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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

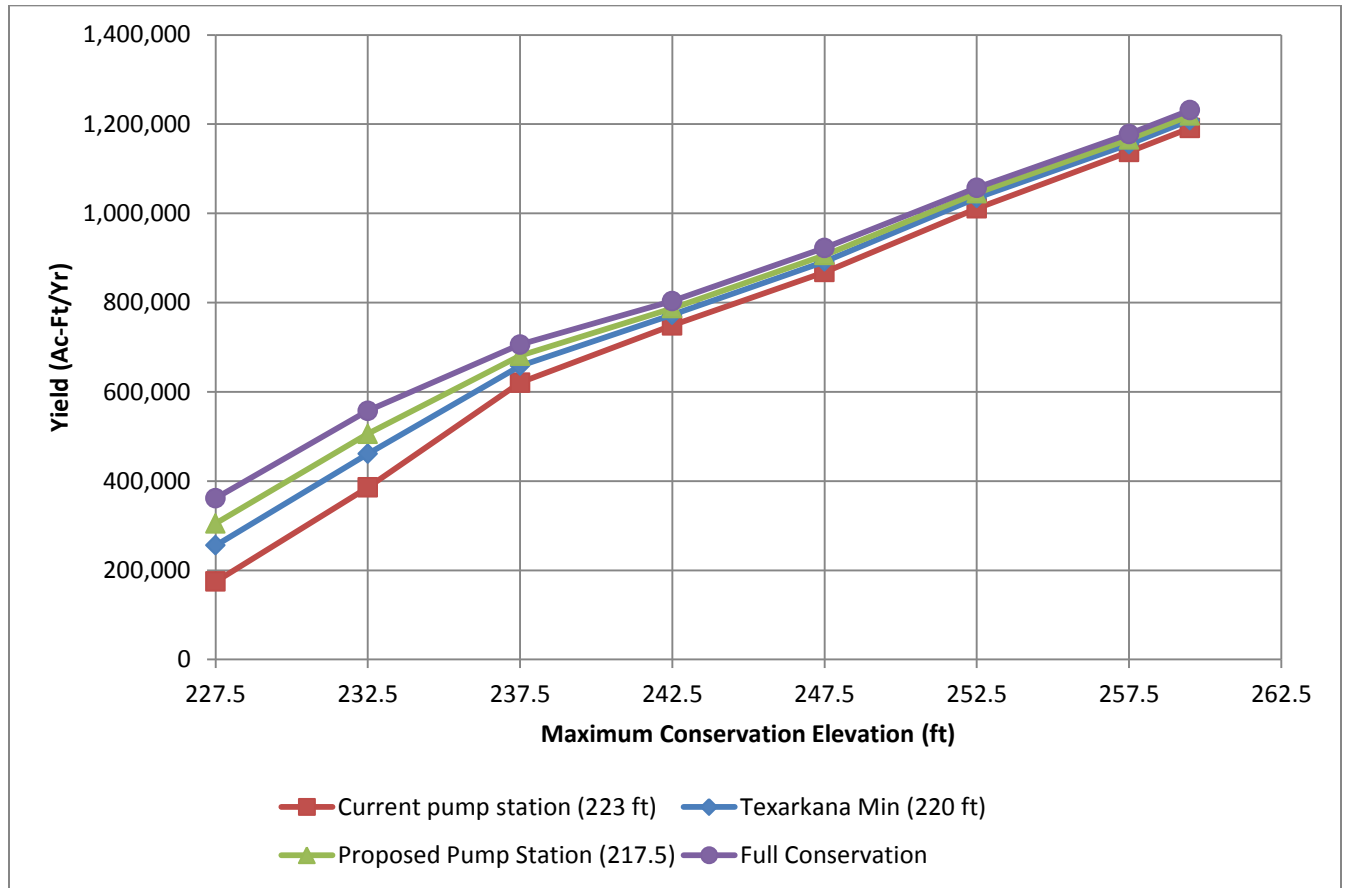
Interim	Current pump station (223 ft)	0
Ultimate	Current pump station (223 ft)	172,753
227.5	Current pump station (223 ft)	174,873
232.5	Current pump station (223 ft)	385,753
237.5	Current pump station (223 ft)	620,623
242.5	Current pump station (223 ft)	748,833
247.5	Current pump station (223 ft)	868,203
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

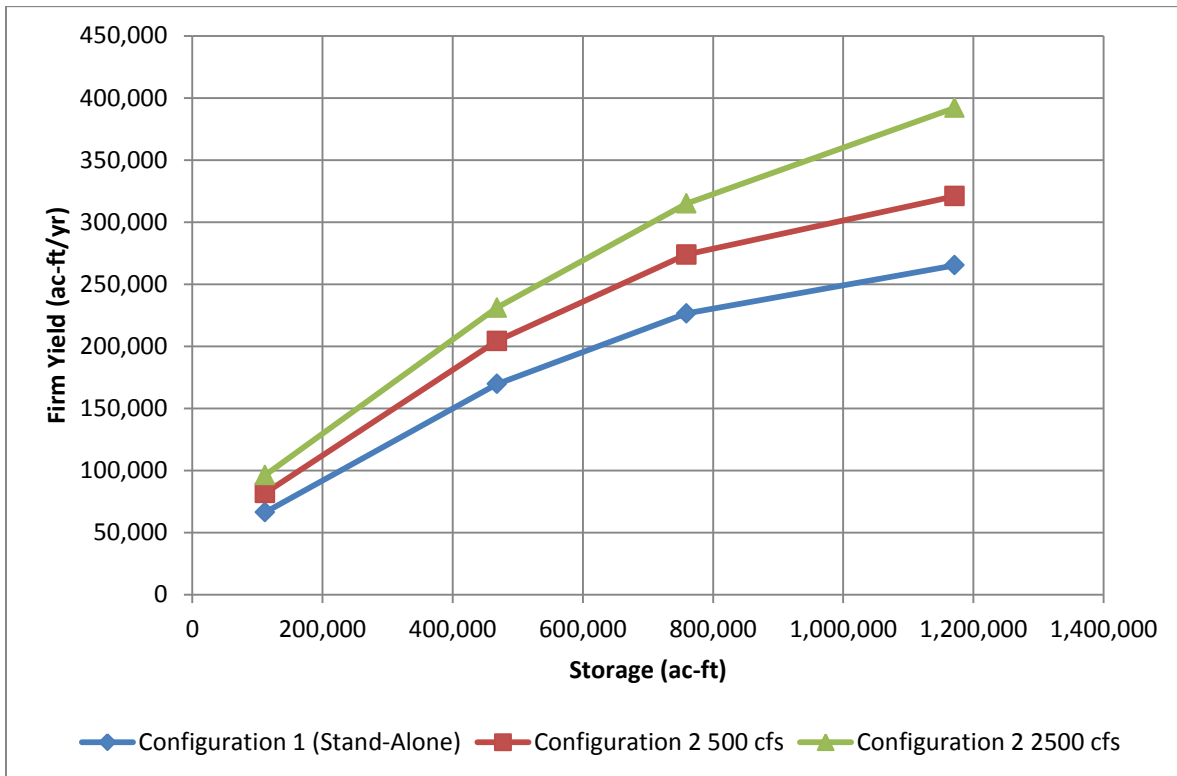
A second set of runs evaluated yields with supplemental pumping from the Sulphur River. The diversion point is assumed to be at the Sulphur River near Talco gage (USGS 07343200). Diversion rates of 500 and 2,500 cfs were evaluated. The 2,500 cfs pumping rate is quite large and was selected to evaluate

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.