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April 11, 2018

Mr. Ron Ellis, Region D Project Manager
Texas Water Development Board
P.O. Box 12321
Austin, Texas 78711

Subject: Procedures for Determining Water Availability and Water Supplies for the 2021 North East Texas Regional Water Plan (Region D)

Dear Mr. Ellis:

The North East Texas Regional Water Planning Group (Region D) met on April 11, 2018 and discussed the process to determine the amount of surface water available from existing and future water management strategies using the guidance provided by the Texas Water Development Board (TWDB) in the base scope of work for the present cycle of Regional Water Planning. During this meeting, Region D discussed specific deviations from, or clarifications of, the standard TWDB guidance that will be employed to develop the 2021 Region D Regional Water Plan consisting of specific items that are either not specified in the TWDB rules, or deviations from the standard TWDB methodologies.

By this letter, Region D requests that the TWDB allow Region D to use these assumptions outlined in the following paragraphs throughout the regional planning process for analyses that determine surface water availability to existing rights, availability of groundwater supplies, and also for analyses to determine the potential supplies available from new water management strategies.

Surface Water Supplies

In its guidelines for Regional Water Planning, the TWDB requires that water availability be based on results derived from the official Texas Commission on Environmental Quality (TCEQ) Water Availability Models (WAMs). The TCEQ WAMs, which have been developed for all river basins in Texas, simulate the management and use of streamflow and reservoirs over a historical period of record, adhering to the prior appropriation doctrine, which governs Texas' water right priority system. The TCEQ WAMs are the fundamental tools used to determine surface water availability for water rights permitting, and contain information about water rights in each respective river basin.

The Region D planning area includes the Cypress Creek, Red River, Sabine, and Sulphur River Basins. For planning purposes, adjustments to these official WAMs are allowable to better reflect current and future surface water conditions in the region. Such adjustments, as proposed herein, require the approval of the TWDB in order to be incorporated into the TCEQ Sulphur River Basin, Cypress Creek River Basin, Red River Basin, and Sabine River Basin WAMs.

The aforementioned TCEQ WAMs for the Sulphur, Cypress Creek, Red, and Sabine River basins contain information on all water rights in these basins. Embedded within the models are certain assumptions that the TCEQ specifies when analyzing water right reliabilities. Water supply availability under drought-of-record conditions is considered in the planning process to insure that water demands can be met under critical circumstances. For surface water supplies, drought-of-record conditions relate to the quantity of water available to meet existing permits as estimated by the official TCEQ WAMs.

There are several versions of each of these WAMs, and the TWDB guidance stipulates that regional water planning groups use the version that TCEQ uses to analyze applications for perpetual water rights. This scenario is often referred to as the WAM "Run 3." The assumptions in the TCEQ WAM Run 3 are conservatively modeled for permitting purposes, but may not necessarily be the most appropriate to apply to the regional water planning process. Such assumptions can be changed by modifying model parameters when the model is used for water planning purposes.

The North East Texas Region D Regional Water Planning Group requests that the TWDB approve the following assumptions and approaches for use in characterizing and representing existing and potential future surface water supplies in the 2021 Region D Regional Water Plan. The WAMs containing the necessary modifications to the TCEQ WAM that incorporate these assumptions will be referred to as the "Region D WAMs." A detailed breakdown of the models and assumptions to be employed for the evaluation of existing water supply and water management strategies (WMS's) is provided in Attachment A. The proposed assumptions to be utilized by Region D include the following items:

GENERAL

- The most recent available versions of the TCEQ WAMs for the Cypress Creek, Red, Sabine, and Sulphur River basins will be obtained from TCEQ. It is anticipated that each WAM will contain the latest approved water rights. This is to ensure that the latest official versions of these WAMs will formulate the basis of subsequent Region D analyses.

- These WAMs will include the official TCEQ assumption of full consumption of existing water rights with no (zero) return flows. This assumption is consistent with surface water permitting and is conservative in the context of evaluations in future water availability.
- Evaluations of reuse will be performed consistently with TCEQ evaluations, incorporating appropriate documented minimum and permitted return flow amounts, as well as source (surface and/or groundwater) for technical considerations. Evaluations of reuse as a WMS may also include consideration of those return flows identified in the most recently available, official TCEQ WAM reflecting recent return flow conditions (WAM Run 8).
- Channel losses employed in the determination of water availability will be based on channel loss factors employed within the official State WAMs.
- Evaluations of Aquifer Storage and Recovery, if determined to be feasible, will consider surface water availability as determined by the WAM compared to demand, with the firm supply being the maximum demand that could be met assuming a repetition of the period of record drought.
- Where environmental flow standards have been adopted by the TCEQ, the standards are incorporated into the applicable official TCEQ WAMs, and will be reflected in evaluations of all Region D water supplies as represented in the WAM. For those basins lacking TCEQ adopted environmental flow standards, TWDB consensus planning criteria will be employed in a manner consistent with TWDB guidelines.

- Subordination of water rights will be modeled in a manner consistent with modeled subordination within the official TCEQ WAMs.
- Water supply determination for municipal and industrial users will be calculated using the results from the WAMs in the following ways:
  - Run of the river rights will be determined in accordance with TWDB guidelines which state that the use-appropriate monthly percentage of the annual firm diversion must be satisfied in each and every month of the simulation period for all surface water diversions.
  - Reservoir source availability will use firm yield as calculated using WAM Run 3, unless a change is specifically requested by a reservoir owner and approved by the RWPG and TWDB, as appropriate per TWDB guidelines.
  - The calculated source availabilities will be compared against existing legal and infrastructure constraints (water treatment plants, pipelines, intakes, sedimentation effects, operational curves, etc.) and will be constrained if the existing infrastructure, physical, or legal capability is not sufficient to facilitate full utilization of the source. The most constrained amount will be used as the firm supply.
- Water supply for irrigation rights will be determined using firm reliability (100%). Per TWDB guidance, in the absence of any supply information or justification of reliable supplies available in a drought of record, supply values will be set equal to zero.
- Per TWDB guidance, in the absence of any supply information or justification of reliable supplies available in a drought of record, livestock supply values will be set equal to zero.

Specifics regarding surface water availability modeling of each river basin are presented by basin below. Considerations regarding the simulation of reservoir conditions with respect to sedimentation effects are then subsequently discussed.

CYPRESS CREEK RIVER BASIN

For the Cypress Creek River Basin, the most recently available official TCEQ WAM Run 3 (ver. June 18, 2015) will be employed. This updated WAM reflects TCEQ's latest updates and corrections, consistent with modifications employed by Region D in the 2016 Region D Plan. The hydrologic period of record of this WAM is 1948-1998.

NECHES RIVER BASIN

For the portion of the Neches River Basin that lies within the Region D planning area, the most recently available official TCEQ WAM Run 3 (ver. October 1, 2012) will be employed. The hydrologic period of record of this WAM is 1940-1996.

RED RIVER BASIN

For the Red River Basin, the most recently available official TCEQ WAM Run 3 (ver. January 2, 2013) will be employed for all availability analyses in the Red River Basin, with two exceptions. Lamar County reservoir yields will be updated based upon modifications of the WAM for the Red River Basin, as developed for the City of Paris by HDR Engineers, as was done previously for the 2011 and 2016 Plans. Specifically, Pat Mayse Reservoir and Lake Crook supplies have been updated. HDR Engineering, at the request of the City of Paris, performed a study in which the water availability for the two lakes was analyzed. HDR developed a drainage area specific water availability model for these two reservoirs, which was based upon information from the U.S. Army Corps of Engineers (USACE) and stream flow data from the Sulphur River gauge at Highway 24. Documentation of this study is provided in Attachment B.

The hydrologic period of record of the official Red River Basin WAM is 1948-1998.

SABINE RIVER BASIN

For the Sabine River Basin, the most recently available official TCEQ WAM Run 3 (ver. July 6, 2015) will be employed for all availability analyses in the basin. The hydrologic period of record of this WAM is 1940-1998.

SULPHUR RIVER BASIN

For the Sulphur River Basin, the most recently available official TCEQ WAM Run 3 (ver. February 1, 2018) will be used as a baseline for all availability analyses in the Sulphur River Basin. The hydrologic period of record of this WAM is 1940-1996.

A comparison has been made between the official TCEQ Sulphur WAM and a modified WAM previously developed by Freese and Nichols, Inc. (FNI) as part of a feasibility study (FNI, 2012, see Attachment C) in the Sulphur River Basin for the Sulphur River Basin Authority (SRBA). The information from that study to be included in the Region D WAM analyses is as follows:

- **Correction for Drainage Area at Control Point C10**
  Changes to correct errors in drainage area for control point C10 (Sulphur River near Talco) as identified by FNI (2012):

  > "In the original TCEQ WAM, primary control point C10, the Sulphur River near Talco (USGS 07343200, aka Sulphur River below Talco 07343210), had a drainage area that was smaller than the next upstream point C20. This results in a flow discontinuity which may impact water availability. Apparently the USGS moved the gage downstream just after the naturalized flows were developed for the Sulphur WAM. 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."

  It has been confirmed that this difference remains in the latest TCEQ Sulphur WAM (February 1, 2018); thus, this correction will be made to all Region D evaluations employing the Sulphur WAM. Specific modifications to be made to the WAM will be as follows:

Changes to .DIS file:

```
** FNI Change - Changed the drainage area for C10 to match USGS drainage area at Sulphur
River Near Talco (1,365 mi2) prior to May 21, 1997.

WP   C10    1365    69.6    43.4

**WP   C10 1353.24    69.6    43.4

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- **Lake Chapman Area/Capacity**
  For the determination of the effects of sedimentation on Lake Jim Chapman storage for water supply, the identified area-capacity relationships for Lake Jim Chapman (based on the 2007 TWDB Volumetric Survey) will be used. Below are the specific modifications to be incorporated as appropriate:

  Changes to .DAT file:

```
Storage and area relationships from 2007 TWDB survey.

**SVRCHAP1        0     2000     8000    20000    45000    63000    85000   132000   194000   239000
255000  310000

**SA              0      850     1925     2920     5625     6525     8100    10800    13800    16400
17200   19305


**

**FNI Change Based on 2007 Volumetric Survey

**ELEV (ft)  396     402     408     414     420     424     428     432     436     438
439     440

SVRCHAP1        0     901   10189   31426   64164   92257  128478  175115  232754  264866
281565  298930

SA              0     746    2471    4549    6349    7851   10412   12908   15668   16457
16976   17958

**
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TRINITY RIVER BASIN

For the portion of the Trinity River Basin that lies within the Region D planning area, the most recently available official TCEQ WAM Run 3 (ver. October 7, 2014) will be employed. The hydrologic period of record of this WAM is 1940-1996.

SIMULATION OF RESERVOIR CONDITIONS (SEDIMENTATION)

Reservoir sedimentation reduces the storage capacity of a reservoir, impacting the beneficial uses of reservoirs such as water supply, flood control, hydropower, navigation, and recreation. Surveys of volumetric storage in a reservoir allow for the derivation of rates and loadings of sediment to the reservoir. The annual loading can then be distributed to determine a revised elevation-area-capacity curve which models the distribution of the total volume of sediment accumulated at the end of an analysis period. The resultant area-capacity relationship is then incorporated into the applicable WAM for the given reservoir.

Generally, for the purposes of the 2021 Region D Plan if a reservoir is calculated to have no firm yield, that result will be assumed for all decades in the 2020-2070 planning horizon. For those reservoirs lacking volumetric surveys, original area-capacity relations employed within WAM Run 3 will be assumed constant. If original area-capacity-elevation relations are not available, the most recent area-capacity-elevation relation for a reservoir will be used as a baseline for future projections. For reservoirs with available volumetric survey information, an annual sediment rate will be calculated or cited from available information, and loadings calculated for Year 2020 and Year 2070. Sediment distribution within the reservoir will be calculated using the Empirical Area Reduction Method (described below), and resultant 2020 and 2070 area-capacity curves will be developed and employed within the applicable WAM to calculate 2020 and 2070 firm yields. The intervening decadal firm yields will then be linearly interpolated.

Empirical Area-Reduction Method

USACE (1989) describes methods for estimating the distribution of sediment deposits in reservoirs. It is noted that empirical methods offer a simple approach useful as a "first approximation," but that their use sacrifices consideration of unique interactions between numerous factors affecting the distribution of sediment deposits in a given reservoir. Such factors include a reservoir's size, shape, sediment quantities and characteristics, sediment sources, progressive vegetative growth on frequently exposed deposits, consolidation of deposits, basin hydrology, and regulation of the reservoir (USACE, 1989).

While five empirical methods are considered in USACE (1989), two are noted as being the most widely used: the Area-Increment Method and the Empirical Area Reduction Method. For the Area-Increment Method, USACE (1989) notes that, "under extreme reservoir operation conditions, or unusual reservoir shape, the Empirical Area Reduction Method should be used," but also notes that both the Area-Increment method and Empirical Area Reduction method, "tend to overpredict the volume of deposits in the conservation pool." Such a tendency is considered in the present context as being reasonably conservative, as such an overprediction in the volume of sediment deposits would more limit the volume available in the conservation pool. More detailed information and modeling beyond the present scope of the regional planning process would be necessary to provide a more detailed characterization of sediment distribution for individual reservoirs in Region D. Given these considerations, it has been assumed that the Empirical Area Reduction Method is sufficient for the purposes of the 2021 Region D Plan. A brief summary of the Empirical Area Reduction Method to be employed for distribution of sediment is provided below.

The Empirical Area-Reduction Method for calculating the distribution of sediment deposits in a reservoir was developed by Borland and Miller (1958) for the Bureau of Reclamation. The basic equation of the empirical area-reduction method is expressed as

$$S = \int_{o}^{y_0} A d_y + \int_{y_0}^{H} K a_p d_y$$

Where,

S = Total sediment volume distributed in the reservoir, typically the volume anticipated to occur in a planning period, e.g. 100-years

o = The original zero elevation of the dam

y_o = The zero elevation of the dam after sediment inflow

A = Reservoir surface area at depth y

d_y = incremental depth

H = Total depth of reservoir commonly determined by the normal water surface

K = a constant of proportionality for converting relative areas to actual areas for a given reservoir

a_p = relative area

p = relative depth

The equation for relative area is expressed as:

$$a_p = Cp^m(1-p)^n$$

Where, C, m and n are coefficients for four standard reservoir types, summarized in Table 1 as reported by the Sedimentation Section of the Bureau of Reclamation (1962). Values were originally developed by Borland & Miller (1958) and have since been refined by Lara (1962).

Table 1: Reservoir types and values of M, C, m, and n

Reservoir Type	Standard Classification	M	C	m	n
Lake	I	3.5-4.5	5.074	1.85	0.35
Flood Plain Foothill	II	2.5-3.5	2.487	0.57	0.41
Hill	III	1.5-2.5	16.967	1.15	2.32
Gorge	IV	1.0-1.5	1.486	-0.25	1.34

Per Borland and Miller (1958), reservoirs are classified based on a shape factor (M). The shape factor is found by plotting reservoir depth as the ordinate against reservoir capacity as the abscissa, on a log-log plot. The reciprocal of the slope of the line passing through the data points is defined as M. The Sedimentation Section of the Bureau of Reclamation (1962) developed a computational procedure employing the empirical area-reduction methodology.

In the 2016 Region D Plan, the most significant impacts to reservoir storage due to sedimentation were observed in Lake Wright Patman. Given the significance of known sedimentation issues for the lake, specific application of the above approach is demonstrated below in the context of the available information base. The approach described below, where determined to be relevant in Region D reservoirs, will be employed for those reservoirs where consideration of significant sedimentation effects is warranted.

Lake Wright Patman

Lake Wright Patman (originally known as Lake Texarkana) was authorized in 1946 as a part of a comprehensive plan for flood control in the Red River Basin (TWDB 2003). Deliberate impoundment of Wright Patman began June 27, 1956, the reservoir water level reached conservation pool elevation in February 1957. The reported original volumetric capacity of the reservoir is 158,000 ac-ft (TWDB, 2010). Two volumetric surveys of the reservoir have been performed by TWDB over the last several decades, described below:

1997 Hydrographic Survey

The Texas Water Development Board conducted a hydrographic survey of Wright Patman Lake during the period December 16 – January 16, 1997 to determine the capacity of the lake at the conservation pool and when the lake was in the flood pool (TWDB 2003). The results of this TWDB survey indicate that the lake's capacity at the conservation pool elevation of 220.6 ft. mean sea level (msl) was 110,900 acre-feet and the area was 18,994 acres. At elevation 230 ft. (msl) the volume was determined to be 392,740 acre-feet with an area of 34,882 acres (TWDB 2003). The estimated reduction in storage capacity at elevation 220.6 feet (msl) since 1956 was 34,400 acre-ft or 1,147 acre-ft per year. At elevation 230 ft. (msl), the reduction in storage calculated was 44,510 acre-feet or 1,483.7 acre-feet per year (TWDB 2003).

2010 Hydrographic Survey

The Texas Water Development Board conducted a hydrographic survey of Lake Wright Patman during the period between March 26 – June 7, 2010 to determine the volumetric capacity of the lake. The results of the TWDB's 2010 survey indicate that the lake's 2010 capacity at the conservation pool elevation of 220.6 ft. (msl) was 97,927 acre-feet, with an area of 18,247 acres. Additionally, refinements in the methodology for calculating reservoir capacity from collected bathymetry prompted the TWDB to re-analyze the 1997 volumetric survey data (TWDB 2010). This re-analysis of the 1997 TWDB volumetric survey resulted in an updated 1997 capacity estimate at 220.6 ft. (msl) of 115,715 acre-feet using the 1997 survey data.

TWDB then calculated sediment rates at 220.6 ft (msl) for three scenarios:

1. The difference between the 2010 surveyed capacity and the original design capacity estimate;
2. The difference between the 2010 surveyed capacity and an estimation of the pre-impoundment capacity performed in 2010; and
3. The difference between the 2010 surveyed capacity and the revised 1997 surveyed capacity estimate.

These calculations and supporting data are presented in Table 2.

Table 2 - Capacity loss comparisons for Lake Wright Patman (recreated from TWDB 2010)

	Comparisons @ 220.6		
	Volume (acre-ft)		Pre-impoundment (acre-ft)
Survey	**Comparison #1**	**Comparison #2**	**Comparison #3**
Original design estimate[a]	158,000	<>	<>
TWDB pre-impoundment estimate based on 2010 survey	<>	<>	137,336[b]
1997 TWDB volumetric survey (revised)	<>	115,638	<>
2010 volumetric survey	97,927	97,927	97,927
Volume difference (acre-ft)	60,073 (38%)	17,711 (15.3%)	39,409 (28.7%)
Number of years	54	13	54
Capacity loss rate (acre-ft/year)	1,112	1,362	730

[a] Source: (TWDB, 1974), note: Wright Patman Dam was completed on May 19, 1954, and deliberate impoundment began on June 27, 1956.

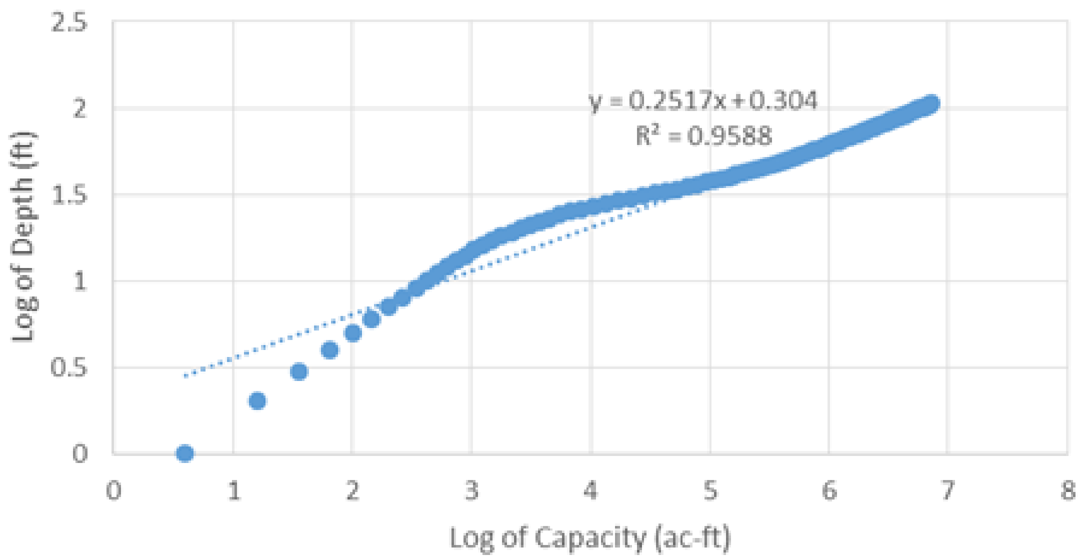
[b] 2010 TWDB surveyed capacity of 97,927 acre-feet plus 2010 TWDB surveyed sediment volume of 39,409 acre-feet.

TWDB (2010) estimates annual losses in Lake Wright Patman's capacity ranges between 730 and 1,362 acre-feet (based on the original and re-analyzed 1997 capacities, respectively) at 220.6 ft (msl) due to sedimentation below the conservation pool elevation. Given that Lake Wright Patman is a flood control reservoir, it is thus necessary to derive an overall sedimentation rate for the entire reservoir (i.e., from bottom elevation up to the top of dam elevation) to develop overall area-capacity relations.

To develop the overall sedimentation rate, the rate of capacity loss due to sedimentation at 220.6 ft (msl) has been assumed as 1,112 ac-ft/yr, as this loss rate derives from comparison of the 2010 TWDB surveyed capacity of 97,927 ac-ft compared to the original estimated design capacity of 158,000 ac-ft. This estimated rate is not as aggressive a loss rate as the 1,362 ac-ft/yr rate derived from comparing the 2010 to the 1997 TWDB surveys, but represents the longer term effects of sediment deposition in the reservoir at 220.6 ft. (msl).

Using the target loss rate of 1,112 ac-ft/yr at 220.6 ft. (msl), the associated volumetric loss over the 54 year timeframe (from 1956 to 2010) is 60,073 ac-ft, as shown above in Table 2. Using the original design elevation-area-capacity relationship as a basis, the shape factor (M) is calculated using the previously described log-log plot of reservoir depth vs. capacity (Borland and Miller, 1958), as shown in Figure 1 for Lake Wright Patman.

Figure 1 - Log-Log Plot of Reservoir Depth vs. Capacity with Best Fit Regression for Lake Wright Patman



The resultant shape factor is the reciprocal of the slope of the best fit regression (i.e. M = 1/.2517 = 3.97). The standards classification for this shape factor for Lake Wright Patman is a "Type I" reservoir. Thus, the equation for the calculation of relative area to be used in the Empirical Area Reduction Method for Lake Wright Patman is as follows:

$$a_p = 5.074p^{1.85}(1-p)^{0.35} \qquad \text{(Eq. 1)}$$

With an equation for relative area and the original design relationship between elevation, area, and capacity for the reservoir, several calculations are necessary to determine the overall sedimentation rate for the entire storage of the reservoir (bottom to top of dam elevation). This overall sedimentation rate is subsequently used to develop area-capacity relationships at future decadal times over the planning horizon (2020 - 2070).

For determination of the overall sedimentation rate, first the relative area of sediment over the entire range of reservoir elevations is calculated using Eq. 1. The average end area calculation is then made to determine incremental volume at each height. The sum of the incremental volumes is the overall sediment volume in the reservoir ($S_{overall}$). Using the aforementioned loss of capacity ($S_{220.6}$) of 60,073 ac-ft at 220.6 ft. (msl) from TWDB (2010) as a target, values for $S_{overall}$ are iterated until $S_{220.6}$ =60,073 ac-ft. The resultant overall sediment volume ($S_{overall}$) for Lake Wright Patman has been calculated to be 104,368 ac-ft of lost capacity over the 54 year period (1956 - 2010) when considering elevations from the bottom of the reservoir to the top of dam. This equates to an overall sedimentation rate of 1,933 ac-ft/yr.

Thus, using the assumed rate of capacity loss in Lake Wright Patman of 1,933 ac-ft/yr, with the distribution of sediment estimated using the Empirical Area Reduction Method, new elevation-area-capacity relations are then developed for 2020 - 2070 (see Figures 2 and 3). These decadal relations of reservoir area and capacity are then incorporated as inputs to the Sulphur WAM.

Figure 2 - Decadal Relations of Volume to Water Surface Elevation for Lake Wright Patman from Application of Empirical Area Reduction Method for Distribution of Sediment Deposits using Total Annual Capacity Loss Rate of 1,933 ac-ft/yr.

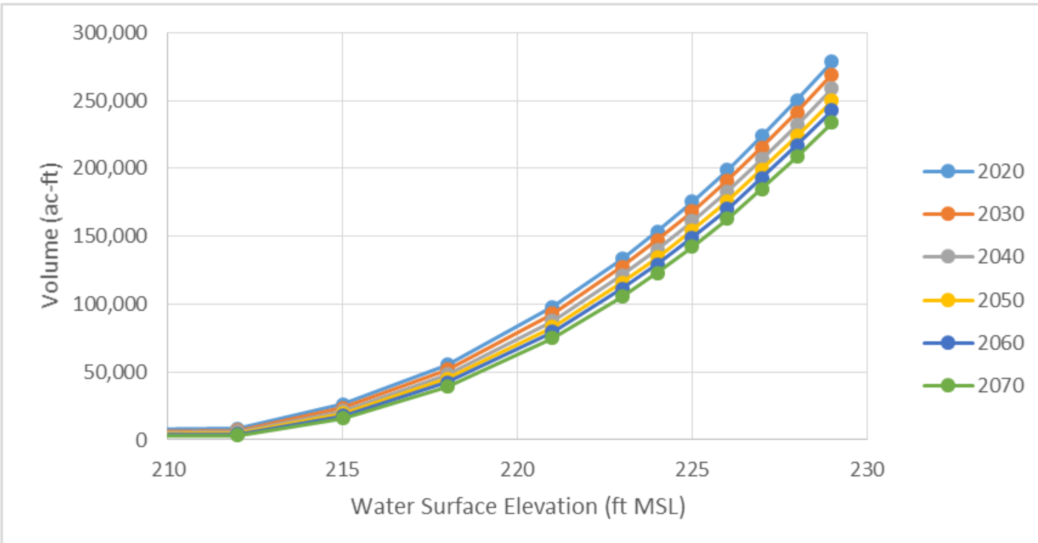
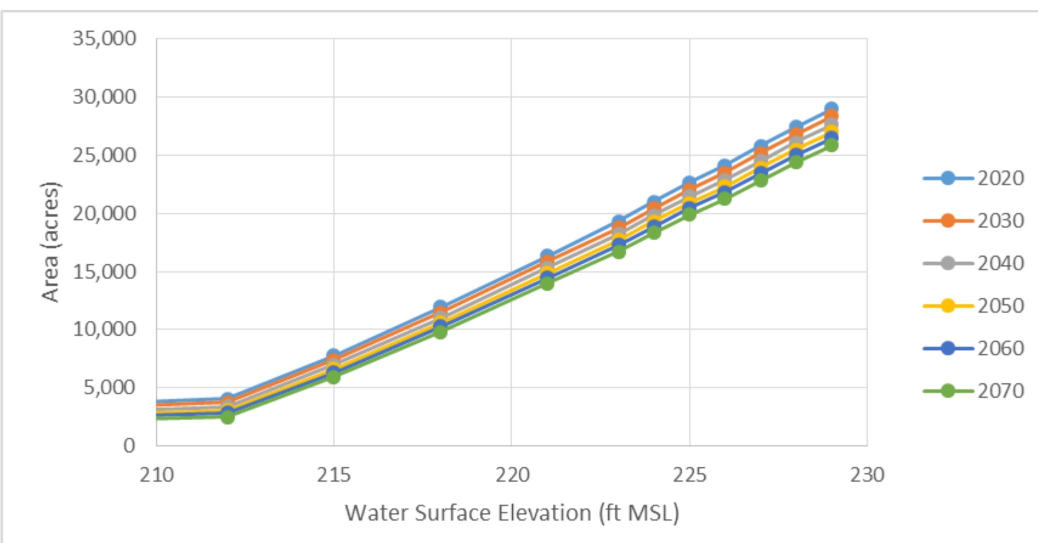


Figure 3: Decadal Relations of Area to Water Surface Elevation for Lake Wright Patman from Application of Empirical Area Reduction Method for Distribution of Sediment Deposits using Total Annual Capacity Loss Rate of 1,933 ac-ft/yr.



Groundwater Supplies

Per TWDB guidelines and in accordance with 31 Texas Administrative Code (TAC) §357.32(d)(2), a regional water planning group with no groundwater conservation districts (GCDs) within its planning area shall determine the availability of relevant aquifers for regional planning purposes. Region D qualifies as there are no GCDs within the planning area.

Thus, groundwater availability will be preliminarily estimated by using the adopted Modeled Available Groundwater (MAG) numbers by the Groundwater Management Areas. Local hydrogeologic conditions will be considered when establishing each entity's portion of the MAG. If there is a greater need for groundwater than estimated by the MAG on a county and aquifer basis, a more refined assessment of groundwater availability will be performed to evaluate if increasing availability can be justified hydrogeologically. For those WUGs/sellers wherein existing or planned pumpage exceeds MAG amounts, a more detailed analysis of the entity's pumping, typical production of the aquifer, and relevant information from applicable GMAs will be considered towards development of the available groundwater supply for the entity. Current infrastructure (number of wells, well field capacity, peaking factors, etc.) will also be considered when evaluating future water management strategies.

References

Borland, W.M., & Miller, C.R.(1960). Distribution of sediment in large reservoirs. Transactions, American Society of Civil Engineers, v. 125, p. 166-180.

Cristofano, E.A. (1953). Area increment method for distributing sediment in a reservoir. U.S. Bureau of Reclamation. Albuquerque, N.M.

FNI (Freese & Nichols, Inc.), July 16, 2012. Modifications to the Sulphur WAM and Preliminary Yields, for Sulphur Basin Watershed Overview Project, Sulphur River Basin Authority. Fort Worth, TX.

Lara, J.M., (1962). "Revision of the Procedure to Compute Sediment Distribution in Large Reservoirs," US Bureau of Reclamation, Denver, CO.

TWDB (Texas Water Development Board), 2003. Volumetric Survey of Wright Patman Lake, prepared for U.S. Army Corps of Engineers, Fort Worth District. Austin, TX.

TWDB (Texas Water Development Board), 2010. Volumetric and Sedimentation Survey of Wright Patman Lake, March - June 2010 Survey, prepared for U.S. Army Corps of Engineers, Fort Worth District, in cooperation with the City of Texarkana. Austin, TX.

USACE (U.S. Army Corps of Engineers), December 15, 1989, changed October 1995. Engineering and Design - Sedimentation Investigations of Rivers and Reservoirs. EM 1110-2-4000, Appendix H, Washington, DC.

The assumptions and methods described herein are recommended to be used throughout the regional planning process for analyses that determine surface and groundwater availability, and also for analyses to determine the potential supplies available from new water management strategies. Where the assumptions described herein do not align with the default methods and approaches described in the TWDB's regional planning guidelines, such assumptions require the approval of the TWDB as a hydrologic variance in order to be incorporated into the Region D analyses.

If you have any questions regarding this request, please contact me at your convenience. We appreciate the TWDB's consideration of this request.

Sincerely,

CAROLLO ENGINEERS, INC.

Tony L. Smith, P.E.
Project Manager

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Enclosures: Attachments A, B, C

cc: Richard LeTourneau
Walt Sears
Stan Hayes

Attachment A
2021 Northeast Texas Regional Water Plan
Base Hydrologic Assumptions

Assumption	Use for Existing Supplies	Use for Water Management Strategies
General		
Use most recent available versions of the TCEQ WAMs.	X	X
WAM Run 3 - full consumption of existing water rights with no (zero) return flows).	X	X
Modeling of reuse to include consideration of minimum and permitted return flows associated with WUG, including identified return flows from TCEQ WAM Run 8.	X	X
Channel losses based on factors employed within official TCEQ WAMs.	X	X
ASR evaluations will consider surface water availability as determined by the WAM compared to demand, with the firm supply being the maximum demand that could be met assuming a repetition of the period of record drought.		X
Adopted environmental flow standards will be used as incorporated into the applicable official TCEQ WAMs	X	X
For those basins lacking TCEQ adopted environmental flow standards, TWDB consensus planning criteria will be employed in a manner consistent with TWDB guidelines.		X
Subordination of water rights will be modeled in a manner consistent with modeled subordination within the official TCEQ WAMs.	X	X

For municipal and industrial users: Run of the river rights will be determined in accordance with TWDB guidelines which state that the use-appropriate monthly percentage of the annual firm diversion must be satisfied in each and every month of the simulation period for all surface water diversions. Reservoirs will use firm yield unless a change is specifically requested by a reservoir owner and approved by the RWPG and TWDB, as appropriate per TWDB guidelines. The calculated source availabilities will be compared against existing legal and infrastructure constraints (water treatment plants, pipelines, intakes, etc.) and will be constrained if the existing infrastructure or legal capability is not sufficient to facilitate full utilization of the source. The most constrained amount will be used as the firm supply.	X	X
For irrigation users, water supply will be determined using firm reliability (100%). In the absence of any supply information or justirication of reliable supplies available in a drought of record, supply values will be set equal to zero.	X	X
For livestock, in the absence of any supply information or justirication of reliable supplies available in a drought of record, supply values will be set to zero.	X	X
Basin Specific		
Cypress River Basin Water Availability Model (Cypress WAM ver. June 18, 2015; TCEQ)	X	X
Red River Basin Water Availability Model (Red WAM ver. January 2, 2013; TCEQ)	X	X
Lake Pat Mayse Water Availability Study (Lamar County reservoir yields; City of Paris, HDR)	X	X

Sabine River Basin Water Availability Model (Sabine WAM ver. July 6, 2015; TCEQ)	X	X
Sulphur River Basin Water Availability Model (Sulphur WAM ver. February 1, 2018; TCEQ)	X	X
- Correction for Drainage Area at Control Point C10	X	X
- Lake Chapman Area/Capacity	X	X
Sedimentation		
For reservoirs with available volumetric survey information, annual sediment rate will be calculated, and loadings calculated for Year 2020 and Year 2070. Sediment distribution will be calculated using the Empirical Area-Reduction method and resultant 2020 and 2070 area-capacity curves developed and employed within WAM. Intervening decadal yields will be linearly interpolated.	X	X
For reservoirs lacking volumetric surveys, original area-capacity relations within TCEQ WAM Run 3 will be assumed constant.	X	X
Groundwater Supplies		
Groundwater availability will be determined using the adopted Modeled Available Groundwater (MAG) numbers. Local hydrogeologic conditions will be considered when establishing each entity's portion of the MAG. For those WUGs/sellers wherein existing or planned pumpage exceeds MAG amounts, a detailed analysis of the entity's pumping, typical production of the aquifer, and relevant information from applicable GMAs will be considered towards development of the available groundwater supply for the entity. Current infrastructure (number of wells, well field capacity, peaking factors, etc.) will also be considered when evaluating future water management strategies.	X	X

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Memo

To:	Reeves Hayter, P.E.		
From:	Cory Shockley, P.E.	Project:	Lake Pat Mayse Water Availability Study
CC:			
Date:	April 27, 2009	Job No:	00085438

RE: Modeling Assumptions for Determining Surface Water Supplies for Select Reservoirs for the Region D Water Plan

The Texas Water Development Board (TWDB) has mandated that the Water Availability Models (WAMs) maintained by the Texas Commission on Environmental Quality (TCEQ) be used for determining surface water supplies for regional water plans. The TCEQ WAMs, which have been developed for all river basins in Texas, simulate the management and use of streamflow and reservoirs over a historical period of record, adhering to the prior appropriation doctrine, which governs Texas' water right priority system. The TCEQ WAMs are the fundamental tools used to determine surface water availability for water rights permitting, and contain information about water rights in each respective river basin.

The TCEQ's Red River Basin WAM contains information on all water rights in the Texas portion of the Red River Basin. Embedded within this model are certain assumptions that the TCEQ specifies when analyzing water right reliabilities. These assumptions are not necessarily the most appropriate to apply to the regional water planning process, and can be changed by modifying model parameters when the model is used for water supply planning purposes.

The City of Paris is currently in the process of evaluating the water supplies available to the City and its customers from Pay Mayse Lake and Lake Crook. As part of this evaluation, the City contracted with HDR Engineering to provide engineering services associated with the *Pat Mayse Lake Study*.

As part of the Pat Mayse Lake Study, HDR is working with the City of Paris to estimate future supplies available from Lake Pat Mayse and Lake Crook. A water availability model (WAM) was developed to estimate reservoir yields. The water availability model developed for this purpose uses the Water Rights Analysis Package (WRAP) model as the core hydrologic simulation program. The latest Red River WAM was obtained from the TCEQ and only the information (flow network, water rights, etc.) pertaining to the Lake Pat Mayse and Lake Crook watersheds were used to simulate the reservoir yields.

There has been some question as to the validity of inflows contained in the Red River WAM with regards to Lake Pat Mayse, so an alternative set of inflows was developed and included in the model runs. These alternative inflows are based on applying a ratio to the flows at the North Sulphur River near Cooper USGS gage (#07343000). This is a long term (1950 – current) stream gage with very few anthropogenic effects upstream, thereby providing a convenient, near-naturalized set of streamflows. The naturalized flows used in the TCEQ Red River WAM are based on a drainage area ratio of the difference between two main stem gages on the Red River that represent rather large watersheds when compared to the Pat Mayse and Lake Crook watersheds.

The USGS gage on the North Sulphur River measures streamflow resulting for a 276 square mile area. This gage was selected as a partner gage for use in developing inflows for Lake Pat Mayse for several reasons;

- Close proximity to Lake Pat Mayse Watershed,
- Similar hydric soil type characteristics,
- Long-term gage record (1950-current), and
- Gage flow closely approximating natural flow.

The Red River WAM was modified to include only those water rights and control points necessary to model the watersheds containing Lakes Pat Mayse and Crook and the watersheds below them down to the confluence with the Red River. Minor water rights in these basins that determine their diversion based off flow triggers in the Red River compact were commented out.

This model also changed the period of record simulated to 1950 through July 2008 to evaluate the effects of the recent drought on the water supplies for the City of Paris.

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TO: File

CC: Becky Griffith, Tony Smith (Espey)

FROM: Jon Albright and Jeremy Rice

SUBJECT: Modifications to the Sulphur WAM and Preliminary Yields

DATE: July 16, 2012

PROJECT: MHP11453

Freese and Nichols Inc. (FNI) has developed an updated version of the Sulphur Water Availability Model (WAM). This model will be used as the basis for all WAM modeling in the Sulphur Basin Watershed Overview Project. These modifications are primarily based on the Texas Water Development Board's Site Protection Study. The following changes were made to the Sulphur WAM:

- Use of current Storage-Area relationships for Lakes Wright Patman and Jim Chapman
- Use of one pool to model Lake Jim Chapman (this facilitates analyzing the impact of changes on the performance of the reservoir).
- Addition of Lake Ralph Hall based on code from TCEQ.
- Addition of Marvin Nichols Site 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 original Sulphur WAM.
- Changes to correct errors in drainage area for control point C10 (Sulphur River near Talco)

Each of these changes is discussed in more detail below.

Preliminary Reservoir Yields

We have used this model to calculate preliminary firm yields of Marvin Nichols 1a and Parkhouse I and II assuming current sediment conditions, with Lake Ralph Hall in place (see Table 1). Note that these yields are slightly different than the Site Protection Study. There are several reasons for this. First, we are assuming current sediment conditions at Lake Wright Patman and Lake Chapman, where the Site Protection Study used original sediment conditions (Run 3). Second, we are assuming overdraft operation of Lake Ralph Hall without environmental bypass, while the Site Protection Study assumed firm yield operation of Ralph Hall with

Consensus Bypass. Third, the Site Protection Study yields in Table 1 are the yields without environmental bypass from the Site Protection Study with the estimated impact of Lake Ralph Hall subtracted from the yield. Since the operation of Lake Ralph Hall is different in the Site Protection Study than in the current study, the impact on yield may be a little different. Finally, the Site Protection Study had the flow discontinuity at control point C10, which may have slightly impacted yields.

Table 1: Preliminary Firm Yields

Proposed Reservoir	**Calculated Firm Yield** (acre-feet per year)	**Site Protection Study Firm Yield** (acre-feet per year)	**Difference** (acre-feet per year)
Marvin Nichols 1a	595,000	596,900	-1,900
Parkhouse I	124,600	124,400	200
Parkhouse II	121,800	119,900	1,900

Future yields calculated for the Sulphur Watershed Overview will assume different sediment conditions for Patman, Chapman and Ralph Hall. However, specific sediment scenarios have not been identified at this time.

Yields of the Talco site will be developed at a later date.

Modifications to Sulphur WAM

Lake Chapman

In the TCEQ WAM, Lake Chapman is modeled with three individual pools, reflecting the three water rights in the reservoir. For this study Lake Chapman is modeled as a single pool. This change facilitates analyzing impacts of other projects on the overall performance of Lake Chapman. The instream flow requirements and diversion were also combined into a single IF and WR record. The model for this study uses the 2007 TWDB Volumetric Survey of Lake Chapman rather than the original storage and area characteristics in the TCEQ WAM.

Changes to DAT File

Change instream flow so that it comes from one pool instead of being divided among 3 pools. This release is continuous and not limited to inflow as in the TCEQ code.

```
**IF   A40      951        19651119       3                  IF4797
**WSRCHAP1   81470                                                1
**IF   A40     2285        19651119       3                  IF4798
```

```
**WSRCHAP2  114265                                              1      -1
**IF   A40    3619        19651119       3                  IF4799
**WSRCHAP3  114265                                              1      -1
**
**
** FNI change: since we are using one pool, we need to change to one IF (5 cfs)
**
IF   A40    3619        19651119       3              IF_Chapman
WSRCHAP1  298930
OR   A40                              -1
```

Change from three pools (corresponding to the three water rights in the lake) to a single pool. Redistribute amounts among the various users reflecting current conditions. EA, EF and AF records no longer needed so they are commented out.

```
**WR   A40   38520   4797M19651119   1                                   4797AM_1       A    4797
**WSRCHAP1   81470                                              1
**
** North Texas Municipal Water District
**WR   A40   54000    479819651119                                         4798_1       A    4798
**WSRCHAP2  114265                                              1      -1
** City of Irving
**WR   A40   54000   4799M19651119                                        4799M_1       A    4799
**WSRCHAP3  114265                                              1      -1
```

```
**
** Upper Trinity Regional Water District
WR   A40   16106   4797M19651119   1                                4797M_UTRWD Chapman    4797
WSRCHAP1  298930                          38598
**
** Local demand (Sulphur Spr and Cooper)
WR   A40   19200   4797M19651119   1                                4797M_SSPRS Chapman    4797
WSRCHAP1  298930                          38598
```

```
**
** North Texas Municipal Water District
WR   A40    3214    479819651119                                         4797_NTMWD Chapman    4797
WSRCHAP1  298930                           38598
**
WR   A40   54000    479819651119                                             4798_1 Chapman    4798
WSRCHAP1  298930                           38598
**
** City of Irving
WR   A40   54000   4799M19651119                                            4799M_1 Chapman    4799
WSRCHAP1  298930                           38598
**WSRCHAP1  304101                           31101
**


** Original TCEQ WAM.  Since we are using one pool we do not need
**EA     1       3  RCHAP1  RCHAP2  RCHAP3
**EF     0       0     .26     .37
**AF     0       0     .26     .60       1
**
```

Storage and area relationships from 2007 TWDB survey.

```
**SVRCHAP1       0    2000    8000   20000   45000   63000   85000  132000  194000  239000  255000  310000
**SA             0     850    1925    2920    5625    6525    8100   10800   13800   16400   17200   19305
**
**FNI Change Based on 2007 Volumetric Survery
**ELEV (ft)  396     402     408     414     420     424     428     432     436     438     439     440
SVRCHAP1       0     901   10189   31426   64164   92257  128478  175115  232754  264866  281565  298930
SA             0     746    2471    4549    6349    7851   10412   12908   15668   16457   16976   17958
**
```

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 WAM) and certain contracts with the Corps.

Note that there are no downstream releases in the setup. At this time we are planning to include any downstream releases in the yield of the reservoir. This model also uses current area and storage relationships from the draft 2010 volumetric survey.

Changes to DAT File

```
** FNI Change: Update storage numbers for Patman: 2010 Survey, 297505 af is capacity at 228.6 ft, 87300
af is capacity at 220 ft

** FNI Change - add group identified for Patman

**

WR   F60   14572   4836M19510305                                          4836M1  PATMAN    4836

**  Interim Curve - Texarkana Contract Minimum (220 ft)

**WSPATMAN  262808                           87300   98162

**

**  Ultimate Curve - Texarkana Contract Minimum (220 ft)

WSPATMAN  298084                           87300  200411

**

WR   F60   10428   4836M19570217                                          4836M2  PATMAN    4836

WSPATMAN  298084                           87300

**

WR   F60   20000   4836M19670919                                          4836M3  PATMAN    4836

**  WR 4836I -  maximize out of basin transfers for full paper right runs (1,2,3,4,6), transfers
deducted from most junior WR fo

WSPATMAN  298084                           87300

**

WR   F60   35000   4836I19570217                                          4836I1  PATMAN    4836

WSPATMAN  298084                           87300

**

WR   F60  100000   4836I19670919                                          4836I2  PATMAN    4836

WSPATMAN  298084                           87300
```

The Sulphur WAM was also modified to use the Draft 2010 TWDB Volumetric Survey of Lake Wright Patman. This survey was extended to higher elevations using previous surveys

```
**SVPATMAN       0    6670   64795  108195  166445  213845  240195  268445  298495  330345  364095  399695

**SA             0    1350   12100   16900   22000   25400   27300   29200   30900   32800   34700   36500
```

```
** FNI change: update SVSA to 2010 survey
**Elev       194     214     219     222     224     226     230     235     241     248     255     260
SVPATMAN       0   18531   70925  125611  171069  220465  340658  542648  858115 1338792 1950548 2473806
SA             0    6243   15397   21231   23924   25435   34882   45924   59567   77777   97430  111880
**
```

Interim and Ultimate curves using 2010 survey

```
**  Monthly Storage Variable Limits
**
** Wright Patman
**
** FNI change - based on Interim Rule Curve and 2010 survey
**Month      JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC
**Elev    220.60  220.60  220.60  224.90  227.44  226.92  226.29  225.67  225.06  220.60  220.60  220.60
**MSPATMAN   98162   98162   98162  192965  262808  246994  227884  212193  196902   98162   98162   98162
**
** FNI change - based on Ultimate Rule Curve and 2010 survey
**Month      JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC
**Elev    224.90  224.90  224.90  226.80  228.60  228.60  228.50  227.80  226.80  226.10  225.50  225.20
MSPATMAN  192965  192965  192965  243345  298084  298084  295043  273755  243345  223023  207932  200411
**
```

Ralph Hall

TCEQ provided a version of the DAT file for the Sulphur WAM with Lake Ralph on October 6, 2011. This code is for overdraft operation of the reservoir. Typical instream flow bypass criteria are not proposed for this reservoir. The following changes were made to the FNI Sulphur WAM.

Changes to DAT file

```
** FNI Change - Added used pattern for Ralph Hall

UC  HALL  0.0730  0.0650  0.0590  0.0850  0.0690  0.0880

UC        0.1230  0.1470  0.1130  0.0870  0.0520  0.0390

**
```

```
** FNI Change - Added in Ralph Hall

CP158211     B10                     7             A70               0

**
```

```
** FNI Change - Added Ralph Hall
WR158211   45000    HALL20040813       1                                   15821F          15821F
WS158211  180000
**
```

```
** FNI Change - Added Ralph Hall
** ELEVATION 460     470     480     490     500     510     520     530     540     550     560     564
SV158211       0      57     397    1027    2357    7521   21849   47989   90104  152630  238693  280506
SA             0    17.9    49.6    79.1     208     941    2003    3307    5189    7345    9914   10985
**
```

Changes to DIS file

TCEQ did not provide a copy of the DIS file. Thus the drainage area was taken from the 2007 TWDB Reservoir Site Protection Study. Memos from TCEQ associated with the draft permit give the drainage area as 102.74 square miles.

```
** FNI change - Added lake Ralph Hall
FD158211     B10       0
** Drainage area based on 2007 Reservoir Site Protection Study
WP158211     101
```

Marvin Nichols 1a, Parkhouse I and Parkhouse II

Code for Marvin Nichols 1a and Parkhouse I and II are from the Reservoir Site Protection Study. The Site Protection Study model used manually calculated naturalized flows for each of these projects rather than using the model to calculate the flows. The drainage areas in the Sulphur WAM do not match USGS drainage areas. In our opinion, USGS drainage areas are more likely to be accurate. The manually calculated flows are based on the USGS drainage areas. These flows were input at new primary control points. The new flows are included with the setup files that accompany this memo.

The Reservoir Site Protection Study model also included evaporation rates for the new projects. 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 at primary control points. The new evaporation files are included with the setup files that accompany this memo.

Changes to DAT file

```
** FNI Change - Municipal Use for Marvin Nichols and Parkhouse (I and II) from Site Protection Study
UC   MUN  0.0651  0.0607  0.0648  0.0697  0.0802  0.0951
UC        0.1161  0.1176  0.1034  0.0905  0.0715  0.0653
**


** FNI Change - Parkhouse South (I) new primary conntrol point C200
**    additional control points A,B and C for application of instream flows
**CP   A10     C60                       1            D120      -3       0
CP   A10    C200                       1            D120      -3       0
CP  C200   C200A                       1                      -3
CP C200A   C200B                       2    C200    NONE
CP C200B   C200C                       2    C200    NONE
CP C200C     C60                       2    C200    NONE
**CP  C110     C60                       7            D120               0
CP  C110    C200                       7            D120               0


** FNI Change - Parkhouse North (II) new primary control point C105
**    additional control points A,B and C for application of instream flows
** CP   B10     C90                       1            D120      -3       0
**
CP   B10    C105                       1             A70      -3       0
CP  C105   C105A                       1                      -3       0
CP C105A   C105B                       2    C105    NONE      -3       0
CP C105B     C90                       2    C105    NONE      -3       0
**



** FNI Change - Marvin Nichols new primary control point E175
**    additional control points A,B for application of instream flows
**CP  E250     E10                       7             E60               0
**CP  E240     E10                       7             E60               0
CP  E250    E175                       7             E60               0
CP  E240    E175                       7             E60               0
CP  E175   E175A                       1                      -3       0
CP E175A   E175B                       2    E175    NONE      -3       0
CP E175B     E10                       2    E175    NONE      -3       0
**
**  FNI change - CPs E190, E200, E210, and E220 used to flow into E180, which has been eliminated.
**    change to flow into Marvin Nichols
**CP  E220     E10                       7             E60               0
**CP  E210     E10                       7             E60               0
**CP  E200     E10                       7             E60               0
**CP  E190     E10                       7             E60               0
CP  E220    E175                       7             E60               0
CP  E210    E175                       7             E60               0
CP  E200    E175                       7             E60               0
CP  E190    E175                       7             E60               0
**CP  D120     D40                       7                               0
```

```
**CP  D110     D40                     7           D120              0
**CP  D100     D40                     7           D120              0



****************************************************************
**  PROPOSED PROJECTS FOR STUDY
**
** FNI Change added Parkhouse I
WR  C200  143600     MUN30000105                                    PARKHOUSE I
WSPARK I  651712
**
** FNI Change added Parkhouse II
WR  C105  148700     MUN30000105   1   0       0                   PARKHOUSE II
WSPARKII  330871
**
** FNI Change - added Marvin Nichols
WR  E175  600900     MUN30000105   1   0       0                 MARVIN_NICHOLS
WSMARVIN 1562669                           0
**



**  FNI Change - Marvin Nichols
**  Area-Capacity Relationship from Site Protection Study:
SVMARVIN       0   23155   42283  101593  229008  483319  614963  765728 1087776 1309166 1562669 1701463
SA             0    5381    7480   12295   20072   30778   35047   40681   51337   59365   67392   71406
** FNI Change - Parkhouse I from Site Protectoin Study
SVPARK I       0   12600   49057  121267  204814  265446  357065  466684  567951  680825  802444  932332
SA             0    2925    6168   10120   13752   16566   20084   23808   26828   29372   31439   33506
** FNI Change - Parkhouse II from Site Protection Study
SVPARKII       0     595    2113    7440   17983   34004   55512   83780  144687  215361  263249  330871
SA             0     111     226    1556    2660    3750    4916    6392    8919   11282   12662   14387
**
```

Changes to DIS file

```
** FNI Change - New control point for Parkhouse I:
WP  C200   655.0
```

```
WP C200A   655.0
FD C200A    C200      -1
WP C200B   655.0
FD C200B    C200      -1
WP C200C   655.0
FD C200C    C200      -1
**
** FNI Change - New Control Point for Parkhouse II
**
WP  C105   421.0
WP C105A   421.0
FD C105A    C105      -1
WP C105B   421.0
FD C105B    C105      -1
**
** FNI Change - New control point for Marvin Nichols
WP  E175  1889.0
WP E175A  1889.0
FD E175A    E175      -1
WP E175B  1889.0
FD E175B    E175      -1
```

Talco Site

At this time the setup for the Talco site is under development. The project will be at control point C10, which is a primary control point.

Correction to Drainage Areas

In the original TCEQ WAM, primary control point C10, the Sulphur River near Talco (USGS 07343200, aka Sulphur River below Talco 07343210), had a drainage area that was smaller than the next upstream point C20. This results in a flow discontinuity which may impact water availability. Apparently the USGS moved the gage downstream just after the naturalized flows were developed for the Sulphur WAM. For this model, we are using a drainage area for C10 of 1365 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.

Changes to DIS file

```
** FNI Change - Changed the drainage area for C10 to match USGS drainage area at Sulphur River Near
Talco (1,365 mi2) prior to May 21, 1997.

WP   C10    1365    69.6    43.4

**WP   C10 1353.24    69.6    43.4

**
```