4.0 WRIGHT PATMAN LAKE YIELD SCENARIOS

As currently operated, Wright Patman Lake provides over 2.5 million acre-feet of storage for floodwaters. Consistent with that mission, water captured in the flood storage space is release as quickly as practicable. Prior studies have suggested that significant additional water supply yield could be generated if the flood storage in Wright Patman Lake were instead managed for water conservation. Resignation of existing storage in this manner is termed a storage reallocation, and was described conceptually in Chapter 2 of this report. This chapter presents the results of analysis conducted to evaluate a wide variety of possible reallocation scenarios at Wright Patman Lake.

4.1 UNMODIFIED WATERSHED SEDIMENTATION CONDITION

4.1.1 Current Watershed Conditions

The dependable yield of a reservoir is largely a function of the amount of inflows and the volume of storage. A reallocation at Wright Patman Lake would be intended to increase the amount of storage dedicated to water supply (also called conservation storage), with a commensurate decrease in the storage dedicated to other purposes. Increasing the volume of conservation storage in a reservoir can result from raising the top of the conservation pool, lowering the bottom of the conservation pool, or both. A variety of combinations of the two variables was investigated to evaluate the potential increase in yield resulting from a hypothetical reallocation at Wright Patman.

With respect to the top of the conservation pool, the initial evaluation considers the Interim Rule curve (monthly variation in the top of the conservation pool between 220.6 ft and 227.5 ft) to be the Existing Condition. Changing to the Ultimate Rule curve (monthly variation in the top of conservation pool between 224.89 ft and 228.64 ft) was evaluated, as were eight scenarios having the top of the conservation pool at a flat elevation (no monthly variation) increasing from 227.5' in five foot increments until the top of the flood pool (259.5 ft) is reached.

Four scenarios for the bottom of the conservation pool were considered. The first of these is the scenario set by the City of Texarkana's existing storage contract with the U.S. Army Corps of Engineers, which limits withdrawals from Wright Patman Lake to the storage above 220.0 ft. (The contract allows withdrawals below 220 feet under "exceptional conditions", but this was not considered in this scenario.) The second scenario considers the preferred minimum operating level for Texarkana's current intake structure and constrains effective storage as a result of those limitations. Based on input from Texarkana Water Utilities (TWU), this scenario considers the effective bottom of conservation pool to be 223.0 ft. The third scenario recognizes that the City of Texarkana has commissioned a study to evaluate a new intake structure that would be located in a deeper part of the lake, less susceptible to siltation and effective over a wider range of conditions. This scenario considers the effective bottom of the conservation pool to be 217.5 ft. Finally, a scenario was evaluated that eliminates the dedicated sediment storage and considers the bottom of the conservation pool to be essentially the bottom of the reservoir.

There are forty possible combinations of the maximum and minimum elevations for the conservation pool described above. The firm yields based on Water Availability Model (WAM) runs for each of these forty scenarios are shown in Table 4-1. A complete description of the WAM modifications associated with each scenario is contained in Appendix C. The data shown in Table 4-1 are representative of current sediment conditions in Wright Patman, with the assumption that Lake Ralph Hall has been built upstream. Lake Ralph Hall is included as a conservative assumption so that the estimated yields for Wright Patman do not include use of flows that would be captured by that reservoir. The WAM yields portrayed in Table 4-1 have been reduced by 7,247 ac-ft/yr to account for a constant release of 10 cfs from Wright Patman Dam, consistent with the requirements of the City's contract with the Corps of Engineers.

Figure 4-1 portrays the firm yield of the eight flat elevation scenarios graphically. Each line represents one of the four bottom-of-conservation-pool scenarios. As expected, the lower the bottom of the conservation pool, the higher the dependable yield, all other things being equal.

Table 4-1: Wright Patman Lake Various Conservation Pool Elevations

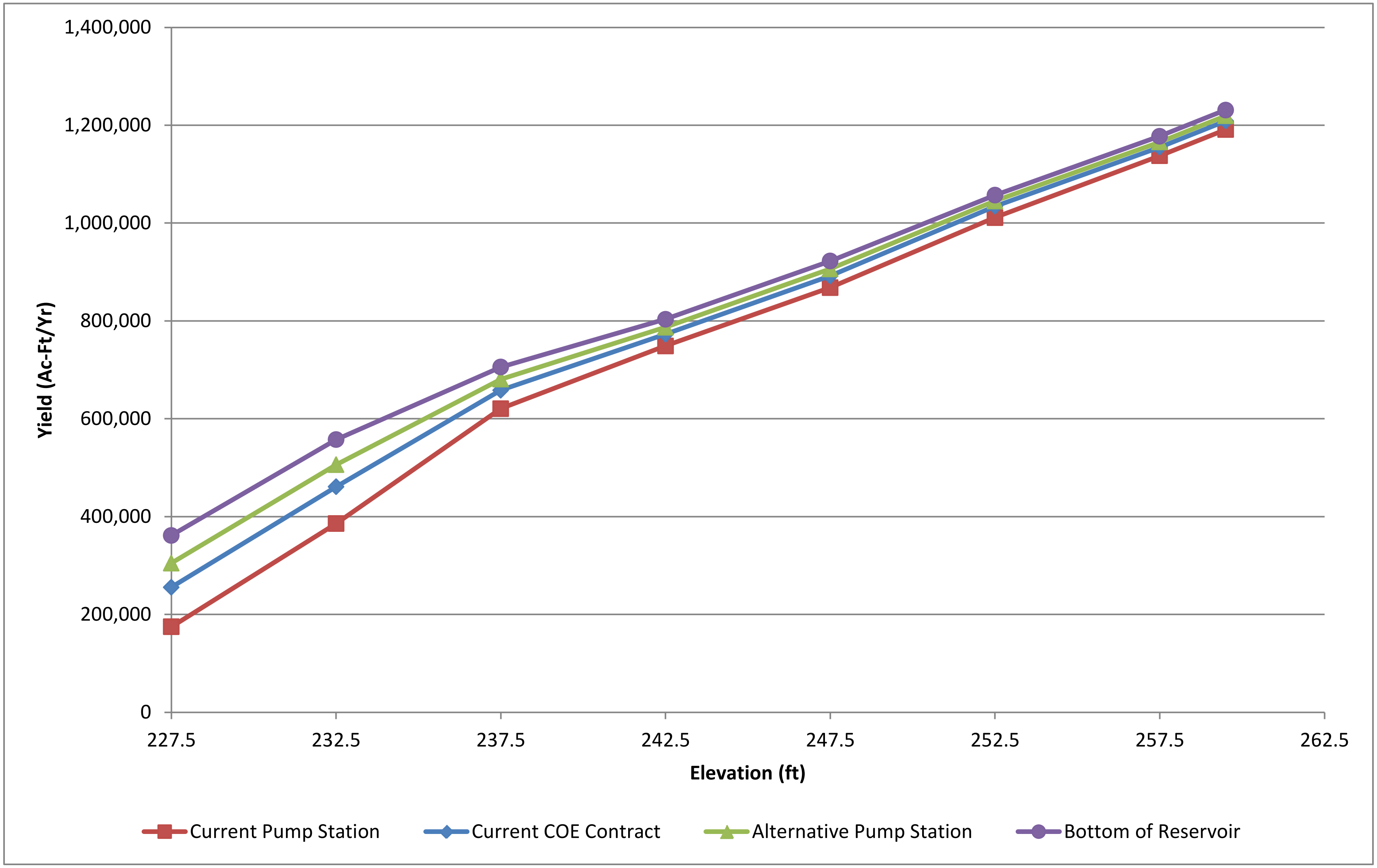
Maximum Conservation Pool Elevation (feet)/Curve	Minimum Conservation Pool Elevation	Sediment Condition	Firm Yield (ac-ft/yr)[1]	Yield above Current Contract[2] (ac-ft/yr)
Interim	Current pump station (223 ft)	Current	0	0
Ultimate	Current pump station (223 ft)	Current	172,753	0
227.5	Current pump station (223 ft)	Current	174,873	0
232.5	Current pump station (223 ft)	Current	385,753	205,753
237.5	Current pump station (223 ft)	Current	620,623	440,623
242.5	Current pump station (223 ft)	Current	748,833	568,833
247.5	Current pump station (223 ft)	Current	868,203	688,203
252.5	Current pump station (223 ft)	Current	1,011,113	831,113
257.5	Current pump station (223 ft)	Current	1,137,533	957,533
259.5	Current pump station (223 ft)	Current	1,191,083	1,011,083
Interim	Texarkana Contract (220 ft)	Current	40,263	0
Ultimate	Texarkana Contract (220 ft)	Current	201,413	21,413
227.5	Texarkana Contract (220 ft)	Current	255,693	75,693
232.5	Texarkana Contract (220 ft)	Current	460,963	280,963
237.5	Texarkana Contract (220 ft)	Current	658,273	478,273
242.5	Texarkana Contract (220 ft)	Current	772,663	592,663
247.5	Texarkana Contract (220 ft)	Current	891,913	711,913
252.5	Texarkana Contract (220 ft)	Current	1,034,363	854,363
257.5	Texarkana Contract (220 ft)	Current	1,155,013	975,013
259.5	Texarkana Contract (220 ft)	Current	1,208,533	1,028,533

Maximum Conservation Pool Elevation (feet)/Curve	Minimum Conservation Pool Elevation	Sediment Condition	Firm Yield (ac-ft/yr)[1]	Yield above Current Contract[2] (ac-ft/yr)
Interim	Proposed pump station (217.5 ft)	Current	123,743	0
Ultimate	Proposed pump station (217.5 ft)	Current	263,303	83,303
227.5	Proposed pump station (217.5 ft)	Current	304,883	124,883
232.5	Proposed pump station (217.5 ft)	Current	505,873	325,873
237.5	Proposed pump station (217.5 ft)	Current	680,773	500,773
242.5	Proposed pump station (217.5 ft)	Current	787,163	607,163
247.5	Proposed pump station (217.5 ft)	Current	906,263	726,263
252.5	Proposed pump station (217.5 ft)	Current	1,045,033	865,033
257.5	Proposed pump station (217.5 ft)	Current	1,165,623	985,623
259.5	Proposed pump station (217.5 ft)	Current	1,219,123	1,039,123
Interim	Full Conservation	Current	205,513	25,513
Ultimate	Full Conservation	Current	331,403	151,403
227.5	Full Conservation	Current	361,643	181,643
232.5	Full Conservation	Current	557,353	377,353
237.5	Full Conservation	Current	705,783	525,783
242.5	Full Conservation	Current	803,483	623,483
247.5	Full Conservation	Current	922,583	742,583
252.5	Full Conservation	Current	1,057,183	877,183
257.5	Full Conservation	Current	1,177,713	997,713
259.5	Full Conservation	Current	1,231,183	1,051,183

[1] Firm yield estimates incorporate a constant downstream release of 10 cfs per the City of Texarkana's contract with the Corps of Engineers.

[2] The current contract between the Corps of Engineers and Texarkana allows for the diversion of 180,000 acre-feet per year, as does Texarkana's Texas water right.

Figure 4-1: Wright Patman Yield vs. Top of Conservation Pool Elevation



It is worth noting that the yield curve in Figure 4-1 does not “break” in the traditional sense. Generally, the rate of increase in yield with increasing storage decreases as the amount of storage increases, and the curve flattens--becoming almost horizontal for very large increases in storage. This is because the watershed generates only so much runoff, and eventually the reservoir storage becomes large enough to effectively capture the maximum amount of runoff. However, in the case of the Sulphur River watershed, Figure 4-1 shows that even with the entire flood pool of Wright Patman reallocated to conservation storage, firm yield is still increasing significantly with increasing in storage. This suggests that a reallocation at Wright Patman would not be constrained by watershed runoff.

Figure 4-1 also shows that the minimum elevation of the conservation pool makes a noticeable difference in dependable yield when the top-of-conservation-pool elevation ranges from current conditions to approximately 237.5 ft. For larger reallocations, where the maximum conservation pool elevation is raised to levels higher than 237.5 ft, the difference in yield attributable to lowering the bottom of the conservation pool becomes less significant.

This study also assessed the effects on Wright Patman of a hypothetical modification to the seniority of water rights between Wright Patman Lake and Jim Chapman Lake. Where the Texas priority rights system requires that Jim Chapman Lake pass inflows to Wright Patman Lake because of its senior water right, the hypothetical scenario would allow Jim Chapman Lake to retain inflows as long as there is empty storage in the conservation pool (440.0 ft). If Jim Chapman Lake and Wright Patman Lake were to be operated as a system, it is unlikely that inflows to Jim Chapman would be passed downstream, and this scenario is intended to reflect that concept. This scenario essentially subordinates the Wright Patman water right to the water rights associated with operation of Jim Chapman Lake. Note that this is a strictly a hypothetical scenario and would only be considered as part of a broader plan for water resources development that included appropriate protection and consideration for downstream users. Results of this subordination on Wright Patman yields, under several scenarios, are compared with values from Table 4-1 in Table 4-2, below.

In general, the modified priority for the water right does reduce the firm yield of Wright Patman Lake; however the affect ranges only from about 1 to 11%. The reason for this lies in the overlap between the critical drought periods for the two reservoirs. Currently, the Wright Patman water right may make a senior water right call on inflows to Jim Chapman Lake (up to the specified amount.) During the critical drought period when the Wright Patman water right is most likely to make such a call, Jim Chapman

Lake is also in its critical drought period and has little or no inflows to release --notwithstanding the seniority of the Wright Patman call. (Priority calls do not apply to previously stored inflows, only inflows into the reservoir during the priority call.)

Table 4-2: Firm Yield of Wright Patman Lake with Modified Water Right Seniority

Maximum Conservation Pool Elevation	Minimum Conservation Pool Elevation	Firm Yield (ac-ft/yr)[1] w/o Modified Water Right	Firm Yield (ac-ft/yr)[1] with Modified Water Right	Difference in Firm Yield (ac-ft/yr)
Per Interim Rule Curve	220 ft	40,263	39,843	420
Per Ultimate Rule Curve	220 ft	201,413	188,513	12,900
Per Interim Rule Curve	223 ft	0	0	0
Per Interim Rule Curve	217.5 ft	123,743	110,253	13,490
Per Interim Rule Curve	Bottom of Reservoir	205,513	195,203	10,310

[1] Firm yield estimates incorporate a constant downstream release of 10 cfs per the City of Texarkana's contract with the Corps of Engineers

Under these conditions, the seniority of the Wright Patman water right does not necessarily result in a release from Jim Chapman Lake. The effect of reducing the seniority of the Wright Patman water right is diminished by the inflow constraint. However, notice that the difference in yield is more significant with reallocation. This is because the higher demand levels and associated additional storage increase the frequency at which priority releases are made from Jim Chapman Lake, increasing the impact of the Lake Chapman releases on the yield of Wright Patman Lake.

4.2.2 Future Watershed Conditions

In order to evaluate the effect of watershed sedimentation on the firm yield of Wright Patman Lake over the period of analysis (50 years) a set of time-series graphs were developed. Time-series graphs were developed only for the scenarios having a minimum conservation pool elevation of 220.ft. Primarily, this is because--as discussed above-- for reallocations generating additional yield on the scale necessary to justify a stand-alone reallocation project, the effect of raising the maximum conservation pool elevation dominates the effect of lowering the minimum conservation pool elevation. Time series data were likewise run for only three of the nine scenarios for increasing the maximum conservation pool elevation. As shown in Table 4-1, reallocations above 252.5 ft generate significantly more dependable yield than the 600,000 to 700,000 acre-feet targeted in this study. It would be difficult, if not impossible, to justify completely eliminating flood storage from Wright Patman in order to gain additional yield for which there is not a demonstrated need. Accordingly, the largest two reallocation scenarios (maximum elevation of 257.5 and 259.5 ft) were dropped from the time series analysis.

Because Figure 4-1 shows that the yield curve has an inflection point at elevation 237.5 ft but is essentially a straight line between elevations 237.5 and 257.5 ft, we did not run all six scenarios between 227.5 and 252.5 ft. Reallocation scenarios with maximum conservation pool elevations of 227.5, 237.5 and 252.5 ft were felt to be indicative of the full range of scenarios. The scenarios for maximum elevations of 232.5, 242.5 and 247.5 ft can be inferred from the time series analysis.

Time series data were developed by analyzing the effect of diminished reservoir storage resulting from sustained sedimentation on reservoir yields at various points in the future. The storage volume lost due to sedimentation was estimated by modeling sediment yields and loads from each sub-basin in the Sulphur Watershed using the Soil and Water Assessment Tool (SWAT) in metric tons per year. The predicted sediment loads were converted to a volume using density data collected from Wright Patman sediment deposits as part of this analysis. The analytical process is described in detail in Appendix D.

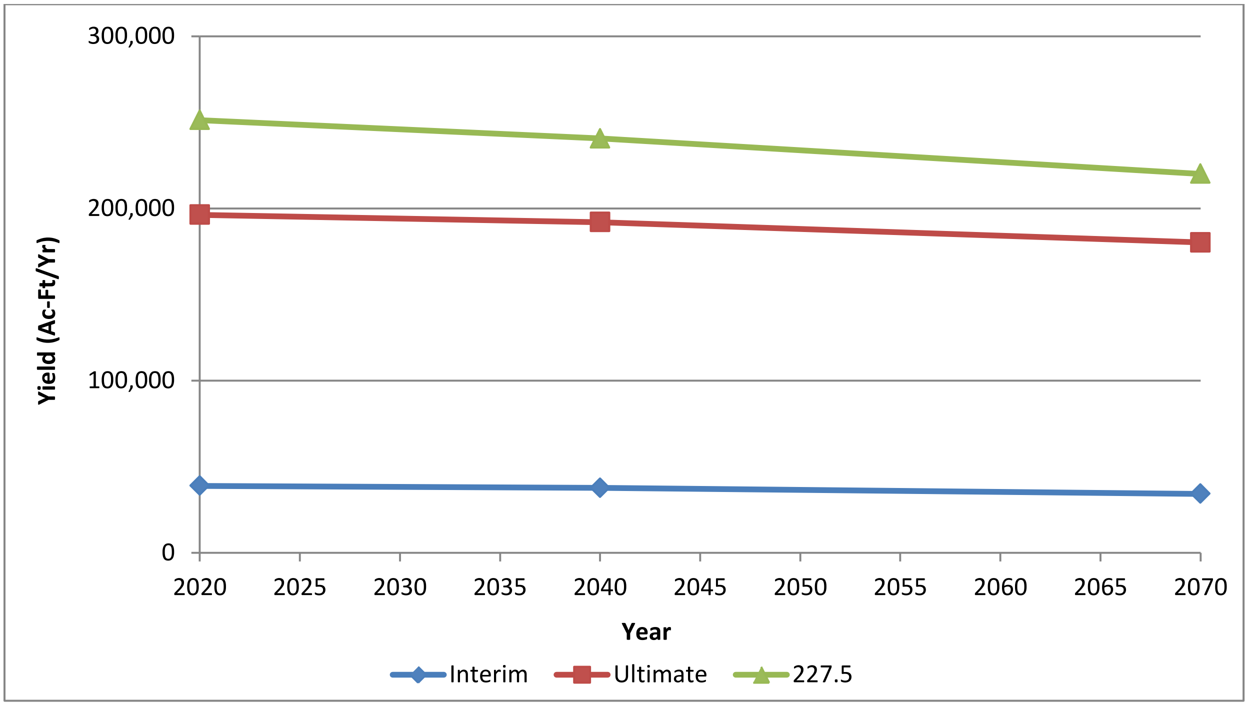
Using the SWAT as discussed above, current sedimentation rates were extrapolated into the future. The effect of future sedimentation on storage and dependable yield was explicitly modeled in the WAM for the years 2020, 2040 and 2070. The results are displayed in Table 4- 3. Interpolating between these points, Figure 4-2 provides a picture of the effect of watershed sedimentation on storage and yield in Wright Patman over time. Each scenario for the top of conservation pool is a different line. Because of the large difference in yield between the two highest storage levels and the other reallocation scenarios, the yields have been put on two different graphs so that the changes in yield can be seen. Note that this analysis assumes that Lake Ralph Hall starts to affect sediment loads at Wright Patman Lake by the year 2020.

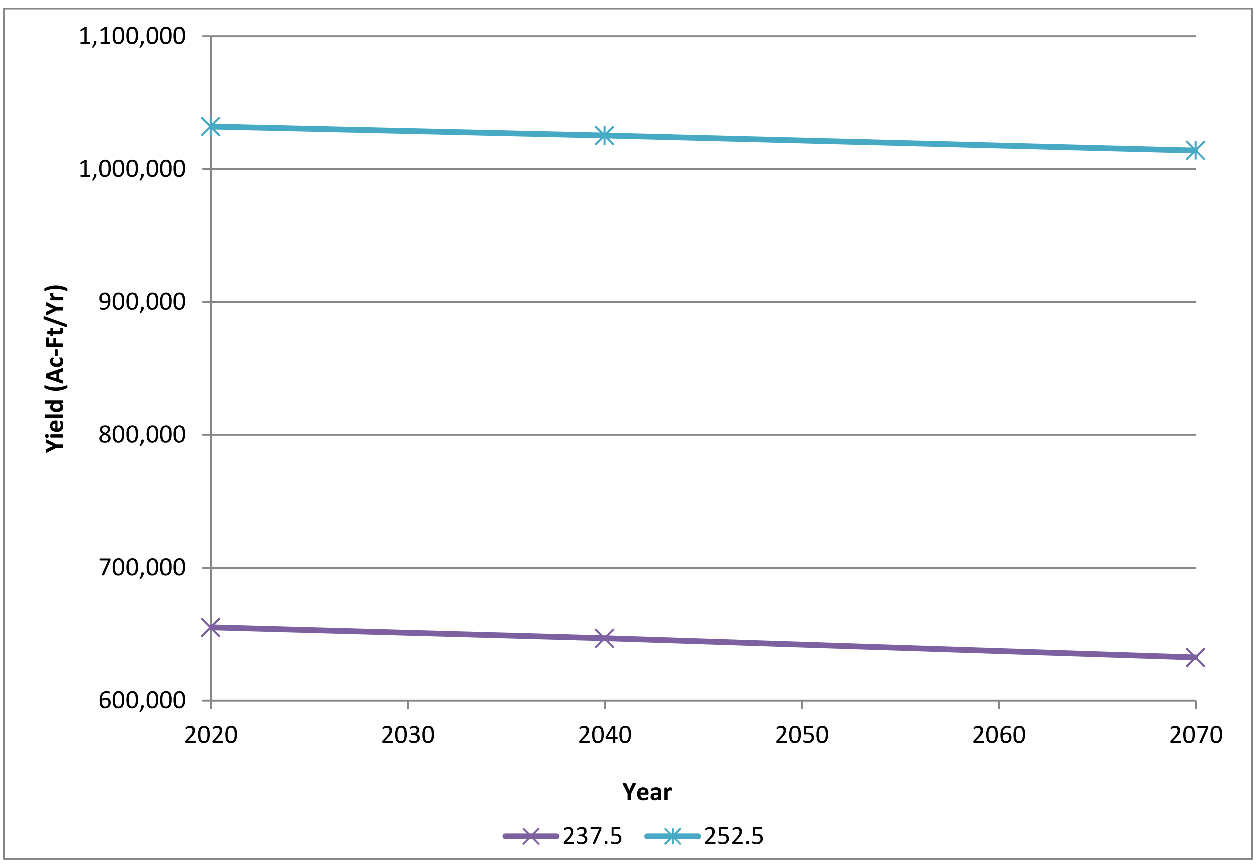
Table 4-3: Firm Yield of Wright Patman Lake in Selected Future Years Considering the Impact of Projected Sedimentation (ac-ft/yr)[1]

Top of Conservation Pool	2020	2040	2070	Reduction 2020-2070
Per the Interim Rule Curve	38,953	37,713	34,283	12%
Per the Ultimate Rule Curve	196,293	192,033	180,283	8.2%
227.5 ft	251,313	240,633	220,153	12%
237.5 ft	655,023	646,873	632,373	3.5%
252.5 ft	1,031,993	1,025,243	1,014,063	1.7%

[1]Firm yield estimates incorporate a constant downstream release of 10 cfs per the City of Texarkana's contract with the Corps of Engineers. Bottom of conservation pool at 220.0 ft for all scenarios.

Figure 4-2: Firm Yield at Wright Patman Lake over Time [1]





4.2 POTENTIAL MODIFICATIONS TO WATERSHED SEDIMENT CONDITION

The next phase of the analysis evaluated the effects of a hypothetical program to reduce erosion and subsequent sedimentation across the Sulphur River watershed. This hypothetical program was developed by identifying Best Management Practices (BMPs) which have been documented to reduce sediment loadings, and evaluating, through the use of Geographic Information Systems (GIS), their relevance in specific sub-basins of the Sulphur River watershed. With-BMP scenarios were then replicated within the SWAT model to predict the reduction in sedimentation attributable to BMP application.

The foundation of this work is two studies conducted in the Cedar Creek watershed in 2009-2010. Lee, et al. (2010) investigated the potential adoption rates of 21 BMPs whose effectiveness for sediment and nutrient reduction in the Cedar Creek watershed was first assessed by Rister et al. (2009). Lee et al. (2010) reduced this list to eight BMPs based on total phosphorus reduction at 100% application rate and the cost of BMP implementation per ton of total phosphorus reduction, with cost effectiveness having the highest priority. Four of the eight BMPs recommended by Lee for reducing phosphorus loads were also the most effective at reducing sediment loads. These BMPs were adopted for the current study. The Cedar Creek watershed and the Sulphur River watershed have similar climate, geology, and soils, and reasonably similar agricultural practices. This analysis assumes that conditions and trends in the Sulphur River watershed can be considered similar to those observed in the Cedar Creek watershed for BMP implementation purposes.

Two BMP's not evaluated by Lee, et al (2010) were added to the analysis based on FNI's experience. FNI noted channel erosion in the majority of sites visited (48 total) during a watershed reconnaissance trip in March 2012 (FNI, 2012). Channel grade control structures have been observed to decrease channel erosion in other streams and rivers in North Texas. It was theorized that they could have the same effect on channel erosion in the Sulphur River watershed. Riparian buffer strips were documented by Narashimhan, et al (2007) to significantly reduce sediment loads, but were eliminated by Lee, et al. (2010) because they were not cost-effective for reducing phosphorus. Because the focus of this effort was sediment reduction, riparian buffer strips were included in the With-BMP evaluation.

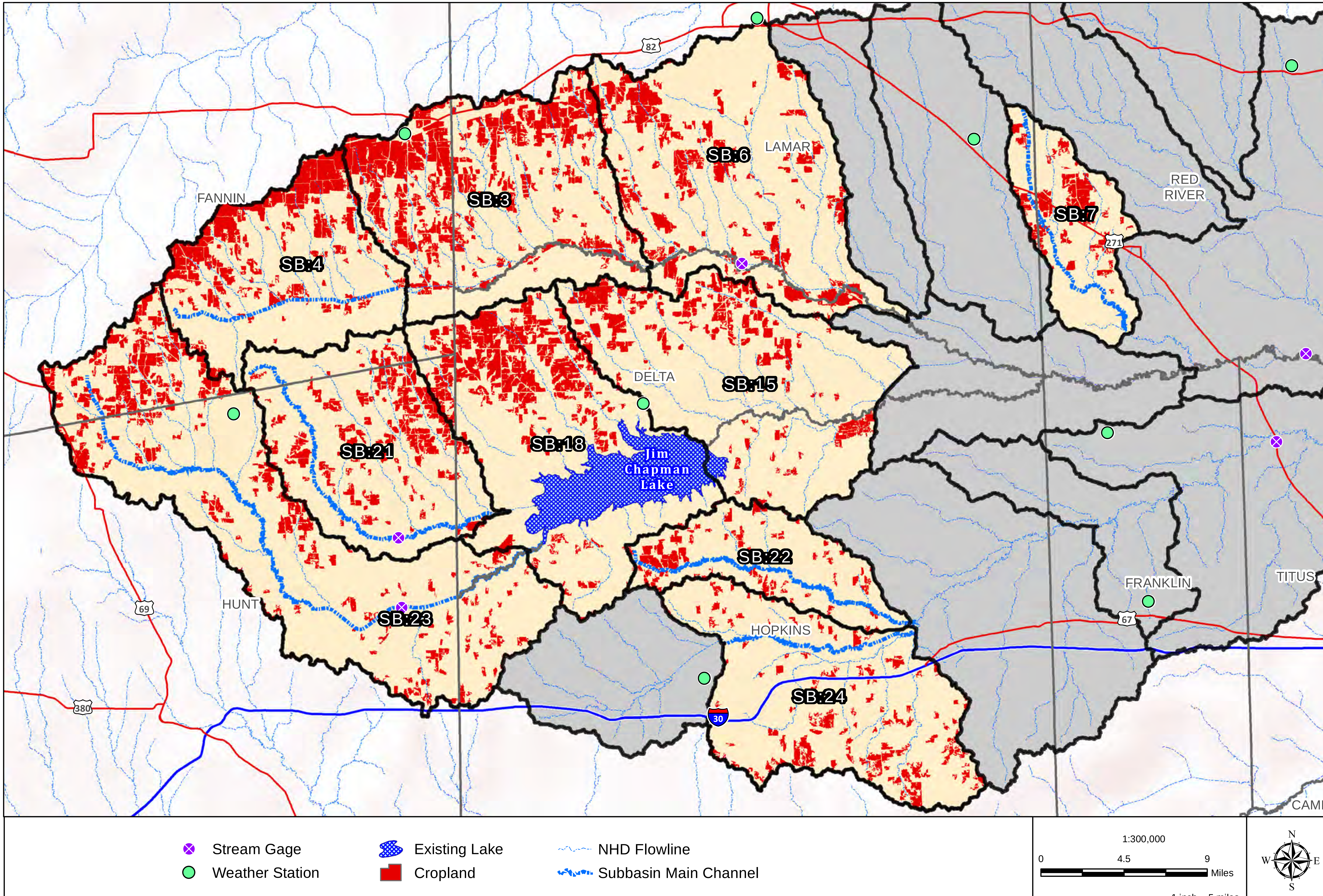
The BMP's assessed for hypothetical implementation within the Sulphur River Basin are as follows:

- Filter Strips
  - Strips of dense vegetation located between agricultural fields and adjacent water bodies. The filter strip intercepts runoff from the upslope sediment source (field with crop, pasture, disturbance, etc.) and filters it before it enters the water body. The vegetation in the filter strip slows the flow velocity of the runoff causing suspended sediment to settle out.
- Terrace
  - An embankment within a field designed to intercept runoff and prevent erosion. Terraces are constructed across the field slope, on a contour. Terraces reduce slope length, thereby reducing surface runoff velocity. Terracing also promotes infiltration of surface water runoff.
- Cropland to Pasture
  - Fields that have traditionally been used for row crop agriculture are converted to improved pasture. Improved pasture is pasture where crops such as hay are planted and grazing is permitted. Runoff rates and volumes are typically higher in row crop agriculture than in any other rural land use. Increased ground cover in an improved pasture reduces surface runoff rates and promotes infiltration.
- Critical Pasture Planting
  - Existing drainage swales in agricultural fields are planted with perennial grasses to decrease erosion and increase roughness. Increased roughness decreases flow velocities, which promotes settling of suspended sediment and increases infiltration.
- Channel Grade Control
  - Channel grade control involves the placement of grade (slope) stabilization structures in stream or river channels. Channel grade control structures are typically constructed of concrete, rock, and/or compacted earth and artificially decrease the slope of the channel. Decreased channel slopes (flatter slopes) produce lower flow velocities, which generate less erosive forces. Slower velocity flow also promotes settling of suspended sediment and increased infiltration through the channel bed and banks.

- Riparian Buffer Strip
  - An area of predominantly trees and/or shrubs located adjacent to a water body (stream, river, lake, etc.). Riparian buffer strips, also known as riparian corridors and riparian forest buffers, reduce the sediment load to a stream from the surround landscape by reducing runoff velocity, causing suspended sediment to drop out.

Additional discussion of BMP selection is included in Appendix B, Technical Memorandum: Sulphur Basin SWAT Model – Sediment BMP Analysis.

BMPs were not modeled across the entire Sulphur River watershed. BMP simulations were focused on the subbasins that produced the highest sediment yields in the baseline SWAT analysis. Using GIS capability, appropriate locations within each of these sub-basins for each BMP were identified. For example, land surface BMPs (filter strips, terraces, converting cropland to pasture, and critical pasture planting) were simulated only on cropland in the target sub-watersheds. In-channel BMPs (channel grade control and riparian buffer strips) were applied only to the target subbasins with an average main channel slope steeper than 0.0008 ft/ft. (Harvey, et al. (2007) reported that the slope of the channel of the North Sulphur River was 0.0008 feet/foot prior to channelization activities starting early in the 20th century. It was assumed that this channel slope was representative of a stable channel slope for the main channels.) Figures 4-3 through 4-7 identify the location of BMP simulation within the target sub-basins, while Table 4-4 displays the extent or number of BMPs simulated.



U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

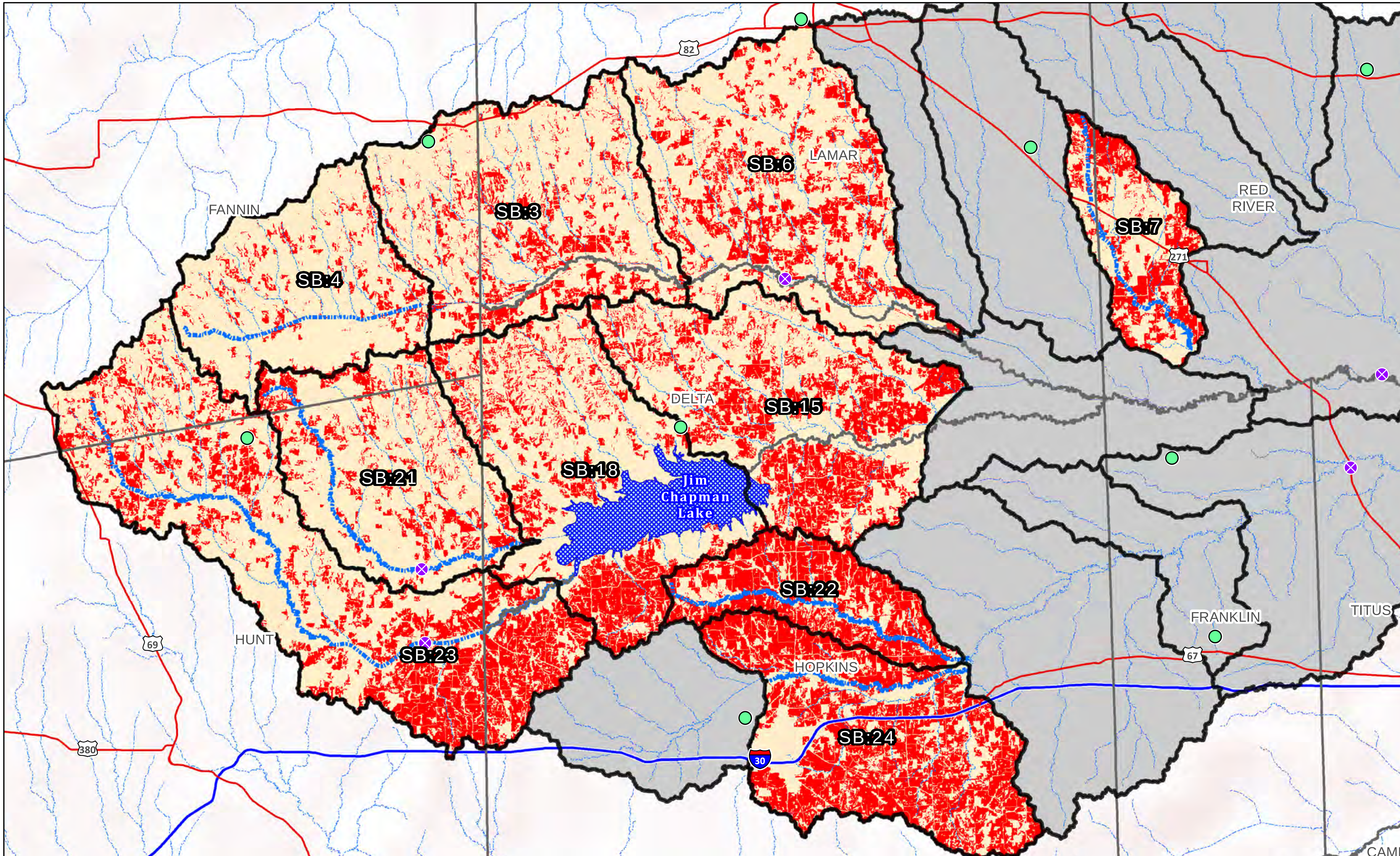
Filter Strips and Cropland to Pastureland Conversion within Target Subbasins

FN PROJECT NO.	MHP11453
DATE CREATED	1/9/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	SubbasinCropland
PREPARED BY	JAW

FREESE AND NICHOLS
4500 International Plaza Suite 200
Fort Worth, Texas 76109-4895
(817) 735-7300

FIGURE 3

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\SubbasinCropland.mxd



U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

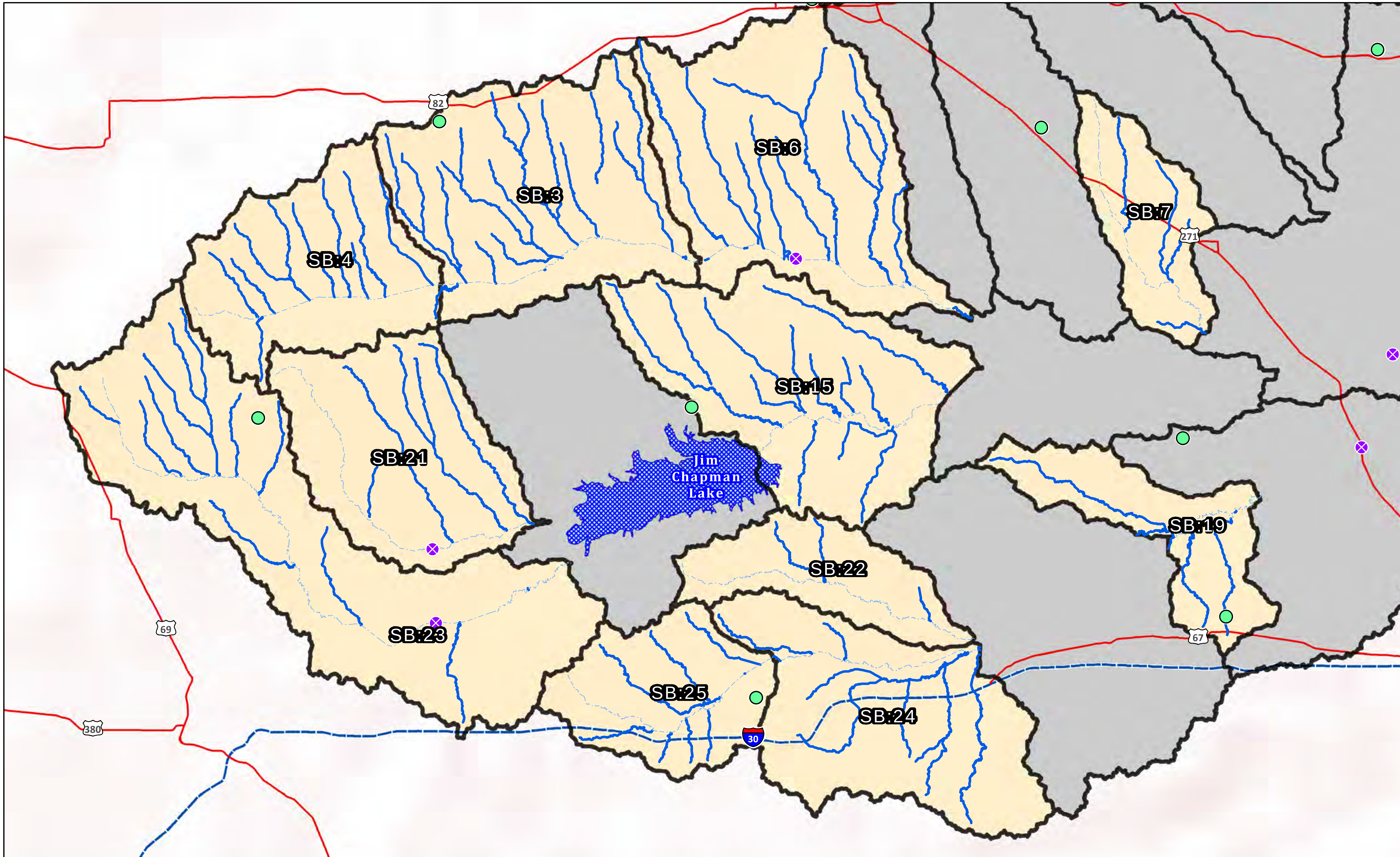
Terracing Applied to Cropland and Pastureland with Slopes Greater than 2% within Target Subbasins

FN PROJECT NO.	MHP11453
DATE CREATED	1/9/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	SubbasinTerracing 2Perc slopes
PREPARED BY	JAW

FREESE NICHOLS
4500 International Plaza Suite 200
Fort Worth, Texas 76109-4895
(817) 735-7300

FIGURE 4

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\SubbasinTerracing 2Perc slopes.mxd



Stream Gage
Weather Station
Existing Lake
Subbasin Tributaries (Manning's N Adjusted)
Subbasin Main Channel

1:300,000
0 4 8 Miles
1 inch = 5 miles

N S E W

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Sulphur River Watershed Overview - SWAT Model

Critical Pasture Planning within Target Subbasins

FN PROJECT NO.	MHP11453
DATE CREATED	1/9/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	SubbasinTributaries
PREPARED BY	JAW

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Fort Worth, Texas 76109-4895
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FIGURE 5

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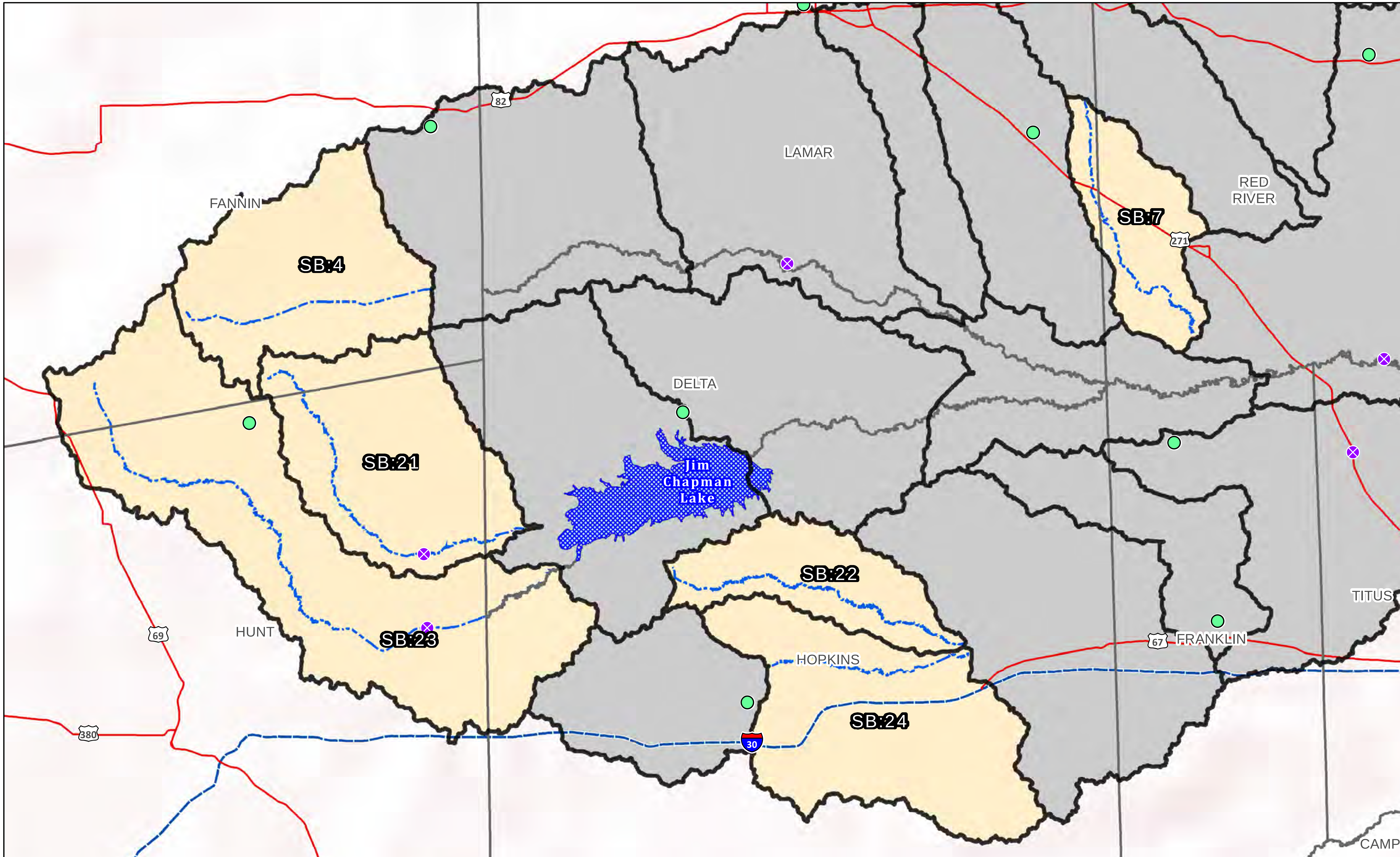

FN PROJECT NO. MHP11453
DATE CREATED 1/9/2013
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME Subbasin MainChannel
PREPARED BY JAW

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Sulphur River Watershed Overview - SWAT Model

Channel Grade Control within Target Subbasins

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(817) 735-7300

Stream Gage
Weather Station
Existing Lake
Subbasin Main Channel (slope > 0.0008 ft/ft)

1:300,000
0 4.5 9 Miles
1 inch = 5 miles

N W E S

FIGURE 6

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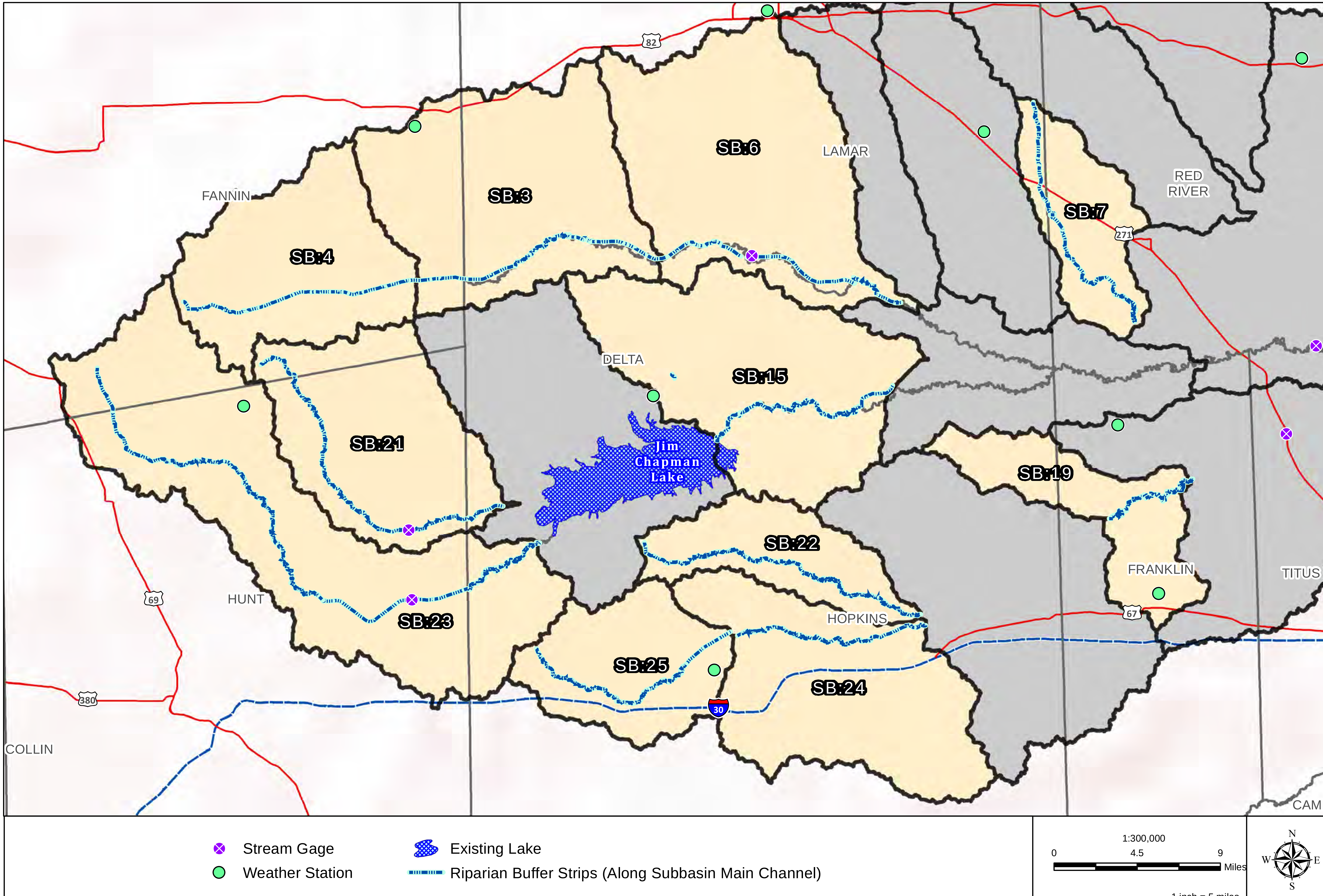

FN PROJECT NO.	MHP11453
DATE CREATED	1/9/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	Subbasin Riparian
PREPARED BY	JAW

U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Applied Riparian Buffer Strips within Target Subbasins

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Fort Worth, Texas 76109-4895
(817) 735-7300

FIGURE 7

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Table 4-4: Number and/or Extent of BMP's included in the Sulphur River SWAT Model

Subbasin	Total Subbasin Area (acres)	Filter Strips (acres)[1]	Terrace (acres)[2]	Cropland to Pasture (acres)[3]	Critical Pasture Planting (linear feet)[4]	Channel Grade Control[5]		Riparian Buffer Strip (linear feet)[6]
						Linear feet	Number of 3-foot drops	
3	93,650	293	10,056	28,990	130,840	--	--	78,740
4	64,339	182	802	17,946	86,352	38,451	9.6	38,451
6	102,034	175	9,433	17,319	147,441	--	--	84,679
7	33,747	64	2,572	6,364	93,832	19,587	1.4	19,587
15	93,060	131	16,973	12,972	159,088	--	--	95,243
18	100,171	207	14,191	20,406	144,849	--	--	90,846
21	70,111	120	3,931	11,857	126,837	40,617	2.3	40,617
22	35,306	60	7,814	5,961	102,822	31,791	2.4	31791
23	137,734	221	22,017	21,847	224,475	156,791	1.6	156,791
24	809,731	111	31,102	10,957	93,930	65,551	4.4	65,551

[1] Filter strip acreage represents the area of cropland that would be taken out of production and converted to filter strips in each subbasin.

[2] Terrace acreage represents the area of cropland and pasture where terraces would be installed in each subbasin.

[3] Cropland to pasture acreage is the total number of acres in each watershed that would be converted from cropland to pasture. At the 100% adoption rate, the cropland to pasture acreage is equal to the total acres of cropland in each subbasin.

[4] Critical pasture planting linear footage is the length of tributary channel in each subsbasin that was affected by the critical pasture planting BMP.

[5] Channel grade control linear footage is a measure of the total channel length impacted in each subbasin that would be affected by grade control practices under a 100% adoption rate. The number of 3-foot drops is provided as an example of how many 3-foot high drop structures would be needed to artificially lower the existing channel slope the equilibrium channel slope of 0.0008 ft/ft. The difference between the existing and equilibrium channel slopes was multiplied by the total main channel length to calculate the expected amount of downcutting need for the channel to reach the equilibrium slope. It is a standard engineering practice to limit drop structure height to three feet in order to avoid dangerous hydraulic conditions that can be generated with greater drop heights.

[6] The riparian buffer strip linear footage represents the number of feet of channel in each subbasin where riparian buffer strips would be established. At the assumed 100% adoption rate, this value is equal to the total main channel length in each subbasin.

BMPs were simulated for 100% of the land cover within each of the target subbasins meeting the application criteria discussed above. It is recognized that a 100% adoption rate is not likely. Factors influencing BMP adoption would be expected to include the cost of implementation, cost of implementation as compared to economic benefit, willingness of landowners to participate, availability of government assistance funding and other variables. Rister, et al. (2009) estimated marginal (expected) rates of BMP adoption in the Cedar Creek watershed through a program of extensive surveys and interviews with local stakeholders including landowners, government agencies, and academics. A similar study would need to be performed in the Sulphur River Basin in order to develop more precise predictions of expected BMP implementation in the face of an actual sediment reduction program. The purpose of this study was rather to identify whether or not such a program could reasonably be expected to have a meaningful effect on the rate of sedimentation in Wright Patman Lake; evaluation of the performance or cost-effectiveness of such a program is beyond the scope of this effort. It is likely that the sediment loads generated using marginal rates of BMP implementation would be higher and more realistic than those generated under assumed 100% BMP application rates.

The scenario simulating application of the six BMPs as described above was labeled the Intensive scenario. In addition to the Intensive scenario, a second sediment reduction scenario was developed and evaluated. This scenario used four of the BMPs judged to be the most feasible, based on evaluation of the initial BMP scenario. This scenario, labeled the Feasible Scenario consisted of simulating four BMPs – Filter Strips, Cropland to Pasture Conversion, Channel Grade Control, and Riparian Buffer Strips- across the watershed in the same manner as for the Intensive scenario.

The average annual sediment load, sediment yield, and total sediment yield results in Tables4- 5,4- 6, and 4- 7 include the percentage reduction from the baseline (non-BMP scenario) to the two alternative BMP scenarios. The differences between terms “sediment load” and “sediment yield” are described in the following bullet points:

- Sediment load
    - Sediment load is the total amount of sediment that passes through the outlet of each sub-basin, carried by flowing water in the channel; also known as sediment discharge.
    - Units = mass per unit time

- Sediment yield
  - Sediment yield is the amount of sediment that enters the main channel in each individual sub-basin per unit area of the sub-basin, originating from overland erosion.
  - Units = mass per unit area per unit time
- Total sediment yield
  - Total sediment yield is the total amount of sediment entering the main channel from overland erosion in each individual sub-basin.
  - Total sediment yield is calculated by multiplying the SWAT-calculated sediment yield by the total area of the individual sub-basin.
  - Units = mass per unit time

Sediment load, sediment yield, and total sediment yield are presented by individual sub-basin.

Figures 4-8 through 4-10 illustrate the changes in sediment loads as reported by the model. The Intensive BMP scenario reduced sediment loads to Wright Patman Lake by 31% (240,767 metric tons) while the Feasible BMP scenario reduced sediment loads to Wright Patman Lake by 28% (223,518 metric tons). Additional information on this analysis is contained in Appendix D.

Table 4-5: Average annual sediment load comparison – Baseline scenario, Intensive BMP scenario and Feasible BMP scenario

Subbasin	Existing Condition Scenario(metric tons)	Intensive BMP Scenario (metric tons)	Intensive BMP Scenario (percent reduction)	Feasible BMP Scenario (metric tons)	Feasible BMP Scenario (percent reduction)
1	2,943	2,943	0%	2,943	0%
2	2,629	2,629	0%	2,629	0%
3	190,004	10,497	94%	14,969	92%
4	80,977	7,293	91%	9,919	88%
5	2,454	2,454	0%	2,454	0%
6	292,656	16841	94%	24,118	92%
7	23,799	579	98%	939	96%
8	3,002	3,002	0%	3002	0%
9	526,960	204,875	61%	216,191	59%
10	444,534	96,785	78%	107,148	76%
11	3,361	3,361	0%	3361	0%
12*	785,823	545,056	31%	562,305	28%
14	3,897	3,897	0%	3,897	0%
15	123,909	31,387	75%	34,149	72%
16	290,776	77,647	73%	104,094	64%
17	267,021	208,859	22%	217,446	19%
18	368,655	12,700	97%	20861	94%
19	212,831	34,655	84%	39,617	81%
20	208,544	26,221	87%	31,179	85%
21	89,022	3127	96%	4,981	94%
22	48,756	295	99%	1,246	97%
23	164,456	3,605	98%	7,876	95%
24	143,982	5,230	96%	9,232	94%
25	2,207	2,207	0%	2,207	0%

*Location of Wright Patman Lake

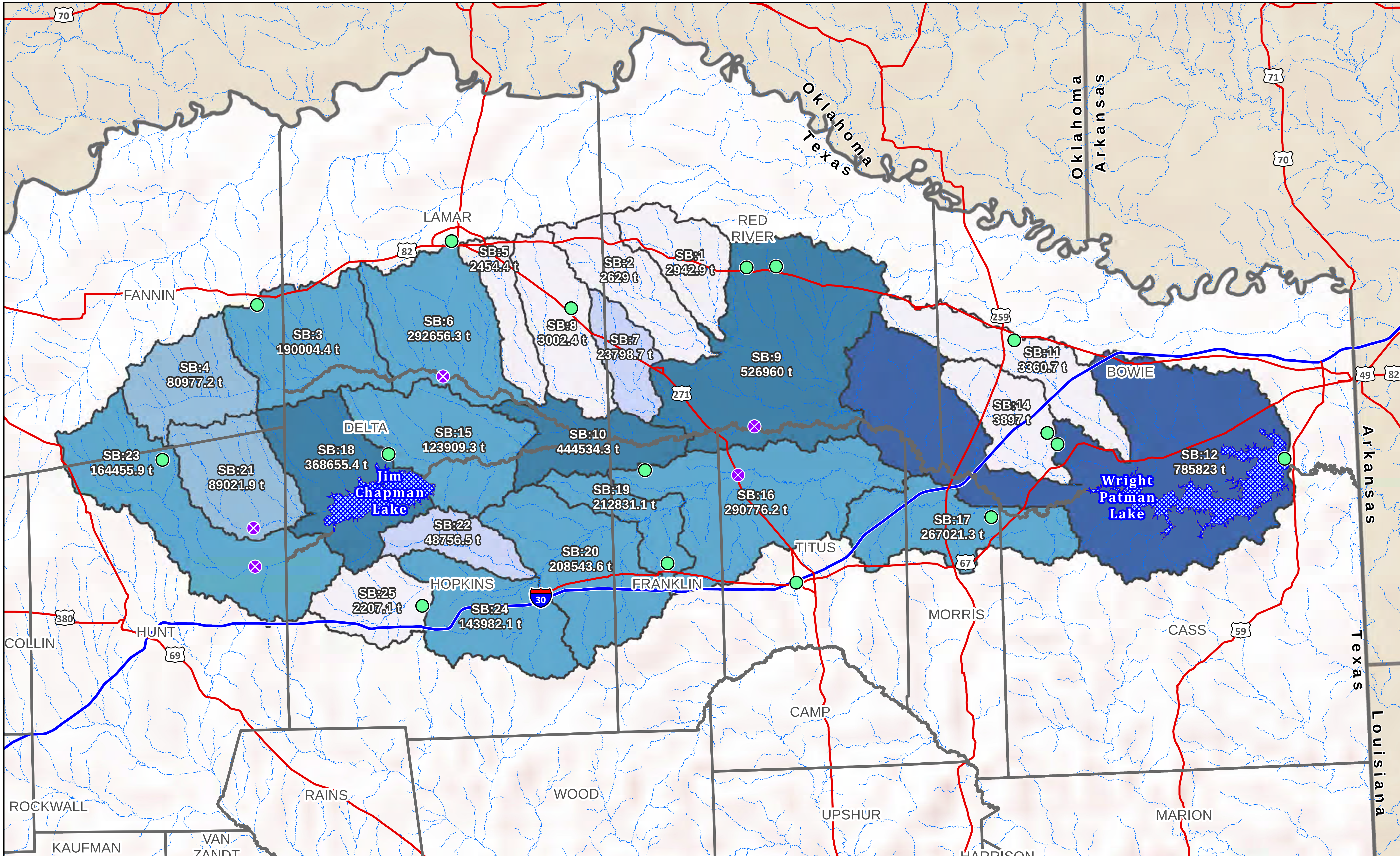
Table 4-6: Average Annual Sediment Yield Comparison – Baseline Scenario, Intensive BMP Scenario and Feasible BMP Scenario

Subbasin	Existing Condition Scenario (metric tons/hectare)	Intensive BMP Scenario (metric tons/hectare)	Intensive BMP Scenario (percent reduction)	Feasible BMP Scenario (metric tons/hectare)	Feasible BMP Scenario (percent reduction)
1	0.147	0.147	0%	0.147	0%
2	0.110	0.110	0%	0.110	0%
3	4.932	0.161	97%	0.280	94%
4	3.110	0.280	91%	0.381	88%
5	0.169	0.169	0%	0.169	0%
6	2.256	0.091	96%	0.161	93%
7	1.743	0.042	98%	0.069	96%
8	0.112	0.112	0%	0.112	0%
9	0.220	0.220	0%	0.220	0%
10	0.123	0.123	0%	0.123	0%
11	0.121	0.121	0%	0.121	0%
12*	0.154	0.154	0%	0.154	0%
14	0.182	0.182	0%	0.182	0%
15	2.263	0.077	97%	0.138	94%
16	0.213	0.213	0%	0.213	0%
17	0.435	0.435	0%	0.435	0%
18	3.449	0.074	98%	0.125	96%
19	0.128	0.128	0%	0.128	0%
20	0.220	0.220	0%	0.220	0%
21	3.138	0.110	96%	0.176	94%
22	3.413	0.020	99%	0.087	97%
23	3.194	0.072	98%	0.155	95%
24	4.531	0.065	99%	0.187	96%
25	0.121	0.121	0%	0.121	0%

Table 4-7: Average annual total sediment yield comparison – Baseline scenario, intensive BMP scenario, and feasible BMP scenario

Subbasin	Existing Condition Scenario(metric tons)	Intensive BMP Scenario (metric tons)	Intensive BMP Scenario (percent reduction)	Feasible BMP Scenario (metric tons)	Feasible BMP Scenario (percent reduction)
1	2,944	2,944	0%	2,944	0%
2	2,263	2,663	0%	2,663	0%
3	186,904	6,094	97%	10,612	94%
4	80,980	7,285	91%	9,918	88%
5	2,451	2,451	0%	2,451	0%
6	93,149	3,775	96%	6,666	93%
7	23,804	573	98%	942	96%
8	3,018	3,018	0%	3,018	0%
9	18,404	18,404	0%	18,404	0%
10	3,026	3,026	0%	3,026	0%
11	3,472	3,472	0%	3,472	0%
12*	21,811	21,811	0%	21,811	0%
14	3,905	3,905	0%	3,905	0%
15	85,218	2,884	97%	5,213	94%
16	12,427	12,427	0%	12,427	0%
17	14,861	14,861	0%	14,861	0%
18	139,823	2,980	98%	5,047	96%
19	2,020	2,020	0%	2,020	0%
20	9,458	9,458	0%	9,458	0%
21	89,024	3,123	96%	4,979	94%
22	48,758	290	99%	1,246	97%
23	178,023	4,013	98%	8,659	95%
24	148,468	2,114	99%	6,130	96%
25	2,199	2,199	0%	2,199	0%

*Location of Wright Patman Lake



FN PROJECT NO. MHP11453
DATE CREATED 1/11/2013
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME Fig8_Sed_Load_Baseline_MTG
PREPARED BY JAW

U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Baseline Scenario - Average Annual Sediment Load (tons)

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4500 International Plaza Suite 200
Fort Worth, Texas 76109-4895
(817) 735-7300

Stream Gage
Weather Station
Existing Lake
NHD Flowline

Baseline Scenario
Average Annual Sediment Load (tons)
Between 1997-2010

0 - 20000
20001 - 50000
50001 - 100000
100001 - 300000
300001 - 600000
600001+

1:575,000
0 4.5 9 18 Miles
1 inch = 9 miles

N W E S

FIGURE 8

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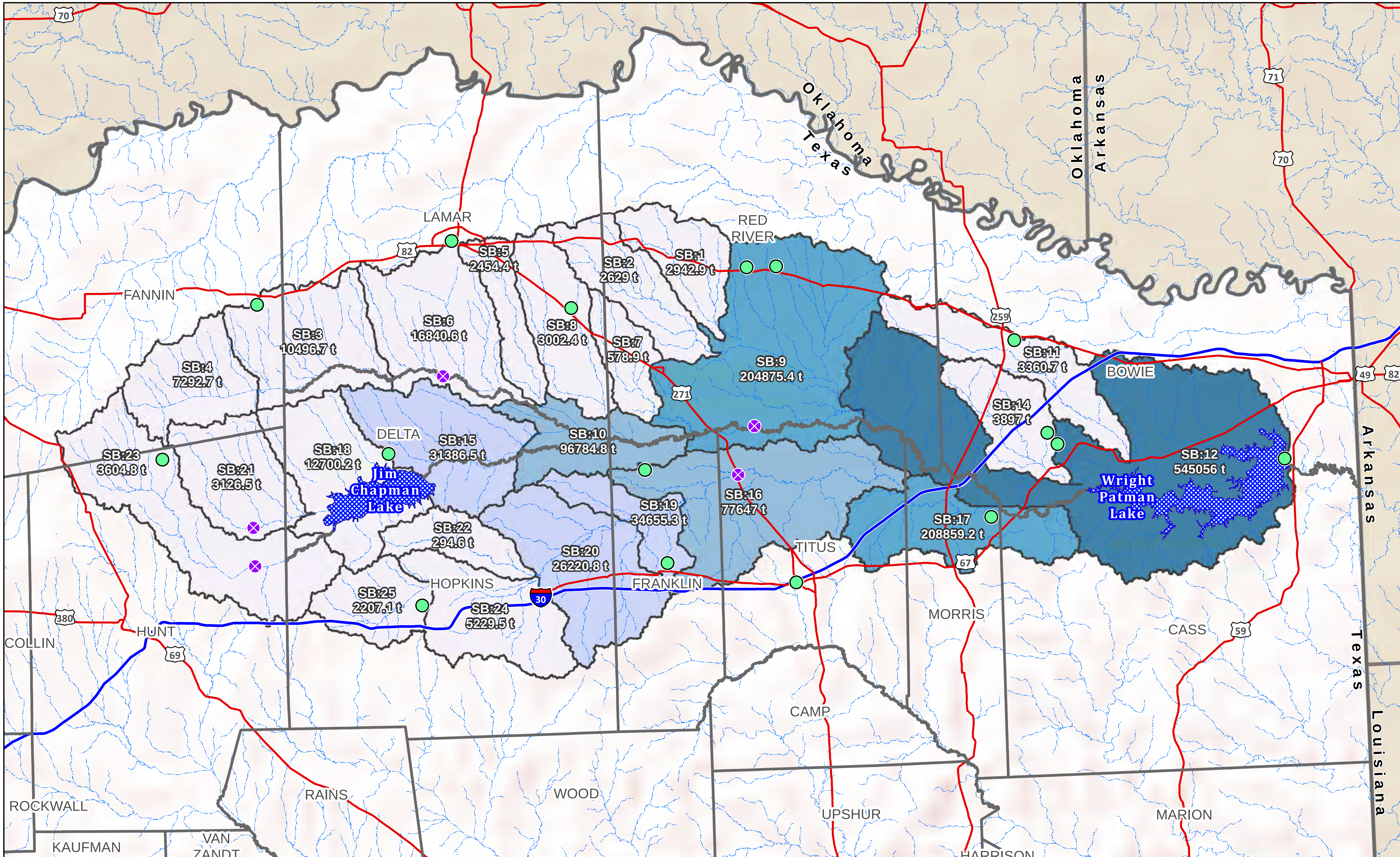

Stream Gage
Weather Station
Existing Lake
NHD Flowline

Intensive BMP Scenario
Average Annual Sediment Load (tons)
Between 1997-2010

0 - 20000
200001 - 50000
50001 - 100000
100001 - 300000
300001 - 600000
600001+

1:575,000
0 4.5 9 18 Miles
1 inch = 9 miles

N W E S

FIGURE 9

U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT
Sulphur River Watershed Overview - SWAT Model
Intensive BMP Scenario- Average Annual Sediment Load (tons)

FN PROJECT NO. MHP11453
DATE CREATED 1/11/2013
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME Fig9_Sed_Load_Intensive_MTG
PREPARED BY JAW

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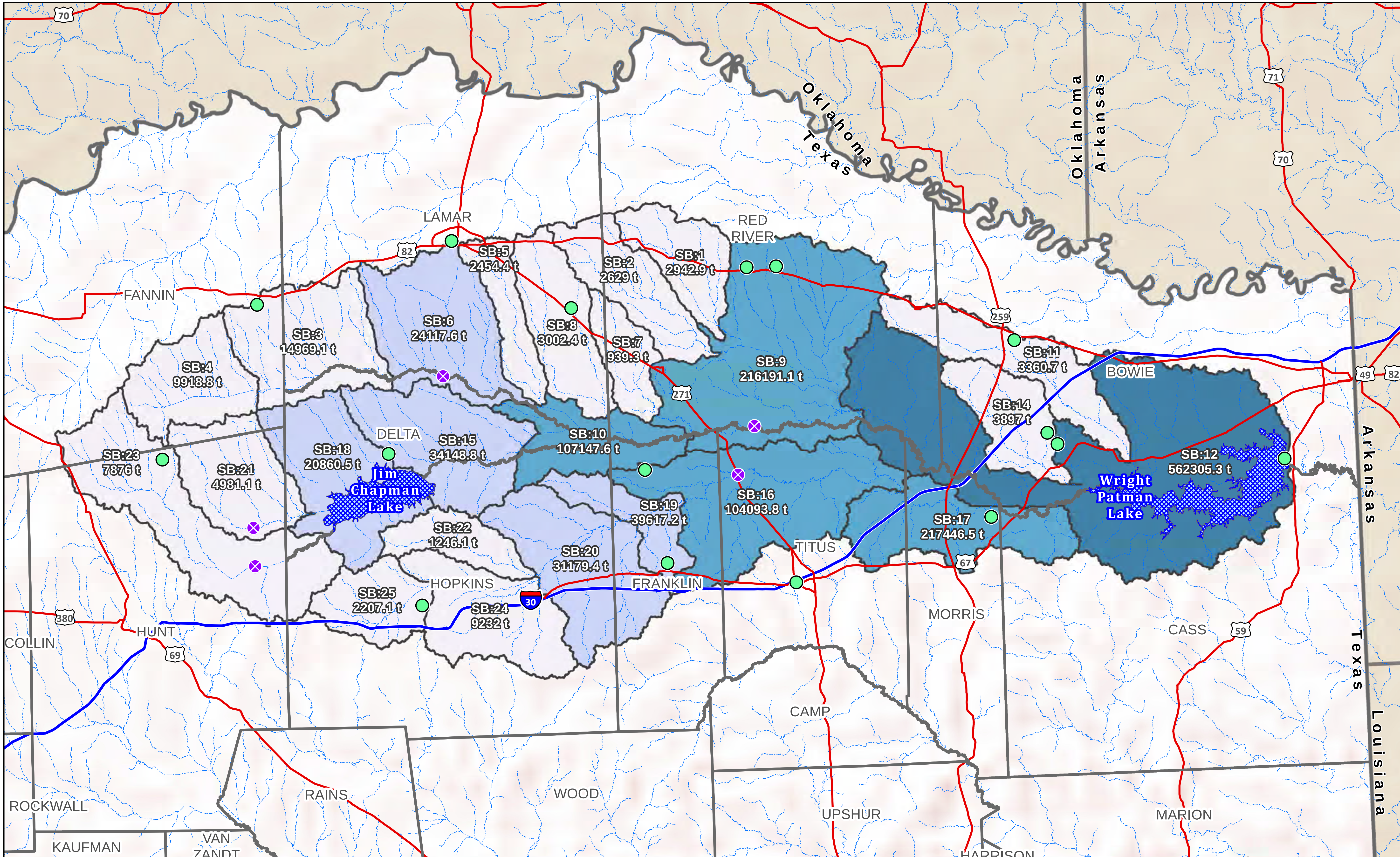

FN PROJECT NO.	MHP11453
DATE CREATED	1/11/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	Fig10_Sed_Load_Feasible_MTG
PREPARED BY	JAW

U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Feasible BMP Scenario- Average Annual Sediment Load (tons)

FREESE NICHOLS
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Fort Worth, Texas 76109-4895
(817) 735-7300

Stream Gage
Weather Station
Existing Lake
NHD Flowline

Feasible BMP Scenario
Average Annual Sediment Load (tons)
Between 1997-2010

0 - 20000
20001 - 50000
50001 - 100000
100001 - 300000
300001 - 600000
600001+

1:575,000
0 4.5 9 18 Miles
1 inch = 9 miles

N W E S

FIGURE 10

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\Arc10\For_Becky\Fig10_Sed_Load_Feasible_MTG.mxd

4.3 EFFECT OF MODIFIED SEDIMENT CONDITION ON WRIGHT PATMAN YIELDS

In order to evaluate the effect of reduced sediment loading to Wright Patman Lake on the dependable yield thereof, the WAM analysis described in Section 4.1 was revised. Specifically, values within the WAM that a) relate the storage volume in the reservoir to the surface area and b) the storage available in the reservoir at a given top-of-conservation-pool elevation were modified to reflect the changes predicted by the SWAT model. Specifically, the reduction in sediment load, measured in tons per year, was converted to a volume (acre-feet) using the measured density from Wright Patman sediment core samples obtained during development and calibration of the SWAT model. Table 4-8 reflects the firm yield of Wright Patman Lake over the 50-year period of analysis under several reallocation scenarios as modified by predicted sediment reductions using the Feasible BMP scenario. All scenarios shown in Table 4-8 assume the minimum (bottom) elevation of the conservation pool to be 220.0 ft and likewise assume a minimum constant release of 10 cfs downstream of Wright Patman per the existing Corps contract.

Figures 4-11 through 4-13 compare the firm yield of Wright Patman Lake over time with and without the sediment mitigation program for each of three reallocation scenarios. In each case, the blue line represents the firm yield associated with anticipated watershed conditions absent a sediment mitigation program whereas the red line reflects the firm yield with the Feasible BMP scenario in place.

Table 4-9 indicates the cumulative increase in dependable yield over the 50-year period of analysis resulting from sediment mitigation for each of three reallocation scenarios portrayed in Figures 4-8 through 4-10 as predicted by the model. The results presented in Table 4-9 are consistent with the observations presented in Figure 4-1 in that the improvement in yield associated with storage generally at the bottom of the reservoir pool is most pronounced for the smaller reallocations and diminishes in relative importance for larger reallocation scenarios.

Table 4-8: Cumulative Savings Resulting from Sediment Mitigation Program Applied over a 50-year Period

Reallocation Scenario – Top of Conservation Pool	Cumulative Savings (Ac-Ft)
227.5 ft	240,000
237.5 ft	170,000
252.5 ft	130,000

Table 4-9: Firm Yield of Wright Patman Lake with Sediment Reduction Program

Conservation Pool Max. Elevation (ft)/Curve	Sediment Condition	Firm Yield (ac-ft/yr)[1]	Sediment Condition[1]	Firm Yield (ac-ft/yr)[2]	Increase in Firm Yield due to BMPs (ac-ft/yr)
Interim	2020	38,953	2020	38,953	0
Ultimate	2020	196,293	2020	196,293	0
227.5	2020	251,313	2020	251,313	0
237.5	2020	655,023	2020	655,023	0
252.5	2020	1,031,993	2020	1,031,993	0
Interim	2040	37,713	2040 with Feasible BMPs	38,303	590
Ultimate	2040	192,033	2040 with Feasible BMPs	194,013	1,980
227.5	2040	240,633	2040 with Feasible BMPs	244,113	3,480
237.5	2040	646,873	2040 with Feasible BMPs	649,323	2,450
252.5	2040	1,025,243	2040 with Feasible BMPs	1,027,243	2,000
Interim	2070	34,283	2070 with Feasible BMPs	35,983	1,700
Ultimate	2070	180,283	2070 with Feasible BMPs	186,113	5,830
227.5	2070	220,153	2070 with Feasible BMPs	230,303	10,150
237.5	2070	632,373	2070 with Feasible BMPs	639,533	7,160
252.5	2070	1,014,063	2070 with Feasible BMPs	1,019,333	5,270

[1]The analysis assumes Lake Ralph Hall will be in place by 2020. Sediment conditions between the current time period and 2020 do not have Ralph Hall in place; after 2020 the sediment conditions includes the effect of Lake Ralph Hall

[2] Firm yield estimates incorporate a constant downstream release of 10 cfs per the City of Texarkana's contract with the Corps of Engineers

Figure 4-11: Yield with Maximum Conservation Elevation at 227.5 Feet

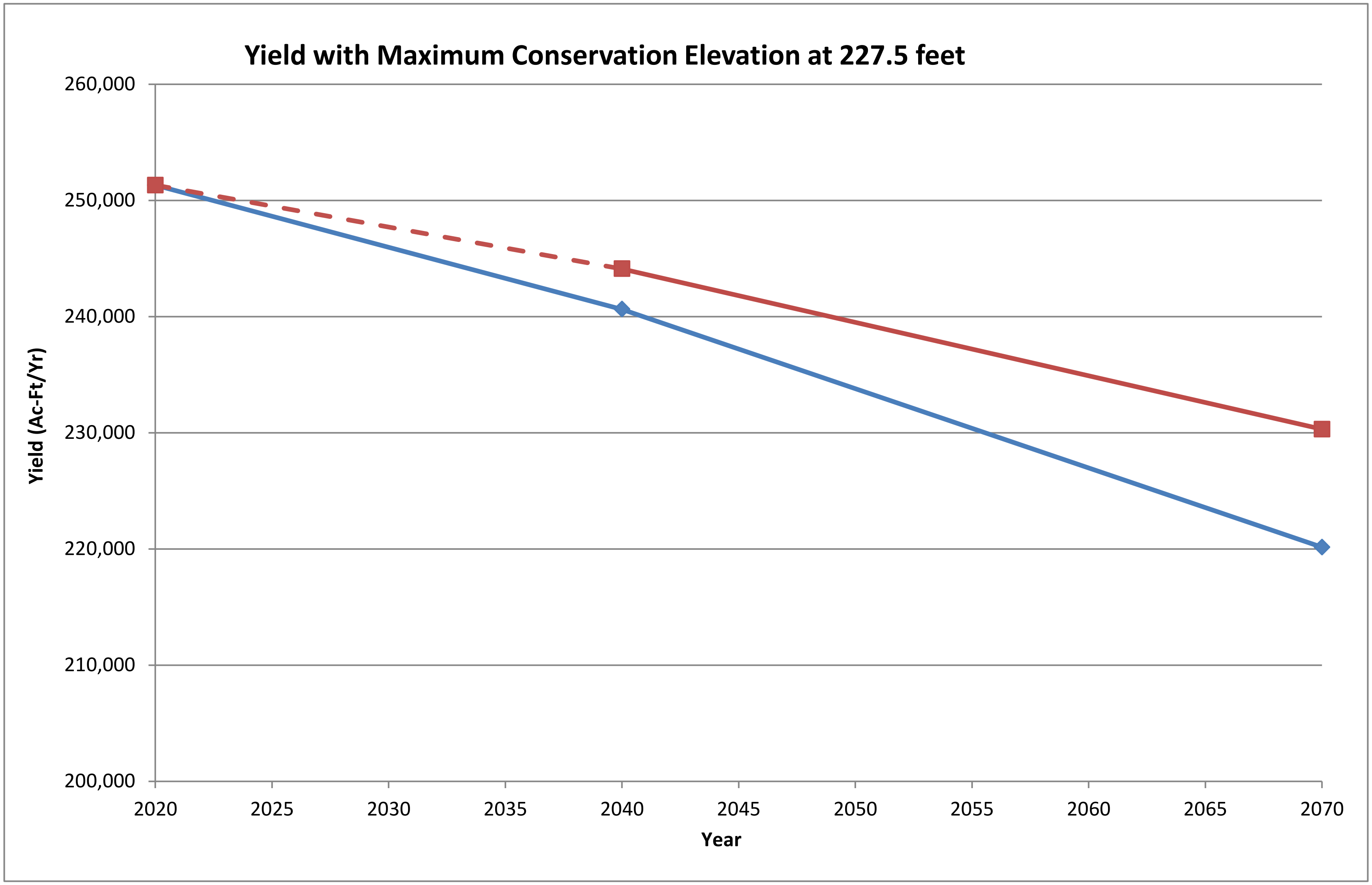


Figure 4-12: Yield at Maximum Conservation Pool Elevation 237.5

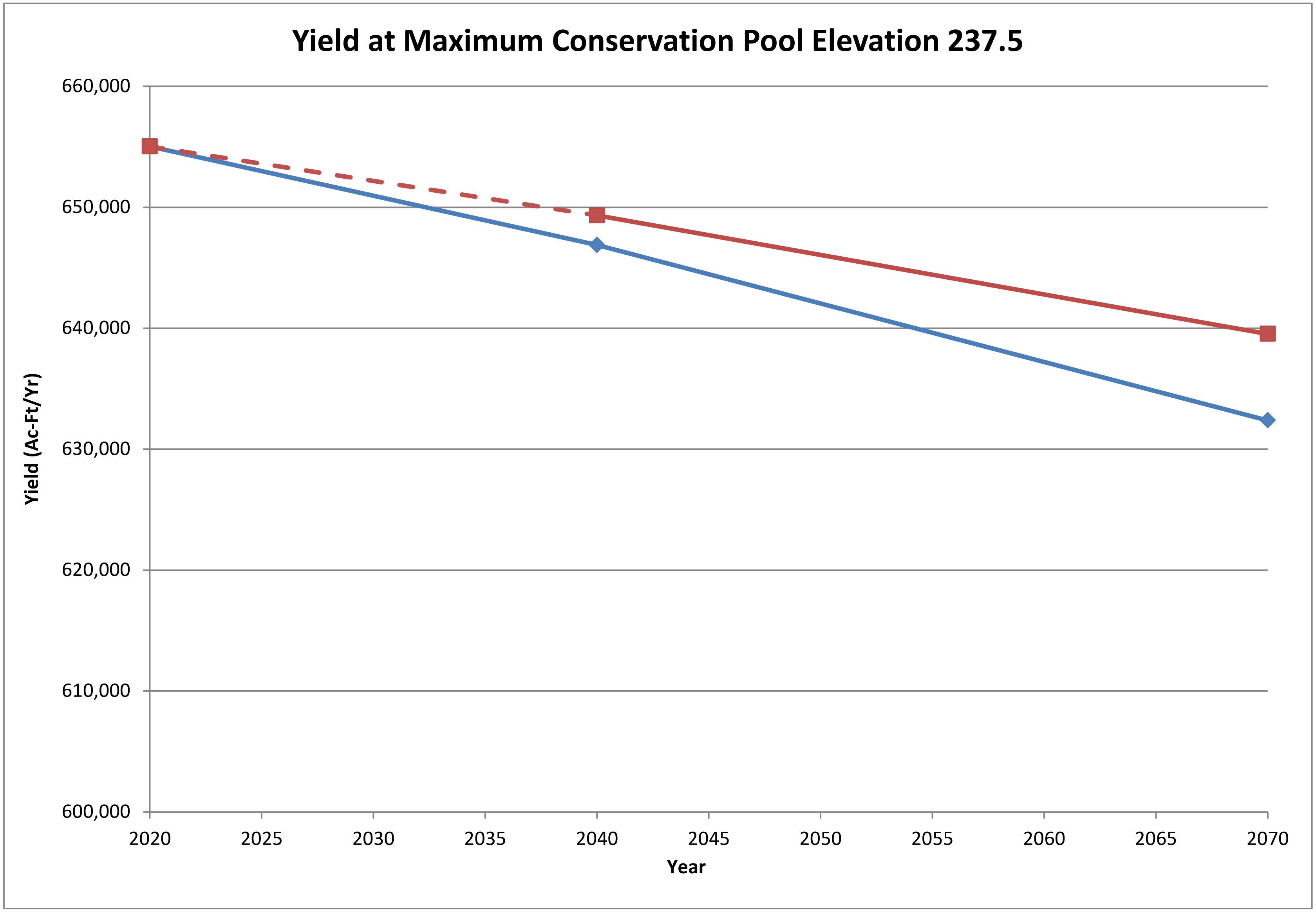
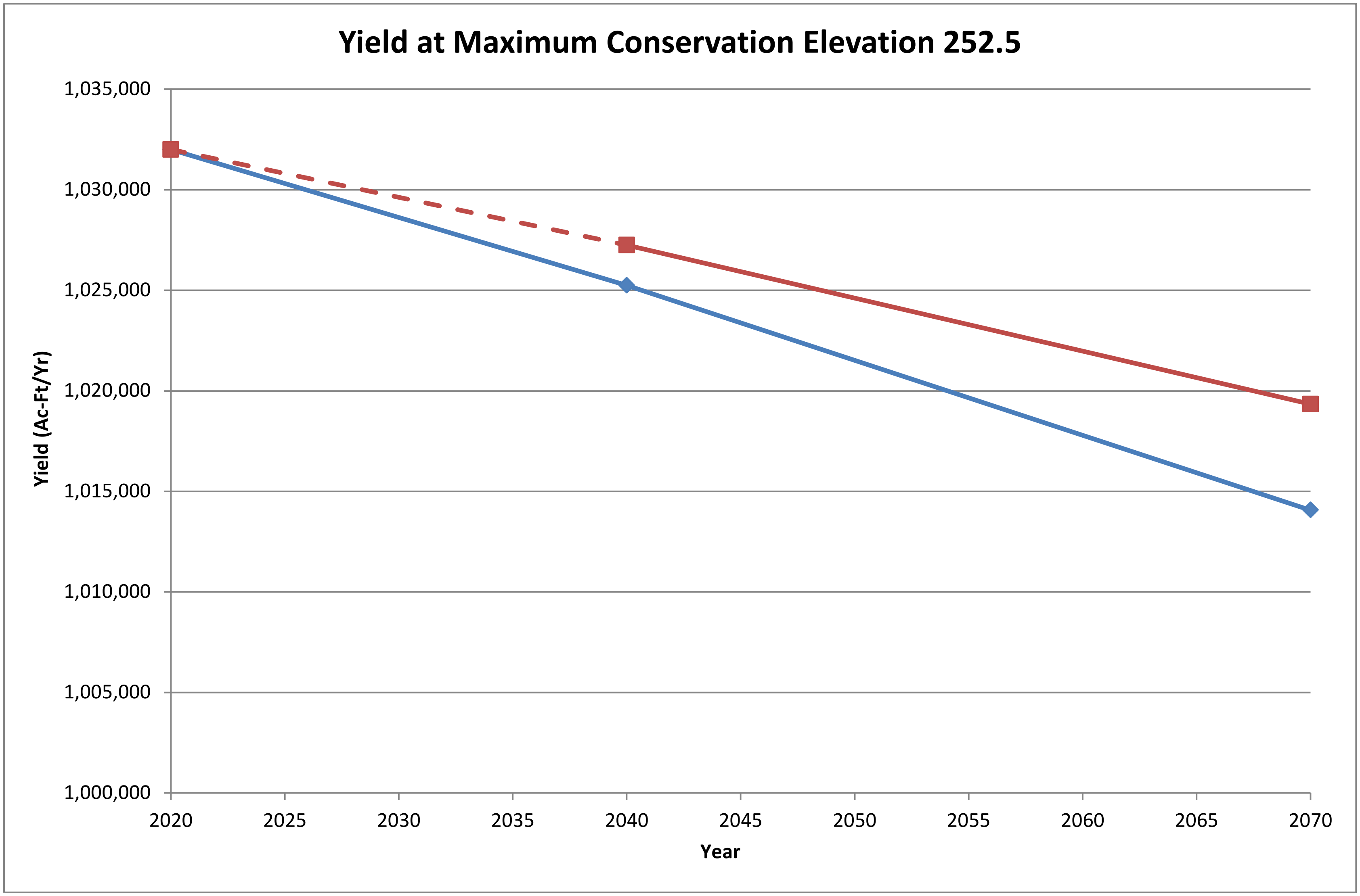


Figure 4-13: Yield at Maximum Conservation Elevation 252.5



The results presented in this section are specific to the predicted effect of a sediment reduction program on firm yields at Wright Patman Lake. The additional benefits which would be realized at other existing, planned, or potential water resources projects in the basin, and to riparian landowners in the basin, were not addressed.

4.4 SUMMARY

In general, the analysis demonstrates that reallocation of storage from flood control or sediment storage to water conservation storage at Wright Patman Lake could substantially increase the firm yield of the project. For scenarios raising the top of the conservation pool (reallocating storage from flood control to water supply), the modeling indicates that firm yield continues to increase significantly with the increase in storage at all elevations. Increasing storage by lowering the bottom of the conservation pool (reallocating dead storage to water supply) also increases yield substantially. With the entire reservoir storage dedicated to water conservation (no sediment storage or flood control storage), the firm yield of the reservoir exceeds 1.2 million acre-feet per year.

Simulation of subordination of the senior Wright Patman right to the more junior Jim Chapman right reduced the firm yield of Wright Patman Lake by an estimated 1-11 % depending on the bottom elevation chosen for the conservation pool (whether or not sediment storage is reallocated) and on whether the Interim or Ultimate rule curve is used as the top of the conservation pool.

Storage in Wright Patman Lake is predicted to decline over time due to ongoing sedimentation from the watershed. Absent a reallocation or other change to Wright Patman Lake operations, the firm yield of the reservoir would be reduced by approximately 12% by the year 2070, even with Lake Ralph Hall in place upstream. The SWAT model indicates that sediment yields and loads within the watershed could be substantially reduced by a program of Best Management Practices. Implementation of four practices at 100% of the applicable locations within ten of the basin’s sub-watersheds is predicted to reduce sedimentation at Wright Patman by 28% (223,518 metric tons per year.) The reduced loss of storage has a beneficial effect on the predicted firm yield of Wright Patman Lake, generally in the 1-5% range depending on the scenario. On a cumulative basis, the additional water supply available as a result of the reduction in sediment may be several hundred thousand acre-feet.