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APPENDIX C - MODELING

This appendix discusses the development of the model used for the Sulphur Basin Watershed Overview Project and the use of this model to evaluate reallocation of Lake Wright Patman and the proposed Marvin Nichols, Parkhouse I, Parkhouse II and Talco reservoir sites.

C-1 Model Development

The modeling for the Sulphur Basin Watershed Overview Project is based on a modified version of the Texas Commission on Environmental Quality's (TCEQ) Sulphur Basin Water Availability Model – Full Authorization Scenario (WAM). There are WAM models for every basin in Texas. TCEQ uses the WAMs to evaluate new water right applications. Water rights issued by the State of Texas must be supported by an availability analyses conducted with the WAMs. Other models may be considered but the primary source must be the WAM. The Texas regional water planning process also requires use of the WAMs for availability analyses. The WAMs include all permanent water rights operating at their full authorized diversions. The Sulphur WAM uses monthly naturalized hydrology from 1940 to 1996.

Texas uses a priority system based on either (1) the date when the water was first beneficially used (applies to older water rights), or (2) the date when a water right application was accepted by TCEQ (applies to newer water rights). The WAMs are designed to evaluate water availability under the priority system, allocating water based on the priority date of the water right. Because of this assumption, the WAMs can produce yield results that are significantly different than models that do not employ the prior rights system, such as the USACOE RiverWare or other models.

The WAMs are an application of the Water Rights Analysis Package (WRAP), a general river basin simulation computer model developed by Dr. Ralph Wurbs of Texas A&M University. WRAP is specifically designed to model prior appropriation water rights.

Modifications to the Sulphur WAM

Major changes to the TCEQ Sulphur WAM include:

- Use of one “accounting” pool to model Lake Jim Chapman rather than individual pools for each water right holder.
- Use of TS records to limit Patman depletions to natural flow (for reallocation scenarios)
- Addition of Lake Ralph Hall, a proposed reservoir that is currently in the permitting process.

- Addition of Marvin Nichols 1a, Parkhouse I, Parkhouse II and Talco sites.
- Manual input of naturalized flows at the Marvin Nichols and Parkhouse I and II sites to correct for problems with drainage areas in the TCEQ Sulphur WAM.
- Correction for change of gaging location for control point C10 (Sulphur River near Talco)
- Use of current and future storage-area relationships. Future storage-area relationships are based on sediment rates determined in the SWAT analyses. The TCEQ WAM uses the capacities authorized in the Texas water rights.

Each of these changes is discussed in more detail below. These discussions assume a familiarity with WRAP code and modeling techniques, as well as the Texas priority system. Model setup files may be found in Appendix C-4, which contains both the WRAP code for each scenario and the WRAP executable files.

Most of the model code associated with new projects is from the Texas Water Development Board's (TWDB) Site Protection Study¹. The Site Protection Study examined potential reservoir sites for protection under state law. This study used the TCEQ WAMs for all of the evaluations.

New projects are assumed to have a priority date that is junior to all other priority authorizations in the Sulphur Basin. This includes reallocation of storage, which must be filled with a priority date that is junior to the existing authorizations. In most cases, the WRAP model's Dual Simulation technique is used so that senior rights do not deplete more water because of new junior authorizations in the same source. A description of Dual Simulation may be found in the WRAP manuals².

None of the projects examined in this study include environmental flow releases. The potential impact of these flow releases on yields is examined in a separate study.

Modeling of Lake Chapman

In the TCEQ WAM, Lake Chapman is modeled with three individual accounting pools, one for each of the three water rights in the reservoir. For this study Lake Chapman is modeled as a single pool. This change

¹ HDR Engineering, R.J. Brandes Co., Freese and Nichols Inc.: Reservoir Site Protection Study, Report 370, prepared for the Texas Water Development Board, July 2008.

² Wurbs, Ralph A: Water Rights Analysis Package (WRAP) Modeling System Reference Manual, prepared for the Texas Commission on Environmental Quality et al., September 2011.

facilitates analyzing impacts of other projects on the overall performance of Lake Chapman. The instream flow requirements were also combined into a single IF record.

Diversions from Lake Chapman were split to reflect current contracts and users as well as the existing water rights in the reservoir.

Modeling of Lake Wright Patman

Lake Wright Patman is operated by the Corps of Engineers. The Corps uses seasonally varying conservation storage, defined by a rule curve. There are two rule curves for the reservoir:

- Interim Curve – the curve used for current operation of the reservoir.
- Ultimate Curve – the curve in the Texas Water Right (and the TCEQ WAM) and certain contracts with the Corps.

Rule curves are implemented in WRAP using MS records. MS records were developed for each sediment condition examined in the study.

The current operation of Lake Wright Patman includes a downstream release ranging from 10 cfs to 96 cfs to maintain water quality downstream of the reservoir. This release is not required by the Texas water right for Lake Patman, and it is unclear if this release would be considered part of the water right diversion from the reservoir. Because of this uncertainty, as well as uncertainty regarding future release policies from the reservoir, downstream releases from Lake Patman were not explicitly modeled. To account for downstream releases from Lake Wright Patman 7,247 acre-feet per year (equivalent to a constant release of 10 cfs) was subtracted from the yields of the reservoir.

The WRAP model defines available flow for a given diversion as the minimum of the flows at the location of the diversion and at every location downstream of the diversion after depletions by downstream senior water rights. On the descending limbs of the rule curves for Lake Patman, the WRAP model releases water from storage at the beginning of each time step, increasing available flow at Lake Patman and points downstream. As a result, there are several occasions when upstream water rights that are junior to Patman deplete more water than would have been available if stored water had not been releases at the beginning of the time step. As a result, when evaluating changing from the current rule curves to a flat conservation storage, some water rights are less reliable even when using Dual Simulation.

In order to minimize this impact, in models with flat storage the existing authorization in Lake Patman were modeled as a series of streamflow depletions for each time step in the model. These month-by-month depletions were implemented using TS records. The TS records were derived from a simulation of Lake Patman operating under its current water right (Ultimate Curve). The water depleted by the TS records is stored in a “dummy” control point and then subsequently used to meet diversions and fill storage in Lake Patman. This technique reduces but does not entirely eliminate the impacts on other water rights. Under Texas water law, granting a new water right cannot adversely affect existing water rights. As a result, this modeling artifact is a subject that may need to be addressed during water right permitting for additional storage in Lake Patman.

Modeling of Lake Ralph Hall

The model code for Lake Ralph Hall was obtained from TCEQ on October 6, 2011. The code is slightly different than the code used in the TWDB Site Protection Study. The TCEQ code has a diversion that is greater than the yield of the reservoir. Instream flow bypass criteria are not proposed for this reservoir and were not included in the TCEQ setup.

For the current study, the drainage area for Lake Ralph Hall was taken from the TWDB Reservoir Site Protection Study. Memos from TCEQ associated with the permitting of Ralph Hall give the drainage area as 102.74 square miles. We did not verify the drainage area in the current study. However, the difference in drainage area is small and should not impact the results of the current study.

Modeling of Marvin Nichols, Parkhouse I and Parkhouse II Reservoirs

The modeling code for the proposed Marvin Nichols, George Parkhouse I and George Parkhouse II reservoir sites is from the TWDB Site Protection Study. Like the Site Protection Study model, the current study uses manually calculated naturalized flows for Marvin Nichols 1a and Parkhouse I and II rather than using the model to calculate the flows. The WRAP model uses drainage area ratios to distribute naturalized gage flows (primary control points) to diversion locations (secondary control points). However, the drainage areas in the Sulphur WAM do not match United States Geological Survey (USGS) drainage areas. In our opinion, USGS drainage areas are more likely to be accurate. To avoid potentially inaccurate flows at the proposed reservoir sites, the manually calculated flows used in the current study use drainage area ratios based on USGS drainage areas. These flows were input at new primary control points.

The current study also uses evaporation rates for the new projects from the Reservoir Site Protection Study. Unlike other evaporation data in the Sulphur WAM, these evaporation rates include corrections for effective runoff based on the naturalized flow at the new primary control points. WRAP does not allow evaporation adjustments based on naturalized flows at primary control points.

TCEQ had eliminated several control points from the Sulphur WAM, so the additional control points for the new projects needed to be modified from the Site Protection Study model.

The Parkhouse I modeling includes code that passes the 5 cfs release from Lake Chapman downstream. This prevents Parkhouse I from impounding the Chapman release. This feature was not considered in the Site Protection Study modeling.

Modeling of Talco Reservoir

The Talco Reservoir is modeled at WAM control point D10, which represents the White Oak Creek near Talco gage (USGS 07343500). The project would probably be located a short distance upstream of the gage, which is on a highway bridge. However, the difference in drainage area between the dam and the gage location would be very small and would have little if any impact on the results.

The diversion location for supplemental pumping from the main stem of the Sulphur River is control point C10, the Sulphur River near Talco gage (USGS 07343210). The modeling of the supplemental pumping uses month-by-month TS records to define available flow for each time step. The TS records were developed by taking monthly WAM regulated flow at control point C10 (Sulphur River nr Talco gage), converting the monthly flow to daily flow based on daily Corps of Engineers flows, and subtracting out flows passed to downstream water rights. The daily available flow (flow after accounting for downstream seniors) was calculated for pump rates of 500 cfs and 2,500 cfs. The daily available flow amounts were summed back into monthly volumes and manually input into the WAM as TS records, with a value for each time step in the simulation. The TS records serve as limits on depletions from the main stem. Different sets of TS records were developed for 2030 and 2070 conditions, under both priority and subordination analyses. TS records were also developed with Chapman reallocation, but only under 2030 conditions.

Talco Alternative 3 Modeling

The modeling of Talco Alternative 3, which includes the use of reallocated storage in Lake Chapman, is considerably more complicated than the other alternatives. Therefore this Appendix includes a detailed description of the WRAP code.

The first step is a backup of the shortages under the existing Lake Chapman water rights. The group identifier Chapman was added to all of the existing Lake Chapman records to simplify the backup coding. The PX 2 limits execution of this code to the second simulation (Dual Simulation technique).

```
WR  A40          30000101  1          0ChapBackup  Chapman
WSRCHAP1 415148          33323
BU          Chapman
PX  2
```

The next step models the local diversion directly from the Talco Reservoir. This diversion is assumed to be 20% of the total yield of the project. In this example, the local diversion of 65,750 acre-feet per year translates into a total diversion of 328,750 acre-feet per year. Note the use of a constant diversion rate. It is assumed that the water from this project would be pumped for use elsewhere at a relatively constant rate.

```
** Constant monthly
UC month      31  28.25    31    30    31    30
UC            31    31    30    31    30    31

WR  D10  65750  month30000101  1  1    0          1TalcoLocal  Yield Chapman
WS TALCO 1170994          0
PX  2
```

The following set of water right records determines the portion of the additional yield that comes from Lake Chapman. The portion from Chapman is based on the ratio of storage in Lake Chapman (after senior water rights have executed) to the total storage in both Chapman and Talco.

The first calculation is the rest of yield from the project, which is four times the local demand set in 1TalcoLocal (the remaining 80% of the total yield). This yield would probably be exported out of the basin.

```
WR dummy          30000102  1          SetXtra  Target Chapman
TO  13  4.0  SET          1TalcoLocal
```

The following two WR records set minimum storages in Chapman and Talco, respectively. These minimums determine the portion of conservation storage used for operation of the two reservoirs as a system. These minimums are designed to protect storage for local use directly from the reservoir and

are determined by iteration of the model. Note that the minimum conservation for Chapman is more than the actual dead storage in Lake Chapman.

```
WR dummy 45000 XMONTH30000102 1 SetChapMin Target Chapmen
WR dummy 10000 XMONTH30000102 1 SetTalcMin Target Talco
```

Calculate the total available storage in the two reservoirs, subtracting out the minimum storages set by SetChapMin and SetTalcMin.

```
WR dummy 30000102 1 SetTotStor Target Chapmen
TO 4 1.0 SET RCHAP1 CONT
TO 4 1.0 ADD TALCO CONT
TO 13 1.0 SUB SetChapMin CONT
TO 13 1.0 SUB SetTalcMin
```

The next target calculation determines the percentage of the total storage that is associated with Lake Chapman. First the minimum storage is subtracted from the total storage in Lake Chapman, and then that number is divided by the total storage determined in the previous step (SetTotStor).

```
WR dummy 30000102 1 SetChapMult Target Chapmen
TO 4 1.0 SET RCHAP1 CONT
TO 13 1.0 SUB SetChapMin CONT
TO 13 1.0 DIV 0 1 SetTotStor
```

These water right records are the actual diversion from Lake Chapman. The diversion target is based on the out-of-basin yield of the system (SetXtra) multiplied by the fraction calculated in the previous step (SetChapMult).

```
WR A40 30000102 1 2XtraYield Chapmen
WSRCHAP1 415148 33323
TO 13 1.0 SET SetXtra CONT
TO 13 1.0 MUL SetChapMult
PX 2
```

The following set of water right records calculates the target for pumping additional water from Talco for storage in Lake Chapman.

The first record sets the capacity of the pipeline, which is 500 cfs in this example.

```
WR dummy 362231 month30000103 1 Set500 Target Chapmen
```

This record is the maximum storage in Talco (SetTalcMax), in this case the storage at elevation 370 feet.

```
WR dummy 1170994 XMONTH30000103 1 SetTalcMax Target Talco
```

These records set the minimum storage at which Talco is considered for system operation, which in this example is 85 percent of the total storage in Talco (SetTalcMin2). This value is determined by iteration of the model. Below this storage water is not pumped from Talco for storage in Lake Chapman.

```
WR dummy          30000103  1          SetTalcMin2  Target  Talco
TO   13   0.85   SET          SetTalcMax
```

These records calculate the total storage between SetTalcMin2 and SetTalcMax. This is used as a divisor in upcoming calculations.

```
WR dummy          30000103  1          SetDenom  Target  Talco
TO   13   1.00   SET          SetTalcMax  CONT
TO   13   1.00   SUB          SetTalcMin2
```

These records calculate the difference between the current storage and the minimum storage calculated in SetTalcMin2. If the current storage is less than SetTalcMin2, then this target is zero (TO records automatically limit calculated targets to positive numbers or zero).

```
WR dummy          30000103  1          SetTalcStor  Target  Talco
TO   4   1.0   SET          TALCO          CONT
TO   13  1.00  SUB          SetTalcMin2
```

These records calculate a factor that will be multiplied by the empty storage in Lake Chapman to determine the amount of water to be pumped from Talco to storage in Lake Chapman. This factor is the percent of storage currently above SetTalcMin2. Note that this factor gets smaller as storage in Talco approaches SetTalcMin2.

```
WR dummy          30000103  1          SetTalcFrac  Target  Talco
TO   13   1.0   SET          SetTalcStor  CONT
TO   13   1.0   DIV          SetDenom
```

These records set the actual target for water pumped from Talco for storage in Lake Chapman. Note that the factor calculated in the previous step is multiplied by 90% of the empty storage in Lake Chapman.

```
WR dummy          30000103  1          SetMakeup  Target  Chapman
TO   5   0.90  SET          RCHAP1        CONT
TO   13   1.0  MUL          SetTalcFrac
```

The next diversion is the part of the out-of-basin water supply diverted from Talco, plus any water that will be stored in Lake Chapman. This water right a) backs up any shortages of the existing priority diversions from Lake Chapman using a BU record, b) adds the out-of-basin yield to the previous step, c)

subtracts out the amount already diverted from Lake Chapman in 2XtraYield above, d) adds the additional water pumped from Talco for storage in Lake Chapman and e) limits the diversion target to the capacity of the pipeline from Talco to Chapman. Water is stored in dummy control point DUMCP, which represents the pipeline from Talco to Chapman.

```

WR D10 30000103 1 1 1 DUMCP 3BackupXtra Talco
WS TALCO 1170994 0
BU 0ChapBackup
TO 13 1.0 ADD SetXtra CONT
TO 11 1.0 SUB 2XtraYield CONT
TO 13 1.0 ADD SetMakeup CONT
TO 13 1.0 MIN Set500
PX 2
    
```

This water right subtracts the out-of-basin water from DUMCP, leaving only the amount that is assumed to be available to fill storage in Lake Chapman.

```

WR DUMCP 30000104 1 4TalcoToOthers Chapmen
BU 0ChapBackup
TO 13 1.0 ADD SetXtra CONT
TO 11 1.0 SUB 2XtraYield
PX 2
    
```

Now fill Lake Chapman with the water in DUMCP. A backup of 4TalcoToOthers is included for situations where not enough water is available from Talco to meet that demand, but there is still water in storage in Lake Chapman.

```

WR A40 30000105 1 5FillChap Yield Chapmen
WSRCHAP1 415148 33323
SO DUMCP
BU 4TalcoToOthers
PX 2
    
```

The final step is supplemental pumping from the Sulphur River. This water right backs up group identifier Yield, which is associated with Talco local demand (1TalcoLocal) and out-of-basin water (5FillChap). This allows water pumped from the Sulphur River to meet shortages.

```

WR D10 30000106 1 1 0 6TalcoFromMS Chapmen
WS TALCO 1170994
BU Yield
**BU 1TalcoLocal
SO C10
PX 2
** 2030 Available for pumping with Chapman reallocation - priority analysis 500 cfs
TS SDL 1940 0 0 0 20638 25541 19181 8653 0 0 0 8167 25334
TS SDL 1941 2818 17699 27976 23161 20999 21222 4885 0 0 0 0 6222
TS SDL 1942 0 0 11614 23165 28876 16972 0 0 1742 0 0 7831
TS SDL 1943 0 0 15264 0 0 0 0 0 0 0 0 0
TS SDL 1944 4568 23925 25191 8559 22718 9916 0 0 0 0 0 21631
TS SDL 1945 8745 14709 30744 8450 9844 15103 16185 0 992 22321 0 0
TS SDL 1946 19562 27769 25408 18650 30744 12666 0 262 0 0 19564 11907
TS SDL 1947 0 0 12900 15639 23515 0 0 0 0 0 8054 26262
    
```

| | | | | | | | | | | | | | | |
|----|-----|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| TS | SDL | 1948 | 16252 | 27195 | 25733 | 0 | 24060 | 0 | 2605 | 0 | 0 | 0 | 0 | 0 |
| TS | SDL | 1949 | 8571 | 24675 | 27182 | 12858 | 8975 | 7161 | 6521 | 0 | 0 | 16733 | 0 | 0 |
| TS | SDL | 1950 | 26899 | 27362 | 0 | 0 | 29637 | 7892 | 9311 | 4915 | 18272 | 0 | 0 | 0 |
| TS | SDL | 1951 | 0 | 21319 | 0 | 0 | 0 | 13884 | 11861 | 0 | 0 | 2187 | 0 | 0 |
| TS | SDL | 1952 | 0 | 0 | 3565 | 23718 | 15772 | 0 | 0 | 0 | 0 | 0 | 5098 | 12571 |
| TS | SDL | 1953 | 0 | 0 | 19072 | 14398 | 25458 | 0 | 10174 | 0 | 0 | 0 | 0 | 18014 |
| TS | SDL | 1954 | 18542 | 6068 | 0 | 0 | 23505 | 0 | 0 | 0 | 0 | 11847 | 0 | 0 |
| TS | SDL | 1955 | 0 | 8418 | 10570 | 14542 | 0 | 0 | 0 | 4484 | 485 | 0 | 0 | 0 |
| TS | SDL | 1956 | 0 | 24811 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TS | SDL | 1957 | 0 | 4985 | 12060 | 18121 | 30563 | 16937 | 0 | 0 | 8199 | 14654 | 24379 | 4807 |
| TS | SDL | 1958 | 14981 | 0 | 19454 | 15302 | 18099 | 9247 | 8661 | 0 | 4334 | 0 | 5164 | 0 |
| TS | SDL | 1959 | 0 | 4714 | 2362 | 2874 | 0 | 7161 | 14757 | 4508 | 4752 | 8158 | 3423 | 13955 |
| TS | SDL | 1960 | 19077 | 4995 | 7609 | 0 | 0 | 0 | 14390 | 7079 | 6425 | 12764 | 0 | 19524 |
| TS | SDL | 1961 | 10135 | 7589 | 7783 | 8817 | 0 | 0 | 4343 | 0 | 2242 | 0 | 2236 | 9747 |
| TS | SDL | 1962 | 7438 | 4815 | 2356 | 8713 | 2918 | 8834 | 7186 | 0 | 11428 | 12292 | 8087 | 2924 |
| TS | SDL | 1963 | 2975 | 0 | 2251 | 0 | 0 | 0 | 2378 | 0 | 0 | 0 | 0 | 0 |
| TS | SDL | 1964 | 0 | 0 | 1983 | 9717 | 0 | 3666 | 0 | 0 | 8786 | 1629 | 4959 | 0 |
| TS | SDL | 1965 | 5575 | 12933 | 0 | 0 | 15458 | 992 | 0 | 0 | 0 | 0 | 0 | 0 |
| TS | SDL | 1966 | 0 | 3967 | 0 | 6942 | 18048 | 0 | 0 | 1404 | 5662 | 3233 | 0 | 0 |
| TS | SDL | 1967 | 0 | 0 | 0 | 19088 | 12340 | 5950 | 9136 | 0 | 5767 | 4275 | 4331 | 10389 |
| TS | SDL | 1968 | 19286 | 7729 | 19012 | 10859 | 19287 | 13214 | 11262 | 1983 | 15772 | 3242 | 3967 | 14041 |
| TS | SDL | 1969 | 1983 | 21587 | 23886 | 8719 | 24964 | 0 | 0 | 0 | 0 | 415 | 0 | 3191 |
| TS | SDL | 1970 | 5333 | 13528 | 21489 | 11152 | 2975 | 0 | 0 | 0 | 3478 | 15708 | 2567 | 0 |
| TS | SDL | 1971 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14732 | 0 | 28328 |
| TS | SDL | 1972 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4368 | 16858 | 6128 |
| TS | SDL | 1973 | 10909 | 11899 | 29412 | 17419 | 11135 | 10324 | 0 | 0 | 13131 | 19154 | 21374 | 14899 |
| TS | SDL | 1974 | 19825 | 0 | 0 | 2975 | 1566 | 16076 | 0 | 0 | 21539 | 7456 | 22732 | 13201 |
| TS | SDL | 1975 | 2691 | 14356 | 19945 | 9881 | 16277 | 13928 | 4914 | 0 | 0 | 0 | 0 | 0 |
| TS | SDL | 1976 | 0 | 0 | 0 | 4959 | 7921 | 6880 | 17897 | 0 | 2870 | 6394 | 0 | 8926 |
| TS | SDL | 1977 | 7904 | 11111 | 13456 | 13633 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TS | SDL | 1978 | 0 | 3080 | 11901 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TS | SDL | 1979 | 16345 | 10181 | 13100 | 9647 | 18618 | 8926 | 4622 | 4594 | 0 | 0 | 0 | 5415 |
| TS | SDL | 1980 | 6942 | 5738 | 0 | 2975 | 5131 | 0 | 0 | 0 | 0 | 7166 | 0 | 4540 |
| TS | SDL | 1981 | 0 | 0 | 0 | 0 | 19235 | 21572 | 1395 | 0 | 0 | 18127 | 9185 | 0 |
| TS | SDL | 1982 | 0 | 4444 | 6257 | 0 | 18383 | 17279 | 11020 | 3002 | 0 | 0 | 4059 | 18831 |
| TS | SDL | 1983 | 0 | 16009 | 12676 | 0 | 0 | 0 | 7636 | 0 | 0 | 0 | 0 | 0 |
| TS | SDL | 1984 | 0 | 6674 | 19544 | 7919 | 0 | 0 | 0 | 0 | 0 | 13050 | 5865 | 14195 |
| TS | SDL | 1985 | 0 | 9677 | 15288 | 6942 | 16634 | 0 | 1219 | 0 | 0 | 2730 | 10445 | 10077 |
| TS | SDL | 1986 | 0 | 6942 | 0 | 11237 | 5771 | 21950 | 5277 | 0 | 0 | 5511 | 12246 | 8073 |
| TS | SDL | 1987 | 8324 | 6941 | 13521 | 0 | 0 | 0 | 0 | 0 | 0 | 5908 | 18545 | 25822 |
| TS | SDL | 1988 | 10136 | 3286 | 10410 | 4273 | 0 | 0 | 0 | 0 | 0 | 0 | 16015 | 6763 |
| TS | SDL | 1989 | 8372 | 17934 | 13712 | 1983 | 16640 | 17570 | 15906 | 3450 | 992 | 0 | 0 | 0 |
| TS | SDL | 1990 | 6942 | 12356 | 19584 | 28218 | 27140 | 7043 | 0 | 0 | 5152 | 5047 | 4450 | 10419 |
| TS | SDL | 1991 | 23386 | 15028 | 3097 | 18953 | 25700 | 7581 | 1457 | 0 | 1068 | 3967 | 12173 | 28469 |
| TS | SDL | 1992 | 21426 | 17564 | 30744 | 0 | 7049 | 26484 | 30744 | 21473 | 8248 | 670 | 12776 | 23021 |
| TS | SDL | 1993 | 27253 | 27769 | 30744 | 29752 | 10328 | 0 | 0 | 0 | 0 | 12893 | 23372 | 30451 |
| TS | SDL | 1994 | 12892 | 8231 | 25891 | 0 | 30744 | 9856 | 18117 | 2532 | 2095 | 9273 | 28682 | 30744 |
| TS | SDL | 1995 | 28196 | 0 | 26740 | 27664 | 30167 | 17748 | 4189 | 0 | 2043 | 0 | 0 | 0 |
| TS | SDL | 1996 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10496 | 14013 | 9797 | 27164 | 22325 |

**

Correction to Drainage Areas

In the original TCEQ WAM, primary control point C10, the Sulphur River near Talco (USGS 07343200, previously called the Sulphur River below Talco gage USGS 07343210), had a drainage area that was smaller than the next upstream point C20. It is impossible for an upstream control point to have a larger drainage area than a downstream control point. This results in a flow discontinuity which may impact water availability. The USGS moved the gage downstream just after the naturalized flows were developed for the Sulphur WAM, and apparently this change was not noticed when the drainage areas were later modified by TCEQ. For this model, we are using a drainage area for C10 of 1,365 square

miles, the drainage area of the gage for the period of the naturalized flows. This is the drainage area used in the original Sulphur WAM, prior to the drainage area updates.

Current and Future Storage-Area Relationships

Tables C1.1 through C.1-5 show the storage-area-elevation relationships for the existing and proposed projects considered in this study. The storage and area portions of these tables were incorporated into the WRAP models used to develop yields of the alternatives considered in the current study.

When the State of Texas grants a water right, the yield and available storage are based on the conditions at the time that the reservoir is built. When granting a water right, the State does not reduce yield or storage based on estimated future conditions, when sediment accumulation in the reservoir will reduce the available supply and storage. Because the water rights are based on initial conditions, the TCEQ WAM uses the storage-area relationships that were in place when the reservoir was built.

For the current study, storage-area relationships in the original TCEQ WAM were replaced with either existing conditions, based on the latest surveys of the reservoir, or future conditions after sediment accumulation. Sediment rates are based on the SWAT modeling performed as part of the current study, as described in the main report and Appendix D. For future conditions, it was assumed that Lake Ralph Hall would be built in 2020 and that other proposed projects (Marvin Nichols, Parkhouse I and II, Talco, or reallocation) would be in place in 2030.

To estimate future sediment conditions, the sediment rates were applied to the most recent storage-area relationships for the reservoirs. For Lake Wright Patman, this was the 2010 volumetric survey from the Texas Water Development Board (TWDB)³. This survey only goes up to elevation 226.3 feet. For elevations above 226.3 feet, data from the 1997 TWDB survey was used⁴. Future sediment conditions for Lake Jim Chapman are based on the 2005/2007 TWDB volumetric survey⁵. The storage-area data for Lake Ralph Hall, Parkhouse I and Parkhouse II are from the Reservoir Site Protection Study. New initial storage conditions for Marvin Nichols and the Talco site were developed for the current study.

³ Texas Water Development Board: Volumetric and Sedimentation Survey of Wright Patman Lake March-June 2010 Survey, prepared for the U.S. Army Corps of Engineers Fort Worth District, August 2012.

⁴ Texas Water Development Board: Volumetric Survey of Wright Patman Lake, Prepared for the U.S. Army Corps of Engineers, Fort Worth District, March 10, 2003.

⁵ Texas Water Development Board: Volumetric Survey of Jim Chapman Lake August 2005/July 2007 Survey, prepared for the U.S. Army Corps of Engineers, Fort Worth District, February 2008.

Table C-1.1 – Lake Wright Patman Elevation-Area-Capacity

| 2030 Current Sedimentation Rate | | | 2030 Mitigated Sedimentation Rate | | | 2070 Current Sed Rate with Marvin Nichols | | | 2070 Mitigated Sed Rate with Marvin Nichols | | | 2070 Current Sed Rate with Parkhouse I | | | 2070 Mitigated Sed Rate with Parkhouse I | | | 2070 Current Sed Rate with Parkhouse II | | | 2070 Mitigated Sed Rate with Parkhouse II | | | 2070 Current Sed Rate with Talco | | | 2070 Mitigated Sed Rate with Talco | | |
|---------------------------------|-----------|------------------|-----------------------------------|-----------|------------------|---|-----------|------------------|---|-----------|------------------|--|-----------|------------------|--|-----------|------------------|---|-----------|------------------|---|-----------|------------------|----------------------------------|-----------|------------------|------------------------------------|-----------|------------------|
| Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) |
| 209.0 | 0 | 0 | 209.0 | 0 | 0 | 209.0 | 0 | 0 | 209.0 | 0 | 0 | 209.0 | 0 | 0 | 209.0 | 0 | 0 | 209.0 | 0 | 0 | 209.0 | 0 | 0 | 209.0 | 0 | 0 | 209.0 | 0 | 0 |
| 210.0 | 443 | 148 | 210.0 | 541 | 180 | 210.0 | 0 | 0 | 210.0 | 0 | 0 | 210.0 | 0 | 0 | 210.0 | 0 | 0 | 210.0 | 0 | 0 | 210.0 | 0 | 0 | 210.0 | 0 | 0 | 210.0 | 0 | 0 |
| 211.0 | 1,125 | 906 | 211.0 | 1,223 | 1,039 | 211.0 | 0 | 0 | 211.0 | 0 | 0 | 211.0 | 0 | 0 | 211.0 | 0 | 0 | 211.0 | 0 | 0 | 211.0 | 0 | 0 | 211.0 | 0 | 0 | 211.0 | 0 | 0 |
| 212.0 | 2,225 | 2,550 | 212.0 | 2,323 | 2,783 | 212.0 | 236 | 79 | 212.0 | 477 | 159 | 212.0 | 0 | 0 | 212.0 | 27 | 9 | 212.0 | 0 | 0 | 212.0 | 45 | 15 | 212.0 | 0 | 0 | 212.0 | 0 | 0 |
| 213.0 | 3,549 | 5,411 | 213.0 | 3,647 | 5,742 | 213.0 | 1,560 | 880 | 213.0 | 1,801 | 1,227 | 213.0 | 392 | 131 | 213.0 | 1,351 | 532 | 213.0 | 825 | 275 | 213.0 | 1,369 | 570 | 213.0 | 243 | 81 | 213.0 | 1,281 | 427 |
| 214.0 | 4,906 | 9,620 | 214.0 | 5,004 | 10,050 | 214.0 | 2,917 | 3,084 | 214.0 | 3,158 | 3,675 | 214.0 | 1,749 | 1,120 | 214.0 | 2,708 | 2,523 | 214.0 | 2,182 | 1,724 | 214.0 | 2,726 | 2,579 | 214.0 | 1,600 | 903 | 214.0 | 2,638 | 2,346 |
| 215.0 | 6,344 | 15,230 | 215.0 | 6,442 | 15,757 | 215.0 | 4,355 | 6,696 | 215.0 | 4,596 | 7,530 | 215.0 | 3,187 | 3,552 | 215.0 | 4,146 | 5,924 | 215.0 | 3,620 | 4,595 | 215.0 | 4,164 | 6,000 | 215.0 | 3,038 | 3,183 | 215.0 | 4,076 | 5,676 |
| 216.0 | 8,156 | 22,461 | 216.0 | 8,254 | 23,086 | 216.0 | 6,167 | 11,931 | 216.0 | 6,408 | 13,007 | 216.0 | 4,999 | 7,611 | 216.0 | 5,958 | 10,949 | 216.0 | 5,432 | 9,090 | 216.0 | 5,976 | 11,043 | 216.0 | 4,850 | 7,092 | 216.0 | 5,888 | 10,630 |
| 217.0 | 9,848 | 31,449 | 217.0 | 9,946 | 32,173 | 217.0 | 7,859 | 18,927 | 217.0 | 8,100 | 20,244 | 217.0 | 6,691 | 13,435 | 217.0 | 7,650 | 17,735 | 217.0 | 7,124 | 15,349 | 217.0 | 7,668 | 17,848 | 217.0 | 6,542 | 12,766 | 217.0 | 7,580 | 17,346 |
| 218.0 | 11,954 | 42,333 | 218.0 | 12,052 | 43,155 | 218.0 | 9,965 | 27,819 | 218.0 | 10,206 | 29,377 | 218.0 | 8,797 | 21,155 | 218.0 | 9,756 | 26,417 | 218.0 | 9,230 | 23,503 | 218.0 | 9,774 | 26,548 | 218.0 | 8,648 | 20,337 | 218.0 | 9,686 | 25,957 |
| 219.0 | 14,060 | 55,326 | 219.0 | 14,158 | 56,245 | 219.0 | 12,071 | 38,820 | 219.0 | 12,312 | 40,619 | 219.0 | 10,903 | 30,986 | 219.0 | 11,862 | 37,209 | 219.0 | 11,336 | 33,767 | 219.0 | 11,880 | 37,358 | 219.0 | 10,754 | 30,018 | 219.0 | 11,792 | 36,679 |
| 220.0 | 15,903 | 70,298 | 220.0 | 16,001 | 71,315 | 220.0 | 13,914 | 51,802 | 220.0 | 14,155 | 53,842 | 220.0 | 12,746 | 42,798 | 220.0 | 13,705 | 49,981 | 220.0 | 13,179 | 46,013 | 220.0 | 13,723 | 50,149 | 220.0 | 12,597 | 41,681 | 220.0 | 13,635 | 49,381 |
| 221.0 | 17,805 | 87,143 | 221.0 | 17,903 | 88,258 | 221.0 | 15,816 | 66,657 | 221.0 | 16,057 | 68,938 | 221.0 | 14,648 | 56,484 | 221.0 | 15,607 | 64,627 | 221.0 | 15,081 | 60,132 | 221.0 | 15,625 | 64,813 | 221.0 | 14,499 | 55,218 | 221.0 | 15,537 | 63,956 |
| 222.0 | 19,894 | 105,983 | 222.0 | 19,992 | 107,195 | 222.0 | 17,905 | 83,507 | 222.0 | 18,146 | 86,029 | 222.0 | 16,737 | 72,164 | 222.0 | 17,696 | 81,268 | 222.0 | 17,170 | 76,246 | 222.0 | 17,714 | 81,472 | 222.0 | 16,588 | 70,749 | 222.0 | 17,626 | 80,526 |
| 223.0 | 21,456 | 126,653 | 223.0 | 21,554 | 127,963 | 223.0 | 19,467 | 102,188 | 223.0 | 19,708 | 104,950 | 223.0 | 18,299 | 89,676 | 223.0 | 19,258 | 99,739 | 223.0 | 18,732 | 94,191 | 223.0 | 19,276 | 99,962 | 223.0 | 18,150 | 88,112 | 223.0 | 19,188 | 98,927 |
| 224.0 | 22,587 | 148,672 | 224.0 | 22,685 | 150,080 | 224.0 | 20,598 | 122,218 | 224.0 | 20,839 | 125,221 | 224.0 | 19,430 | 108,538 | 224.0 | 20,389 | 119,560 | 224.0 | 19,863 | 113,486 | 224.0 | 20,407 | 119,802 | 224.0 | 19,281 | 106,824 | 224.0 | 20,319 | 118,678 |
| 225.0 | 23,368 | 171,648 | 225.0 | 23,466 | 173,154 | 225.0 | 21,379 | 143,205 | 225.0 | 21,620 | 146,449 | 225.0 | 20,211 | 128,356 | 225.0 | 21,170 | 140,338 | 225.0 | 20,644 | 133,738 | 225.0 | 21,188 | 140,598 | 225.0 | 20,062 | 126,494 | 225.0 | 21,100 | 139,386 |
| 226.0 | 24,098 | 195,380 | 226.0 | 24,196 | 196,984 | 226.0 | 22,109 | 164,949 | 226.0 | 22,350 | 168,433 | 226.0 | 20,941 | 148,931 | 226.0 | 21,900 | 161,872 | 226.0 | 21,374 | 154,745 | 226.0 | 21,918 | 162,151 | 226.0 | 20,792 | 146,920 | 226.0 | 21,830 | 160,849 |
| 226.3 | 24,811 | 202,716 | 226.3 | 24,909 | 204,349 | 226.3 | 22,822 | 171,688 | 226.3 | 23,063 | 175,245 | 226.3 | 21,654 | 155,320 | 226.3 | 22,613 | 168,549 | 226.3 | 22,087 | 161,264 | 226.3 | 22,631 | 168,833 | 226.3 | 21,505 | 153,264 | 226.3 | 22,543 | 167,505 |
| 230.0 | 34,882 | 312,620 | 230.0 | 34,882 | 314,445 | 230.0 | 32,893 | 274,196 | 230.0 | 33,036 | 278,478 | 230.0 | 31,725 | 253,479 | 230.0 | 32,586 | 270,108 | 230.0 | 32,158 | 261,035 | 230.0 | 32,605 | 270,460 | 230.0 | 31,576 | 250,868 | 230.0 | 32,516 | 268,802 |

Table C-1.2 – Marvin Nichols Elevation-Area-Capacity

| 2030 Conditions (Initial) | | | 2070 Current Sedimentation Rates | | | 2070 Mitigated Sedimentation Rates | | |
|---------------------------|-----------|------------------|----------------------------------|-----------|------------------|------------------------------------|-----------|------------------|
| Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) |
| 270 | 0 | 0 | 270 | 0 | 0 | 270 | 0 | 0 |
| 271 | 554 | 185 | 271 | 0 | 0 | 271 | 309 | 103 |
| 272 | 1,107 | 999 | 272 | 511 | 170 | 272 | 862 | 665 |
| 273 | 1,661 | 2,374 | 273 | 1,064 | 941 | 273 | 1,416 | 1,793 |
| 274 | 2,215 | 4,306 | 274 | 1,618 | 2,273 | 274 | 1,970 | 3,479 |
| 275 | 2,769 | 6,792 | 275 | 2,172 | 4,161 | 275 | 2,524 | 5,720 |
| 276 | 3,322 | 9,833 | 276 | 2,726 | 6,605 | 276 | 3,077 | 8,516 |
| 277 | 3,876 | 13,429 | 277 | 3,279 | 9,603 | 277 | 3,631 | 11,866 |
| 278 | 4,430 | 17,578 | 278 | 3,833 | 13,155 | 278 | 4,185 | 15,770 |
| 279 | 4,983 | 22,282 | 279 | 4,387 | 17,262 | 279 | 4,738 | 20,229 |
| 280 | 5,537 | 27,540 | 280 | 4,940 | 21,923 | 280 | 5,292 | 25,242 |
| 281 | 6,391 | 33,499 | 281 | 5,794 | 27,284 | 281 | 6,146 | 30,956 |
| 282 | 7,245 | 40,312 | 282 | 6,648 | 33,501 | 282 | 7,000 | 37,524 |
| 283 | 8,099 | 47,980 | 283 | 7,502 | 40,571 | 283 | 7,854 | 44,946 |
| 284 | 8,952 | 56,502 | 284 | 8,356 | 48,496 | 284 | 8,708 | 53,223 |
| 285 | 9,806 | 65,878 | 285 | 9,210 | 57,276 | 285 | 9,561 | 62,354 |
| 286 | 10,660 | 76,108 | 286 | 10,064 | 66,909 | 286 | 10,415 | 72,340 |
| 287 | 11,514 | 87,192 | 287 | 10,917 | 77,397 | 287 | 11,269 | 83,179 |
| 288 | 12,368 | 99,131 | 288 | 11,771 | 88,738 | 288 | 12,123 | 94,873 |
| 289 | 13,222 | 111,923 | 289 | 12,625 | 100,934 | 289 | 12,977 | 107,420 |
| 290 | 14,076 | 125,570 | 290 | 13,479 | 113,984 | 290 | 13,831 | 120,822 |
| 291 | 15,059 | 140,135 | 291 | 14,462 | 127,952 | 291 | 14,814 | 135,141 |
| 292 | 16,043 | 155,683 | 292 | 15,446 | 142,903 | 292 | 15,798 | 150,445 |
| 293 | 17,026 | 172,215 | 293 | 16,429 | 158,838 | 293 | 16,781 | 166,731 |
| 294 | 18,009 | 189,730 | 294 | 17,413 | 175,757 | 294 | 17,764 | 184,002 |
| 295 | 18,993 | 208,229 | 295 | 18,396 | 193,659 | 295 | 18,748 | 202,256 |
| 296 | 19,976 | 227,711 | 296 | 19,380 | 212,545 | 296 | 19,731 | 221,493 |
| 297 | 20,960 | 248,177 | 297 | 20,363 | 232,414 | 297 | 20,715 | 241,714 |
| 298 | 21,943 | 269,627 | 298 | 21,346 | 253,267 | 298 | 21,698 | 262,919 |
| 299 | 22,927 | 292,060 | 299 | 22,330 | 275,103 | 299 | 22,682 | 285,107 |
| 300 | 23,910 | 315,476 | 300 | 23,313 | 297,923 | 300 | 23,665 | 308,279 |
| 301 | 25,042 | 339,950 | 301 | 24,445 | 321,800 | 301 | 24,797 | 332,508 |

2030 Conditions (Initial)

| | | |
|-----|--------|-----------|
| 302 | 26,174 | 365,556 |
| 303 | 27,306 | 392,294 |
| 304 | 28,437 | 420,163 |
| 305 | 29,569 | 449,165 |
| 306 | 30,701 | 479,298 |
| 307 | 31,833 | 510,563 |
| 308 | 32,965 | 542,960 |
| 309 | 34,097 | 576,489 |
| 310 | 35,228 | 611,150 |
| 311 | 36,806 | 647,165 |
| 312 | 38,383 | 684,756 |
| 313 | 39,961 | 723,926 |
| 314 | 41,538 | 764,673 |
| 315 | 43,116 | 806,997 |
| 316 | 44,693 | 850,899 |
| 317 | 46,270 | 896,378 |
| 318 | 47,848 | 943,435 |
| 319 | 49,425 | 992,070 |
| 320 | 51,003 | 1,042,282 |
| 321 | 53,558 | 1,094,557 |
| 322 | 56,113 | 1,149,387 |
| 323 | 58,668 | 1,206,773 |
| 324 | 61,223 | 1,266,714 |
| 325 | 63,778 | 1,329,210 |
| 326 | 66,333 | 1,394,262 |
| 327 | 68,889 | 1,461,869 |
| 328 | 71,444 | 1,532,031 |

2070 Current Sedimentation Rates

| | | |
|-----|--------|-----------|
| 302 | 25,577 | 346,809 |
| 303 | 26,709 | 372,950 |
| 304 | 27,841 | 400,223 |
| 305 | 28,973 | 428,628 |
| 306 | 30,104 | 458,165 |
| 307 | 31,236 | 488,833 |
| 308 | 32,368 | 520,634 |
| 309 | 33,500 | 553,566 |
| 310 | 34,632 | 587,631 |
| 311 | 36,209 | 623,048 |
| 312 | 37,787 | 660,043 |
| 313 | 39,364 | 698,616 |
| 314 | 40,941 | 738,766 |
| 315 | 42,519 | 780,494 |
| 316 | 44,096 | 823,799 |
| 317 | 45,674 | 868,682 |
| 318 | 47,251 | 915,142 |
| 319 | 48,829 | 963,180 |
| 320 | 50,406 | 1,012,795 |
| 321 | 52,961 | 1,064,473 |
| 322 | 55,516 | 1,118,707 |
| 323 | 58,071 | 1,175,496 |
| 324 | 60,627 | 1,234,841 |
| 325 | 63,182 | 1,296,740 |
| 326 | 65,737 | 1,361,195 |
| 327 | 68,292 | 1,428,206 |
| 328 | 70,847 | 1,497,771 |

2070 Mitigated Sedimentation Rates

| | | |
|-----|--------|-----------|
| 302 | 25,929 | 357,868 |
| 303 | 27,061 | 384,361 |
| 304 | 28,192 | 411,986 |
| 305 | 29,324 | 440,742 |
| 306 | 30,456 | 470,631 |
| 307 | 31,588 | 501,651 |
| 308 | 32,720 | 533,803 |
| 309 | 33,852 | 567,087 |
| 310 | 34,984 | 601,503 |
| 311 | 36,561 | 637,273 |
| 312 | 38,138 | 674,619 |
| 313 | 39,716 | 713,544 |
| 314 | 41,293 | 754,046 |
| 315 | 42,871 | 796,125 |
| 316 | 44,448 | 839,782 |
| 317 | 46,025 | 885,017 |
| 318 | 47,603 | 931,829 |
| 319 | 49,180 | 980,218 |
| 320 | 50,758 | 1,030,185 |
| 321 | 53,313 | 1,082,215 |
| 322 | 55,868 | 1,136,801 |
| 323 | 58,423 | 1,193,941 |
| 324 | 60,978 | 1,253,638 |
| 325 | 63,533 | 1,315,889 |
| 326 | 66,089 | 1,380,696 |
| 327 | 68,644 | 1,448,058 |
| 328 | 71,199 | 1,517,975 |

Table C-1.3 – Parkhouse I Elevation-Area Capacity

| 2030 Conditions (Initial) | | | 2070 Current Sedimentation Rates | | | 2070 Mitigated Sedimentation Rates | | |
|---------------------------|-----------|------------------|----------------------------------|-----------|------------------|------------------------------------|-----------|------------------|
| Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) |
| 335 | 0 | 0 | 335 | 0 | 0 | 335 | 0 | 0 |
| 336 | 6 | 2 | 336 | 0 | 0 | 336 | 0 | 0 |
| 337 | 12 | 11 | 337 | 0 | 0 | 337 | 0 | 0 |
| 338 | 19 | 27 | 338 | 0 | 0 | 338 | 0 | 0 |
| 339 | 25 | 48 | 339 | 0 | 0 | 339 | 0 | 0 |
| 340 | 28 | 74 | 340 | 0 | 0 | 340 | 0 | 0 |
| 341 | 71 | 122 | 341 | 0 | 0 | 341 | 35 | 12 |
| 342 | 113 | 213 | 342 | 0 | 0 | 342 | 78 | 67 |
| 343 | 156 | 347 | 343 | 23 | 8 | 343 | 121 | 166 |
| 344 | 199 | 525 | 344 | 66 | 51 | 344 | 164 | 308 |
| 345 | 242 | 745 | 345 | 109 | 137 | 345 | 207 | 493 |
| 346 | 285 | 1,008 | 346 | 152 | 267 | 346 | 250 | 721 |
| 347 | 328 | 1,314 | 347 | 195 | 440 | 347 | 292 | 992 |
| 348 | 370 | 1,663 | 348 | 238 | 656 | 348 | 335 | 1,306 |
| 349 | 413 | 2,054 | 349 | 280 | 915 | 349 | 378 | 1,662 |
| 350 | 456 | 2,489 | 350 | 323 | 1,216 | 350 | 421 | 2,062 |
| 351 | 868 | 3,140 | 351 | 735 | 1,731 | 351 | 832 | 2,677 |
| 352 | 1,279 | 4,207 | 352 | 1,146 | 2,664 | 352 | 1,244 | 3,708 |
| 353 | 1,691 | 5,687 | 353 | 1,558 | 4,011 | 353 | 1,655 | 5,153 |
| 354 | 2,102 | 7,579 | 354 | 1,969 | 5,770 | 354 | 2,067 | 7,010 |
| 355 | 2,513 | 9,884 | 355 | 2,381 | 7,942 | 355 | 2,478 | 9,280 |
| 356 | 2,925 | 12,600 | 356 | 2,792 | 10,526 | 356 | 2,890 | 11,961 |
| 357 | 3,336 | 15,729 | 357 | 3,204 | 13,521 | 357 | 3,301 | 15,055 |
| 358 | 3,748 | 19,269 | 358 | 3,615 | 16,928 | 358 | 3,713 | 18,560 |
| 359 | 4,159 | 23,221 | 359 | 4,026 | 20,747 | 359 | 4,124 | 22,476 |
| 360 | 4,571 | 27,584 | 360 | 4,438 | 24,978 | 360 | 4,536 | 26,805 |
| 361 | 4,970 | 32,354 | 361 | 4,837 | 29,614 | 361 | 4,935 | 31,539 |
| 362 | 5,369 | 37,522 | 362 | 5,236 | 34,649 | 362 | 5,334 | 36,672 |
| 363 | 5,769 | 43,090 | 363 | 5,636 | 40,084 | 363 | 5,733 | 42,205 |
| 364 | 6,168 | 49,057 | 364 | 6,035 | 45,918 | 364 | 6,133 | 48,137 |
| 365 | 6,567 | 55,423 | 365 | 6,434 | 52,152 | 365 | 6,532 | 54,468 |
| 366 | 6,966 | 62,189 | 366 | 6,833 | 58,785 | 366 | 6,931 | 61,199 |
| 367 | 7,366 | 69,354 | 367 | 7,233 | 65,817 | 367 | 7,330 | 68,328 |
| 368 | 7,765 | 76,919 | 368 | 7,632 | 73,248 | 368 | 7,730 | 75,858 |
| 369 | 8,164 | 84,882 | 369 | 8,031 | 81,079 | 369 | 8,129 | 83,786 |
| 370 | 8,563 | 93,245 | 370 | 8,430 | 89,309 | 370 | 8,528 | 92,114 |

2030 Conditions (Initial)

| Elevation (ft) | Area (ac) | Capacity (ac-ft) |
|----------------|-----------|------------------|
| 371 | 9,082 | 102,067 |
| 372 | 9,601 | 111,407 |
| 373 | 10,120 | 121,267 |
| 374 | 10,639 | 131,645 |
| 375 | 11,158 | 142,543 |
| 376 | 11,677 | 153,959 |
| 377 | 12,196 | 165,894 |
| 378 | 12,715 | 178,349 |
| 379 | 13,234 | 191,322 |
| 380 | 13,752 | 204,814 |
| 381 | 14,456 | 218,917 |
| 382 | 15,159 | 233,723 |
| 383 | 15,863 | 249,232 |
| 384 | 16,566 | 265,446 |
| 385 | 17,270 | 282,363 |
| 386 | 17,973 | 299,983 |
| 387 | 18,677 | 318,307 |
| 388 | 19,380 | 337,334 |
| 389 | 20,084 | 357,065 |
| 390 | 20,787 | 377,499 |
| 391 | 21,542 | 398,663 |
| 392 | 22,297 | 420,581 |
| 393 | 23,052 | 443,255 |
| 394 | 23,808 | 466,684 |
| 395 | 24,563 | 490,868 |
| 396 | 25,318 | 515,807 |
| 397 | 26,073 | 541,502 |
| 398 | 26,828 | 567,951 |
| 399 | 27,583 | 595,156 |
| 400 | 28,338 | 623,116 |
| 401 | 28,855 | 651,712 |

2070 Current Sedimentation Rates

| Elevation (ft) | Area (ac) | Capacity (ac-ft) |
|----------------|-----------|------------------|
| 371 | 8,949 | 97,998 |
| 372 | 9,468 | 107,205 |
| 373 | 9,987 | 116,932 |
| 374 | 10,506 | 127,178 |
| 375 | 11,025 | 137,942 |
| 376 | 11,544 | 149,226 |
| 377 | 12,063 | 161,028 |
| 378 | 12,582 | 173,349 |
| 379 | 13,101 | 186,190 |
| 380 | 13,620 | 199,549 |
| 381 | 14,323 | 213,519 |
| 382 | 15,026 | 228,192 |
| 383 | 15,730 | 243,569 |
| 384 | 16,433 | 259,649 |
| 385 | 17,137 | 276,433 |
| 386 | 17,840 | 293,920 |
| 387 | 18,544 | 312,111 |
| 388 | 19,247 | 331,006 |
| 389 | 19,951 | 350,604 |
| 390 | 20,654 | 370,905 |
| 391 | 21,409 | 391,936 |
| 392 | 22,164 | 413,721 |
| 393 | 22,920 | 436,262 |
| 394 | 23,675 | 459,558 |
| 395 | 24,430 | 483,610 |
| 396 | 25,185 | 508,416 |
| 397 | 25,940 | 533,977 |
| 398 | 26,695 | 560,294 |
| 399 | 27,450 | 587,366 |
| 400 | 28,205 | 615,193 |
| 401 | 28,722 | 643,656 |

2070 Mitigated Sedimentation Rates

| Elevation (ft) | Area (ac) | Capacity (ac-ft) |
|----------------|-----------|------------------|
| 371 | 9,047 | 100,901 |
| 372 | 9,566 | 110,206 |
| 373 | 10,085 | 120,030 |
| 374 | 10,604 | 130,374 |
| 375 | 11,123 | 141,236 |
| 376 | 11,642 | 152,617 |
| 377 | 12,161 | 164,517 |
| 378 | 12,679 | 176,936 |
| 379 | 13,198 | 189,874 |
| 380 | 13,717 | 203,331 |
| 381 | 14,421 | 217,399 |
| 382 | 15,124 | 232,170 |
| 383 | 15,828 | 247,645 |
| 384 | 16,531 | 263,823 |
| 385 | 17,235 | 280,705 |
| 386 | 17,938 | 298,290 |
| 387 | 18,642 | 316,578 |
| 388 | 19,345 | 335,571 |
| 389 | 20,048 | 355,266 |
| 390 | 20,752 | 375,666 |
| 391 | 21,507 | 396,794 |
| 392 | 22,262 | 418,678 |
| 393 | 23,017 | 441,316 |
| 394 | 23,772 | 464,710 |
| 395 | 24,528 | 488,859 |
| 396 | 25,283 | 513,763 |
| 397 | 26,038 | 539,422 |
| 398 | 26,793 | 565,837 |
| 399 | 27,548 | 593,006 |
| 400 | 28,303 | 620,931 |
| 401 | 28,820 | 649,492 |

Table C-1.4 – Parkhouse II Elevation-Area-Capacity

| 2030 Conditions (Initial) | | | 2070 Current Sedimentation Rates | | | 2070 Mitigated Sedimentation Rates | | |
|---------------------------|-----------|------------------|----------------------------------|-----------|------------------|------------------------------------|-----------|------------------|
| Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) |
| 340 | 0 | 0 | 340 | 0 | 0 | 340 | 0 | 0 |
| 341 | 10 | 3 | 341 | 0 | 0 | 341 | 0 | 0 |
| 342 | 20 | 18 | 342 | 0 | 0 | 342 | 0 | 0 |
| 343 | 30 | 42 | 343 | 0 | 0 | 343 | 7 | 2 |
| 344 | 39 | 77 | 344 | 0 | 0 | 344 | 17 | 14 |
| 345 | 49 | 121 | 345 | 0 | 0 | 345 | 27 | 35 |
| 346 | 59 | 175 | 346 | 0 | 0 | 346 | 36 | 66 |
| 347 | 69 | 239 | 347 | 0 | 0 | 347 | 46 | 108 |
| 348 | 79 | 313 | 348 | 0 | 0 | 348 | 56 | 159 |
| 349 | 89 | 397 | 349 | 0 | 0 | 349 | 66 | 220 |
| 350 | 99 | 490 | 350 | 0 | 0 | 350 | 76 | 291 |
| 351 | 111 | 595 | 351 | 0 | 0 | 351 | 89 | 373 |
| 352 | 124 | 713 | 352 | 0 | 0 | 352 | 101 | 467 |
| 353 | 137 | 843 | 353 | 0 | 0 | 353 | 114 | 575 |
| 354 | 150 | 987 | 354 | 0 | 0 | 354 | 127 | 695 |
| 355 | 162 | 1,142 | 355 | 0 | 0 | 355 | 139 | 828 |
| 356 | 175 | 1,311 | 356 | 0 | 0 | 356 | 152 | 974 |
| 357 | 188 | 1,492 | 357 | 0 | 0 | 357 | 165 | 1,133 |
| 358 | 200 | 1,686 | 358 | 0 | 0 | 358 | 178 | 1,304 |
| 359 | 213 | 1,893 | 359 | 0 | 0 | 359 | 190 | 1,488 |
| 360 | 226 | 2,113 | 360 | 0 | 0 | 360 | 203 | 1,685 |
| 361 | 448 | 2,443 | 361 | 109 | 36 | 361 | 425 | 1,992 |
| 362 | 669 | 2,998 | 362 | 330 | 246 | 362 | 646 | 2,524 |
| 363 | 891 | 3,775 | 363 | 552 | 682 | 363 | 868 | 3,278 |
| 364 | 1,112 | 4,775 | 364 | 774 | 1,342 | 364 | 1,090 | 4,255 |
| 365 | 1,334 | 5,997 | 365 | 995 | 2,224 | 365 | 1,311 | 5,454 |
| 366 | 1,556 | 7,440 | 366 | 1,217 | 3,328 | 366 | 1,533 | 6,875 |
| 367 | 1,777 | 9,105 | 367 | 1,439 | 4,654 | 367 | 1,755 | 8,517 |
| 368 | 1,999 | 10,993 | 368 | 1,660 | 6,202 | 368 | 1,976 | 10,382 |
| 369 | 2,221 | 13,101 | 369 | 1,882 | 7,972 | 369 | 2,198 | 12,468 |
| 370 | 2,442 | 15,432 | 370 | 2,103 | 9,964 | 370 | 2,420 | 14,775 |
| 371 | 2,660 | 17,983 | 371 | 2,321 | 12,175 | 371 | 2,637 | 17,303 |
| 372 | 2,878 | 20,751 | 372 | 2,539 | 14,605 | 372 | 2,855 | 20,049 |
| 373 | 3,096 | 23,737 | 373 | 2,757 | 17,252 | 373 | 3,073 | 23,012 |
| 374 | 3,314 | 26,942 | 374 | 2,975 | 20,118 | 374 | 3,291 | 26,194 |
| 375 | 3,532 | 30,364 | 375 | 3,193 | 23,201 | 375 | 3,509 | 29,593 |

2030 Conditions (Initial)

| Elevation (ft) | Area (ac) | Capacity (ac-ft) |
|----------------|-----------|------------------|
| 376 | 3,750 | 34,004 |
| 377 | 3,968 | 37,862 |
| 378 | 4,185 | 41,938 |
| 379 | 4,403 | 46,232 |
| 380 | 4,621 | 50,744 |
| 381 | 4,916 | 55,512 |
| 382 | 5,211 | 60,575 |
| 383 | 5,507 | 65,934 |
| 384 | 5,802 | 71,587 |
| 385 | 6,097 | 77,536 |
| 386 | 6,392 | 83,780 |
| 387 | 6,687 | 90,319 |
| 388 | 6,982 | 97,153 |
| 389 | 7,277 | 104,283 |
| 390 | 7,573 | 111,707 |
| 391 | 7,909 | 119,447 |
| 392 | 8,246 | 127,524 |
| 393 | 8,582 | 135,937 |
| 394 | 8,919 | 144,687 |
| 395 | 9,255 | 153,773 |
| 396 | 9,591 | 163,196 |
| 397 | 9,928 | 172,955 |
| 398 | 10,264 | 183,051 |
| 399 | 10,601 | 193,483 |
| 400 | 10,937 | 204,252 |
| 401 | 11,282 | 215,361 |
| 402 | 11,627 | 226,816 |
| 403 | 11,972 | 238,615 |
| 404 | 12,317 | 250,759 |
| 405 | 12,662 | 263,249 |
| 406 | 13,007 | 276,083 |
| 407 | 13,352 | 289,263 |
| 408 | 13,697 | 302,787 |
| 409 | 14,042 | 316,657 |
| 410 | 14,387 | 330,871 |

2070 Current Sedimentation Rates

| Elevation (ft) | Area (ac) | Capacity (ac-ft) |
|----------------|-----------|------------------|
| 376 | 3,411 | 26,502 |
| 377 | 3,629 | 30,022 |
| 378 | 3,847 | 33,759 |
| 379 | 4,064 | 37,714 |
| 380 | 4,282 | 41,887 |
| 381 | 4,577 | 46,316 |
| 382 | 4,873 | 51,040 |
| 383 | 5,168 | 56,060 |
| 384 | 5,463 | 61,374 |
| 385 | 5,758 | 66,984 |
| 386 | 6,053 | 72,889 |
| 387 | 6,348 | 79,089 |
| 388 | 6,643 | 85,585 |
| 389 | 6,939 | 92,375 |
| 390 | 7,234 | 99,461 |
| 391 | 7,570 | 106,862 |
| 392 | 7,907 | 114,600 |
| 393 | 8,243 | 122,674 |
| 394 | 8,580 | 131,085 |
| 395 | 8,916 | 139,832 |
| 396 | 9,253 | 148,916 |
| 397 | 9,589 | 158,337 |
| 398 | 9,926 | 168,093 |
| 399 | 10,262 | 178,187 |
| 400 | 10,598 | 188,616 |
| 401 | 10,943 | 199,387 |
| 402 | 11,288 | 210,503 |
| 403 | 11,633 | 221,963 |
| 404 | 11,978 | 233,769 |
| 405 | 12,323 | 245,919 |
| 406 | 12,668 | 258,415 |
| 407 | 13,013 | 271,255 |
| 408 | 13,358 | 284,441 |
| 409 | 13,703 | 297,972 |
| 410 | 14,048 | 311,847 |

2070 Mitigated Sedimentation Rates

| Elevation (ft) | Area (ac) | Capacity (ac-ft) |
|----------------|-----------|------------------|
| 376 | 3,727 | 33,211 |
| 377 | 3,945 | 37,046 |
| 378 | 4,163 | 41,099 |
| 379 | 4,381 | 45,371 |
| 380 | 4,598 | 49,860 |
| 381 | 4,894 | 54,605 |
| 382 | 5,189 | 59,645 |
| 383 | 5,484 | 64,981 |
| 384 | 5,779 | 70,612 |
| 385 | 6,074 | 76,538 |
| 386 | 6,369 | 82,759 |
| 387 | 6,664 | 89,275 |
| 388 | 6,960 | 96,086 |
| 389 | 7,255 | 103,193 |
| 390 | 7,550 | 110,595 |
| 391 | 7,886 | 118,312 |
| 392 | 8,223 | 126,366 |
| 393 | 8,559 | 134,757 |
| 394 | 8,896 | 143,484 |
| 395 | 9,232 | 152,547 |
| 396 | 9,569 | 161,947 |
| 397 | 9,905 | 171,683 |
| 398 | 10,242 | 181,756 |
| 399 | 10,578 | 192,166 |
| 400 | 10,915 | 202,912 |
| 401 | 11,260 | 213,998 |
| 402 | 11,605 | 225,430 |
| 403 | 11,950 | 237,206 |
| 404 | 12,295 | 249,328 |
| 405 | 12,640 | 261,795 |
| 406 | 12,985 | 274,606 |
| 407 | 13,330 | 287,763 |
| 408 | 13,675 | 301,265 |
| 409 | 14,020 | 315,111 |
| 410 | 14,365 | 329,303 |

Table C-1.5 – Talco Elevation-Area-Capacity

| 2030 Conditions (Initial) | | | 2070 Current Sedimentation Rates | | | 2070 Mitigated Sedimentation Rates | | |
|---------------------------|-----------|------------------|----------------------------------|-----------|------------------|------------------------------------|-----------|------------------|
| Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) | Elevation (ft) | Area (ac) | Capacity (ac-ft) |
| 290 | 11 | 0 | 290 | 0 | 0 | 290 | 0 | 0 |
| 300 | 200 | 325 | 300 | 0 | 0 | 300 | 130 | 434 |
| 310 | 2,076 | 8,519 | 310 | 1,871 | 6,238 | 310 | 2,007 | 9,262 |
| 320 | 5,401 | 44,292 | 320 | 5,196 | 40,193 | 320 | 5,332 | 44,627 |
| 330 | 11,151 | 128,310 | 330 | 10,947 | 119,143 | 330 | 11,082 | 124,961 |
| 340 | 16,896 | 265,211 | 340 | 16,691 | 256,326 | 340 | 16,827 | 263,507 |
| 350 | 24,096 | 467,881 | 350 | 23,891 | 458,164 | 350 | 24,026 | 466,704 |
| 360 | 34,423 | 758,945 | 360 | 34,218 | 747,168 | 360 | 34,354 | 757,068 |
| 370 | 48,382 | 1,170,994 | 370 | 48,177 | 1,157,158 | 370 | 48,312 | 1,168,418 |

C-2 Wright Patman Yield Modeling

Yields of Lake Wright Patman were determined for various reallocation scenarios using current, 2020, 2040 and 2070 sediment conditions. Reallocation scenarios include current and proposed modifications to the top of conservation storage (Interim Curve, Ultimate Curve and flat storages between 227.5 feet and 259.5 feet), as well as various minimum storages (217.5 feet, 220 feet, 223 feet and full use of storage). All yields are run without environmental bypass or other releases. Environmental bypass will be determined in another study. Other releases from Lake Wright Patman were not explicitly modeled. The yields in this memorandum have been reduced by 7,247 acre-feet per year to account for the constant 10 cfs release specified in the Texarkana contract.

Current Conditions

Firm yields of Wright Patman were determined assuming current sediment conditions for 40 reallocation scenarios:

- Interim Curve with the following minimum elevations:
 - 220.0 feet, the minimum elevation in the Texarkana contract with the Corps
 - 223.0 feet, the desired minimum operating level for the current Texarkana intake⁶
 - 217.5 feet, the desired minimum operating level for a new proposed intake⁷
 - Full use of storage
- Ultimate Curve with the following minimum elevations
 - 220.0 feet, the minimum elevation in the Texarkana contract with the Corps
 - 223.0 feet, the desired minimum operating level for the current Texarkana intake
 - 217.5 feet, the desired minimum operating level for a new proposed intake
 - Full use of storage

⁶ Texarkana Water Utilities, personal communication.

⁷ Robert Murray, MTG Engineers, personal communication.

- Flat conservation pools at 227.5 feet, 232.5 feet, 237.5 feet, 242.5 feet, 247.5 feet, 252.5 feet, 257.5 feet and 259.5 feet with the same minimum elevations
 - 220.0 feet, the minimum elevation in the Texarkana contract with the Corps
 - 223.0 feet, the desired minimum operating level for the current Texarkana intake
 - 217.5 feet, the desired minimum operating level for a new proposed intake
 - Full use of storage

Yields are shown in Table C-2.1. Figure C-2.1 compares the yields with various minimum storages for the eight flat conservation pools.

Current sediment conditions reflect the fact that that Lake Ralph Hall has not been built. However, for this study FNI included Lake Ralph Hall in the WAM. This gives a conservative estimate of the available yield since water used by Lake Ralph Hall is not considered to be available for diversions in excess of the existing Wright Patman water right. Lake Ralph Hall is operated without environmental bypass, which is consistent with analyses provided by TCEQ.

Note that the yield with the Interim Curve and a minimum elevation of 223 feet is zero. This is because the Interim Curve has a maximum elevation 220.6 feet during the winter months, which is below the desired minimum operating level for the Texarkana intake. As a result, the reservoir cannot supply water respecting both the desired minimum elevation for the Texarkana intake and the maximum conservation storage, so the yield is assumed to be zero.

The Full Storage scenario assumes that a minimum of 8,162 acre-feet of storage is left in Lake Wright Patman. The minimum storage was determined by subtracting the loss in storage below elevation 220.6 feet due to sediment accumulation from the reported sediment storage of 68,000 acre-feet⁸.

⁸ U.S. Army Corps of Engineers: Pertinent Data, Wright Patman Lake, available on-line at <http://www.swf-wc.usace.army.mil/cgi-bin/rcshtml.pl?page=Pertinent>

Table C-2.1 – Wright Patman Reallocation Yields – Current Sediment Conditions

| Maximum Elevation (feet)/Curve | Minimum Elevation | Firm Yield (acre-feet/year)* |
|--------------------------------|-----------------------------|------------------------------|
| Interim | Texarkana Contract (220 ft) | 40,263 |
| Ultimate | Texarkana Contract (220 ft) | 201,413 |
| 227.5 | Texarkana Contract (220 ft) | 255,693 |
| 232.5 | Texarkana Contract (220 ft) | 460,963 |
| 237.5 | Texarkana Contract (220 ft) | 658,273 |
| 242.5 | Texarkana Contract (220 ft) | 772,663 |
| 247.5 | Texarkana Contract (220 ft) | 891,913 |
| 252.5 | Texarkana Contract (220 ft) | 1,034,363 |
| 257.5 | Texarkana Contract (220 ft) | 1,155,013 |
| 259.5 | Texarkana Contract (220 ft) | 1,208,533 |

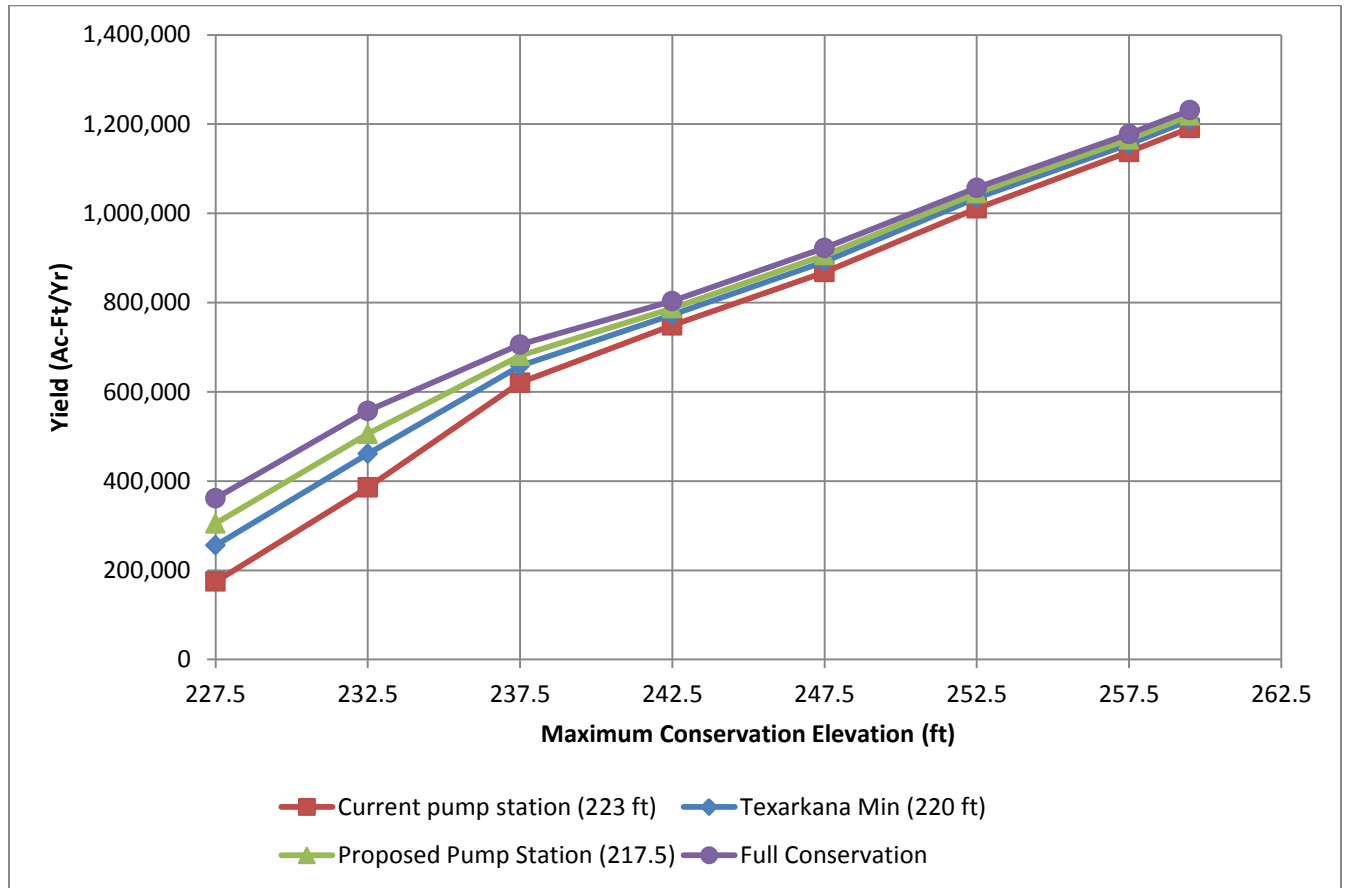
| | | |
|----------|-------------------------------|-----------|
| Interim | Current pump station (223 ft) | 0 |
| Ultimate | Current pump station (223 ft) | 172,753 |
| 227.5 | Current pump station (223 ft) | 174,873 |
| 232.5 | Current pump station (223 ft) | 385,753 |
| 237.5 | Current pump station (223 ft) | 620,623 |
| 242.5 | Current pump station (223 ft) | 748,833 |
| 247.5 | Current pump station (223 ft) | 868,203 |
| 252.5 | Current pump station (223 ft) | 1,011,113 |
| 257.5 | Current pump station (223 ft) | 1,137,533 |
| 259.5 | Current pump station (223 ft) | 1,191,083 |

| | | |
|----------|----------------------------------|-----------|
| Interim | Proposed pump station (217.5 ft) | 123,743 |
| Ultimate | Proposed pump station (217.5 ft) | 263,303 |
| 227.5 | Proposed pump station (217.5 ft) | 304,883 |
| 232.5 | Proposed pump station (217.5 ft) | 505,873 |
| 237.5 | Proposed pump station (217.5 ft) | 680,773 |
| 242.5 | Proposed pump station (217.5 ft) | 787,163 |
| 247.5 | Proposed pump station (217.5 ft) | 906,263 |
| 252.5 | Proposed pump station (217.5 ft) | 1,045,033 |
| 257.5 | Proposed pump station (217.5 ft) | 1,165,623 |
| 259.5 | Proposed pump station (217.5 ft) | 1,219,123 |

| | | |
|----------|--------------|-----------|
| Interim | Full Storage | 205,513 |
| Ultimate | Full Storage | 331,403 |
| 227.5 | Full Storage | 361,643 |
| 232.5 | Full Storage | 557,353 |
| 237.5 | Full Storage | 705,783 |
| 242.5 | Full Storage | 803,483 |
| 247.5 | Full Storage | 922,583 |
| 252.5 | Full Storage | 1,057,183 |
| 257.5 | Full Storage | 1,177,713 |
| 259.5 | Full Storage | 1,231,183 |

* Yields have been reduced by 7,247 acre-feet/year to account for the required 10 cfs release from the reservoir

Figure C-2-1 – Wright Patman Yield vs. Top of Conservation Pools Elevations



Future Yields

Future yields calculated for the Wright Patman Reallocation assumed future sediment conditions for Wright Patman, Jim Chapman and Lake Ralph Hall. Table C-2.22 shows the annual sediment rates at major reservoirs before the construction of Lake Ralph Hall, after construction of Ralph Hall with current sedimentation rates, and after construction of Ralph Hall with a Sediment Reduction Program using feasible BMPs. These sediment rates are based on the SWAT modeling performed for the current study, described in Appendix D.

The sediment rates in Table C-2.2 were used to develop five future sediment scenarios:

- 2020 Conditions
- 2040 Conditions
- 2040 Conditions with Sediment Reduction Program
- 2070 Conditions

- 2070 Conditions with Sediment Reduction Program

Table C-2.2 – Annual Reservoir Sediment Rates from SWAT Analyses

(Values in acre-feet/year)

| Reservoir | Without Ralph Hall | With Ralph Hall | With Ralph Hall and Sediment Reduction Program |
|---------------|--------------------|-----------------|--|
| Ralph Hall | 131.6 | 131.6 | 16.1 |
| Wright Patman | 1,320.0 | 1,277.2 | 913.9 |
| Jim Chapman | 599.2 | 599.2 | 33.9 |

The sediment scenarios assume that Lake Ralph Hall is built in 2020. In the 2020 condition scenario it was assumed sediment accumulates in Lake Wright Patman at the current sedimentation rate without Ralph Hall and without implementation of a Sediment Reduction Program (1,320 acre-feet/year). For 2040 and 2070 scenarios without the Sediment Reduction Program, sediment accumulates in Lake Wright Patman beginning with the calculated 2020 storage at the “With Ralph Hall” sediment rate (1,277.2 acre-feet/year). For the Sediment Reduction Program scenarios, it is assumed that the BMPs are in place and effective by 2020, and that after 2020 sediment accumulates in Lake Wright Patman at the reduced rate (913.9 acre-feet/year). For the sediment scenarios, it is also assumed that Lake Chapman and Lake Ralph Hall storage is reduced using the appropriate rates, with and without a Sediment Reduction Program.

Table C-2.3 shows the yield of the various Wright Patman reallocation scenarios taking into consideration the sediment scenarios described above. Rather than assessing the entire suite of reallocation scenarios, this analysis is limited to a the scenarios with a minimum storage of 220.0 feet and the Interim Curve, Ultimate Curve and flat storage at 227.5, 237.5 and 252.5 feet. The minimum storage of 220.0 feet is the bottom of the current conservation pool, and it is considered unlikely that water below the conservation storage would be available for water supply. The elevations for the flat conservation storage reallocation scenarios are selected because they define the break points in the yield curve (see Figure C-2.1).

Table C-2.3 – Wright Patman Reallocation Yields

| Max Elevation (feet)/Curve | Min Elevation | Sediment Condition | Firm Yield (acre-feet/year)* |
|----------------------------|-----------------------------|-------------------------|------------------------------|
| Interim | Texarkana Contract (220 ft) | 2020 without Ralph Hall | 38,953 |
| Ultimate | Texarkana Contract (220 ft) | 2020 without Ralph Hall | 196,293 |
| 227.5 | Texarkana Contract (220 ft) | 2020 without Ralph Hall | 251,313 |
| 237.5 | Texarkana Contract (220 ft) | 2020 without Ralph Hall | 655,023 |
| 252.5 | Texarkana Contract (220 ft) | 2020 without Ralph Hall | 1,031,993 |

| | | | |
|----------|-----------------------------|----------------------|-----------|
| Interim | Texarkana Contract (220 ft) | 2040 with Ralph Hall | 37,713 |
| Ultimate | Texarkana Contract (220 ft) | 2040 with Ralph Hall | 192,033 |
| 227.5 | Texarkana Contract (220 ft) | 2040 with Ralph Hall | 240,633 |
| 237.5 | Texarkana Contract (220 ft) | 2040 with Ralph Hall | 646,873 |
| 252.5 | Texarkana Contract (220 ft) | 2040 with Ralph Hall | 1,025,243 |

| | | | |
|----------|-----------------------------|----------------------|-----------|
| Interim | Texarkana Contract (220 ft) | 2070 with Ralph Hall | 34,283 |
| Ultimate | Texarkana Contract (220 ft) | 2070 with Ralph Hall | 180,283 |
| 227.5 | Texarkana Contract (220 ft) | 2070 with Ralph Hall | 220,153 |
| 237.5 | Texarkana Contract (220 ft) | 2070 with Ralph Hall | 632,373 |
| 252.5 | Texarkana Contract (220 ft) | 2070 with Ralph Hall | 1,014,063 |

| | | | |
|----------|-----------------------------|---|-----------|
| Interim | Texarkana Contract (220 ft) | 2040 with Ralph Hall and Sediment Reduction Program | 38,303 |
| Ultimate | Texarkana Contract (220 ft) | 2040 with Ralph Hall and Sediment Reduction Program | 194,013 |
| 227.5 | Texarkana Contract (220 ft) | 2040 with Ralph Hall and Sediment Reduction Program | 244,113 |
| 237.5 | Texarkana Contract (220 ft) | 2040 with Ralph Hall and Sediment Reduction Program | 649,323 |
| 252.5 | Texarkana Contract (220 ft) | 2040 with Ralph Hall and Sediment Reduction Program | 1,027,243 |

| | | | |
|----------|-----------------------------|---|-----------|
| Interim | Texarkana Contract (220 ft) | 2070 with Ralph Hall and Sediment Reduction Program | 35,983 |
| Ultimate | Texarkana Contract (220 ft) | 2070 with Ralph Hall and Sediment Reduction Program | 186,113 |
| 227.5 | Texarkana Contract (220 ft) | 2070 with Ralph Hall and Sediment Reduction Program | 230,303 |
| 237.5 | Texarkana Contract (220 ft) | 2070 with Ralph Hall and Sediment Reduction Program | 639,533 |
| 252.5 | Texarkana Contract (220 ft) | 2070 with Ralph Hall and Sediment Reduction Program | 1,019,333 |

* Yields have been reduced by 7,247 acre-feet/year to account for the required 10 cfs release from the reservoir

In addition to the individual yields calculated in Table C-2.3 the cumulative water supply savings due to sediment mitigation for the entire times series (50 years) was calculated. The additional cumulative savings in each different top of pool scenario is shown in Table C-2.4.

Table C-2.4 – Wright Patman Reallocation Cumulative Savings

| Top of Conservation Pool (feet) | Cumulative Savings (acre-feet) |
|---------------------------------|--------------------------------|
| 227.5 | 240,000 |
| 237.5 | 170,000 |
| 252.5 | 130,000 |

C-3 Alternative Project Yields

This section describes yield analyses for the Marvin Nichols, Parkhouse I, Parkhouse II and Talco alternatives. Each of these alternatives was considered as a single project, built in 2030. Evaluation of combinations of these projects will be examined in future studies. Yields are determined without bypass of environmental flows. The impact of environmental flows on project yields will be determined in another study.

All runs were made with Lake Wright Patman operating using the Interim Rule Curve, the current operating procedure for the reservoir.

Reservoir Yields – Marvin Nichols, Parkhouse I and Parkhouse II

Table C-3.1 shows the firm yields of Marvin Nichols 1a and Parkhouse I and II. Yields were calculated for 2030 (initial construction of reservoir) and 2070 conditions, assuming current sediment rates and with implementation of a Sediment Reduction Program using feasible BMPs, as described in Appendix D. It is assumed that Lake Ralph Hall will be built in 2020. For the Sediment Reduction Program, it was assumed that BMP implementation would begin in 2020 and be fully implemented by 2030. Current sediment rates were assumed through 2020 and then linearly decreased to the reduced sediment rates by 2030. The reduced sediment rates resulting from the Sediment Reduction Program were assumed after 2030.

**Table C-3.1 – Firm Yields for Marvin Nichols, Parkhouse I and Parkhouse II
(acre-feet per year)**

| Reservoir | 2030 Yields | | | | 2070 Yields | | | |
|--------------|-----------------------|-----------------------|----------------------------|-----------------------|-----------------------|-----------------------|----------------------------|-----------------------|
| | Current Sedimentation | | Sediment Reduction Program | | Current Sedimentation | | Sediment Reduction Program | |
| | Priority | Patman Subordina-tion | Priority | Patman Subordina-tion | Priority | Patman Subordina-tion | Priority | Patman Subordina-tion |
| Nichols | 590,000 | 659,600 | 589,900 | 659,600 | 581,300 | 650,200 | 586,400 | 655,400 |
| Parkhouse I | 124,300 | 135,300 | 124,300 | 135,300 | 123,500 | 134,500 | 123,900 | 134,900 |
| Parkhouse II | 124,200 | 135,300 | 124,200 | 135,300 | 121,000 | 132,000 | 123,900 | 134,900 |

**Table C-3.2 – Sediment Rates for Alternative Project Analyses –
Nichols, Parkhouse I and Parkhouse II**

| Time Period | Parkhouse I | | Wright Patman | |
|--|------------------|----------------|------------------|----------------|
| | Metric Tons/Year | Acre-Feet/Year | Metric Tons/Year | Acre-Feet/Year |
| Current to 2020, Current Sedimentation Rates | n/a | n/a | 812181.25 | 1320.0 |
| 2020 to 2030, Current Sedimentation Rates | n/a | n/a | 785823.03 | 1277.2 |
| After 2030, Current Sedimentation Rates | 123909.3 | 201.4 | 729025.5 | 1184.9 |
| After 2030, Sediment Reduction Program | 34148.8 | 55.5 | 550702.3 | 895.0 |

| Time Period | Parkhouse II | | Wright Patman | |
|--|------------------|----------------|------------------|----------------|
| | Metric Tons/Year | Acre-Feet/Year | Metric Tons/Year | Acre-Feet/Year |
| Current to 2020, Current Sedimentation Rates | n/a | n/a | 812181.25 | 1320.0 |
| 2020 to 2030, Current Sedimentation Rates | n/a | n/a | 785823.03 | 1277.2 |
| After 2030, Current Sedimentation Rates | 292656.3 | 475.6 | 637610.4 | 1036.3 |
| After 2030, Sediment Reduction Program | 24117.6 | 39.2 | 546293.7 | 887.9 |

| Time Period | Marvin Nichols | | Wright Patman | |
|--|------------------|----------------|------------------|----------------|
| | Metric Tons/Year | Acre-Feet/Year | Metric Tons/Year | Acre-Feet/Year |
| Current to 2020, Current Sedimentation Rates | n/a | n/a | 812181.25 | 1320.0 |
| 2020 to 2030, Current | n/a | n/a | 785823.03 | 1277.2 |

| Time Period | Marvin Nichols | | Wright Patman | |
|---|------------------|----------------|------------------|----------------|
| | Metric Tons/Year | Acre-Feet/Year | Metric Tons/Year | Acre-Feet/Year |
| Sedimentation Rates | | | | |
| After 2030, Current Sedimentation Rates | 526960.0 | 856.5 | 477250.7 | 775.7 |
| After 2030, Sediment Reduction Program | 216191.1 | 351.4 | 447695.6 | 727.6 |

Reservoir Yields - Talco Site

The Talco site is a proposed reservoir on White Oak Creek. This site was investigated in previous studies as the Marvin Nichols IIA site⁹. The dam would be located just upstream of U.S. 271 near the town of Talco. The U.S. 271 bridge is also the site of the USGS White Oak Creek near Talco stream gage (USGS 07343500).

This analysis includes three different scenarios:

- Configuration 1 - Stand-alone yield of the reservoir
- Configuration 2 - Supplemental pumping from the main stem of the Sulphur River
- Configuration 3 - System operation of the reservoir with supplemental pumping from the Sulphur River and utilization of 130,000 acre-feet of reallocated storage in Jim Chapman Lake.

When determining future sediment conditions for the model, it was assumed that Lake Ralph Hall would be built in 2020 and the Talco project in 2030. Sedimentation rates are shown in Table C-3.3. For the Sediment Reduction program, it was assumed that implementation of feasible BMPs would begin in 2020 and be fully implemented by 2030. Current sediment rates were assumed through 2020 and then linearly decreased to the reduced sediment rates by 2030. The reduced sediment rates were assumed after 2030.

⁹ Freese and Nichols, Inc.: Sulphur River Basin Reservoir Study, prepared for the North Texas Municipal Water District and the Tarrant Regional Water District, October 2000.

Table C-3.3 – Sediment Rates for Talco Project Analyses

| Time Period | Talco | | Wright Patman | |
|--|------------------|----------------|------------------|----------------|
| | Metric Tons/Year | Acre-Feet/Year | Metric Tons/Year | Acre-Feet/Year |
| Current to 2020, Current Sedimentation Rates | n/a | n/a | 812181.25 | 1320.0 |
| 2020 to 2030, Current Sedimentation Rates | n/a | n/a | 785823.03 | 1277.2 |
| After 2030, Current Sedimentation Rates | 212831.1 | 345.9 | 760683.4 | 1236.3 |
| After 2030, Sediment Reduction Program | 39617.2 | 64.4 | 566742.2 | 921.1 |

Stand-Alone Yield (Configuration 1)

Table C-3.4 shows the firm yield of the Talco site for maximum storage elevations ranging from 328 feet to 370 feet. 370 feet is the maximum elevation that can be developed for the site. Above 370 feet water would spill over into the adjacent Sulphur River watershed. Table C-3.4 also contains the surface area of the Talco Reservoir at various elevations under initial (2030) conditions. For comparison, the surface area of Marvin Nichols at elevation 328 feet is 71,444 acres, the surface area of Parkhouse I at elevation 401 feet is 28,855 acres and the surface area of Parkhouse II at elevation 410 feet is 14,387 acres.

Table C-3.4 – Stand-Alone Yields of the Talco Site (Configuration 1)

| Maximum Elevation (feet) | Storage (acre-feet) | Surface Area (acres) | Yield (acre-feet/year) | Yield (MGD) |
|--------------------------|---------------------|----------------------|------------------------|-------------|
| 328 | 111,506 | 10,001 | 66,280 | 59.1 |
| 350 | 467,881 | 24,096 | 169,630 | 151.3 |
| 355 | 613,413 | 29,260 | 204,160 | 182.1 |
| 360 | 758,945 | 34,423 | 226,440 | 202.0 |
| 370 | 1,170,994 | 48,382 | 265,150 | 236.5 |

Yield with Supplemental Pumping – Configuration 2

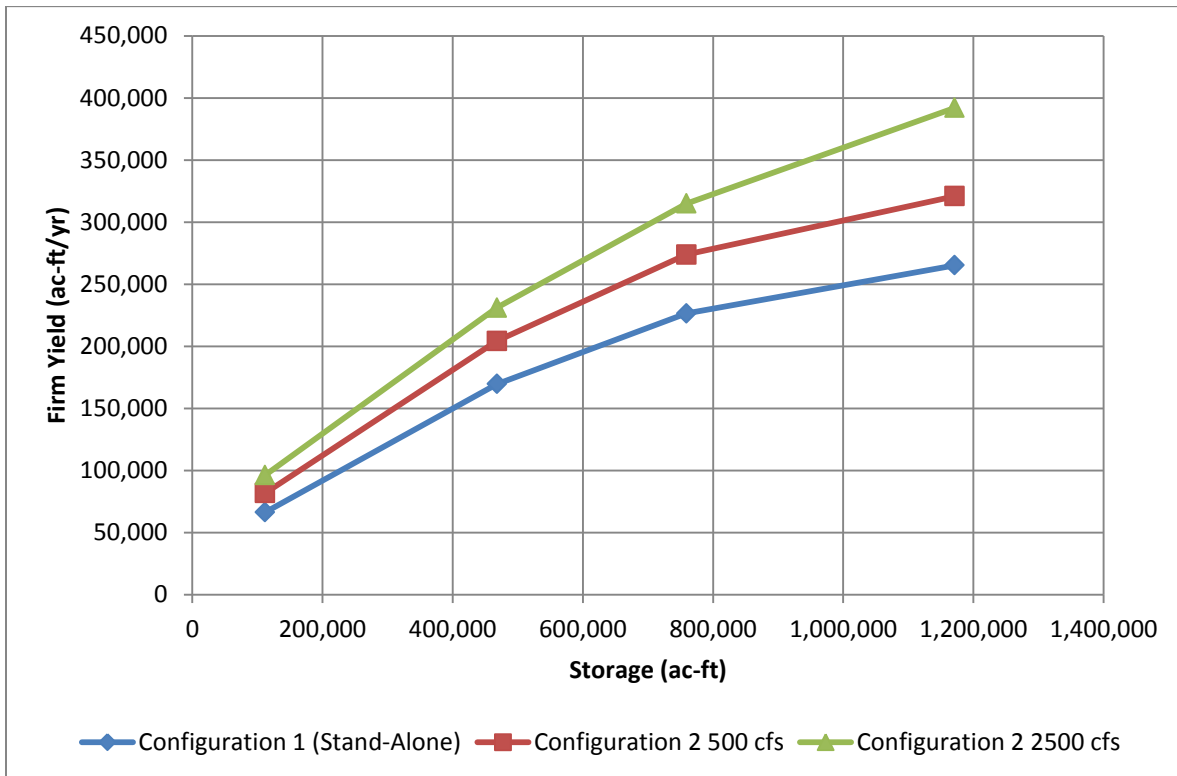
A second set of runs evaluated yields with supplemental pumping from the Sulphur River. The diversion point is assumed to be at the Sulphur River near Talco gage (USGS 07343200). Diversion rates of 500 and 2,500 cfs were evaluated. The 2,500 cfs pumping rate is quite large and was selected to evaluate

the amount of water that could conceivably be developed from the system with minimal infrastructure constraint. The supplemental diversion point is within the footprint of the proposed Marvin Nichols site. Table C-3.5 is a summary of the yields with supplemental pumping. Figure C-3.1 compares the yields with supplemental pumping to the stand-alone yield of the reservoir.

Table C-3.5 – Yields at the Talco Site with Supplemental Pumping from the Sulphur River (Configuration 2)

| Maximum Elevation (feet) | Storage (acre-feet) | 500 cfs Pumping Rate | | 2,500 cfs Pumping Rate | |
|--------------------------|---------------------|------------------------|-------------|------------------------|-------------|
| | | Yield (acre-feet/year) | Yield (MGD) | Yield (acre-feet/year) | Yield (MGD) |
| 328 | 111,506 | 81,710 | 72.9 | 96,180 | 85.8 |
| 350 | 467,881 | 204,200 | 182.2 | 231,000 | 206.1 |
| 360 | 758,945 | 273,800 | 244.3 | 314,900 | 280.9 |
| 370 | 1,170,994 | 320,860 | 286.2 | 392,000 | 349.7 |

Figure C-3-1 – Comparison of Stand-Alone Yields and Yields with Supplemental Pumping



Available water from the Sulphur River was determined by converting the monthly WAM regulated flows to daily flows based on daily factors developed for the 2003 *System Operation Assessment of Lake Wright Patman and Lake Jim Chapman*¹⁰. These daily factors are based on the percentage of monthly flow volume that occurred on each day, using hydrology from the Corps of Engineers SUPER model of the Sulphur Basin. Water passed to downstream water rights was subtracted from the daily flows to determine how much water was available for the supplemental pumping. The daily available flows were then summed up by month and input into the WAM using TS records.

System Operation with Jim Chapman Lake Reallocation – Configuration 3

The third set of runs looks at combining the Talco project with supplemental pumping operating in combination with storage reallocation in Lake Jim Chapman. Available water from the Talco project would be pumped to Lake Chapman to supplement natural flows into the reservoir. The pipeline capacity from the Talco project to Lake Chapman was assumed to be either 500 cfs or 2,500 cfs. Supplemental pumping from the Sulphur River to the Talco Reservoir was evaluated using the same 500 and 2,500 cfs diversion rates used in the runs described above. A new set of TS records defining monthly available flows were developed with the Lake Chapman reallocation upstream. All runs assume that 20% of the yield of the reservoir is reserved for local use and is diverted directly from the Talco Reservoir. The remaining yield is diverted from Lake Chapman. Table C-3.6 is a summary of the results.

The last column of Table C-3.6 is the additional yield of the Talco project after taking into account the 145,560 acre-feet per year of yield associated with the reallocation of storage in Lake Jim Chapman. Note that the net project yields are only slightly different than the yields without the use of Jim Chapman storage. This is because the critical drought periods for the two projects are similar. There are only a few occasions when there is additional flow at the Talco site and there is also empty storage in Lake Chapman, and none during the critical drought period of the reservoirs.

¹⁰ Freese and Nichols, Inc.: *System Operation Assessment of Lake Wright Patman and Lake Jim Chapman*, prepared for the U.S. Army Corps of Engineers, Fort Worth District, January 2003.

Table C-3.6 – Yields with Supplemental Pumping to Lake Chapman (Configuration 3)

| Talco Maximum Elevation (feet) | Maximum Makeup Pumping (cfs) | Maximum Pumping to Chapman (cfs) | Total Project Yield (acre-feet/year) | Net Project Yield* (acre-feet/year) |
|--------------------------------|------------------------------|----------------------------------|--------------------------------------|-------------------------------------|
| 328 | 500 | 500 | 246,520 | 100,980 |
| 350 | 500 | 500 | 350,020 | 204,480 |
| 360 | 500 | 500 | 418,770 | 273,230 |
| 370 | 500 | 500 | 475,270 | 329,730 |
| 328 | 2,500 | 500 | 267,020 | 121,480 |
| 350 | 2,500 | 500 | 384,645 | 239,105 |
| 360 | 2,500 | 500 | 460,270 | 314,730 |
| 370 | 2,500 | 500 | 541,020 | 395,480 |
| 328 | 2,500 | 2,500 | 267,020 | 121,480 |
| 350 | 2,500 | 2,500 | 386,520 | 240,980 |
| 360 | 2,500 | 2,500 | 461,520 | 315,980 |
| 370 | 2,500 | 2,500 | 543,020 | 397,480 |

*Net project yield is the total yield less 145,560 acre-feet/year associated with Lake Chapman reallocation.