 | 0 | 0 | 0 | 5,528 | 5,322 | 15,323 |
| 1979 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1980 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6,882 | 0 | 0 | 0 | 6,882 |
| 1981 | 135 | 0 | 0 | 684 | 0 | 0 | 0 | 40 | 0 | 0 | 0 | 496 | 1,355 |
| 1982 | 0 | 0 | 0 | 127 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 127 |
| 1983 | 0 | 0 | 0 | 0 | 3,004 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 3,017 |
| 1984 | 0 | 0 | 0 | 0 | 1,108 | 53 | 1 | 0 | 0 | 0 | 0 | 0 | 1,162 |
| 1985 | 0 | 0 | 0 | 0 | 0 | 0 | 216 | 1 | 0 | 0 | 0 | 0 | 217 |
| 1986 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 0 | 190 | 2,265 | 1,207 | 2,222 | 99 | 11,735 | 4,883 | 0 | 0 | 22,601 |
| 1988 | 0 | 0 | 0 | 0 | 134 | 6 | 1,230 | 5 | 357 | 943 | 0 | 0 | 2,675 |
| 1989 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 38 | 99 | 180 |
| 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 274 | 235 | 0 | 0 | 0 | 0 | 509 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 0 | 74 | 0 | 0 | 0 | 0 | 0 | 74 |
| 1992 | 0 | 0 | 0 | 1,102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,102 |
| 1993 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 3 | 0 | 0 | 0 | 0 | 34 |
| 1994 | 0 | 0 | 0 | 5,142 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5,142 |

**Table 1-2 (Continued)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 0 | 0 | 0 | 0 | 0 | 0 | 388 | 11 | 0 | 0 | 0 | 85 | 484 |
| 1996 | 692 | 83 | 362 | 333 | 961 | 2,129 | 1,126 | 0 | 0 | 0 | 0 | 0 | 5,686 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 51 | 0 | 0 | 0 | 0 | 0 | 51 |
| 1998 | 0 | 0 | 0 | 959 | 138 | 23 | 0 | 0 | 3,005 | 0 | 0 | 0 | 4,125 |
| 1999 | 0 | 0 | 0 | 0 | 0 | 0 | 284 | 0 | 44 | 0 | 211 | 0 | 539 |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2001 | 0 | 0 | 0 | 0 | 1,330 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,330 |
| 2002 | 0 | 0 | 0 | 0 | 0 | 108 | 1,017 | 1,947 | 0 | 0 | 0 | 0 | 3,072 |
| 2003 | 0 | 0 | 0 | 142 | 2,513 | 5,593 | 177 | 23 | 511 | 24 | 730 | 117 | 9,830 |
| 2004 | 2,832 | 0 | 0 | 949 | 1,586 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 5,380 |
| 2005 | 0 | 0 | 0 | 2,576 | 100 | 7 | 6 | 0 | 0 | 0 | 0 | 0 | 2,689 |
| 2006 | 5 | 398 | 0 | 290 | 3 | 0 | 0 | 0 | 0 | 344 | 480 | 3,945 | 5,465 |
| 2007 | 0 | 0 | 0 | 0 | 8,540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8,540 |
| 2008 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 |
| 2009 | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 26 |
| 2010 | 0 | 0 | 0 | 0 | 700 | 0 | 145 | 0 | 669 | 0 | 0 | 538 | 2,052 |
| 2011 | 0 | 0 | 104 | 3,971 | 0 | 93 | 2 | 0 | 0 | 0 | 9 | 1,879 | 6,058 |
| 2012 | 0 | 0 | 0 | 0 | 776 | 402 | 192 | 27 | 0 | 0 | 0 | 16 | 1,413 |
| 2013 | 768 | 543 | 959 | 689 | 5,177 | 2,748 | 42 | 1 | 0 | 0 | 0 | 0 | 10,927 |
| 2014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Min | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Max | 2,832 | 543 | 959 | 5,142 | 8,540 | 6,570 | 3,604 | 3,636 | 11,735 | 6,322 | 5,528 | 5,322 | 22,601 |
| Median | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 1,162 |

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**Table 1-3: Monthly Lake Chapman Inflow**
(Values in acre-feet per month)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1938 | 170,856 | 86,058 | 17,723 | 119,469 | 1,477 | 22,341 | 1,109 | 666 | 160 | 8 | 880 | 86 | 420,833 |
| 1939 | 5,233 | 48,003 | 44,854 | 71,906 | 1,928 | 2,883 | 1,108 | 10 | 0 | 0 | 0 | 144 | 176,069 |
| 1940 | 52 | 1,822 | 1,762 | 48,253 | 43,808 | 44,729 | 40,178 | 172 | 652 | 71 | 31,312 | 75,253 | 288,064 |
| 1941 | 35,639 | 26,001 | 58,860 | 42,969 | 129,579 | 80,853 | 28,575 | 2,590 | 852 | 4,148 | 10,949 | 24,842 | 445,857 |
| 1942 | 3,952 | 10,275 | 27,440 | 167,008 | 78,956 | 35,114 | 1,942 | 2,668 | 9,681 | 397 | 7,360 | 24,670 | 369,463 |
| 1943 | 175 | 2,123 | 41,668 | 5,889 | 18,783 | 35,325 | 172 | 0 | 0 | 79 | 1,126 | 4,310 | 109,650 |
| 1944 | 11,234 | 34,590 | 50,286 | 12,648 | 106,613 | 15,383 | 1,019 | 2,928 | 522 | 0 | 4,844 | 34,612 | 274,679 |
| 1945 | 14,892 | 76,260 | 114,100 | 32,499 | 12,936 | 53,535 | 26,688 | 100 | 7,723 | 41,749 | 2,873 | 37 | 383,392 |
| 1946 | 32,738 | 71,633 | 28,463 | 21,609 | 99,310 | 36,932 | 452 | 12,817 | 221 | 179 | 111,885 | 24,902 | 441,141 |
| 1947 | 7,747 | 378 | 15,742 | 19,924 | 27,295 | 5,086 | 22 | 5,916 | 319 | 228 | 16,519 | 50,516 | 149,692 |
| 1948 | 35,408 | 32,184 | 37,564 | 15,521 | 63,898 | 2,731 | 3,538 | 69 | 0 | 44 | 0 | 1,963 | 192,920 |
| 1949 | 92,233 | 62,642 | 39,309 | 14,871 | 15,011 | 9,816 | 4,564 | 1,307 | 892 | 48,789 | 243 | 2,948 | 292,625 |
| 1950 | 52,970 | 144,434 | 6,795 | 7,162 | 82,000 | 17,375 | 8,081 | 1,276 | 69,921 | 141 | 25 | 45 | 390,225 |
| 1951 | 775 | 40,802 | 581 | 281 | 3,946 | 109,890 | 9,078 | 1 | 4 | 705 | 1,100 | 290 | 167,453 |
| 1952 | 3,559 | 1,701 | 4,629 | 95,063 | 30,335 | 5,361 | 1 | 0 | 0 | 0 | 13,997 | 20,101 | 174,747 |
| 1953 | 10,706 | 1,041 | 25,376 | 93,763 | 49,982 | 25 | 10,715 | 496 | 22 | 127 | 7,705 | 26,508 | 226,466 |
| 1954 | 39,000 | 6,010 | 118 | 10,812 | 39,638 | 3,523 | 0 | 0 | 0 | 45,643 | 10,885 | 518 | 156,147 |
| 1955 | 1,187 | 20,629 | 20,838 | 16,202 | 7,959 | 58 | 2,255 | 2,961 | 760 | 1,401 | 0 | 0 | 74,250 |
| 1956 | 13 | 19,462 | 30 | 372 | 21,413 | 1,322 | 0 | 0 | 0 | 0 | 2,269 | 1,846 | 46,727 |
| 1957 | 6,052 | 14,223 | 45,765 | 233,325 | 186,847 | 62,720 | 367 | 3,830 | 27,450 | 27,116 | 133,834 | 9,911 | 751,440 |
| 1958 | 31,012 | 764 | 48,871 | 85,381 | 127,741 | 26,531 | 14,375 | 71 | 2,951 | 525 | 767 | 667 | 339,656 |
| 1959 | 994 | 11,454 | 7,234 | 6,059 | 2,028 | 8,172 | 18,866 | 1,414 | 1,272 | 19,031 | 16,461 | 60,745 | 153,730 |
| 1960 | 44,658 | 14,845 | 9,736 | 2,013 | 14,342 | 20,567 | 10,509 | 1,472 | 7,127 | 18,062 | 695 | 101,516 | 245,542 |
| 1961 | 47,922 | 16,482 | 36,060 | 8,748 | 974 | 12,823 | 3,336 | 1,271 | 4,203 | 59 | 13,496 | 30,677 | 176,051 |
| 1962 | 12,228 | 9,424 | 5,076 | 23,119 | 6,548 | 32,271 | 17,966 | 3,065 | 61,941 | 9,045 | 36,975 | 4,281 | 221,939 |
| 1963 | 11,624 | 210 | 5,414 | 7,315 | 11,021 | 1,059 | 14,973 | 40 | 0 | 0 | 0 | 3 | 51,659 |
| 1964 | 12 | 92 | 8,456 | 20,713 | 16,209 | 21,873 | 3 | 0 | 20,034 | 403 | 32,288 | 1,097 | 121,180 |
| 1965 | 22,081 | 105,860 | 1,268 | 535 | 107,645 | 3,268 | 39 | 24 | 5,491 | 46 | 646 | 28 | 246,931 |
| 1966 | 659 | 24,776 | 801 | 181,661 | 88,133 | 66 | 454 | 2,148 | 5,851 | 1,693 | 74 | 627 | 306,943 |
| 1967 | 184 | 92 | 1,815 | 50,066 | 43,187 | 70,014 | 1,084 | 91 | 21,082 | 33,123 | 18,737 | 40,202 | 279,677 |
| 1968 | 31,566 | 14,836 | 91,996 | 49,368 | 73,383 | 36,829 | 24,543 | 3,853 | 19,033 | 2,666 | 23,217 | 36,108 | 407,398 |
| 1969 | 56,251 | 91,473 | 63,236 | 21,272 | 162,559 | 2,284 | 33 | 1 | 0 | 5,129 | 2,223 | 26,186 | 430,647 |
| 1970 | 9,298 | 53,015 | 79,126 | 54,509 | 5,670 | 3,186 | 41 | 31 | 8,115 | 40,748 | 4,004 | 1,446 | 259,189 |
| 1971 | 1,015 | 7,570 | 3,516 | 71 | 91 | 118 | 288 | 9,351 | 1,688 | 115,100 | 755 | 175,638 | 315,201 |
| 1972 | 4,461 | 647 | 5,214 | 247 | 716 | 786 | 30 | 7 | 222 | 12,623 | 35,436 | 15,659 | 76,048 |
| 1973 | 28,838 | 30,799 | 79,475 | 96,970 | 12,384 | 32,486 | 673 | 229 | 68,075 | 70,455 | 88,712 | 33,428 | 542,524 |
| 1974 | 68,908 | 3,583 | 8,373 | 77,443 | 13,084 | 101,584 | 108 | 506 | 66,635 | 8,591 | 129,080 | 61,194 | 539,089 |
| 1975 | 14,944 | 126,278 | 56,099 | 40,929 | 72,290 | 78,212 | 1,609 | 215 | 43 | 27 | 47 | 189 | 390,882 |
| 1976 | 35 | 91 | 5,126 | 51,587 | 32,644 | 12,199 | 35,540 | 444 | 4,041 | 21,414 | 3,235 | 45,475 | 211,831 |
| 1977 | 25,674 | 54,305 | 124,278 | 46,035 | 1,764 | 15,147 | 304 | 3,117 | 810 | 35 | 4,623 | 790 | 276,882 |
| 1978 | 4,474 | 32,752 | 30,422 | 1,999 | 4,650 | 6,461 | 28 | 6 | 0 | 0 | 3,179 | 2,460 | 86,431 |
| 1979 | 57,893 | 28,396 | 51,521 | 31,583 | 119,361 | 41,507 | 2,118 | 4,701 | 398 | 186 | 391 | 17,674 | 355,729 |
| 1980 | 30,586 | 19,602 | 250 | 8,119 | 24,871 | 869 | 43 | 2 | 4,357 | 5,376 | 184 | 18,738 | 112,997 |
| 1981 | 119 | 99 | 14,995 | 1,243 | 29,290 | 155,120 | 1,477 | 77 | 65 | 90,646 | 39,966 | 779 | 333,876 |
| 1982 | 1,120 | 13,073 | 7,805 | 9,304 | 210,020 | 38,193 | 6,768 | 362 | 519 | 79 | 11,549 | 58,393 | 357,185 |
| 1983 | 1,706 | 77,739 | 48,761 | 3,745 | 14,597 | 2,962 | 20,661 | 175 | 61 | 513 | 855 | 423 | 172,198 |
| 1984 | 391 | 18,251 | 89,885 | 13,172 | 5,584 | 329 | 59 | 39 | 17 | 34,690 | 12,662 | 70,018 | 245,097 |
| 1985 | 11,175 | 19,811 | 75,969 | 43,698 | 64,707 | 8,420 | 381 | 1 | 0 | 3,581 | 59,159 | 43,044 | 329,946 |
| 1986 | 196 | 42,129 | 355 | 46,349 | 16,138 | 48,688 | 4,543 | 90 | 3,675 | 6,404 | 54,817 | 17,350 | 240,734 |
| 1987 | 23,548 | 24,731 | 80,880 | 703 | 10,109 | 11,375 | 313 | 28 | 10,242 | 8,804 | 141,059 | 106,822 | 418,614 |
| 1988 | 23,094 | 19,683 | 15,841 | 20,893 | 115 | 191 | 34,575 | 107 | 2,095 | 4,708 | 38,587 | 14,270 | 174,159 |
| 1989 | 37,629 | 67,067 | 28,287 | 4,208 | 60,439 | 84,940 | 46,354 | 1,692 | 990 | 192 | 326 | 159 | 332,283 |
| 1990 | 10,734 | 58,200 | 122,866 | 78,017 | 125,085 | 31,598 | 29 | 1,448 | 607 | 2,902 | 13,617 | 13,662 | 458,765 |
| 1991 | 54,577 | 24,613 | 11,957 | 52,520 | 40,437 | 20,888 | 283 | 11 | 2 | 4,898 | 53,776 | 156,766 | 420,728 |
| 1992 | 40,493 | 40,562 | 54,934 | 674 | 117,584 | 74,939 | 54,228 | 11,857 | 1,850 | 3,235 | 0 | 42,587 | 442,943 |
| 1993 | 17,173 | 84,446 | 54,839 | 69,378 | 11,780 | 1,898 | 3,981 | 4,760 | 3,729 | 92,963 | 23,960 | 79,541 | 448,448 |
| 1994 | 9,340 | 32,727 | 44,198 | 12,095 | 82,550 | 4,580 | 56,200 | 4,485 | 6,129 | 21,695 | 82,177 | 55,813 | 411,989 |

**Table 1-3 (Continued)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 50,935 | 3,291 | 48,950 | 51,025 | 124,671 | 29,857 | 1,408 | 2,543 | 4,181 | 563 | 60 | 32 | 317,516 |
| 1996 | 3,316 | 2,450 | 3,459 | 6,464 | 3,023 | 2,711 | 5,927 | 5,851 | 2,729 | 14,259 | 130,481 | 19,938 | 200,608 |
| 1997 | 5,681 | 148,094 | 57,144 | 91,614 | 4,411 | 33,596 | 0 | 0 | 0 | 0 | 871 | 98,916 | 440,327 |
| 1998 | 96,008 | 41,216 | 46,980 | 3,463 | 0 | 817 | 0 | 0 | 0 | 48,365 | 50,027 | 129,328 | 416,204 |
| 1999 | 64,387 | 3,009 | 8,555 | 19,490 | 20,114 | 8,723 | 0 | 0 | 0 | 0 | 216 | 6,478 | 130,972 |
| 2000 | 2,469 | 5,371 | 32,233 | 8,731 | 15,911 | 72,686 | 0 | 478 | 0 | 95 | 103,178 | 90,910 | 332,062 |
| 2001 | 33,116 | 139,968 | 111,469 | 45,548 | 6,962 | 0 | 0 | 155 | 7,599 | 8,575 | 597 | 152,709 | 506,698 |
| 2002 | 28,943 | 35,996 | 80,916 | 69,699 | 9,326 | 0 | 0 | 0 | 0 | 117,162 | 996 | 36,861 | 379,899 |
| 2003 | 3,069 | 21,860 | 10,180 | 3,105 | 6,581 | 6,155 | 0 | 0 | 0 | 885 | 0 | 0 | 51,835 |
| 2004 | 3,521 | 24,247 | 11,082 | 3,517 | 1,458 | 10,827 | 1,925 | 0 | 432 | 4,673 | 40,134 | 13,427 | 115,243 |
| 2005 | 60,364 | 15,317 | 12,435 | 5,154 | 22 | 854 | 0 | 0 | 0 | 1,016 | 0 | 322 | 95,484 |
| 2006 | 228 | 823 | 81,372 | 696 | 735 | 0 | 563 | 178 | 0 | 0 | 2,561 | 25,595 | 112,751 |
| 2007 | 61,843 | 1,755 | 6,464 | 12,331 | 26,144 | 92,261 | 103,856 | 7,833 | 2,180 | 12,153 | 0 | 14,876 | 341,696 |
| 2008 | 0 | 32,477 | 176,614 | 51,416 | 3,372 | 4,199 | 0 | 0 | 0 | 0 | 139 | 0 | 268,217 |
| 2009 | 0 | 1,569 | 16,110 | 44,152 | 132,771 | 226 | 0 | 1,926 | 14,565 | 193,093 | 29,585 | 25,863 | 459,860 |
| 2010 | 58,439 | 79,014 | 43,008 | 621 | 313 | 264 | 0 | 0 | 28 | 0 | 1,385 | 423 | 183,495 |
| 2011 | 2,803 | 5,105 | 428 | 6,226 | 52,729 | 649 | 653 | 1,656 | 0 | 0 | 0 | 7,561 | 77,810 |
| 2012 | 59,010 | 9,080 | 87,523 | 13,640 | 8,737 | 2,142 | 0 | 0 | 0 | 0 | 111 | 908 | 181,151 |
| 2013 | 7,170 | 1,803 | 2,285 | 4,118 | 5,371 | 7,283 | 1,474 | 383 | 1,021 | 234 | 1,870 | 15,713 | 48,725 |
| 2014 | 780 | 738 | 4,846 | 24,700 | 52,262 | 4,826 | 2,160 | 0 | 0 | 2,533 | 0 | 1,753 | 94,598 |
| Min | 0 | 91 | 30 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46,727 |
| Max | 170,856 | 148,094 | 176,614 | 233,325 | 210,020 | 155,120 | 103,856 | 12,817 | 69,921 | 193,093 | 141,059 | 175,638 | 751,440 |
| Median | 11,175 | 19,683 | 27,440 | 19,490 | 16,209 | 8,723 | 1,019 | 175 | 607 | 1,401 | 3,179 | 15,659 | 274,679 |

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**Table 1-4: Monthly Lake Chapman Passage for Lake Wright Patman Senior Right**
(Values in acre-feet per month)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1938 | 0 | 0 | 0 | 0 | 1,170 | 0 | 802 | 359 | 0 | 0 | 0 | 0 | 2,330 |
| 1939 | 0 | 0 | 0 | 0 | 1,621 | 2,586 | 801 | 0 | 0 | 0 | 0 | 0 | 5,007 |
| 1940 | 0 | 1,542 | 1,455 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,996 |
| 1941 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1942 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1943 | 0 | 0 | 0 | 0 | 18,476 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18,476 |
| 1944 | 0 | 0 | 0 | 0 | 0 | 0 | 712 | 553 | 0 | 0 | 0 | 0 | 1,265 |
| 1945 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1946 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1947 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5,609 | 0 | 0 | 0 | 0 | 5,609 |
| 1948 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1949 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1950 | 0 | 0 | 0 | 6,865 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6,865 |
| 1951 | 0 | 0 | 0 | 0 | 3,639 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,639 |
| 1952 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1953 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1954 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1955 | 0 | 0 | 0 | 0 | 7,652 | 0 | 1,948 | 0 | 0 | 0 | 0 | 0 | 9,599 |
| 1956 | 0 | 0 | 0 | 75 | 0 | 1,025 | 0 | 0 | 0 | 0 | 0 | 0 | 1,099 |
| 1957 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1958 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1959 | 0 | 0 | 0 | 0 | 1,721 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,721 |
| 1960 | 0 | 0 | 0 | 1,716 | 14,035 | 20,270 | 0 | 0 | 0 | 0 | 0 | 0 | 36,020 |
| 1961 | 0 | 0 | 0 | 0 | 667 | 5,225 | 0 | 0 | 0 | 0 | 0 | 0 | 5,891 |
| 1962 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1963 | 0 | 0 | 0 | 7,018 | 0 | 503 | 2,832 | 0 | 0 | 0 | 0 | 0 | 10,353 |
| 1964 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1965 | 0 | 0 | 0 | 238 | 0 | 0 | 0 | 0 | 937 | 0 | 349 | 0 | 1,523 |
| 1966 | 352 | 0 | 121 | 0 | 0 | 0 | 147 | 1,841 | 0 | 0 | 0 | 0 | 2,459 |
| 1967 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1968 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1969 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,822 | 0 | 0 | 4,822 |
| 1970 | 0 | 0 | 0 | 0 | 0 | 2,889 | 0 | 0 | 0 | 0 | 0 | 0 | 2,889 |
| 1971 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9,044 | 1,391 | 0 | 0 | 0 | 10,434 |
| 1972 | 0 | 0 | 6 | 0 | 409 | 489 | 0 | 0 | 0 | 12,316 | 0 | 0 | 13,219 |
| 1973 | 0 | 0 | 0 | 0 | 0 | 0 | 366 | 0 | 0 | 0 | 0 | 0 | 366 |
| 1974 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1975 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1976 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1977 | 0 | 0 | 0 | 0 | 1,457 | 14,850 | 0 | 2,810 | 513 | 0 | 0 | 0 | 19,628 |
| 1978 | 0 | 0 | 0 | 1,702 | 4,343 | 6,164 | 0 | 0 | 0 | 0 | 2,882 | 2,153 | 17,242 |
| 1979 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1980 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,060 | 0 | 0 | 0 | 4,060 |
| 1981 | 0 | 0 | 0 | 946 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 946 |
| 1982 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1983 | 0 | 0 | 0 | 0 | 9,635 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9,635 |
| 1984 | 0 | 0 | 0 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| 1985 | 0 | 0 | 0 | 0 | 0 | 0 | 74 | 0 | 0 | 0 | 0 | 0 | 74 |
| 1986 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 0 | 406 | 9,802 | 11,078 | 6 | 0 | 9,945 | 0 | 0 | 0 | 31,235 |
| 1988 | 0 | 0 | 0 | 0 | 0 | 0 | 34,268 | 0 | 1,798 | 1,418 | 0 | 0 | 37,483 |
| 1989 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 0 | 0 | 0 | 377 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 377 |
| 1993 | 0 | 0 | 0 | 0 | 0 | 0 | 3,674 | 4,453 | 0 | 0 | 0 | 0 | 8,126 |
| 1994 | 0 | 0 | 0 | 11,798 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11,798 |

**Table 1-4 (Continued)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 0 | 0 | 0 | 0 | 0 | 0 | 1,101 | 2,236 | 0 | 0 | 0 | 0 | 3,336 |
| 1996 | 0 | 2,170 | 3,152 | 6,167 | 2,716 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14,204 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1998 | 0 | 0 | 0 | 3,166 | 0 | 520 | 0 | 0 | 0 | 0 | 0 | 0 | 3,685 |
| 1999 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 2,808 | 6,274 | 5,858 | 0 | 0 | 0 | 578 | 0 | 0 | 15,516 |
| 2004 | 3,214 | 0 | 0 | 3,220 | 1,151 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7,584 |
| 2005 | 0 | 0 | 0 | 3,311 | 0 | 557 | 0 | 0 | 0 | 709 | 0 | 15 | 4,591 |
| 2006 | 0 | 543 | 0 | 0 | 428 | 0 | 256 | 0 | 0 | 0 | 2,264 | 25,288 | 28,777 |
| 2007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2008 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2009 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2010 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| 2011 | 0 | 0 | 0 | 5,929 | 0 | 352 | 346 | 1,349 | 0 | 0 | 0 | 7,254 | 15,228 |
| 2012 | 0 | 0 | 0 | 0 | 8,430 | 1,845 | 0 | 0 | 0 | 0 | 0 | 601 | 10,875 |
| 2013 | 6,863 | 0 | 1,978 | 3,821 | 5,064 | 6,986 | 1,167 | 76 | 724 | 0 | 0 | 0 | 26,675 |
| 2014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Min | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Max | 6,863 | 2,170 | 3,152 | 11,798 | 18,476 | 20,270 | 34,268 | 9,044 | 9,945 | 12,316 | 2,882 | 25,288 | 37,483 |
| Median | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 946 |

*This space left blank intentionally*

**Table 1-5: Monthly Flows at Marvin Nichols Site***
(Values in acre-feet per month)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1938 | 642,783 | 352,790 | 76,911 | 481,224 | 10,579 | 88,312 | 4,346 | 2,706 | 626 | 37 | 3,462 | 329 | 1,664,105 |
| 1939 | 19,739 | 179,460 | 175,386 | 291,980 | 10,977 | 11,256 | 4,516 | 47 | 1 | 0 | 1 | 559 | 693,922 |
| 1940 | 210 | 7,062 | 6,208 | 189,242 | 166,121 | 183,980 | 158,861 | 748 | 2,590 | 277 | 107,916 | 301,222 | 1,124,437 |
| 1941 | 147,385 | 103,434 | 231,870 | 153,865 | 525,217 | 319,122 | 113,528 | 12,591 | 3,523 | 16,311 | 42,443 | 96,260 | 1,765,549 |
| 1942 | 17,858 | 40,429 | 108,281 | 622,532 | 343,343 | 133,140 | 8,814 | 4,073 | 16,633 | 1,105 | 14,492 | 47,843 | 1,358,543 |
| 1943 | 67,674 | 11,571 | 185,359 | 74,067 | 28,580 | 158,020 | 4,572 | 364 | 651 | 4,754 | 3,944 | 16,644 | 556,200 |
| 1944 | 51,721 | 130,053 | 333,965 | 112,829 | 498,338 | 135,742 | 2,466 | 4,123 | 12,159 | 281 | 31,224 | 145,037 | 1,457,938 |
| 1945 | 187,904 | 297,109 | 694,496 | 737,405 | 67,510 | 335,441 | 86,742 | 6,404 | 10,370 | 227,739 | 18,252 | 2,811 | 2,672,183 |
| 1946 | 249,072 | 457,432 | 114,712 | 130,352 | 470,249 | 294,950 | 7,395 | 15,295 | 6,179 | 1,349 | 491,286 | 175,597 | 2,413,868 |
| 1947 | 66,666 | 8,523 | 111,370 | 139,152 | 236,500 | 13,675 | 804 | 6,548 | 3,255 | 588 | 53,517 | 275,297 | 915,895 |
| 1948 | 168,624 | 195,828 | 227,083 | 52,131 | 372,238 | 21,296 | 9,872 | 2,179 | 279 | 391 | 938 | 3,222 | 1,054,081 |
| 1949 | 250,566 | 294,321 | 243,245 | 101,349 | 113,925 | 39,234 | 11,329 | 5,211 | 3,594 | 241,902 | 42,192 | 32,989 | 1,379,857 |
| 1950 | 336,019 | 656,641 | 77,782 | 21,505 | 445,607 | 53,232 | 33,744 | 30,784 | 335,980 | 12,996 | 1,321 | 866 | 2,006,477 |
| 1951 | 21,580 | 288,980 | 32,589 | 16,123 | 35,162 | 283,828 | 30,204 | 2,070 | 4,762 | 9,383 | 11,100 | 21,667 | 757,448 |
| 1952 | 76,441 | 33,393 | 68,277 | 543,465 | 136,438 | 38,732 | 4,386 | 1,717 | 2 | 0 | 37,736 | 145,875 | 1,086,462 |
| 1953 | 67,676 | 99,796 | 115,035 | 215,510 | 475,294 | 3,085 | 23,069 | 2,780 | 2,326 | 692 | 13,698 | 61,615 | 1,080,576 |
| 1954 | 158,226 | 67,665 | 6,623 | 45,521 | 341,673 | 26,219 | 234 | 22 | 8 | 80,308 | 56,929 | 6,605 | 790,033 |
| 1955 | 9,170 | 58,361 | 118,571 | 142,346 | 25,860 | 4,231 | 28,368 | 13,943 | 14,879 | 43,651 | 440 | 773 | 460,593 |
| 1956 | 1,347 | 203,042 | 5,545 | 4,365 | 88,387 | 3,812 | 1,444 | 876 | 699 | 536 | 11,217 | 3,556 | 324,826 |
| 1957 | 19,870 | 63,098 | 141,257 | 692,807 | 819,981 | 426,976 | 16,379 | 10,037 | 52,653 | 79,477 | 492,181 | 56,782 | 2,871,498 |
| 1958 | 192,767 | 20,526 | 168,566 | 243,890 | 656,342 | 74,721 | 81,442 | 6,529 | 20,609 | 6,707 | 40,215 | 13,067 | 1,525,381 |
| 1959 | 9,276 | 101,972 | 60,752 | 62,294 | 15,242 | 106,102 | 117,338 | 31,477 | 11,202 | 55,965 | 48,043 | 268,034 | 887,697 |
| 1960 | 251,145 | 72,703 | 82,353 | 7,402 | 34,640 | 60,642 | 97,974 | 17,318 | 80,632 | 115,225 | 14,356 | 446,754 | 1,281,144 |
| 1961 | 171,663 | 89,043 | 175,641 | 185,274 | 24,265 | 26,818 | 28,907 | 3,316 | 10,676 | 3,435 | 47,223 | 169,762 | 936,023 |
| 1962 | 113,459 | 109,361 | 103,674 | 113,386 | 74,263 | 86,997 | 62,117 | 3,952 | 158,307 | 73,098 | 154,445 | 65,180 | 1,118,239 |
| 1963 | 62,664 | 5,078 | 62,119 | 30,071 | 39,592 | 4,567 | 20,658 | 462 | 52 | 11 | 40 | 1,368 | 226,682 |
| 1964 | 297 | 3,675 | 45,487 | 148,669 | 70,966 | 56,534 | 134 | 2,708 | 53,968 | 9,746 | 97,598 | 21,045 | 510,827 |
| 1965 | 77,963 | 386,331 | 36,637 | 11,094 | 307,196 | 22,120 | 210 | 104 | 10,568 | 195 | 829 | 894 | 854,141 |
| 1966 | 3,187 | 85,852 | 4,572 | 516,264 | 518,426 | 8,029 | 567 | 14,034 | 18,118 | 33,612 | 2,006 | 20,044 | 1,224,711 |
| 1967 | 18,648 | 9,323 | 20,326 | 319,176 | 276,066 | 247,723 | 47,873 | 190 | 44,651 | 79,358 | 117,722 | 176,874 | 1,357,930 |
| 1968 | 126,586 | 114,212 | 416,476 | 246,418 | 392,272 | 240,527 | 79,739 | 19,730 | 78,178 | 16,097 | 129,200 | 236,301 | 2,095,736 |
| 1969 | 147,548 | 542,789 | 329,016 | 122,258 | 621,193 | 16,949 | 777 | 75 | 70 | 11,386 | 7,645 | 79,824 | 1,879,530 |
| 1970 | 62,386 | 202,061 | 359,386 | 211,214 | 100,863 | 9,598 | 983 | 924 | 22,705 | 136,142 | 31,243 | 9,434 | 1,146,939 |
| 1971 | 7,078 | 32,513 | 14,982 | 1,153 | 12,237 | 909 | 14,809 | 67,823 | 4,324 | 366,649 | 33,867 | 747,328 | 1,303,672 |
| 1972 | 46,309 | 6,897 | 12,158 | 1,057 | 1,948 | 2,275 | 541 | 356 | 2,687 | 35,301 | 177,285 | 107,573 | 394,387 |
| 1973 | 113,215 | 176,533 | 511,603 | 455,777 | 103,716 | 174,829 | 2,078 | 835 | 191,854 | 257,634 | 451,496 | 209,293 | 2,648,863 |
| 1974 | 220,600 | 42,302 | 13,619 | 101,975 | 59,311 | 318,653 | 1,589 | 1,005 | 173,693 | 60,540 | 454,619 | 244,633 | 1,692,539 |
| 1975 | 44,409 | 380,452 | 165,366 | 101,609 | 226,223 | 173,882 | 12,370 | 2,977 | 261 | 71 | 1,190 | 1,103 | 1,109,913 |
| 1976 | 2,070 | 3,175 | 48,264 | 146,054 | 136,675 | 117,532 | 244,621 | 1,294 | 11,615 | 43,276 | 11,459 | 129,672 | 895,707 |
| 1977 | 86,422 | 209,595 | 317,137 | 327,946 | 19,541 | 21,395 | 1,247 | 4,368 | 849 | 42 | 11,794 | 4,708 | 1,005,044 |
| 1978 | 22,875 | 61,825 | 122,130 | 18,898 | 21,432 | 13,823 | 29 | 6 | 3 | 0 | 30,418 | 16,953 | 308,392 |
| 1979 | 248,919 | 143,517 | 235,289 | 224,757 | 404,766 | 197,202 | 22,398 | 20,490 | 17,476 | 1,081 | 9,482 | 102,794 | 1,628,171 |
| 1980 | 128,521 | 146,944 | 14,280 | 93,360 | 118,101 | 18,694 | 134 | 2 | 22,956 | 38,789 | 7,590 | 70,217 | 659,588 |
| 1981 | 3,303 | 13,137 | 42,258 | 7,971 | 180,682 | 435,588 | 26,139 | 1,799 | 2,683 | 444,643 | 198,239 | 5,212 | 1,361,654 |
| 1982 | 15,802 | 69,883 | 85,611 | 61,889 | 759,022 | 272,486 | 56,166 | 13,869 | 1,609 | 2,791 | 115,404 | 501,955 | 1,956,487 |
| 1983 | 31,936 | 262,520 | 240,941 | 36,608 | 58,729 | 21,640 | 70,019 | 430 | 134 | 738 | 2,134 | 11,219 | 737,048 |
| 1984 | 7,217 | 91,556 | 358,096 | 95,211 | 86,062 | 1,416 | 4,004 | 707 | 454 | 142,731 | 110,108 | 250,514 | 1,148,076 |
| 1985 | 48,405 | 145,468 | 274,594 | 154,033 | 171,678 | 43,488 | 7,180 | 221 | 3 | 12,887 | 126,825 | 221,325 | 1,206,107 |
| 1986 | 4,574 | 179,160 | 14,817 | 219,047 | 91,624 | 161,825 | 60,870 | 129 | 12,004 | 21,562 | 144,913 | 100,872 | 1,011,397 |
| 1987 | 93,265 | 95,650 | 286,327 | 8,319 | 17,922 | 23,774 | 10,149 | 901 | 41,959 | 37,629 | 303,376 | 410,073 | 1,329,344 |
| 1988 | 131,076 | 76,864 | 79,259 | 80,882 | 1,382 | 307 | 43,120 | 2,640 | 3,070 | 8,652 | 179,715 | 101,228 | 708,195 |
| 1989 | 121,635 | 420,506 | 179,824 | 84,137 | 421,644 | 488,201 | 230,299 | 17,017 | 10,534 | 938 | 439 | 1,373 | 1,976,547 |
| 1990 | 202,122 | 227,624 | 537,685 | 323,885 | 544,500 | 113,813 | 8,114 | 2,756 | 16,525 | 31,588 | 64,590 | 106,734 | 2,179,936 |
| 1991 | 256,321 | 122,577 | 76,546 | 279,418 | 195,932 | 50,136 | 5,192 | 6,296 | 6,873 | 120,345 | 256,042 | 594,227 | 1,969,905 |
| 1992 | 162,136 | 183,057 | 278,700 | 17,741 | 199,338 | 169,756 | 220,161 | 131,291 | 28,739 | 4,697 | 49,410 | 276,359 | 1,721,385 |
| 1993 | 176,529 | 200,449 | 306,252 | 171,423 | 78,484 | 16,294 | 4,141 | 5,168 | 4,967 | 274,719 | 89,353 | 323,410 | 1,651,189 |
| 1994 | 68,667 | 116,211 | 228,547 | 29,420 | 208,228 | 58,581 | 144,523 | 10,251 | 13,731 | 40,093 | 249,163 | 247,897 | 1,415,312 |

**Table 1-5 (Continued)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 242,814 | 60,710 | 149,943 | 211,434 | 460,904 | 83,496 | 4,610 | 3,256 | 8,816 | 1,253 | 667 | 2,336 | 1,230,239 |
| 1996 | 8,362 | 3,196 | 7,584 | 14,667 | 51,428 | 36,201 | 14,015 | 59,414 | 37,357 | 72,451 | 470,005 | 216,663 | 991,343 |
| 1997 | 43,545 | 574,707 | 282,007 | 366,885 | 64,369 | 90,190 | 1,215 | 1,322 | 86 | 9,692 | 12,230 | 229,857 | 1,676,105 |
| 1998 | 381,642 | 175,561 | 198,820 | 23,613 | 14,839 | 934 | 0 | 719 | 20,945 | 101,564 | 90,982 | 313,380 | 1,322,999 |
| 1999 | 152,720 | 75,589 | 114,952 | 79,161 | 41,655 | 23,749 | 3,948 | 1 | 159 | 2,358 | 787 | 24,341 | 519,420 |
| 2000 | 6,887 | 21,140 | 108,824 | 70,619 | 171,021 | 257,505 | 57,214 | 478 | 613 | 319 | 459,358 | 348,484 | 1,502,462 |
| 2001 | 310,330 | 566,198 | 603,768 | 167,053 | 48,464 | 54,364 | 13,650 | 10,298 | 80,337 | 71,972 | 14,687 | 628,373 | 2,569,494 |
| 2002 | 91,923 | 209,076 | 297,625 | 340,317 | 58,184 | 1,216 | 4,646 | 5,262 | 3,463 | 240,468 | 28,627 | 93,609 | 1,374,416 |
| 2003 | 56,296 | 96,012 | 90,888 | 7,317 | 23,950 | 30,952 | 764 | 170 | 1,395 | 1,315 | 2,385 | 2,454 | 313,898 |
| 2004 | 14,529 | 81,714 | 44,639 | 12,782 | 24,630 | 72,393 | 13,855 | 1,189 | 452 | 6,328 | 97,724 | 51,876 | 422,111 |
| 2005 | 197,848 | 79,296 | 47,607 | 29,964 | 1,018 | 1,623 | 2,916 | 1,724 | 3,305 | 1,126 | 1,041 | 765 | 368,233 |
| 2006 | 3,854 | 7,125 | 247,213 | 18,939 | 3,695 | 2,985 | 4,230 | 1,552 | 95 | 2,758 | 5,619 | 38,910 | 336,975 |
| 2007 | 245,625 | 18,315 | 19,573 | 59,763 | 77,161 | 280,122 | 395,025 | 61,792 | 8,581 | 29,520 | 3,519 | 47,579 | 1,246,575 |
| 2008 | 7,020 | 136,782 | 687,809 | 314,717 | 51,866 | 23,394 | 2,009 | 8,520 | 10,330 | 11,223 | 7,681 | 6,303 | 1,267,654 |
| 2009 | 7,980 | 7,887 | 87,576 | 100,140 | 784,633 | 6,381 | 25,547 | 55,226 | 98,272 | 936,079 | 165,393 | 211,477 | 2,486,591 |
| 2010 | 159,261 | 451,224 | 161,850 | 41,643 | 18,852 | 20,932 | 7,600 | 695 | 7,584 | 5,489 | 8,924 | 3,381 | 887,435 |
| 2011 | 13,593 | 21,314 | 6,146 | 43,226 | 171,793 | 3,201 | 662 | 1,874 | 1,632 | 980 | 2,201 | 33,119 | 299,741 |
| 2012 | 174,243 | 90,331 | 380,664 | 89,518 | 27,347 | 11,924 | 8,402 | 304 | 2,337 | 2,799 | 1,719 | 6,784 | 796,372 |
| 2013 | 18,871 | 11,428 | 7,194 | 23,798 | 37,806 | 30,540 | 3,477 | 391 | 14,478 | 14,095 | 31,402 | 114,718 | 308,198 |
| 2014 | 24,452 | 29,222 | 47,759 | 94,394 | 133,902 | 30,108 | 19,626 | 14,616 | 13,435 | 18,017 | 5,428 | 13,637 | 444,596 |
| Min | 210 | 3,175 | 4,572 | 1,057 | 1,018 | 307 | 0 | 1 | 1 | 0 | 1 | 329 | 226,682 |
| Max | 642,783 | 656,641 | 694,496 | 737,405 | 819,981 | 488,201 | 395,025 | 131,291 | 335,980 | 936,079 | 492,181 | 747,328 | 2,871,498 |
| Median | 67,676 | 96,012 | 114,952 | 101,349 | 91,624 | 39,234 | 8,814 | 2,706 | 6,873 | 11,223 | 31,224 | 65,180 | 1,148,076 |

* includes flows originating above Lake Ralph Hall and Lake Chapman

*This space left blank intentionally*

**Table 1-6: Monthly Marvin Nichols Passage for Lake Wright Patman Senior Right**
(Values in acre-feet per month)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1938 | 0 | 0 | 0 | 0 | 10,579 | 0 | 4,346 | 2,706 | 763 | 336 | 0 | 550 | 19,281 |
| 1939 | 0 | 0 | 0 | 0 | 10,977 | 11,256 | 4,516 | 344 | 298 | 307 | 298 | 722 | 28,720 |
| 1940 | 465 | 7,062 | 6,208 | 0 | 0 | 0 | 0 | 0 | 0 | 513 | 0 | 0 | 14,249 |
| 1941 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1942 | 0 | 0 | 0 | 0 | 0 | 0 | 7,179 | 0 | 0 | 0 | 0 | 0 | 7,179 |
| 1943 | 0 | 5,548 | 0 | 0 | 28,580 | 0 | 4,707 | 671 | 948 | 287 | 0 | 0 | 40,743 |
| 1944 | 0 | 0 | 0 | 0 | 0 | 0 | 2,466 | 2,056 | 0 | 588 | 0 | 0 | 5,110 |
| 1945 | 0 | 0 | 0 | 0 | 13,516 | 0 | 0 | 0 | 0 | 0 | 0 | 221 | 13,737 |
| 1946 | 0 | 0 | 0 | 0 | 0 | 0 | 7,250 | 2,785 | 0 | 0 | 0 | 0 | 10,036 |
| 1947 | 0 | 1,625 | 0 | 0 | 0 | 6,276 | 1,089 | 6,548 | 3,233 | 0 | 0 | 0 | 18,772 |
| 1948 | 0 | 0 | 0 | 18,670 | 0 | 0 | 6,641 | 2,417 | 576 | 0 | 0 | 1,566 | 29,872 |
| 1949 | 0 | 0 | 0 | 0 | 0 | 0 | 4,614 | 0 | 0 | 0 | 0 | 0 | 4,614 |
| 1950 | 0 | 0 | 0 | 21,505 | 0 | 0 | 0 | 0 | 0 | 0 | 289 | 1,128 | 22,922 |
| 1951 | 0 | 0 | 0 | 16,140 | 35,162 | 0 | 0 | 1,268 | 0 | 0 | 0 | 0 | 52,569 |
| 1952 | 0 | 0 | 0 | 0 | 0 | 0 | 4,692 | 2,024 | 299 | 307 | 0 | 0 | 7,324 |
| 1953 | 0 | 0 | 0 | 5,709 | 0 | 3,357 | 12,579 | 2,161 | 0 | 591 | 0 | 0 | 24,398 |
| 1954 | 0 | 0 | 0 | 35,007 | 0 | 10,155 | 541 | 329 | 305 | 4,448 | 0 | 0 | 50,786 |
| 1955 | 0 | 0 | 0 | 0 | 25,860 | 4,470 | 28,368 | 11,289 | 0 | 0 | 737 | 1,080 | 71,806 |
| 1956 | 1,641 | 0 | 3,443 | 4,365 | 67,281 | 3,812 | 1,444 | 876 | 699 | 536 | 9,246 | 2,017 | 95,360 |
| 1957 | 9,633 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9,633 |
| 1958 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1959 | 3,126 | 0 | 0 | 0 | 15,242 | 57,170 | 17,382 | 0 | 0 | 0 | 0 | 0 | 92,921 |
| 1960 | 0 | 0 | 0 | 7,402 | 34,640 | 60,642 | 25,419 | 0 | 0 | 0 | 0 | 0 | 128,103 |
| 1961 | 0 | 0 | 0 | 0 | 24,265 | 19,517 | 0 | 0 | 0 | 0 | 0 | 0 | 43,782 |
| 1962 | 0 | 0 | 0 | 36,531 | 0 | 19,378 | 3,584 | 1,194 | 0 | 0 | 0 | 0 | 60,687 |
| 1963 | 0 | 5,148 | 0 | 30,071 | 28,878 | 4,309 | 8,825 | 729 | 349 | 318 | 337 | 1,672 | 80,638 |
| 1964 | 592 | 3,863 | 23,899 | 2,234 | 0 | 14,724 | 438 | 3,015 | 0 | 0 | 0 | 0 | 48,767 |
| 1965 | 0 | 0 | 0 | 11,094 | 34,472 | 0 | 478 | 387 | 6,312 | 456 | 829 | 1,173 | 55,203 |
| 1966 | 3,187 | 0 | 4,199 | 53,478 | 0 | 8,261 | 567 | 14,034 | 0 | 0 | 0 | 0 | 83,726 |
| 1967 | 0 | 0 | 305 | 61,225 | 0 | 0 | 12,937 | 406 | 0 | 0 | 0 | 0 | 74,873 |
| 1968 | 0 | 0 | 0 | 45,187 | 0 | 15,278 | 0 | 0 | 0 | 0 | 0 | 0 | 60,465 |
| 1969 | 3,476 | 0 | 0 | 0 | 0 | 0 | 1,051 | 381 | 367 | 11,386 | 2,194 | 0 | 18,857 |
| 1970 | 0 | 0 | 0 | 42,029 | 0 | 9,598 | 1,249 | 1,200 | 14,887 | 0 | 0 | 3,677 | 72,642 |
| 1971 | 3,132 | 0 | 3,783 | 1,379 | 12,453 | 1,088 | 14,828 | 67,823 | 4,324 | 12,150 | 0 | 0 | 120,962 |
| 1972 | 0 | 2,658 | 7,257 | 1,107 | 1,948 | 2,275 | 818 | 656 | 2,762 | 35,301 | 18,832 | 0 | 73,616 |
| 1973 | 0 | 0 | 0 | 0 | 0 | 0 | 2,078 | 913 | 3,216 | 0 | 0 | 0 | 6,207 |
| 1974 | 0 | 0 | 1,717 | 29,193 | 0 | 0 | 1,788 | 806 | 0 | 0 | 0 | 0 | 33,505 |
| 1975 | 0 | 0 | 0 | 0 | 0 | 0 | 11,068 | 3,069 | 0 | 351 | 1,440 | 1,221 | 17,151 |
| 1976 | 2,342 | 3,364 | 0 | 0 | 0 | 0 | 0 | 1,157 | 0 | 0 | 0 | 0 | 6,864 |
| 1977 | 0 | 0 | 0 | 0 | 19,541 | 21,395 | 1,250 | 4,368 | 849 | 314 | 0 | 600 | 48,318 |
| 1978 | 0 | 0 | 0 | 18,898 | 21,432 | 13,823 | 308 | 307 | 300 | 307 | 30,418 | 16,953 | 102,748 |
| 1979 | 21,002 | 0 | 0 | 0 | 0 | 0 | 1,490 | 0 | 0 | 0 | 0 | 0 | 22,492 |
| 1980 | 0 | 0 | 0 | 0 | 10,992 | 3,296 | 398 | 307 | 22,956 | 0 | 0 | 0 | 37,950 |
| 1981 | 3,491 | 0 | 5,523 | 7,971 | 0 | 0 | 0 | 2,029 | 0 | 0 | 0 | 4,740 | 23,755 |
| 1982 | 0 | 0 | 0 | 49,040 | 71,488 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 120,528 |
| 1983 | 0 | 5,834 | 0 | 13,158 | 54,075 | 0 | 1,278 | 562 | 0 | 0 | 0 | 0 | 74,906 |
| 1984 | 0 | 0 | 7,105 | 0 | 72,875 | 1,416 | 4,252 | 975 | 734 | 0 | 0 | 0 | 87,359 |
| 1985 | 0 | 0 | 0 | 0 | 0 | 0 | 7,180 | 527 | 300 | 905 | 0 | 0 | 8,913 |
| 1986 | 1,731 | 0 | 0 | 0 | 0 | 0 | 0 | 346 | 0 | 0 | 0 | 0 | 2,077 |
| 1987 | 0 | 0 | 0 | 8,319 | 17,922 | 23,774 | 10,149 | 1,180 | 41,959 | 28,852 | 0 | 0 | 132,156 |
| 1988 | 0 | 0 | 0 | 0 | 1,574 | 413 | 43,120 | 2,840 | 3,070 | 5,669 | 0 | 0 | 56,687 |
| 1989 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,053 | 410 | 1,521 | 2,985 |
| 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 8,392 | 1,615 | 0 | 0 | 0 | 0 | 10,008 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 4,244 | 5,216 | 0 | 0 | 0 | 0 | 0 | 9,460 |
| 1992 | 0 | 0 | 0 | 17,741 | 61,837 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 79,578 |
| 1993 | 0 | 0 | 0 | 0 | 17,307 | 11,856 | 4,141 | 5,168 | 0 | 0 | 0 | 0 | 38,472 |
| 1994 | 0 | 0 | 0 | 29,420 | 61,072 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90,492 |

**Table 1-6 (Continued)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 0 | 0 | 0 | 0 | 0 | 0 | 4,610 | 3,256 | 0 | 0 | 0 | 2,611 | 10,477 |
| 1996 | 5,353 | 3,196 | 7,584 | 14,667 | 51,428 | 33,788 | 8,395 | 0 | 0 | 0 | 0 | 0 | 124,411 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 1,522 | 0 | 0 | 0 | 0 | 0 | 1,522 |
| 1998 | 0 | 0 | 0 | 23,613 | 15,146 | 934 | 307 | 1,026 | 21,242 | 0 | 0 | 0 | 62,270 |
| 1999 | 0 | 0 | 0 | 0 | 10,277 | 0 | 4,255 | 308 | 456 | 0 | 868 | 824 | 16,990 |
| 2000 | 3,001 | 5,840 | 0 | 0 | 0 | 0 | 0 | 307 | 0 | 0 | 0 | 0 | 9,148 |
| 2001 | 0 | 0 | 0 | 0 | 39,674 | 0 | 1,929 | 515 | 0 | 0 | 0 | 0 | 42,119 |
| 2002 | 0 | 0 | 0 | 0 | 0 | 1,513 | 4,953 | 5,569 | 1,226 | 0 | 0 | 0 | 13,262 |
| 2003 | 0 | 0 | 0 | 7,317 | 23,950 | 30,952 | 1,071 | 477 | 1,692 | 1,315 | 2,682 | 2,761 | 72,219 |
| 2004 | 14,529 | 0 | 0 | 12,782 | 24,630 | 0 | 0 | 1,496 | 0 | 0 | 0 | 0 | 53,437 |
| 2005 | 0 | 0 | 0 | 28,419 | 1,303 | 1,623 | 3,223 | 2,031 | 3,602 | 1,126 | 1,041 | 765 | 43,135 |
| 2006 | 3,854 | 7,125 | 8,119 | 18,540 | 3,695 | 3,282 | 4,230 | 1,681 | 95 | 2,758 | 5,619 | 38,910 | 97,909 |
| 2007 | 0 | 0 | 4,504 | 40,680 | 45,262 | 0 | 0 | 0 | 0 | 0 | 1,373 | 0 | 91,819 |
| 2008 | 1,611 | 0 | 0 | 0 | 0 | 0 | 2,316 | 0 | 0 | 0 | 0 | 0 | 3,927 |
| 2009 | 0 | 5,098 | 0 | 12,121 | 0 | 6,452 | 105 | 0 | 0 | 0 | 0 | 0 | 23,777 |
| 2010 | 0 | 0 | 0 | 0 | 18,852 | 12,260 | 7,907 | 1,002 | 7,853 | 0 | 0 | 3,265 | 51,141 |
| 2011 | 2,375 | 227 | 6,025 | 43,226 | 44,477 | 3,201 | 662 | 1,874 | 1,929 | 1,287 | 2,498 | 33,119 | 140,903 |
| 2012 | 18,794 | 0 | 0 | 0 | 27,347 | 11,924 | 8,709 | 611 | 2,634 | 3,106 | 1,905 | 6,784 | 81,816 |
| 2013 | 18,871 | 9,905 | 7,194 | 23,798 | 37,806 | 30,540 | 3,477 | 391 | 14,478 | 0 | 0 | 0 | 146,460 |
| 2014 | 0 | 0 | 0 | 0 | 6,626 | 0 | 13,331 | 0 | 0 | 0 | 0 | 224 | 20,181 |
| Min | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Max | 21,002 | 9,905 | 23,899 | 61,225 | 72,875 | 60,642 | 43,120 | 67,823 | 41,959 | 35,301 | 30,418 | 38,910 | 146,460 |
| Median | 0 | 0 | 0 | 0 | 1,303 | 0 | 1,788 | 562 | 0 | 0 | 0 | 0 | 40,743 |

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**Table 1-7: Monthly Total Flows at Lake Wright Patman***
(Values in acre-feet per month)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1938 | 1,046,787 | 719,799 | 188,680 | 889,904 | 31,243 | 163,156 | 8,217 | 5,230 | 1,137 | 105 | 6,345 | 580 | 3,061,183 |
| 1939 | 32,139 | 290,791 | 338,401 | 556,680 | 30,023 | 20,476 | 8,867 | 124 | 2 | 0 | 2 | 969 | 1,278,474 |
| 1940 | 443 | 12,123 | 10,701 | 343,798 | 283,660 | 362,409 | 296,614 | 2,762 | 4,851 | 516 | 155,096 | 569,459 | 2,042,432 |
| 1941 | 290,895 | 194,091 | 428,150 | 234,589 | 1,018,549 | 586,518 | 204,723 | 31,096 | 7,590 | 29,639 | 74,159 | 170,570 | 3,270,569 |
| 1942 | 43,783 | 72,630 | 201,115 | 1,065,826 | 689,650 | 255,875 | 27,335 | 5,267 | 25,651 | 1,882 | 22,230 | 64,462 | 2,475,706 |
| 1943 | 152,185 | 21,940 | 334,195 | 158,495 | 36,841 | 299,255 | 9,783 | 815 | 1,351 | 9,771 | 7,172 | 29,664 | 1,061,467 |
| 1944 | 97,131 | 222,031 | 627,575 | 253,032 | 914,763 | 289,027 | 4,230 | 5,303 | 25,235 | 590 | 51,290 | 258,786 | 2,748,993 |
| 1945 | 382,208 | 459,776 | 1,310,646 | 1,621,927 | 129,008 | 642,421 | 161,446 | 9,143 | 15,264 | 432,707 | 36,365 | 6,059 | 5,206,970 |
| 1946 | 476,937 | 862,741 | 224,608 | 253,137 | 821,795 | 651,143 | 14,562 | 17,164 | 14,983 | 2,534 | 906,168 | 346,126 | 4,591,898 |
| 1947 | 127,008 | 22,815 | 206,286 | 273,560 | 466,132 | 29,300 | 3,428 | 6,976 | 7,130 | 1,119 | 84,957 | 522,401 | 1,751,112 |
| 1948 | 324,005 | 366,309 | 437,343 | 104,274 | 693,063 | 61,708 | 17,923 | 4,614 | 598 | 684 | 1,871 | 4,817 | 2,017,209 |
| 1949 | 326,722 | 612,711 | 479,512 | 218,789 | 230,984 | 69,711 | 20,342 | 11,340 | 6,247 | 410,308 | 173,367 | 58,452 | 2,618,485 |
| 1950 | 606,638 | 1,238,199 | 183,444 | 41,081 | 822,209 | 102,091 | 42,323 | 75,906 | 583,671 | 43,256 | 2,906 | 1,918 | 3,743,642 |
| 1951 | 44,404 | 515,229 | 95,161 | 27,156 | 65,056 | 391,997 | 63,760 | 4,280 | 8,558 | 13,676 | 23,348 | 51,633 | 1,304,258 |
| 1952 | 161,769 | 69,315 | 127,896 | 980,930 | 300,181 | 97,848 | 11,820 | 3,786 | 48 | 38 | 56,823 | 336,389 | 2,146,843 |
| 1953 | 138,418 | 194,972 | 202,030 | 275,950 | 1,026,830 | 8,370 | 47,874 | 5,874 | 10,338 | 1,120 | 21,619 | 117,064 | 2,050,459 |
| 1954 | 299,017 | 149,291 | 28,192 | 74,342 | 598,840 | 49,002 | 537 | 48 | 13 | 98,759 | 130,147 | 12,979 | 1,441,167 |
| 1955 | 19,737 | 98,849 | 182,890 | 287,146 | 39,251 | 9,365 | 45,174 | 23,131 | 23,493 | 82,174 | 867 | 1,483 | 813,560 |
| 1956 | 2,197 | 344,912 | 21,334 | 6,543 | 153,076 | 5,759 | 3,061 | 883 | 737 | 871 | 24,415 | 3,621 | 567,409 |
| 1957 | 22,923 | 116,983 | 197,382 | 939,982 | 1,250,292 | 677,926 | 48,340 | 15,839 | 62,019 | 136,680 | 831,134 | 113,545 | 4,413,045 |
| 1958 | 429,183 | 74,599 | 281,569 | 373,302 | 1,317,761 | 106,155 | 179,057 | 9,091 | 31,944 | 14,408 | 73,694 | 40,515 | 2,931,278 |
| 1959 | 12,577 | 226,791 | 170,092 | 147,233 | 34,760 | 106,102 | 117,338 | 84,383 | 11,753 | 71,601 | 63,077 | 375,305 | 1,421,012 |
| 1960 | 527,879 | 147,695 | 205,771 | 16,078 | 35,050 | 61,129 | 158,651 | 19,262 | 80,632 | 157,040 | 40,437 | 643,773 | 2,093,397 |
| 1961 | 299,846 | 175,878 | 220,781 | 475,300 | 36,268 | 40,702 | 78,681 | 11,834 | 13,527 | 6,502 | 61,654 | 351,101 | 1,772,074 |
| 1962 | 202,862 | 280,469 | 314,043 | 144,559 | 205,151 | 86,997 | 83,113 | 7,112 | 181,728 | 86,076 | 154,445 | 193,884 | 1,940,439 |
| 1963 | 116,883 | 13,795 | 124,090 | 40,730 | 114,574 | 14,665 | 22,571 | 2,807 | 151 | 16 | 53 | 1,513 | 451,848 |
| 1964 | 386 | 7,171 | 61,609 | 202,477 | 204,791 | 72,541 | 293 | 3,010 | 73,646 | 32,549 | 109,039 | 53,075 | 820,587 |
| 1965 | 88,622 | 552,888 | 117,709 | 25,454 | 388,890 | 82,668 | 1,117 | 116 | 12,390 | 1,230 | 951 | 920 | 1,272,955 |
| 1966 | 4,948 | 129,046 | 12,007 | 516,264 | 1,210,244 | 17,099 | 3,154 | 23,278 | 28,831 | 57,062 | 2,564 | 39,492 | 2,043,989 |
| 1967 | 63,815 | 29,945 | 39,991 | 319,176 | 525,938 | 326,170 | 52,631 | 505 | 48,003 | 79,358 | 200,067 | 222,965 | 1,908,564 |
| 1968 | 189,289 | 222,714 | 566,539 | 269,712 | 595,084 | 240,527 | 160,622 | 29,471 | 84,621 | 19,197 | 129,200 | 314,348 | 2,821,324 |
| 1969 | 147,548 | 696,442 | 488,065 | 258,192 | 738,719 | 54,055 | 1,460 | 123 | 70 | 11,386 | 10,305 | 79,824 | 2,486,189 |
| 1970 | 109,379 | 222,124 | 593,338 | 228,337 | 314,525 | 12,550 | 8,020 | 2,101 | 24,304 | 167,275 | 43,275 | 11,211 | 1,736,439 |
| 1971 | 10,619 | 56,641 | 34,120 | 1,679 | 13,514 | 3,211 | 22,055 | 90,027 | 4,763 | 391,572 | 97,653 | 1,101,354 | 1,827,208 |
| 1972 | 103,626 | 21,878 | 15,551 | 5,397 | 2,805 | 5,095 | 1,929 | 364 | 2,687 | 36,116 | 260,674 | 212,826 | 668,948 |
| 1973 | 143,662 | 340,620 | 704,207 | 654,871 | 277,649 | 297,717 | 5,729 | 950 | 192,144 | 284,277 | 702,789 | 427,237 | 4,031,852 |
| 1974 | 422,900 | 126,463 | 34,823 | 137,894 | 138,816 | 448,255 | 5,822 | 2,202 | 195,495 | 126,205 | 643,872 | 511,686 | 2,794,433 |
| 1975 | 85,893 | 688,341 | 299,618 | 213,184 | 382,794 | 234,436 | 17,781 | 9,218 | 673 | 185 | 1,190 | 1,354 | 1,934,667 |
| 1976 | 2,379 | 6,253 | 115,615 | 215,420 | 263,589 | 181,337 | 350,681 | 2,453 | 13,150 | 43,276 | 18,268 | 143,887 | 1,356,308 |
| 1977 | 96,063 | 330,670 | 344,342 | 638,045 | 61,151 | 28,361 | 2,852 | 5,543 | 1,120 | 75 | 51,990 | 11,548 | 1,571,760 |
| 1978 | 46,757 | 89,080 | 192,900 | 52,888 | 23,055 | 16,152 | 94 | 6 | 3 | 0 | 30,915 | 16,953 | 468,803 |
| 1979 | 282,103 | 202,802 | 386,127 | 455,105 | 510,573 | 259,808 | 35,473 | 48,599 | 49,093 | 2,960 | 25,875 | 134,031 | 2,392,549 |
| 1980 | 325,744 | 305,104 | 36,521 | 218,584 | 180,360 | 37,930 | 2,490 | 2,334 | 22,956 | 48,804 | 16,538 | 83,944 | 1,281,309 |
| 1981 | 7,334 | 36,655 | 54,491 | 14,459 | 301,812 | 626,472 | 72,631 | 2,393 | 2,855 | 516,341 | 251,741 | 8,275 | 1,895,459 |
| 1982 | 22,961 | 99,673 | 126,437 | 77,184 | 759,022 | 421,005 | 155,671 | 22,775 | 1,739 | 2,909 | 115,404 | 887,199 | 2,691,979 |
| 1983 | 113,815 | 262,520 | 421,911 | 87,785 | 65,292 | 49,543 | 91,131 | 646 | 160 | 842 | 3,151 | 24,383 | 1,121,179 |
| 1984 | 18,261 | 111,203 | 363,582 | 277,006 | 87,907 | 2,481 | 4,004 | 923 | 473 | 221,128 | 303,864 | 495,514 | 1,886,346 |
| 1985 | 115,163 | 257,016 | 582,403 | 344,134 | 301,294 | 105,491 | 9,524 | 726 | 71 | 12,887 | 137,921 | 477,982 | 2,344,612 |
| 1986 | 13,943 | 386,317 | 36,865 | 440,575 | 201,892 | 266,027 | 95,747 | 368 | 12,467 | 21,720 | 144,913 | 213,783 | 1,834,617 |
| 1987 | 164,502 | 151,103 | 736,447 | 29,909 | 17,922 | 41,657 | 16,352 | 2,029 | 43,483 | 37,629 | 492,998 | 874,063 | 2,608,094 |
| 1988 | 413,260 | 156,983 | 161,047 | 158,421 | 2,322 | 439 | 82,128 | 3,872 | 3,101 | 8,652 | 294,968 | 316,274 | 1,601,467 |
| 1989 | 174,506 | 766,258 | 310,460 | 246,556 | 699,739 | 712,660 | 260,780 | 36,761 | 11,615 | 1,252 | 707 | 1,373 | 3,222,667 |
| 1990 | 241,043 | 392,372 | 1,106,258 | 651,017 | 992,211 | 253,092 | 17,423 | 14,868 | 18,959 | 40,035 | 126,485 | 257,142 | 4,110,905 |
| 1991 | 545,576 | 275,050 | 216,022 | 480,204 | 457,944 | 68,739 | 11,312 | 6,296 | 11,140 | 120,345 | 502,765 | 953,151 | 3,648,544 |
| 1992 | 301,454 | 360,107 | 688,351 | 56,894 | 220,596 | 215,024 | 446,308 | 385,270 | 47,393 | 7,569 | 100,091 | 643,389 | 3,472,446 |
| 1993 | 458,832 | 276,458 | 710,790 | 312,490 | 132,959 | 21,924 | 4,852 | 5,463 | 5,048 | 467,266 | 161,666 | 635,921 | 3,193,669 |
| 1994 | 137,593 | 215,229 | 515,944 | 45,680 | 233,357 | 120,513 | 237,494 | 19,612 | 14,480 | 41,524 | 435,043 | 488,924 | 2,505,393 |

**Table 1-7 (Continued)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 481,154 | 194,353 | 264,307 | 390,919 | 697,825 | 114,449 | 7,188 | 3,865 | 11,457 | 1,692 | 857 | 2,797 | 2,170,863 |
| 1996 | 9,952 | 3,727 | 7,584 | 19,028 | 98,380 | 45,601 | 14,015 | 114,878 | 60,470 | 104,681 | 580,882 | 627,117 | 1,686,315 |
| 1997 | 112,421 | 952,366 | 687,186 | 541,287 | 272,311 | 177,947 | 7,291 | 9,610 | 370 | 10,067 | 24,127 | 326,446 | 3,121,429 |
| 1998 | 912,774 | 371,307 | 386,644 | 51,045 | 33,405 | 4,818 | 390 | 924 | 45,312 | 222,884 | 161,744 | 590,537 | 2,781,784 |
| 1999 | 270,277 | 210,185 | 301,351 | 168,437 | 99,634 | 42,105 | 6,625 | 219 | 417 | 2,358 | 1,994 | 27,781 | 1,131,383 |
| 2000 | 9,084 | 28,758 | 186,536 | 160,925 | 337,369 | 550,892 | 182,850 | 536 | 613 | 526 | 593,665 | 512,147 | 2,563,901 |
| 2001 | 748,339 | 977,725 | 1,181,579 | 322,776 | 74,401 | 79,447 | 30,042 | 10,298 | 90,932 | 176,584 | 18,971 | 1,073,934 | 4,785,028 |
| 2002 | 122,909 | 352,581 | 488,702 | 633,998 | 122,499 | 4,967 | 9,657 | 5,262 | 5,424 | 293,547 | 72,447 | 127,729 | 2,239,722 |
| 2003 | 157,664 | 147,794 | 256,155 | 18,970 | 40,726 | 49,826 | 3,210 | 658 | 2,051 | 1,737 | 2,691 | 2,454 | 683,936 |
| 2004 | 16,840 | 151,014 | 103,266 | 22,833 | 85,254 | 143,784 | 37,407 | 1,803 | 821 | 6,962 | 97,724 | 85,433 | 753,141 |
| 2005 | 257,798 | 119,396 | 80,429 | 61,637 | 6,937 | 1,950 | 3,817 | 3,555 | 3,823 | 1,824 | 1,041 | 1,228 | 543,435 |
| 2006 | 4,079 | 9,023 | 357,343 | 57,332 | 6,121 | 3,482 | 4,230 | 2,190 | 337 | 2,775 | 6,175 | 38,910 | 491,997 |
| 2007 | 489,851 | 51,662 | 27,660 | 86,009 | 97,804 | 297,923 | 747,043 | 100,214 | 11,621 | 31,215 | 3,519 | 55,929 | 2,000,450 |
| 2008 | 12,328 | 207,497 | 946,339 | 672,307 | 160,789 | 54,054 | 17,505 | 12,255 | 17,869 | 23,360 | 14,373 | 17,354 | 2,156,030 |
| 2009 | 21,215 | 19,198 | 193,331 | 155,463 | 1,275,378 | 11,036 | 45,739 | 163,999 | 155,459 | 1,592,539 | 413,219 | 384,502 | 4,431,078 |
| 2010 | 256,545 | 826,702 | 262,901 | 132,656 | 37,476 | 66,699 | 12,345 | 1,493 | 7,749 | 8,401 | 12,371 | 4,070 | 1,629,408 |
| 2011 | 23,351 | 32,331 | 17,510 | 43,841 | 217,985 | 7,350 | 942 | 1,884 | 1,815 | 1,090 | 2,709 | 47,798 | 398,606 |
| 2012 | 174,243 | 233,419 | 583,995 | 198,055 | 38,067 | 16,216 | 8,639 | 1,242 | 2,337 | 3,869 | 3,683 | 8,594 | 1,272,359 |
| 2013 | 27,805 | 24,000 | 8,378 | 41,500 | 47,781 | 55,442 | 4,089 | 923 | 19,451 | 31,404 | 92,500 | 261,708 | 614,981 |
| 2014 | 91,207 | 86,379 | 96,261 | 198,261 | 189,949 | 57,051 | 27,120 | 20,549 | 14,053 | 19,002 | 6,937 | 18,371 | 825,140 |
| Min | 386 | 3,727 | 7,584 | 1,679 | 2,322 | 439 | 94 | 6 | 2 | 0 | 2 | 580 | 398,606 |
| Max | 1,046,787 | 1,238,199 | 1,310,646 | 1,621,927 | 1,317,761 | 712,660 | 747,043 | 385,270 | 583,671 | 1,592,539 | 906,168 | 1,101,354 | 5,206,970 |
| Median | 127,008 | 194,972 | 216,022 | 213,184 | 204,791 | 69,711 | 17,423 | 4,614 | 11,140 | 14,408 | 51,990 | 113,545 | 2,000,450 |

* includes flows originating above Lake Ralph Hall, Lake Chapman and the Marvin Nichols site.

*This space left blank intentionally*

Since the model has new hydrology, we compared the new flows to historical gage data. Data were summed to monthly to facilitate the comparison. We used a scatter plot, which compares the month-by-month flows, as well as a double mass curve, which compares running sums of both sets of data. The double mass plot shows the long-term relationship between the datasets.

Figure 1-2 compares the flows at the Sulphur River near Talco gage. Historical gage data are available beginning in October 1956. The USACE flows are about 80 percent of the historical flows, which makes sense because the USACE flows assume both Lake Chapman (built in 1991) and Lake Ralph Hall (not yet constructed) are upstream and fully operational for the entire period. There is some variation in the monthly scatter data but the overall comparison between the two datasets is very good, as shown by the double mass plot.

Figure 1-3 compares the flows at the Marvin Nichols site to the Sulphur River at IH 30 near Dalby Springs gage, which is located downstream of the reservoir site. Data at the Dalby Springs gage are available beginning in October 2008. The comparisons show a good correlation, particularly considering that the USACE flows were developed using other gages. Figure 1-4 compares the Dalby Springs flows to the modeled inflows into Lake Wright Patman, located downstream of the gage. Again these flows show a good correlation ($R^2 = 0.96$).

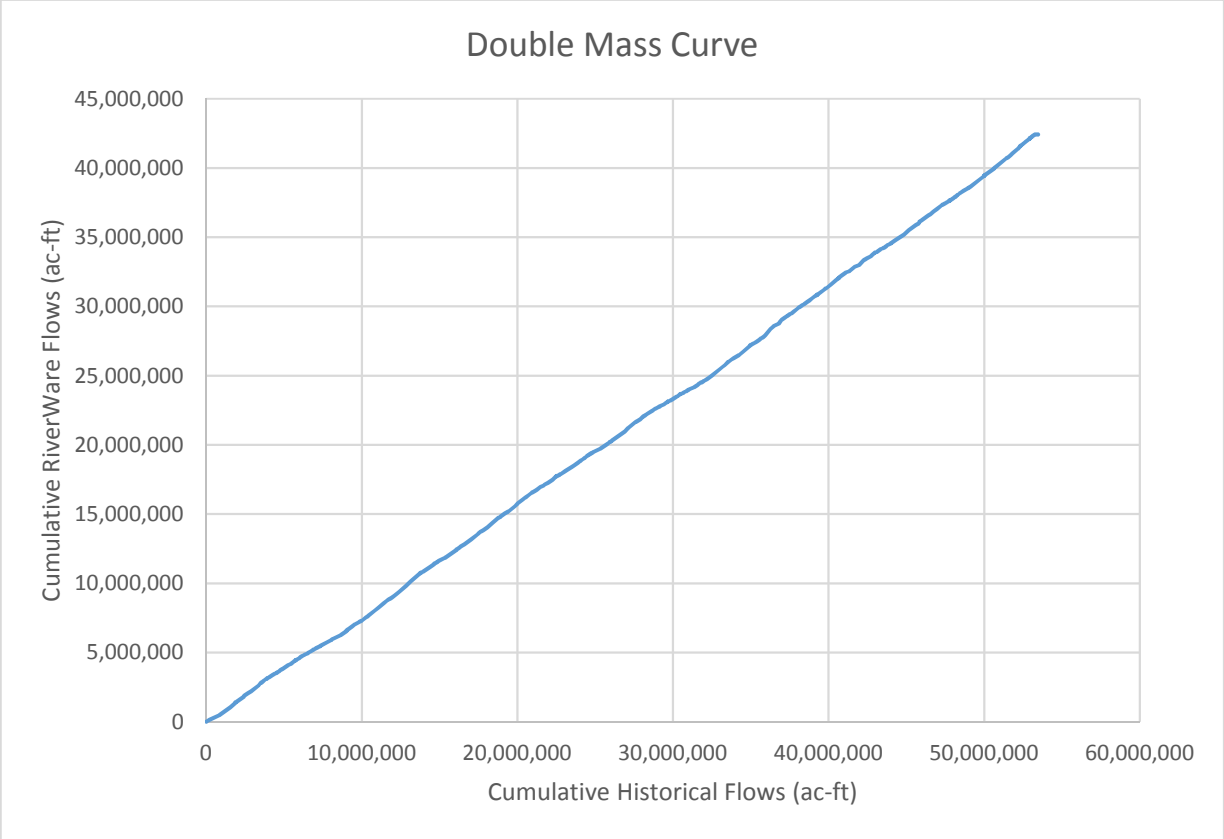
Figure 1-5 compares the modeled flows for the North Sulphur River near Cooper and the White Oak Creek near Talco gages. The flows in the model are identical to the historical flows.

## Priority Assumption

One of the additions FNI made to the USACE RiverWare Model was the incorporation of priority assumptions in the modeling. The purpose of this is to mimic the priority operation in the WAM model. The USACE model cannot fully replicate the WAM because it only includes three reservoirs with water rights, Lakes Ralph Hall, Chapman and Patman. Smaller reservoirs and water rights are not included in the model setup, and the hydrology in the USACE model has not been adjusted to account for the historical operation of these water rights. It would be a considerable effort to make the USACE model fully replicate the WAM.

The RiverWare software actually has built-in water accounting features that are designed to simulate priority allocation of water. However, these features could not be implemented within the timeframe required for the current study. Instead, a separate analysis was run using a specially developed WRAP model, referred to as the SBG SB WRAP model. This model was used to determine the priority releases to be included in the USACE model. The priority releases will be the same regardless of the storage volume in either Marvin Nichols Reservoir or Lake Wright Patman.

**Figure 1-2: Comparison of Monthly USACE Flows to Historical Flows**
**Sulphur River near Talco (10/1956 to 12/2014)**



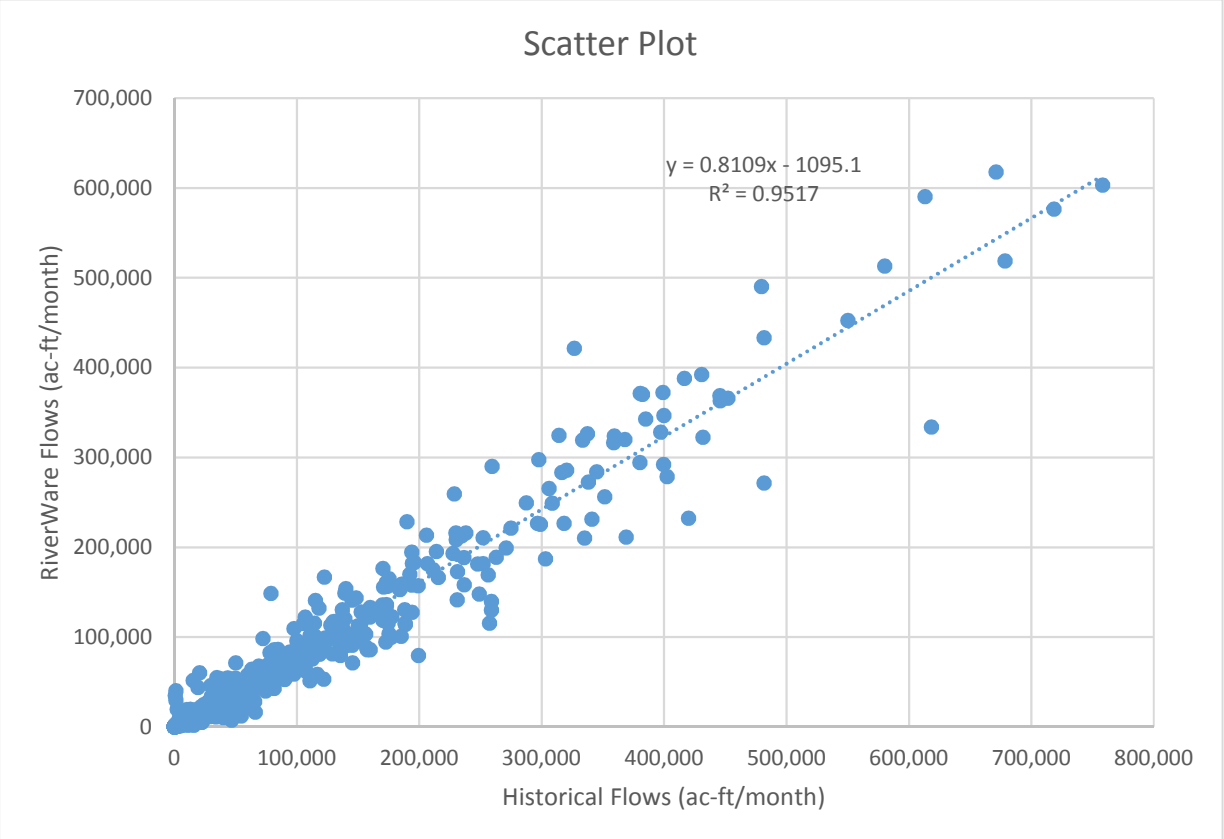
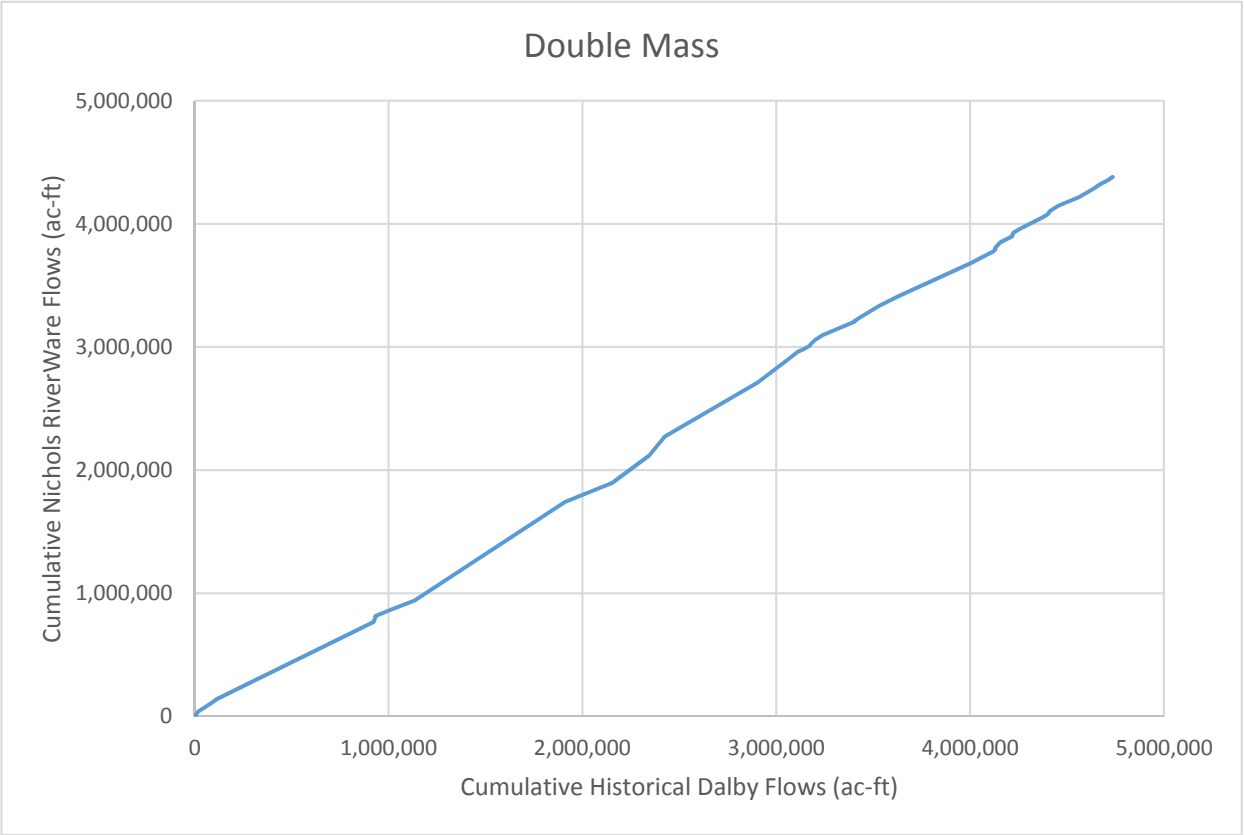



**Figure 1-3: Comparison of Monthly USACE Flows to Historical Flows**
**Dalby Springs Gage vs Marvin Nichols Inflows (10/2008 to 12/2014)**



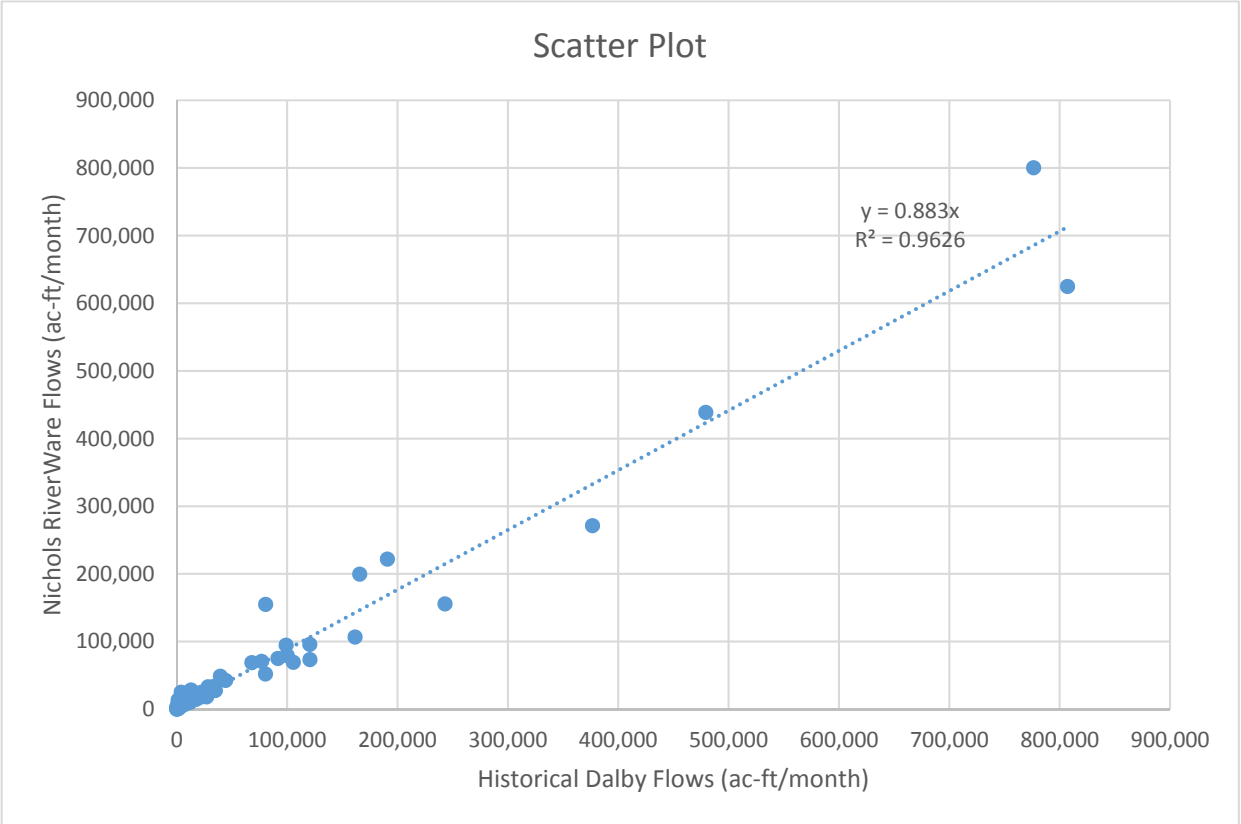
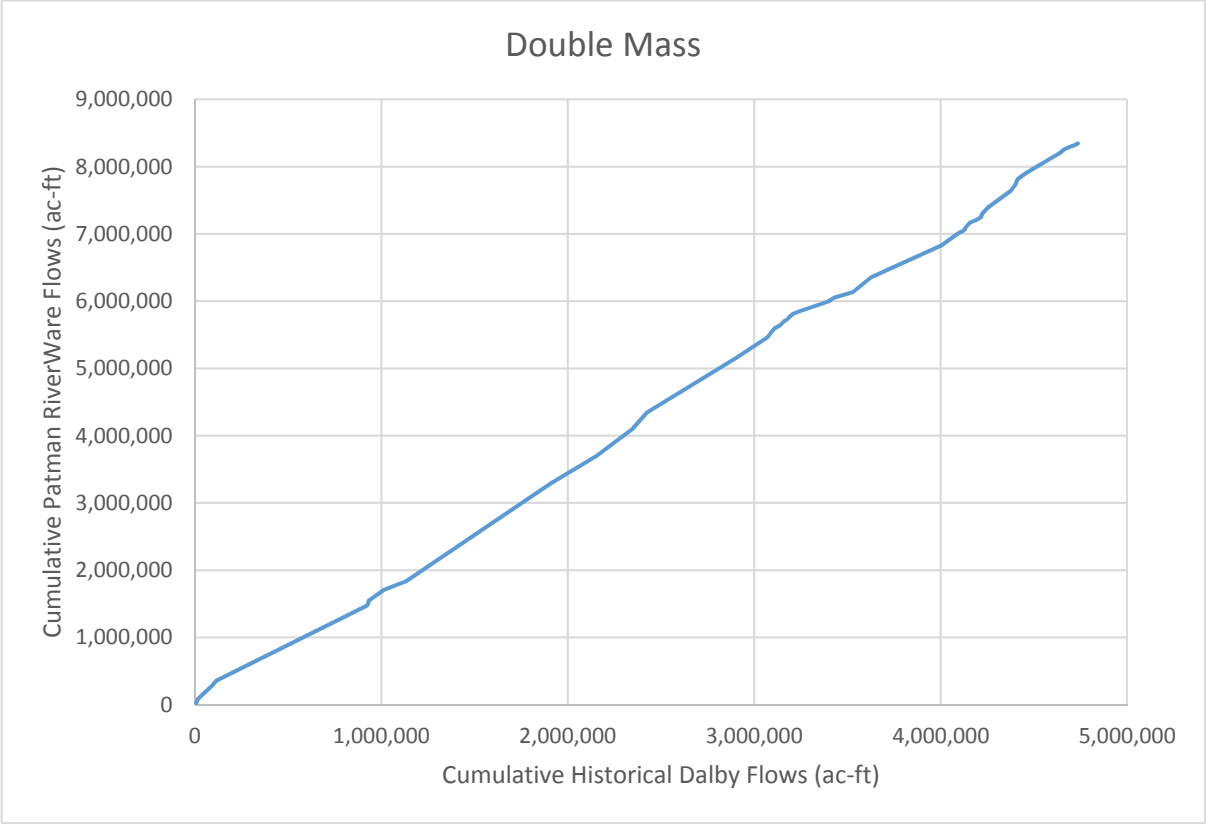



**Figure 1-4: Comparison of Monthly USACE Flows to Historical Flows**
**Dalby Springs Gage vs Patman Inflows (10/2008 to 12/2014)**



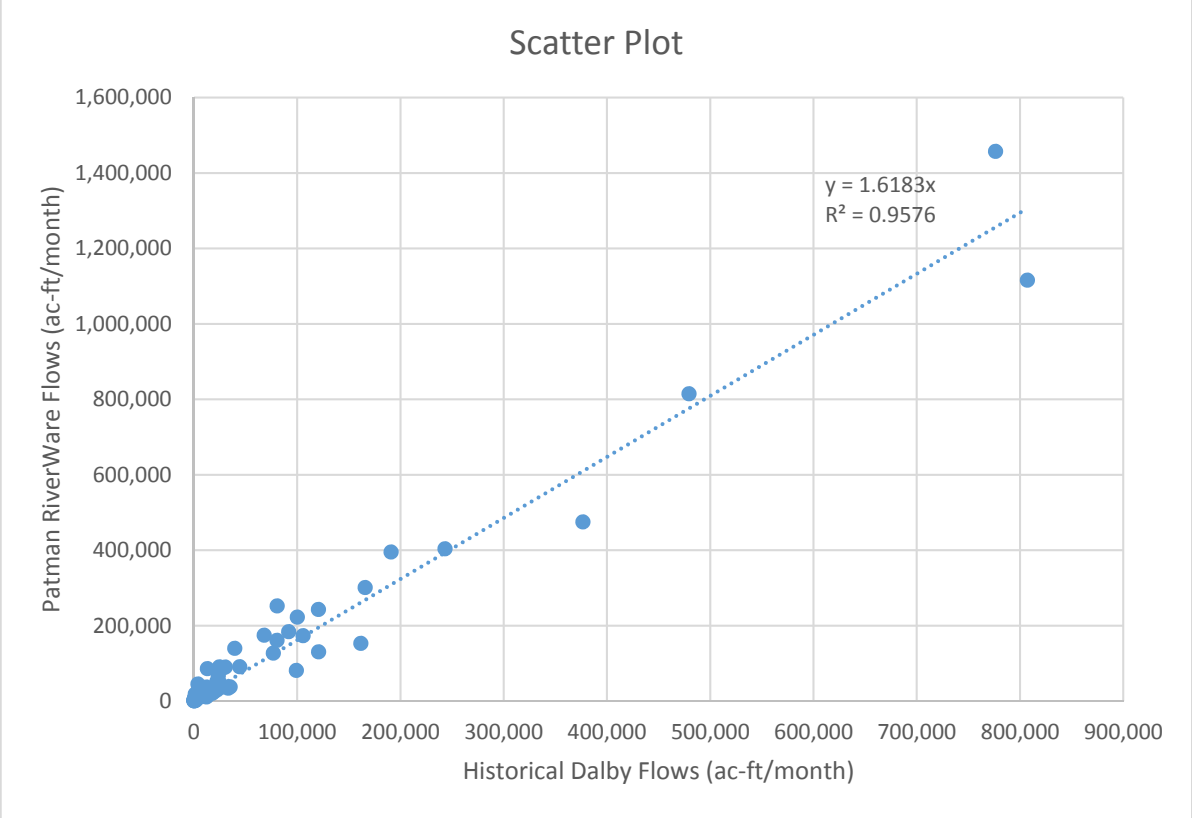
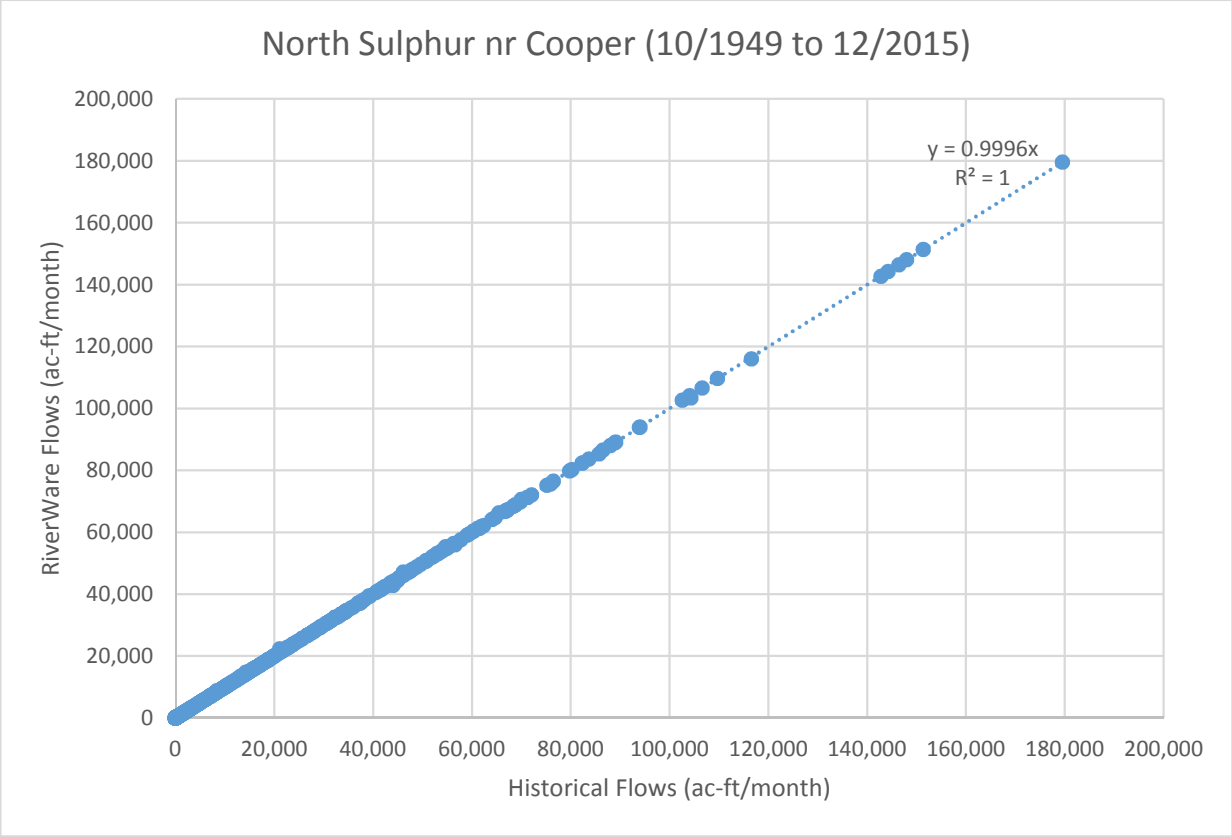
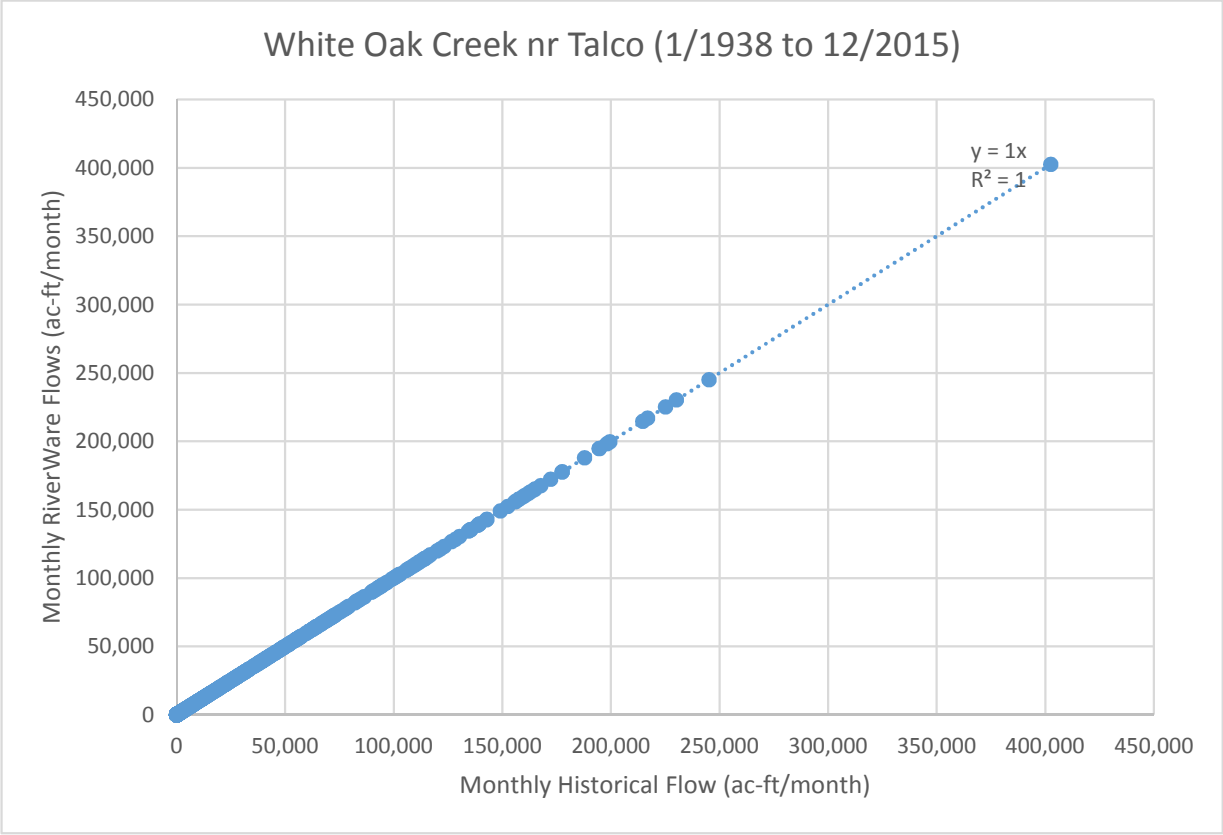



**Figure 1-5: Comparison of Monthly USACE Flows to Historical Flows**
**North Sulphur nr Cooper and White Oak nr Talco**



*Water Rights Included in the Modeling*

Table 1-8 shows the authorized diversions and storage for Lakes Ralph Hall, Chapman and Patman, the reservoirs included in the USACE RiverWare Model. (Marvin Nichols Reservoir does not yet have a water right). The most senior of these water rights is the first 60,000 ac-ft/yr of diversion and the storage associated with Lake Patman. These authorizations have 1951 and 1957 priority dates. The next most senior are the diversions out of Lake Chapman (a.k.a. Lake Cooper), which total 146,520 ac-ft/yr and have a 1965 priority date. The remaining 120,000 ac-ft/yr of the Lake Patman right are junior to Lake Chapman. Lake Ralph Hall is junior to all of the other rights in the USACE RiverWare Model.

**Table 1-8: Summary of Water Rights Included in USACE RiverWare Model**

| Reservoir | Owner | Water Right Number [a] | Priority Date | Type of Use | Permitted Diversion (ac-ft/yr) | Permitted Storage (ac-ft/yr) |
|---|---|---|---|---|---|---|
| Lake Wright Patman | City of Texarkana | CA 03-4836 | 3/5/1951 | Mun | 14,572 | 386,900 [b] |
| | | | 2/17/1957 | Mun | 10,428 | |
| | | | | Ind | 35,000 | |
| | | | 9/19/1967 | Mun | 20,000 | |
| | | | | Ind | 100,000 | |
| | | | *Patman Total* | | *180,000* | *386,900* |
| Lake Jim Chapman | Sulphur River MWD, City of Commerce [c] | CA 03-4797 | 11/19/1965 | Mun | 26,960 | 81,470 |
| | | | | Ind | 11,560 | |
| | | | *SRMWD Total* | | *38,520* | *81,470* |
| | NTMWD | CA 03-4798 | 11/19/1965 | Mun | 54,000 | 114,265 |
| | Irving | CA 03-4799 | 11/19/1965 | Mun | 44,820 | 114,265 |
| | | | | Ind | 9,180 | |
| | | | *Irving Total* | | *54,000* | *114,265* |
| | *Chapman Total* | | | | *146,520* | *310,000* |
| Lake Ralph Hall [d] | Upper Trinity Regional Water District | P/A 03-5821 | 8/13/2004 | Mun, Ind, Ag | 45,000 | 180,000 |

Notes:

a CA = Certification of Adjudication, P/A = Permit/Application.

b Authorized Patman storage is maximum amount specified in rule curve. The rule curve in the water right is identical to the USACE Ultimate Curve.

c 16,106 ac-ft/yr of CA 03-4797 committed to Upper Trinity Regional Water District and 3,214 ac-ft/yr committed to NTMWD. Remainder committed to Cities of Sulphur Springs and Cooper.

d Authorizations based on draft permit for Lake Ralph Hall, which at the time of this report is still pending.

*Implementation of Priority in the USACE RiverWare Model*

The USACE RiverWare Model only has the features in the Sulphur Basin shown in Figure 1-1. (The USACE Model would require extensive modification to simulate all of the water rights in the basin like the WRAP model). In order to verify that the priority operation of the basin could be modeled using only the major features found in the USACE RiverWare Model, a condensed version of the full FNI WAM was developed, which only includes the features in Figure 1-6. This model used only the WAM flows associated with these features, extracted from the full FNI WAM. This condensed model verified that most of the priority releases being passed from both Lake Chapman and Lake Ralph Hall are associated with Lake Wright Patman's senior rights. In other words, the interaction between Lakes Chapman, Ralph Hall, and Patman is responsible for the majority of the regulatory flow of water through the basin, and other water rights are small and minimally impact the results.

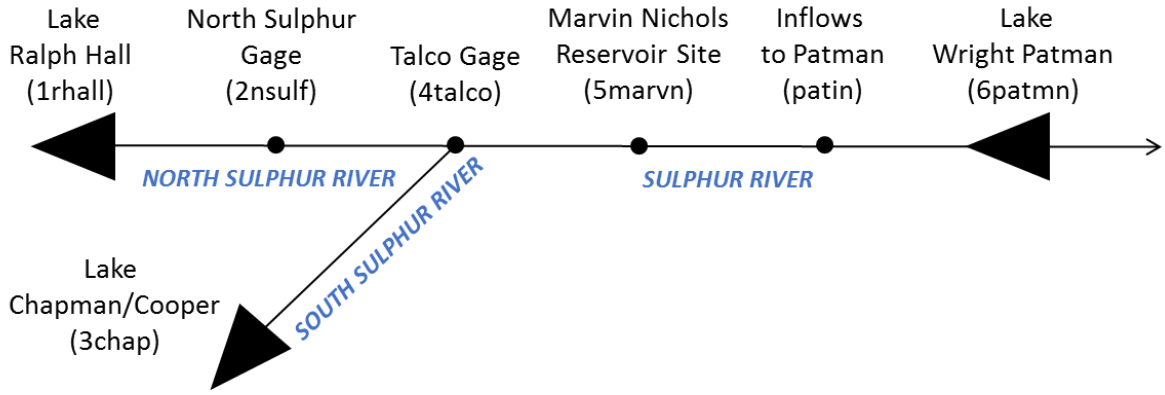



**Figure 1-6: Schematic of the FNI SB WRAP Model**

The priority releases from the condensed FNI Sulphur WAM model only cover the period from 1940 to 1996. For this study, we needed priority releases for the full period of the USACE RiverWare Model, 1938 to 2014. To do this we developed a modified version of the condensed model that used the hydrology from the USACE model, the SBG SB WRAP Model. This model was used to determine monthly data series of flows passed to Lake Patman's senior rights from Lake Ralph Hall, Lake Chapman, and at the Marvin Nichols site. The passage of priority flows is independent of the storage in either Marvin Nichols or Patman, and can therefore be used for all scenarios in the current study. The reservoirs, priorities, diversions and storage amounts used in the SBG SB WRAP model are shown in Table 1-9. The storage amounts shown in Table 1-9 reflect current sediment conditions in the reservoirs and so differ from the full permitted amounts authorized in the water rights shown in Table 1-8.

**Table 1-9: Reservoirs, Priorities, Diversions, and Storage Capacities as Represented in the FNI SB WRAP Model**

| Reservoir | Priority Date | Diversion (ac-ft/yr) | Storage Capacity (ac-ft) |
|---|---|---|---|
| Wright Patman | 3/5/1951 | 14,572 | 298,084 (87,300 inactive)[1] |
| | 2/17/1957 | 10,428 | |
| | 9/19/1967 | 20,000 | |
| | 2/17/1957 | 35,000 | |
| | 9/19/1967 | 100,000 | |
| *Total* | | *180,000* | |
| Jim Chapman | 11/19/1965 | 16,106 | 298,930 (38,598 inactive)[2] |
| | 11/19/1965 | 19,200 | |
| | 11/19/1965 | 3,214 | |
| | 11/19/1965 | 54,000 | |
| | 11/19/1965 | 54,000 | |
| *Total* | | *146,520* | |
| Ralph Hall | 8/13/2004 | 45,000 | 160,235 |

1. For Lake Wright Patman, capacity is the maximum amount specified in the Ultimate Rule Curve; storage capacities are based on the 2010 TWDB volumetric survey, modified to include storage above 226.3 feet.
2. For Lake Chapman, storage capacities are based on the 2007 TWDB volumetric survey

The operations of water rights holders that are not explicitly considered in the SBG SB WRAP model are inherently reflected in the model hydrology because the flow at these control points is based on historical hydrology from stream gages. The amount of water appropriated by these rights is reflected in the historical record, which has not been adjusted to account for the operation of these rights. (WAM hydrology has been adjusted for the operation of all rights).

WRAP does not directly track the amount of water passed at any given point for senior water rights – it must be calculated. In general, the flow passed for downstream senior water rights at a given control point is equal to the regulated flow less the unappropriated flow. In WRAP, regulated flows represent the physical streamflow after accounting for all the water rights. Unappropriated flows are the portion of the regulated flow that has not been reserved for senior rights (Wurbs, 2013). Unappropriated flows are equal to zero when all of the flow at a given control point has been reserved for instream flows or senior rights. For this application, we assumed that if a control point has a reservoir, the priority releases are zero during months when the reservoir was full and spilling. For Lake Chapman, the constant 5 cfs releases were subtracted from the regulated flows when calculating the amount passed for Lake Patman because it cannot be determined what portion of the 5 cfs release was reserved for Patman's senior right. These releases are explicitly modeled in the USACE RiverWare Model and would be the same in both platforms.

The monthly priority release was calculated based on the WRAP simulation, and then disaggregated to daily bypass requirements by assuming a uniform distribution throughout the month. The daily bypass requirements for each control point were then input into the USACE RiverWare Model as mandatory releases. Tables 1-2, 1-4, and 1-6 contain the monthly priority releases.

Based on the complete 1938-2014 period of record, the portion of flow passed downstream for Lake Patman's senior water rights is 4% at Lake Ralph Hall, 2% at Lake Chapman and 4% at the proposed Nichols Reservoir.

There are two variations in priority releases incorporated into the USACE RiverWare Model. In the first, all reservoirs (Ralph Hall, Chapman and Marvin Nichols) make priority releases for Lake Patman's senior water right. In the second, Marvin Nichols and Lake Patman are operated as a system, so no priority releases are made from Marvin Nichols for Patman's senior right; only Chapman and Ralph Hall make releases. In the latter case (system operation of Nichols and Patman), Nichols can divert and impound priority releases from Ralph Hall and Chapman. This is consistent with the way priority operations are simulated in WRAP. Under this assumption, Nichols can use and impound water that has been appropriated by Lake Patman's senior right.

## Instream Flows and Low Flow Releases

In addition to the priority operations discussed above, the USACE RiverWare Model was further modified to include the estimated environmental flow requirements previously identified for Nichols Reservoir and Lake Patman by RPS Group. These environmental flows were developed using the Lyons criteria, which recommends minimum streamflows of 40% of the monthly median flows for October through February and 60% of the monthly median flows for March through September (Bounds and Lyons, 1979). Following standard practice for Texas water rights, passage of flow for environmental needs is limited to the inflow into the reservoir. During days when the Lyons flow requirement is greater than the inflow into the reservoir, the minimum environmental flow requirement was set equal to the inflow. The monthly flow requirements at Nichols and Patman determined by the Lyons method are shown in Table 1-10. The Lyons flows at Patman are applied only to diversions from Lake Patman in excess of 180,000 ac-ft/yr and the filling of junior storage. Junior storage in Lake Patman is defined as the storage above the Ultimate Rule Curve (Figure 1-7). The Ultimate Rule Curve is specified in both the Lake Patman water right (CA 03-4836) and the contract between the City of Texarkana and the USACE. This rule curve sets the maximum authorized impoundment on a monthly basis. Both the water right and the USACE contract only report monthly maximum elevations, which are indicated by the dashed line in Figure 1-7. For the purposes of this study, we linearly interpolated between the maximum elevations corresponding to each month to obtain a continuous daily function shown by the dark line in Figure 1-7.

Lake Wright Patman has another set of required monthly releases that are included in the current USACE RiverWare Model, in addition to the Lyons flows. As modeled, 10 cfs must be released from Patman from November to April and 96 cfs from May to October (Figure 1-7). The 10 cfs release is specified in the contract between Texarkana and the USACE, and the USACE Operating Manual for Lake Wright Patman recommends that the summer releases range from 10 to 96 cfs. In contrast to Lyons flows, these releases occur at all times regardless of inflows. The environmental releases in the USACE RiverWare Model have been coded so that

they are never less than either 10 cfs or 96 cfs, depending on the season, even if Lyons bypass requirements are being used. This assumption was made so that low-flow releases are never less than under current operations.

**Table 1-10: Lyons Environmental Bypass Requirements for the Proposed Nichols Reservoir and Lake Wright Patman**
(Values in acre-feet per month and cubic feet per second)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Nichols** (Ac-Ft/Mo) | 4,192 | 5,687 | 11,712 | 6,963 | 9,409 | 4,163 | 893 | 414 | 494 | 496 | 1,416 | 3,271 |
| (cfs) | 68.2 | 102.4 | 190.5 | 117.0 | 153.0 | 70.0 | 14.5 | 6.7 | 8.3 | 8.1 | 23.8 | 53.2 |
| | | | | | | | | | | | | |
| **Patman** (Ac-Ft/Mo) | 87,755 | 60,336 | 154,045 | 91,434 | 16,583 | 26,598 | 8,412 | 4,206 | 3,963 | 11,633 | 16,257 | 62,570 |
| (cfs) | 1,427.2 | 1,086.4 | 2,505.3 | 1,536.6 | 269.7 | 447.0 | 136.8 | 68.4 | 66.6 | 189.2 | 273.2 | 1,017.6 |

Note: August and September bypass for Lake Wright Patman are less than the 96 cfs constant release used in current Patman operation. In runs with the current release option, a minimum value of 96 cfs is assumed.

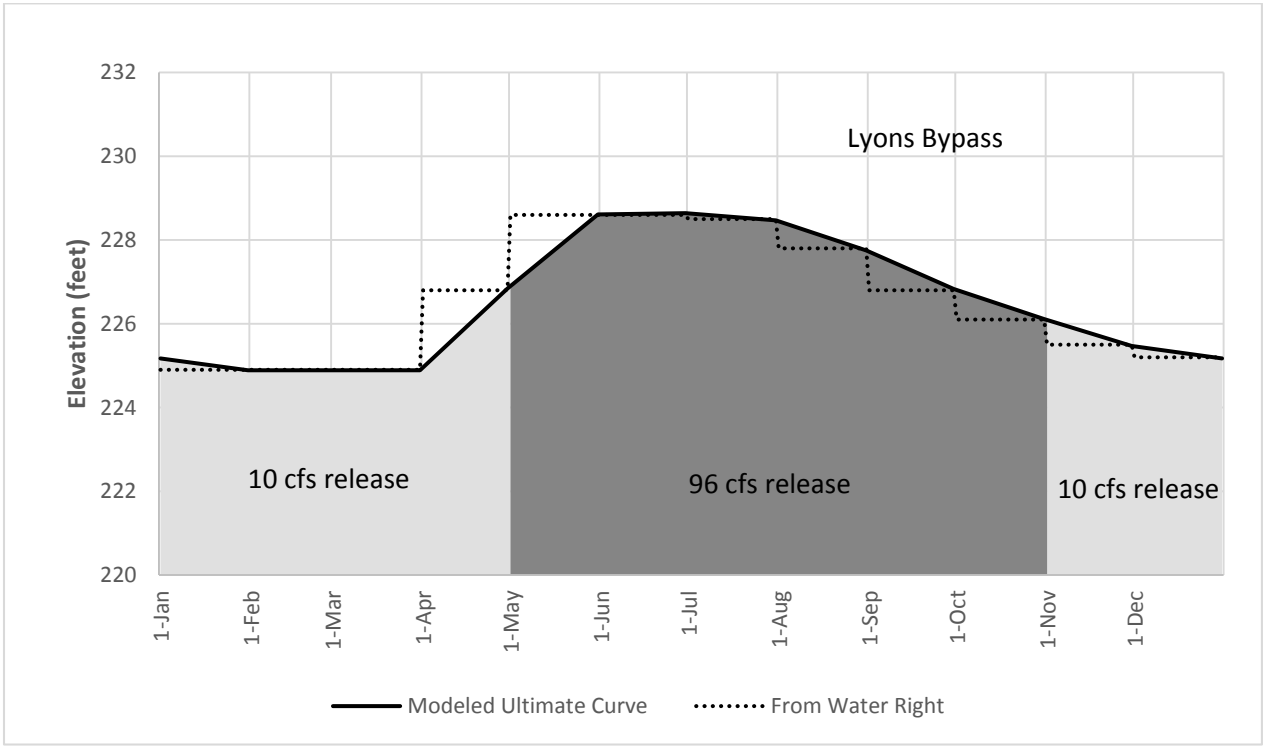



**Figure 1-7: Lake Wright Patman Ultimate Rule Curve and Current Release Requirements**

There is also a 5 cfs required release out of Lake Chapman, which is consistent with the both the TCEQ WAM and USACE operation policies.

In all cases, environmental and low flow releases can be used to meet the needs of downstream senior water rights, and vice versa. Therefore the total release from the reservoir is the maximum of either the environmental flow release or the flow passed for Patman's senior rights.

Some runs in this study use an alternative version of the Wright Patman Lyons bypass in Table 1-10. The alternative version of the Lyons bypass is based on the modeled inflows into Lake Wright Patman under current operations. The alternative Lyons bypass is shown in Table 1-11. Figure 1-8 compares the alternative Lyons flows to the outflow-based Lyons flows found in Table 1-10 and the current USACE minimum releases for Lake Wright Patman.

**Table 1-11: Alternative Lake Wright Patman Lyons Environmental Bypass Requirements Based on Modeled Inflows**
(Values in acre-feet per month and cubic feet per second)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Patman** (Ac-Ft/Mo) | 25,621 | 41,006 | 87,762 | 59,708 | 60,416 | 23,593 | 5,274 | 1,511 | 1,621 | 1,557 | 4,658 | 17,229 |
| (cfs) | 416.7 | 731.8 | 1,427.3 | 1,003.4 | 982.6 | 396.5 | 85.8 | 24.6 | 27.2 | 25.3 | 78.3 | 280.2 |

Note: July through November bypass for Lake Wright Patman are less than the 96 cfs constant release used in current Patman operation. In runs with the current release option, a minimum value of 96 cfs is assumed.

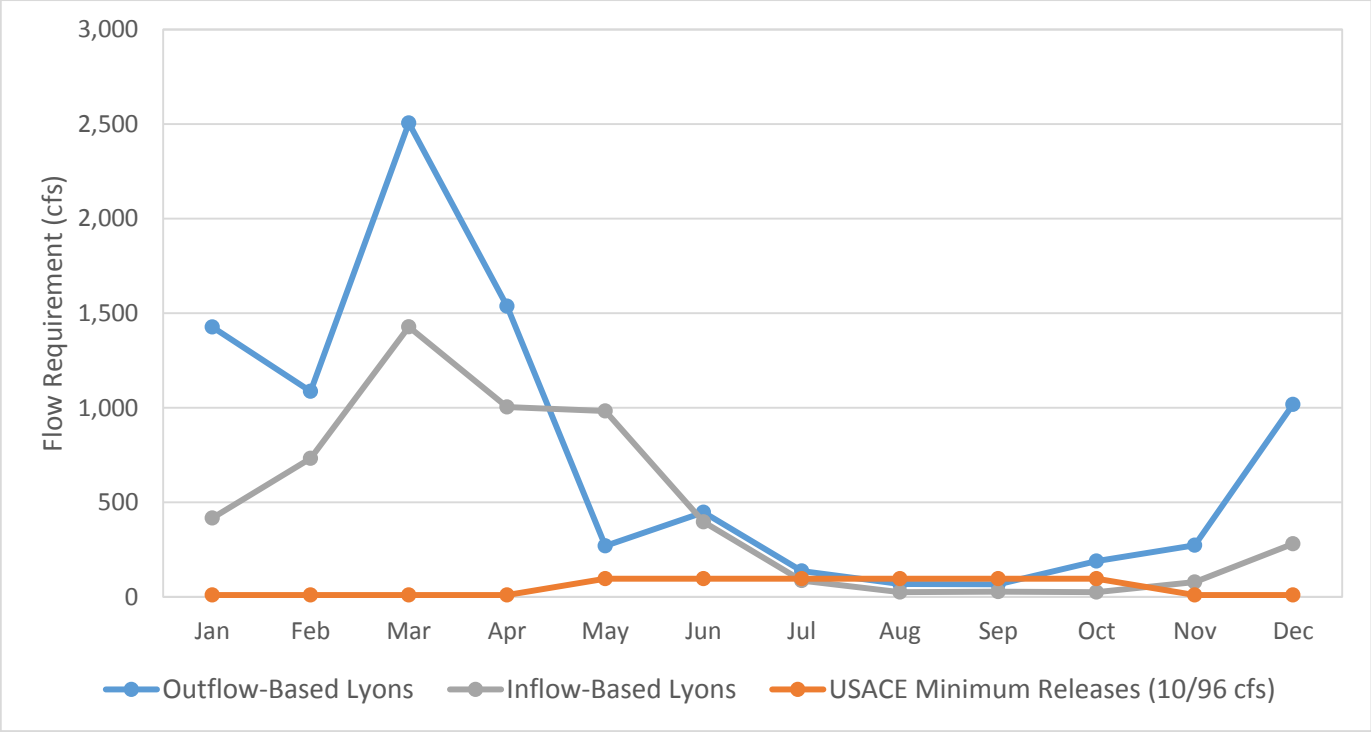



**Figure 1-8: Comparison of Lyons Flows and USACE Minimum Release Requirements**

## Yield Calculation

Firm yields were calculated by assuming a constant daily diversion at each reservoir, as opposed to a seasonal pattern, which is consistent with USACE protocols. Firm yields were calculated for the proposed Marvin Nichols reservoir first before calculating the yield for Lake Wright Patman because it is assumed that (a) Marvin Nichols will be senior to the reallocated diversion and storage in Lake Wright Patman and (b) Nichols is upstream of Lake Patman.

Yields are reported in Attachment 2 and the main text of this memorandum.

## References

Bounds, R. L. and Lyons, B. W. (1979). "Existing Reservoir and Stream Management Recommendations Statewide Minimum Stream Flow Recommendations." Federal Aid Project F-30-R-4. Texas Parks and Wildlife Department, Austin, Texas.

Freese and Nichols, Inc. for Sulphur Basin Group (2014). "Technical Memorandum on Hydrologic Yields." Prepared for the Sulphur River Basin Authority.

Wurbs, R. A. (2013). "Water Rights Analysis Package (WRAP) Modeling System Reference Manual." TR-255, 10th Ed., Texas Water Resources Institute, College Station, TX.

# Attachment 2 Yield Studies

## Stand-Alone Yields of Lake Wright Patman

Table 2-1 shows the stand-alone yields (yields with only Lakes Chapman and Ralph Hall upstream) for Lake Wright Patman reallocation. These yields use the primary assumptions used in this study, including:

- A 96 cfs minimum release from May through October, with a 10 cfs minimum release the remainder of the year
- Lyons environmental bypass from Table 1-10 applied to reallocated storage above the Ultimate Rule Curve and diversions greater than 180,000 acre-feet per year
- Priority bypasses from Lakes Chapman and Ralph Hall for the existing portion of Patman's water right (Ultimate Rule Curve and 180,000 acre-feet per year of diversions)

The yields in Table 2-1 are shown with the Ultimate Rule Curve and for flat pools at 232.5, 242.5 and 252.5 feet msl. The Ultimate Rule Curve is a monthly varying top of conservation storage that varies between elevation 228.64 feet and 224.89 feet. The Ultimate Rule Curve is incorporated in the USACE contract with the City of Texarkana. However, it has never been implemented (a lower interim rule curve is in use), so changing the operation to this curve would either precede or be part of the reallocation process.

**Table 2-1: Stand-Alone Yields Lake Wright Patman Reallocation**

| Patman Conservation Elevation (feet) | Total Yield | | New Yield* |
|---|---|---|---|
| | cfs | acre-feet per year | acre-feet per year |
| Ultimate | 139.8 | 101,244 | 0 |
| 232.5 | 381.3 | 276,201 | 96,201 |
| 242.5 | 605.1 | 438,336 | 258,336 |
| 252.5 | 875.8 | 634,477 | 454,477 |

* New Yield is the yield above 180,000 acre-feet per year, the current authorized diversion from Lake Wright Patman

Table 2-2 compares the Lake Wright Patman yields at elevation 242.5 feet from the January 2014 *Watershed Overview Sulphur River Basin Report* to the yields from the current study. The yields from the Watershed Overview were done with the Sulphur Basin Water Availability Model (WAM), which only has hydrology through 1996 and does not include the more recent drought-of-record conditions. It also has different assumptions, including a constant 10 cfs release instead of the 96 cfs release from May through October, and no environmental bypass. The yields from the current study are reported using similar assumptions, so they are different than the yields reported in Table 2-1. A yield based on only the hydrology from 1940 to 1996 is included in Table 2-2 as well. Note that the yields from the current study using similar assumptions are about

3 percent less than the WAM yields. However, the new drought of record conditions have reduced the yield substantially. Yields in Table 2-2 are only for the new portion of the supply and do not include the 180,000 acre-feet per year currently authorized from Lake Wright Patman.

**Table 2-2: Comparison of Wright Patman Stand-Alone Yields from Current Study to WAM Yields from Previous Studies**

| | WAM Yields | RiverWare Yields 1938 to 2014 Hydrology | RiverWare Yields 1940 to 1996 Hydrology |
|---|---|---|---|
| acre-feet/year | 592,663 | 424,593 | 574,890 |
| cfs | 818.1 | 586.1 | 793.5 |

Note: WAM yields are from the Sulphur Basin Watershed Overview Study. RiverWare Yields are from the current study. RiverWare yields were adjusted to have similar assumptions to those used in the WAM.

Independent stand-alone yields of the proposed Marvin Nichols Reservoir would be the same as the combination yields shown in the next section. Marvin Nichols is assumed to be senior to Lake Wright Patman reallocation, so the yield is independent of the downstream reservoir.

## Combination Yields

Figure 2-1 shows the Marvin Nichols Reservoir and Lake Wright Patman reallocation that were used to determine configurations that meet the supply goals. The black line shows the conservation elevation combinations that meet the 604,000 acre-feet per year supply goal. The blue dots represent the individual runs that were used to determine the black line. The red dots show the yields with Marvin Nichols at 313.5 feet or 328 feet conservation with various elevations of Wright Patman reallocation. The red dots are intended to bracket the results. The data used to make the graph are shown in Table 2-3.

These yields have the following assumptions:

- The yields represent “new” supplies and do not include the 180,000 acre-feet per year already authorized from Lake Wright Patman.
- Priority releases from upstream reservoirs and Marvin Nichols for the existing Lake Wright Patman water right. Marvin Nichols and the other reservoirs do not, however, make priority releases for the new storage and diversions associated with the Patman reallocation.
- Environmental flow releases based on the Lyons method.
- A 96 cfs release from Lake Wright Patman from May to October, with a 10 cfs release at other times of the year.

These assumptions are described in Attachment 1.

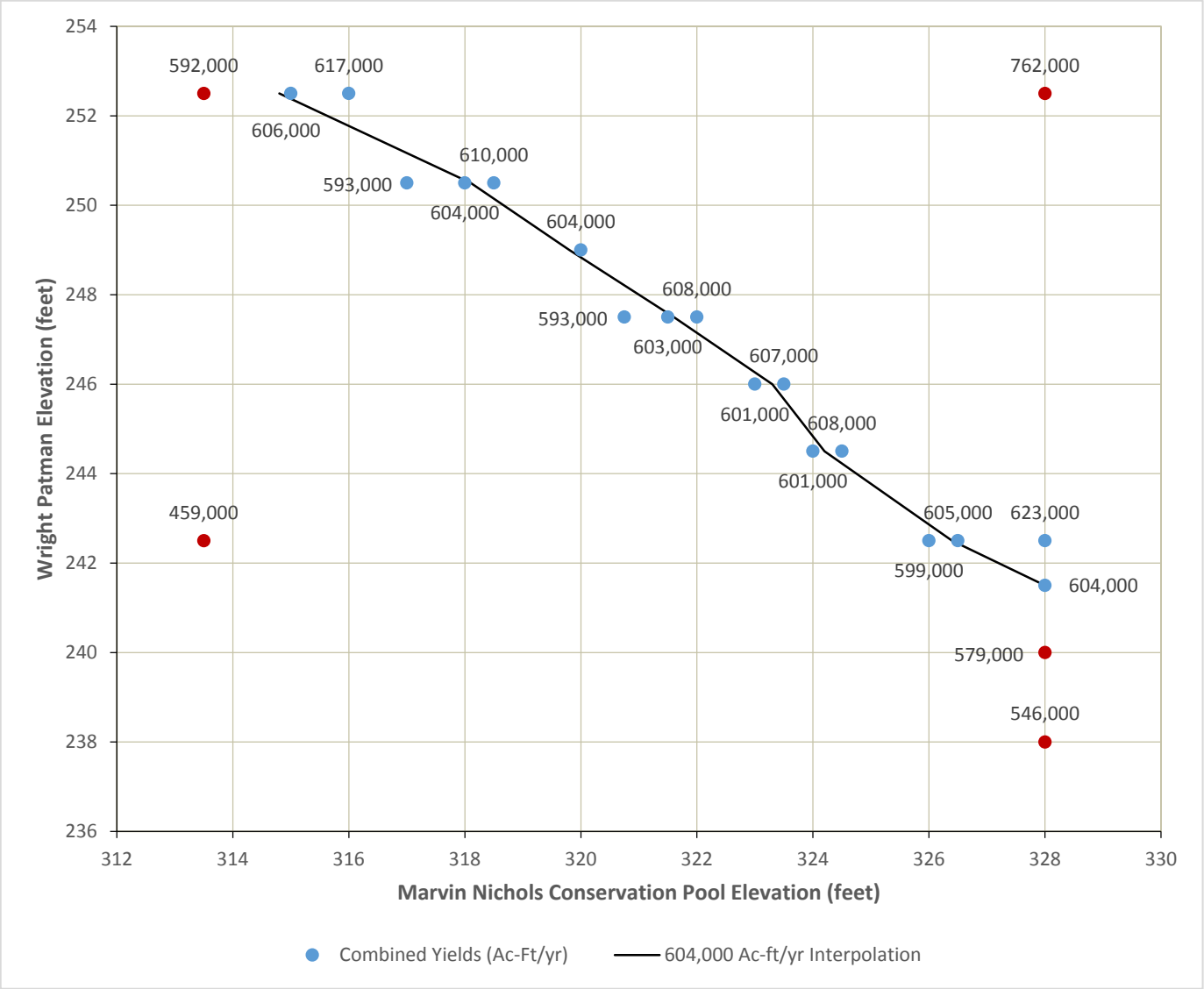



**Figure 2-1: Combined Yields of Wright Patman Reallocation and the Proposed Marvin Nichols Reservoir**

**Table 2-3: Combined Yields of Wright Patman Reallocation and the Proposed Marvin Nichols Reservoir**

| Patman Elevation (feet) | Marvin Nichols Elevation (feet) | New Patman Yield (acre-feet/year) | Marvin Nichols Yield (acre-feet/year) | Combined Yield (acre-feet/year) |
|---|---|---|---|---|
| 238.0 | 328.0 | 81,000 | 464,000 | 545,000 |
| 240.0 | 328.0 | 113,000 | 466,000 | 579,000 |
| 241.5 | 328.0 | 137,000 | 467,000 | 604,000 |
| 242.5 | 313.5 | 159,000 | 299,000 | 458,000 |
| 242.5 | 326.0 | 159,000 | 440,000 | 599,000 |
| 242.5 | 326.5 | 159,000 | 446,000 | 605,000 |
| 242.5 | 328.0 | 159,000 | 464,000 | 623,000 |
| 244.5 | 324.0 | 184,000 | 417,000 | 601,000 |
| 244.5 | 324.5 | 184,000 | 423,000 | 607,000 |
| 246.0 | 323.0 | 195,000 | 406,000 | 601,000 |
| 246.0 | 323.5 | 195,000 | 412,000 | 607,000 |
| 247.5 | 320.8 | 214,000 | 380,000 | 594,000 |
| 247.5 | 321.5 | 214,000 | 390,000 | 604,000 |
| 247.5 | 322.0 | 213,000 | 395,000 | 608,000 |
| 249.0 | 320.0 | 234,000 | 371,000 | 605,000 |
| 250.5 | 317.0 | 258,000 | 336,000 | 594,000 |
| 250.5 | 318.0 | 258,000 | 347,000 | 605,000 |
| 250.5 | 318.5 | 258,000 | 353,000 | 611,000 |
| 252.5 | 313.5 | 293,000 | 299,000 | 592,000 |
| 252.5 | 328.0 | 291,000 | 471,000 | 762,000 |
| 252.5 | 315.0 | 292,000 | 314,000 | 606,000 |
| 252.5 | 316.0 | 292,000 | 325,000 | 617,000 |

Using these assumptions, with Marvin Nichols at elevation 328 feet (the largest version of Nichols), the minimum reallocation elevation for Lake Wright Patman that meets the supply goal is 241.5 feet. At the largest version of Patman reallocation (elevation 252.5 feet), the minimum conservation elevation for Marvin Nichols required to meet the demand goal is around 315 feet.

## Impact of Modeling Assumptions on Yield

There are four key modeling assumptions that are impacting the firm yield at Lake Wright Patman and Marvin C. Nichols Reservoir: 1) Priority Releases, 2) Lyons Flows, 3) Period of Record, and 4) Patman Minimum Releases. More information on these assumptions may be found in Attachment 1. In order to determine how much each assumption is impacting the yield, they are treated as four on-off switches (Figure 2-2) as follows:

- *Priority Releases* 'On' (Yes) uses water rights priorities to allocate water; 'Off' (No) means water is allocated in a natural upstream to downstream order.
- *Lyons Flows* 'On' (Yes) means that the required environmental releases determined using the Lyons method are activated; 'Off' (No) means the Lyons flows criteria is absent from the modeling. The Lyons flows in this set of modeling are shown in Table 1-10.
- *Period of Record* 'On' (1938-2014) means the period of record is 1938 to 2014; 'Off' (1938-1996) means it is 1938 to 1996.
- *Patman Releases* 'On' (10/96 cfs) means that 96 cfs is released from the reservoir from May through October and 10 cfs is released the remaining months; 'Off' (10 cfs) means that a constant 10cfs is released year-round.

By turning these four switches on and off in various combinations (there is a total of 16 unique combinations), we are able to estimate how much each modeling assumption impacts the yield.

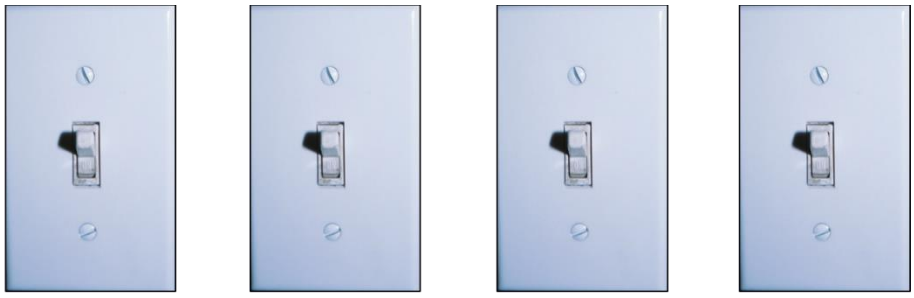



**Figure 2-2: Key Modeling Assumptions Represented as Four On-Off Switches.**

*Impact on Stand-Alone Yields*

Stand-alone yields for Marvin Nichols Reservoir with various combinations of these switches are shown in Figure 2-3 and Table 2-4. These yields assume a conservation pool elevation of 313.5 feet. Stand-alone yields for Lake Wright Patman (i.e. without Nichols Reservoir upstream) at a conservation pool elevation of 242.5 feet are presented in Figure 2-4 and Table 2-5. The yields reported for Patman are the firm yields in excess of 180,000 ac-ft/yr (i.e. "new" yield). In other words, if we were to consider strictly firm yields the total yields from Patman would be 180,000 ac-ft/yr higher.

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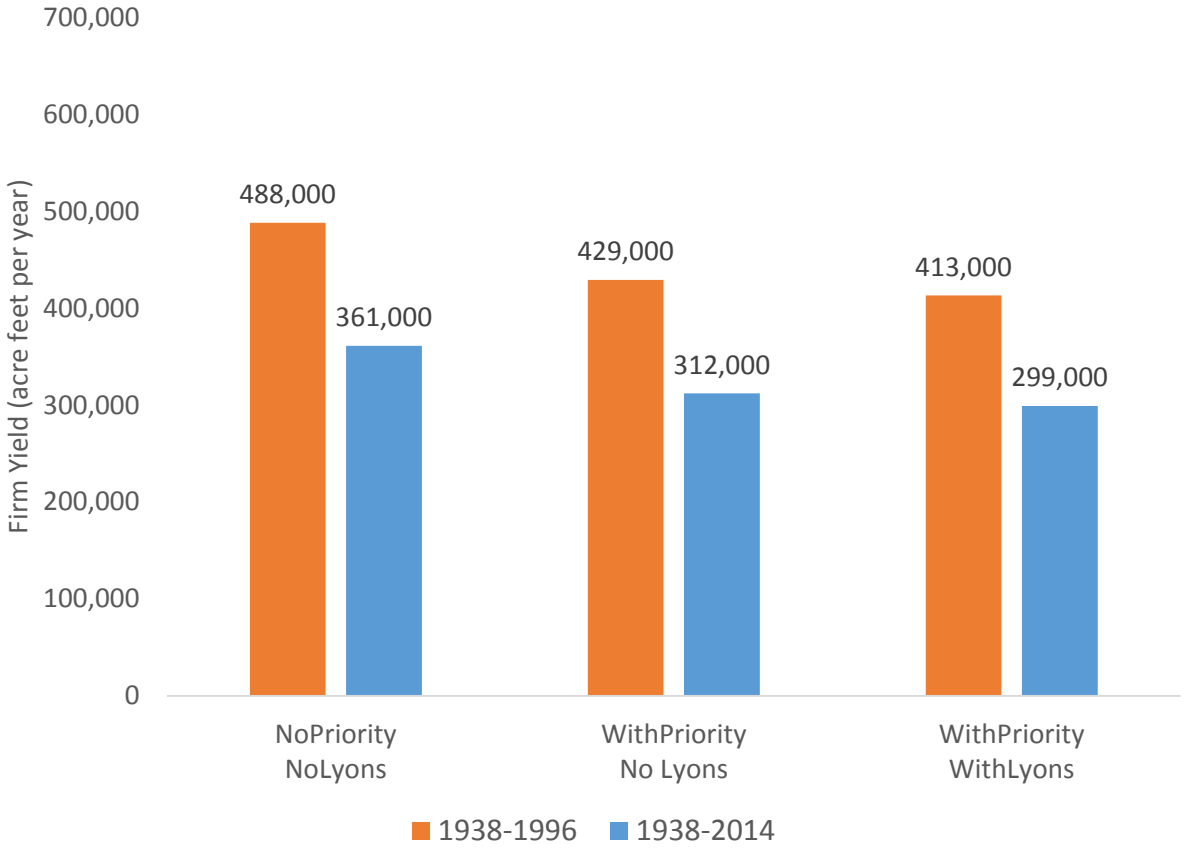


**Figure 2-3: Firm Yields for the Proposed Marvin Nichols Reservoir with a Conservation Pool Elevation of 313.5 feet under Various Modeling Assumptions**

**Table 2-4: Firm Yields for the Proposed Marvin Nichols Reservoir with a Conservation Pool Elevation of 313.5 feet under Various Modeling Assumptions**

| Priority? | Lyons? | Period of Record | Firm Yield (ac-ft/yr) |
|---|---|---|---|
| | | | |
| No | No | 1938-2014 | 361,000 |
| Yes | No | 1938-2014 | 312,000 |
| Yes | Yes | 1938-2014 | 299,000 |
| | | | |
| No | No | 1938-1996 | 488,000 |
| Yes | No | 1938-1996 | 429,000 |
| Yes | Yes | 1938-1996 | 413,000 |

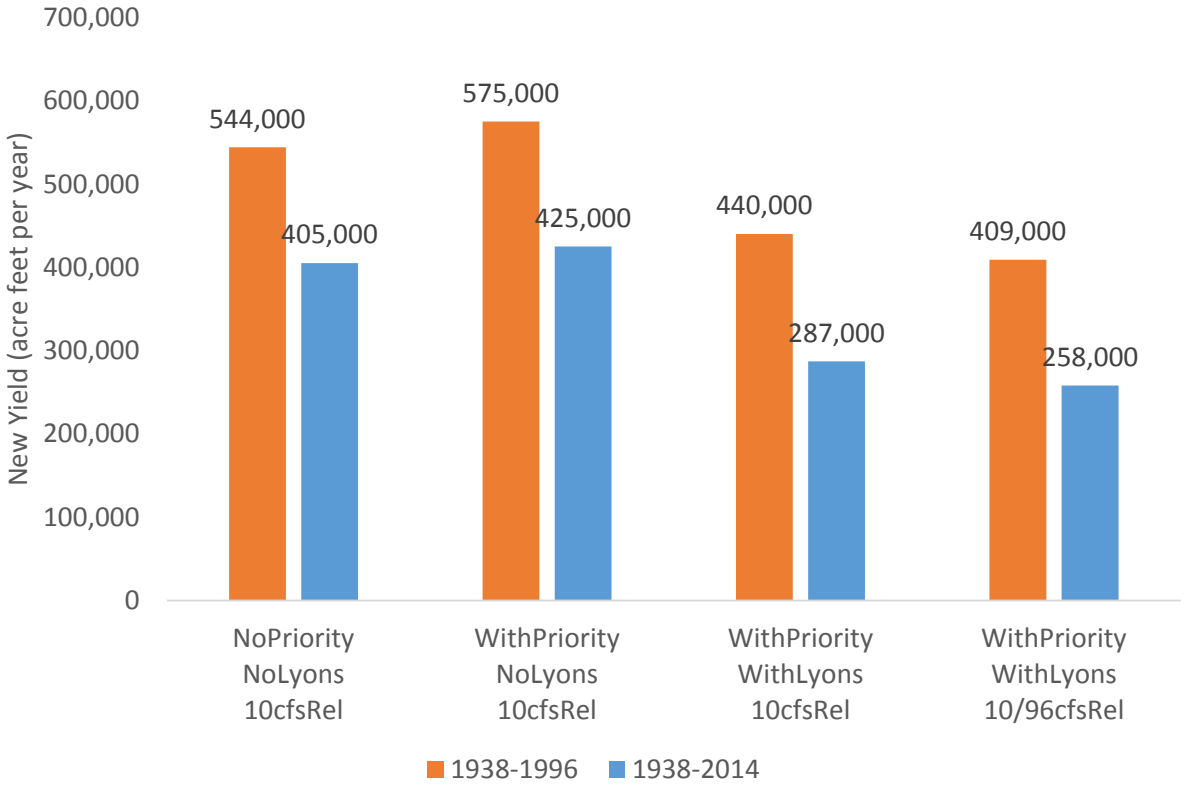


**Figure 2-4: New Yields for Lake Wright Patman Reallocation with a Conservation Pool Elevation of 242.5 feet under Various Modeling Assumptions**

**Table 2-5: New Yields for Lake Wright Patman Reallocation with a Conservation Pool Elevation of 242.5 feet under Various Modeling Assumptions**

| Priority? | Lyons? | Patman Releases | Period of Record | New Yield (ac-ft/yr) |
|---|---|---|---|---|
| No | No | 10 cfs | 1938-2014 | 405,000 |
| Yes | No | 10 cfs | 1938-2014 | 425,000 |
| Yes | Yes | 10 cfs | 1938-2014 | 287,000 |
| Yes | Yes | 10/96 cfs | 1938-2014 | 258,000 |
| No | No | 10 cfs | 1938-1996 | 544,000 |
| Yes | No | 10 cfs | 1938-1996 | 575,000 |
| Yes | Yes | 10 cfs | 1938-1996 | 440,000 |
| Yes | Yes | 10/96 cfs | 1938-1996 | 409,000 |

*Impact of Assumptions on Combination Yields*

The impact of the four modeling switches on the combined yields for Nichols at 313.5 feet and Patman reallocation at 242.5 feet are presented in Figure 2-5 and Table 2-6. The WAM yields from the *Watershed Overview Sulphur River Basin Report* are included for comparison purposes.

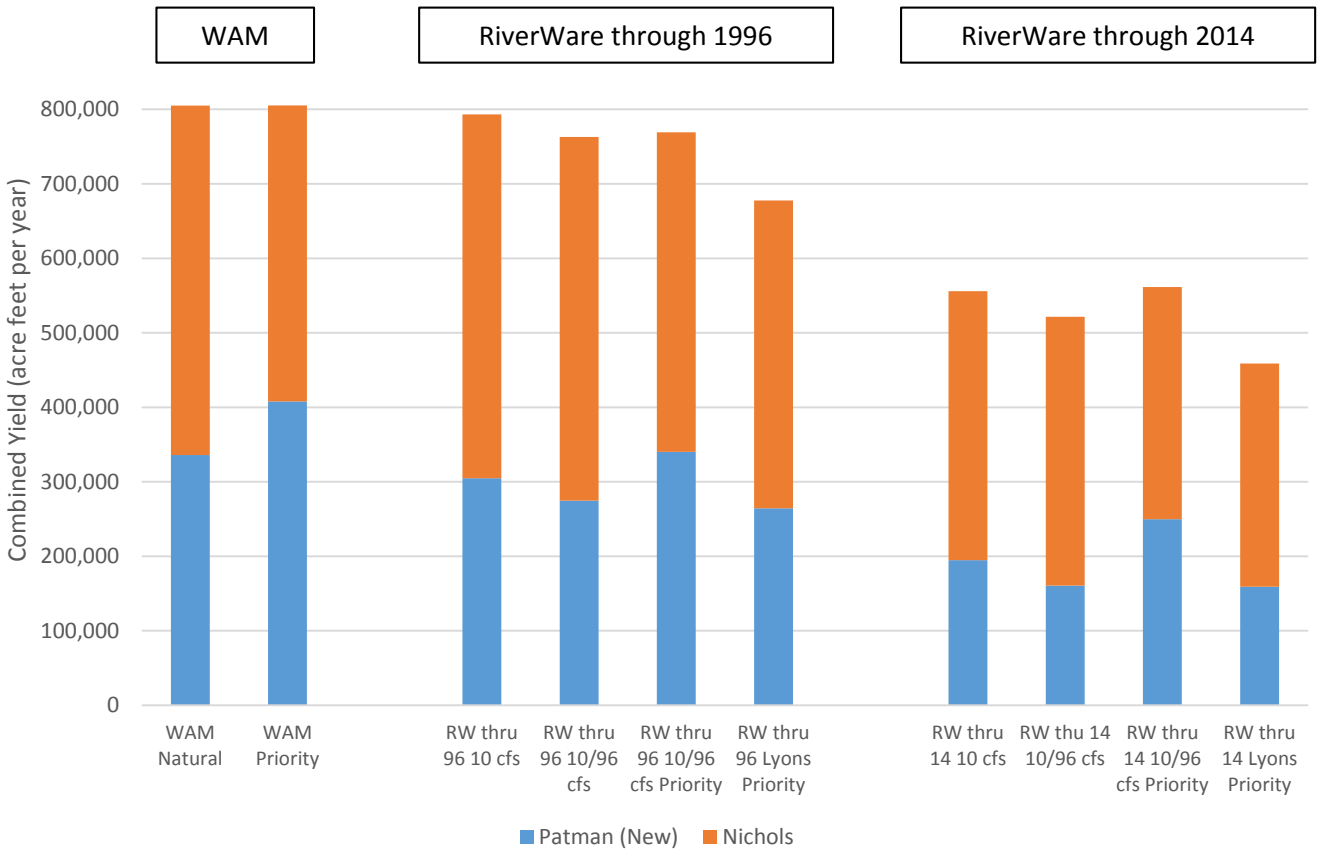


**Figure 2-5: Combined Yields for Lake Wright Patman Reallocation and Marvin Nichols Reservoir under Various Modeling Assumptions**

**Table 2-6: Combined Yields for Lake Wright Patman Reallocation and Marvin Nichols Reservoir under Various Modeling Assumptions**

| Run | Priority? | Lyons? | Patman Releases | Period of Record | Patman (New) | Nichols (ac-ft/yr) | Total (ac-ft/yr) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| WAM Natural | No | No | 10 cfs | 1940-1996 | 336,000 | 469,000 | 805,000 |
| WAM Priority | Yes | No | 10 cfs | 1940-1996 | 408,000 | 397,000 | 805,000 |
| | | | | | | | |
| RW thru 96 10 cfs | No | No | 10 cfs | 1938-1996 | 305,000 | 488,000 | 793,000 |
| RW thru 96 10/96 cfs | No | No | 10/96 cfs | 1938-1996 | 275,000 | 488,000 | 763,000 |
| thru 96 10/96 cfs Priority | Yes | No | 10/96 cfs | 1938-1996 | 340,000 | 429,000 | 769,000 |
| thru 96 Lyons Priority | Yes | Yes | 10/96 cfs | 1938-1996 | 264,000 | 413,000 | 677,000 |
| | | | | | | | |
| RW thru 14 10 cfs | No | No | 10 cfs | 1938-2014 | 195,000 | 361,000 | 556,000 |
| RW thru 14 10/96 cfs | No | No | 10/96 cfs | 1938-2014 | 161,000 | 361,000 | 522,000 |
| thru 14 10/96 cfs Priority | Yes | No | 10/96 cfs | 1938-2014 | 250,000 | 312,000 | 562,000 |
| thru 14 Lyons Priority | Yes | Yes | 10/96 cfs | 1938-2014 | 159,000 | 299,000 | 458,000 |

Note: Modeling assumes Lake Wright Patman reallocation to 242.5 feet and Marvin Nichols at 313.5 feet.

## Impacts of Alternative Model Assumptions

We also explored reasonable modifications to the assumptions in order to estimate the maximum potential combined yield from these two projects. Because the new drought of record is unchangeable, there are three modeling assumptions that could be adjusted: 1) Nichols Priority Releases, 2) Patman Lyons Flows, and 3) Patman Minimum Releases. These alternatives are described in Attachment 1. In order to determine how much yield could be won back by modifying each assumption, they are treated as three different on-off switches (Figure 2-6) as follows:

- *Nichols Priority Releases* 'On' (Yes) uses strict water rights priorities to allocate water; 'Off' (No at Nichols) follows water rights priorities except that the rights in Patman are made subordinate to Marvin Nichols.

- *Patman Lyons Flows* 'On' (Yes) means that the environmental releases from Table 1-10 are used; 'Off' (New) means the alternative Patman Lyons flow calculations based on the inflow to the reservoir (Table 1-11) are used instead.

- *Patman Minimum Releases* 'On' (Yes) means that 96 cfs is released from the reservoir from May through October and 10 cfs is released the remaining months; 'Off' (No) means that a constant 10cfs is released year-round.

By turning these three switches on and off in various combinations (there is a total of 8 unique combinations), we are able to estimate how much modifying each assumption impacts the yield. For illustration purposes, a ninth run was included that removes the Lyons flows requirement from Patman completely in order to estimate the maximum possible yield, however this modification may not be reasonable. The 9 runs were conducted for three different elevations for Lake Wright Patman (232.5 ft, 237.5 ft and 242.5 ft), assuming a Nichols elevation of 328.0 ft. The need shown in Figures 2-8 through 2-10 is equal to the goal supply of 604,000 acre-feet per year. The period of analysis is 1938 to 2014. Combined yields for Patman at 232.5 feet and Nichols at 328.0 feet are presented in Figure 2-7 and Table 2-7. Combined yields for Patman at 237.5 feet and Nichols at 328.0 feet are presented in Figure 2-8 and Table 2-8. Combined yields for Patman at 242.5 feet and Nichols at 328.0 feet are presented in Figure 2-9 and Table 2-9.

Note that only a Patman reallocation to elevation 242.5 feet meets or exceeds the supply goal of 604,000 acre-feet per year for all assumptions. A reallocation to 237.5 only meets the supply goal if a lower environmental bypass is assumed for the Patman reallocation and the 96 cfs minimum release from Patman is not used. None of the options meet the goal at elevation 232.5 feet.

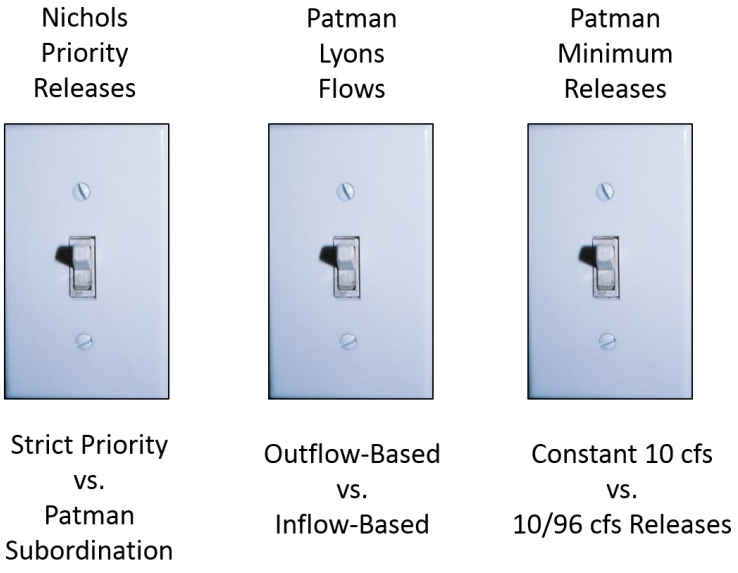


**Figure 2-6: Model Alternatives Represented as Three On-Off Switches**

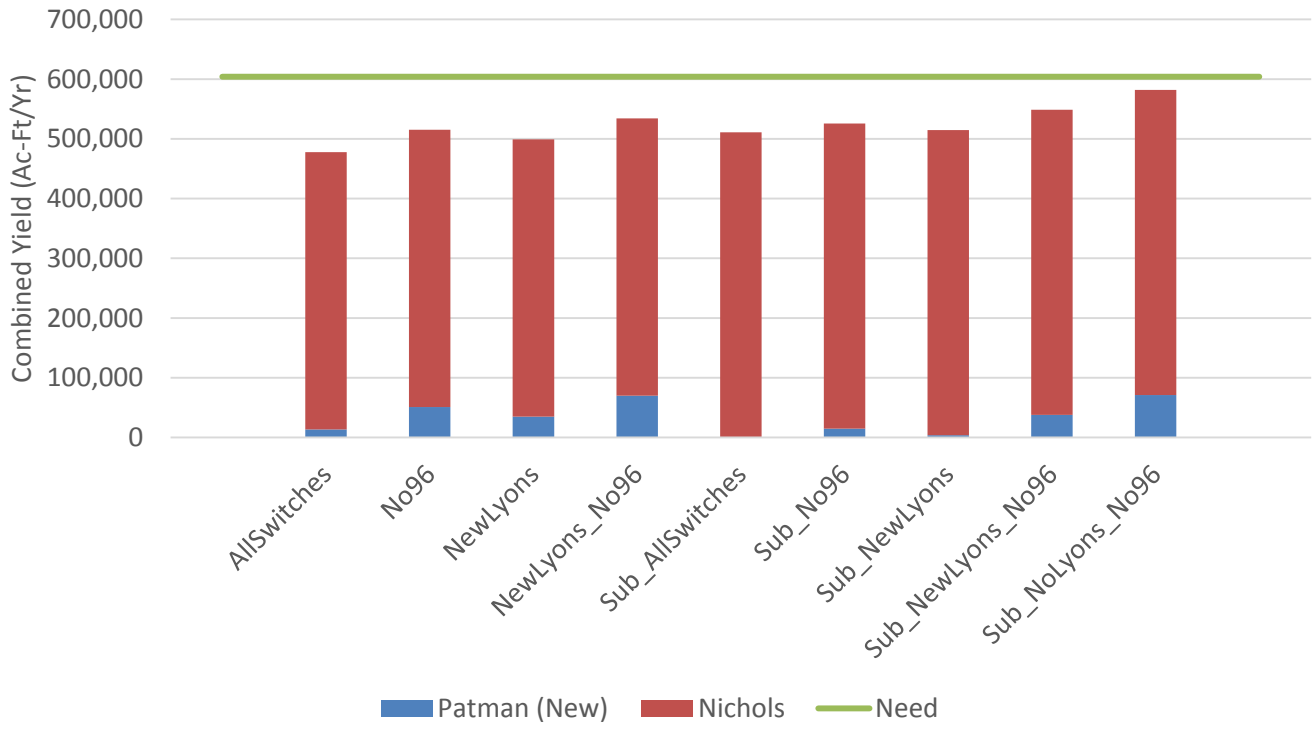


**Figure 2-7: Combined Yields for Lake Wright Patman Reallocation at 232.5 feet and Marvin Nichols Reservoir at 328.0 feet under Various Modeling Assumptions**

**Table 2-7: Combined Yields for Lake Wright Patman Reallocation at 232.5 feet and Marvin Nichols Reservoir at 328.0 feet under Various Modeling Assumptions**

| Run | Priority? | Lyons? | 96 cfs? | Patman (New) | Nichols (Ac-Ft/Yr) | Total (Ac-Ft/Yr) |
|---|---|---|---|---|---|---|
| AllSwitches | Yes | Yes | Yes | 14,000 | 464,000 | 478,000 |
| No96 | Yes | Yes | No | 51,000 | 464,000 | 515,000 |
| NewLyons | Yes | New | Yes | 35,000 | 464,000 | 499,000 |
| NewLyons_No96 | Yes | New | No | 70,000 | 464,000 | 534,000 |
| Sub_AllSwitches | No at Nichols | Yes | Yes | 0 | 511,000 | 511,000 |
| Sub_No96 | No at Nichols | Yes | No | 15,000 | 511,000 | 526,000 |
| Sub_NewLyons | No at Nichols | New | Yes | 4,000 | 511,000 | 515,000 |
| Sub_NewLyons_No96 | No at Nichols | New | No | 38,000 | 511,000 | 549,000 |
| Sub_NoLyons_No96 | No at Nichols | No | No | 71,000 | 511,000 | 582,000 |

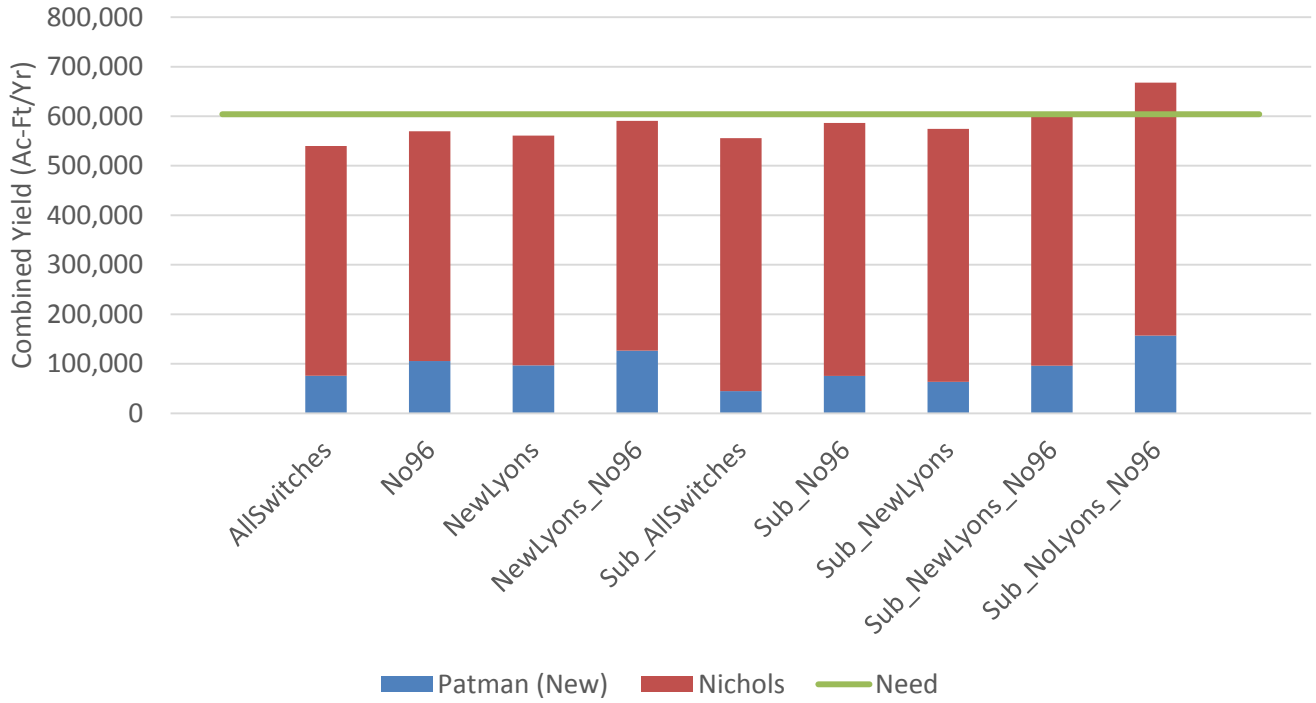


**Figure 2-8: Combined Yields for Lake Wright Patman Reallocation at 237.5 feet and Marvin Nichols Reservoir at 328.0 feet under Various Modeling Assumptions**

**Table 2-8: Combined Yields for Lake Wright Patman Reallocation at 237.5 feet and Marvin Nichols Reservoir at 328.0 feet under Various Modeling Assumptions**

| Run | Priority? | Lyons? | 96 cfs? | Patman (New) | Nichols (Ac-Ft/Yr) | Total (Ac-Ft/Yr) |
|---|---|---|---|---|---|---|
| AllSwitches | Yes | Yes | Yes | 76,000 | 464,000 | 540,000 |
| No96 | Yes | Yes | No | 105,000 | 464,000 | 569,000 |
| NewLyons | Yes | New | Yes | 97,000 | 464,000 | 561,000 |
| NewLyons_No96 | Yes | New | No | 126,000 | 464,000 | 590,000 |
| Sub_AllSwitches | No at Nichols | Yes | Yes | 45,000 | 511,000 | 556,000 |
| Sub_No96 | No at Nichols | Yes | No | 75,000 | 511,000 | 586,000 |
| Sub_NewLyons | No at Nichols | New | Yes | 63,000 | 511,000 | 574,000 |
| Sub_NewLyons_No96 | No at Nichols | New | No | 96,000 | 511,000 | 607,000 |
| Sub_NoLyons_No96 | No at Nichols | No | No | 157,000 | 511,000 | 668,000 |

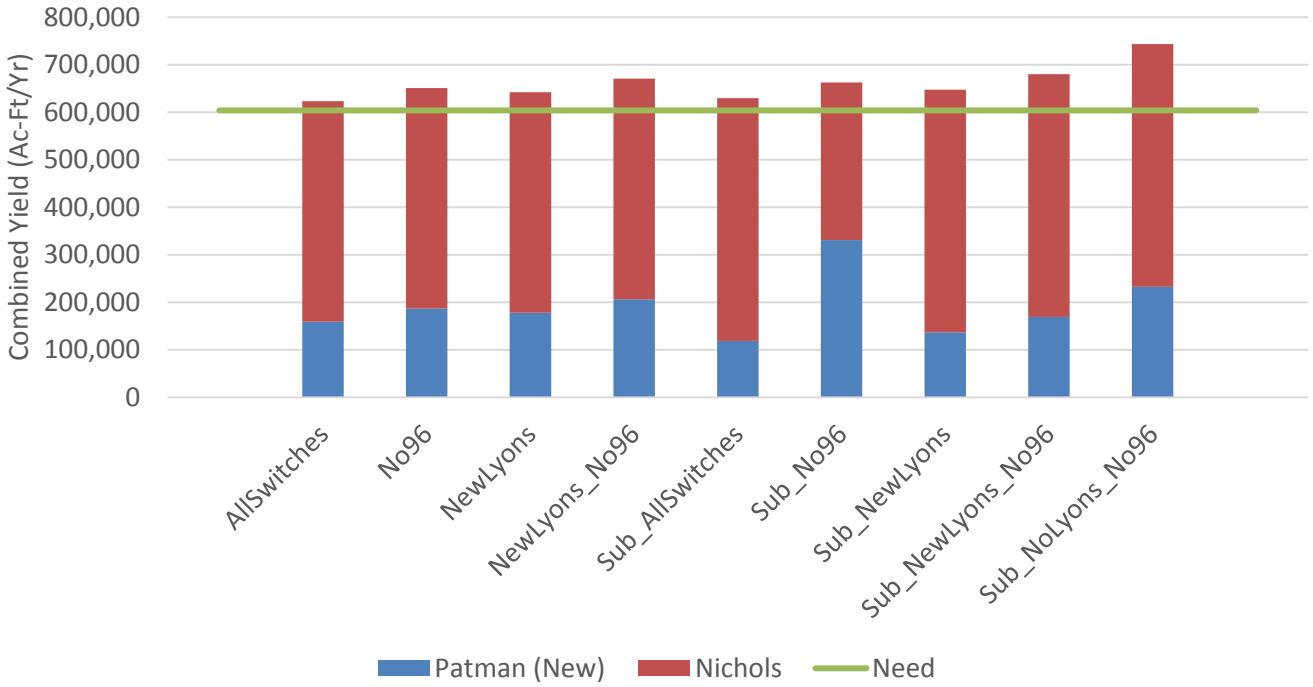


**Figure 2-9: Combined Yields for Lake Wright Patman Reallocation at 242.5 feet and Marvin Nichols Reservoir at 328.0 feet under Various Modeling Assumptions**

**Table 2-9: Combined Yields for Lake Wright Patman Reallocation at 242.5 feet and Marvin Nichols Reservoir at Elevation of 328.0 feet under Various Modeling Assumptions**

| Run | Priority? | Lyons? | 96 cfs? | Patman (New) | Nichols (Ac-Ft/Yr) | Total (Ac-Ft/Yr) |
|---|---|---|---|---|---|---|
| AllSwitches | Yes | Yes | Yes | 159,000 | 464,000 | 623,000 |
| No96 | Yes | Yes | No | 187,000 | 464,000 | 651,000 |
| NewLyons | Yes | New | Yes | 178,000 | 464,000 | 642,000 |
| NewLyons_No96 | Yes | New | No | 206,000 | 464,000 | 670,000 |
| Sub_AllSwitches | No at Nichols | Yes | Yes | 119,000 | 511,000 | 630,000 |
| Sub_No96 | No at Nichols | Yes | No | 331,000 | 332,000 | 663,000 |
| Sub_NewLyons | No at Nichols | New | Yes | 137,000 | 511,000 | 648,000 |
| Sub_NewLyons_No96 | No at Nichols | New | No | 169,000 | 511,000 | 680,000 |
| Sub_NoLyons_No96 | No at Nichols | No | No | 232,000 | 511,000 | 743,000 |