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Sulphur River Basin Feasibility Study

Final Cost Rollup Report

Prepared for:

Sulphur River Basin Authority

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EXECUTIVE SUMMARY

This study provides cost estimates for four alternative reservoir sites in the Sulphur River Basin, Texas as well as three reallocation scenarios at Wright Patman Lake, Texas. The alternative reservoirs that were evaluated in this study include previously established reservoir sites historically known as George Parkhouse I, George Parkhouse II, Marvin Nichols 1A, and Talco. Multiple sizes were evaluated for the reservoirs at the Marvin Nichols 1A site (3) and the Talco site (2). The Talco site was also evaluated in two configurations – as a standalone reservoir on White Oak Creek (Configuration 1), and as a reservoir on White Oak Creek with diversions from the Sulphur River for the purposes of "scalping" flood flows (Configuration 2). Cost estimates were evaluated for a total of sixty possible combinations of one or two of these alternatives.

Cost estimates for the new reservoir alternatives include six categories:

- Costs for the construction of the dam embankment and spillway
- Real estate costs
- Costs for relocations of facilities that would be inundated by the new (or larger) reservoir such as roads, bridges, pipelines, cemeteries, etc. ("Conflicts")
- Other reservoir costs such as engineering support, permitting, and mitigation
- Costs for the infrastructure (pipelines and pump stations) to transmit raw water from the newly-developed source to the users
- Annual Operation and Maintenance costs for the reservoir and transmission infrastructure, including pumping costs

Wright Patman Lake reallocation scenarios are estimated separately due to their unique cost structure. Cost estimates were developed for three reallocation scenarios:

- Top of Conservation pool at a year-round elevation of 232.5 feet-NGVD
- Top of Conservation pool at a year-round elevation of 242.5 feet-NGVD
- Top of Conservation pool at a year-round elevation of 252.5 feet-NGVD

Costs include a 30 % allowance to cover engineering and contingencies for pipelines and a 35 % allowance to cover engineering and contingencies for other facilities, such as pump stations, dams, and reservoir conflicts. Real estate costs include a 25% contingency.

Spillway/embankment costs for the new reservoir alternatives range from approximately $157 million to over $890 million. Not surprisingly, these costs are determined largely by the scale of the project, with alternatives yielding less than 200,000 acre-feet per year on the low end of the range, and alternatives yielding over 1,000,000 acre-feet per year on the high end of the range. Estimates for conflict resolution vary widely between alternatives, ranging from a low of approximately $25 million for the Marvin Nichols 296.5 alternative, to a high of almost $250 million for the larger Talco alternative. Conflicts costs as a percentage of embankment and spillway cost range from 14% to as much as 68%.

Transmission costs dominate the total cost effort for all alternatives and economies of scale are largely absent. For even the smallest alternative (George Parkhouse II), the estimated cost of the transmission system is more than two times the estimate of the reservoir cost. For larger alternatives with greater transmission distances, estimated transmission costs approach three to four times the current estimate of the reservoir cost. Transmission costs are particularly sensitive to the distance pumped. For example, both the Wright Patman 242.5 reallocation and the Marvin Nichols 328 alternatives yield approximately 600,000 acre-feet per year. However, the transmission costs for the Wright Patman alternative, which is farther from the Dallas-Fort Worth area where much of the water would be used, are estimated at $4.1 billion in contrast to $3.2 billion for the Marvin Nichols alternative. This difference is significantly greater than the estimated cost of the reservoir construction.

Operation and Maintenance costs are estimated as a function of reservoir and pipeline scale and vary directly with the size of the project. They also vary with the length of the transmission system. Power generation emissions dominate the carbon footprint analysis, comprising 81% of the carbon footprint on the average. Almost all the variation in carbon footprint between alternatives is determined by the scale of the project (i.e., the amount of water being transported) and/or the length of the transmission system required.

Total capital costs range from $1.2 billion to over $10 billion. Not surprisingly, the variation is largely explained by the scale (yield) of the project and the distance water must be transported.

Annual costs, comprised of the debt service on the reservoir and transmission components of the project, the estimated Operations and Maintenance costs for both the reservoir and transmission components of the project, and the pumping costs, range from $98.4 million to $769 million.

Unit costs of water were estimated based both on 100% of the predicted yield and on the yields net of predicted eFlow requirements developed using the Lyons approach. Conclusions relative to the most cost-effective alternatives based on unit costs are highly dependent on whether one focuses on unit costs during or after debt service and on eFlow predictions. The preliminary assessment of likely eFlow requirements are substantially higher on a percentage basis for Wright Patman reallocation alternatives than for the new reservoir alternatives. This is primarily a result of conservative assumptions necessitated by lack of available stream gage data prior to construction of Wright Patman.

Comparison of alternatives for cost-effectiveness focuses on the subgroup of projects that yield between 500,000 and 1,000,000 acre-feet per year (29 alternatives). Four of those alternatives include the Talco Configuration 2 components, which appear to be suspect in terms of cost-efficiency. Unit costs for the remaining 25 alternatives range from $599.25 per acre-foot to $733.37 per acre-foot during debt service, or from $146.87 per acre-foot to $189.27 per acre-foot after debt service. Within this range, the most cost effective group of alternatives is comprised of some combination of the following components:

- Marvin Nichols 328
- Marvin Nichols 313.5
- Wright Patman 232.5
- Wright Patman 242.5
- Talco 350 – Configuration 1
- Talco 370 – Configuration 1
- Parkhouse I
- Parkhouse II

The only stand-alone alternative appearing in the select group is Marvin Nichols 328, and the two Parkhouse alternatives appear only in combination with Marvin Nichols 328 or 313.5. None of the Talco Configuration 2, Wright Patman 252.5 (largest) or Marvin Nichols 296.5 (smallest) made it into this most cost effective subset. In general, the larger Marvin Nichols scales, the smaller Wright Patman scale and the Talco Configuration 1 alternatives appear to merit further consideration, at least on the basis of unit costs.

1.0 INTRODUCTION

The Sulphur Basin Group (SBG) has been hired by the Sulphur River Basin Authority (SRBA) to develop components of the overall cost estimates for four alternative reservoir sites in the Sulphur River Basin and for a potential reallocation project at Wright Patman Lake. Several of the alternatives have more than one scale/size or configuration. These cost components are to be combined with cost estimates previously developed by or for the Fort Worth District, U.S. Army Corps of Engineers (USACE) to develop comprehensive cost estimates for these alternatives as well as for combinations of alternatives. It is anticipated that one or more preferred alternatives will provide a future water supply source for members of the Joint Committee for Program Development (JCPD), which includes Tarrant Regional Water District (TRWD), Dallas Water Utilities (DWU), North Texas Municipal Water District (NTMWD), Upper Trinity Regional Water District (UTRWD), and the City of Irving, along with in-basin users represented by the Sulphur River Basin Authority (SRBA).

The alternative reservoirs that were evaluated in this study include a reservoir at the George Parkhouse I, George Parkhouse II, Marvin Nichols 1A, and Talco sites. The Talco site has been previously evaluated as the Marvin Nichols IIA site. Each alternative is depicted in Figure 1-1. Multiple sizes for reservoirs are evaluated at the Marvin Nichols site (3) and the Talco sites (2). The Talco site is also evaluated in two configurations – as a standalone reservoir on White Oak Creek (Configuration 1) and as a reservoir on White Oak Creek with diversions from the Sulphur River to “scalp” flood flows (Configuration 2). These configurations of the Talco alternative are shown in Figure 1-2.

Wright Patman Lake is an existing flood control lake located on the Sulphur River in Bowie and Cass Counties, Texas. The top of Wright Patman Dam is at elevation 286 feet-NGVD. In terms of normal operations, elevation 259.5 feet-NGVD is considered the top of the flood control pool. At this elevation, Wright Patman Lake would have a cumulative storage capacity of 2,659,000 acre-feet. The top of conservation pool under the existing storage contract with the City of Texarkana, Texas ranges from an elevation of 220.6 feet-NGVD to 227.5 feet-NGVD depending on the time of year. Theoretically, reallocation of almost any portion of the flood storage is possible. For purposes of this analysis, cost estimates were developed for three reallocation scenarios:

- Top of Conservation pool at a year-round elevation of 232.5 feet-NGVD
- Top of Conservation pool at a year-round elevation of 242.5 feet-NGVD
- Top of Conservation pool at a year-round elevation of 252.5 feet-NGVD

Figure 1-1 Alternative Reservoir Sites

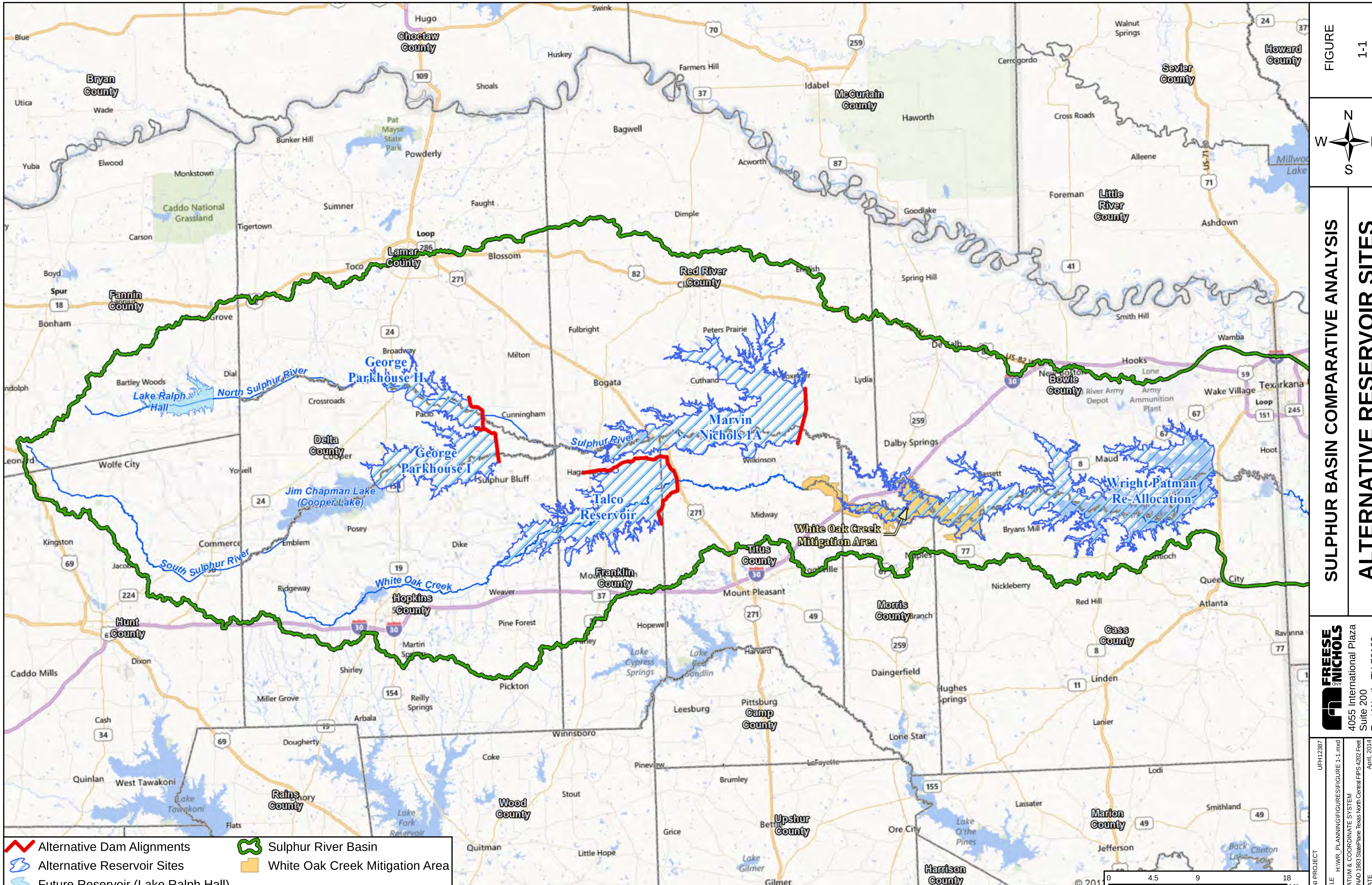
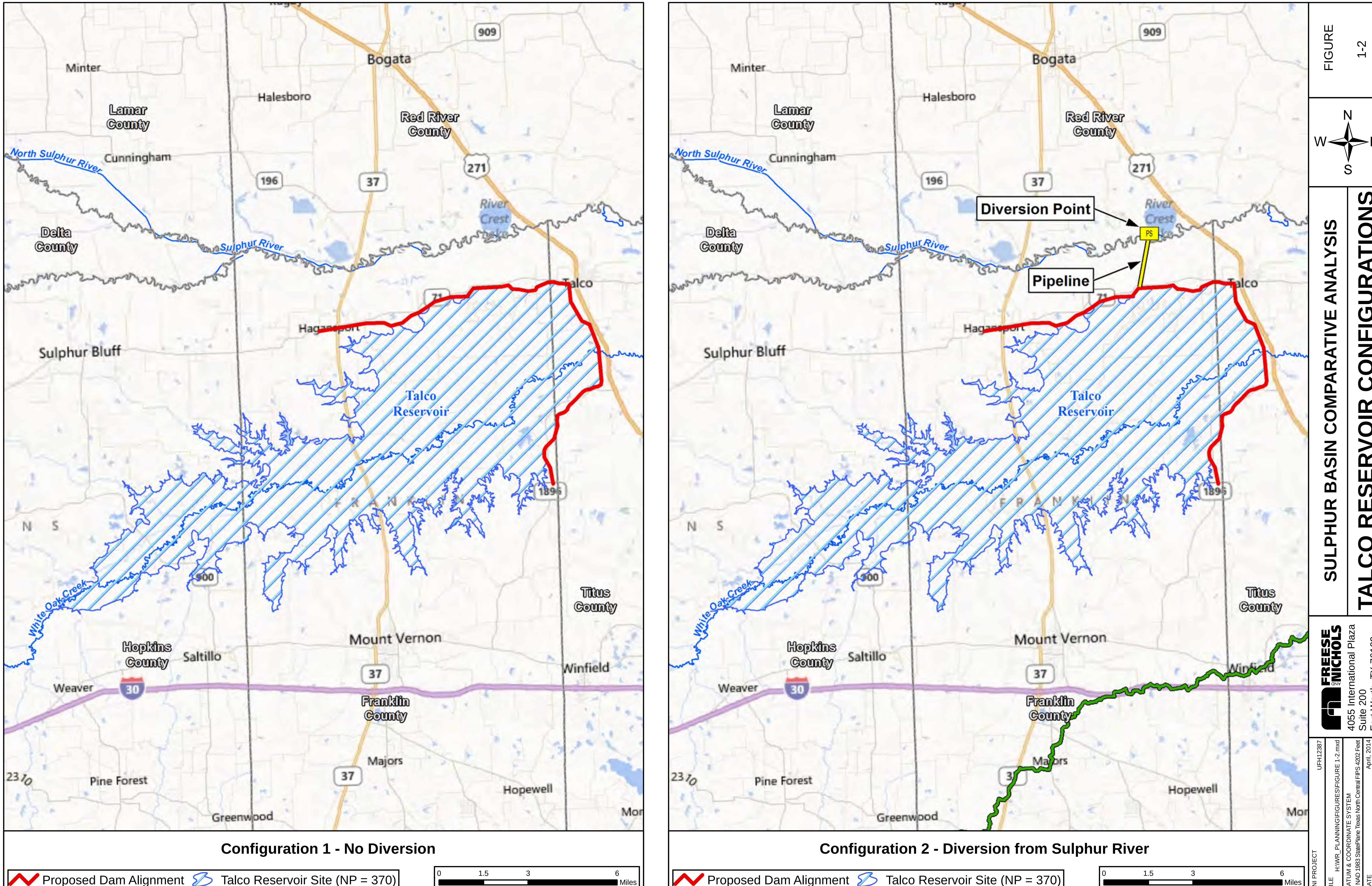


Figure 1-2 Talco Reservoir Configurations



A total of twelve individual alternatives have been evaluated in this analysis. These alternatives are listed in Table 1-1, showing the proposed Conservation Pool elevation and estimated total yield, along with a brief description of the rationale for selecting the particular scale considered. The Reservoir Site Protection Study referenced in Table 1-1 was produced in 2008 by the Texas Water Development Board as a statewide assessment of feasible reservoir sites (see References for additional information).

Table 1-1 Reservoir Alternatives Evaluated

Reservoir Alternative	Conservation Pool (feet-NGVD)	Estimated Total Yield (acre-ft/yr)	Comments
Wright Patman (Re-Allocation)	232.5	281,000	Smallest pool size that provides significant increase in yield
Wright Patman (Re-Allocation)	242.5	592,700	Generally equivalent to scale of MN1A 328
Wright Patman (Re-Allocation)	252.5	854,400	Approximates target total yield for basin (after eFlows)
Marvin Nichols 1A	296.5	200,000	Scale set to provide approximately 200,000 acre-ft/yr yield
Marvin Nichols 1A	313.5	400,000	Scale set to provide approximately 400,000 acre-ft/yr yield
Marvin Nichols 1A	328.0	590,000	Scale from Site Protection Study (2008)
Talco Reservoir (Configuration 1)	350.0	169,600	Approximates original MNIIA scale
Talco Reservoir (Configuration 2)	350.0	217,100	Includes 1,000 cfs scalping flows from Sulphur River
Talco Reservoir (Configuration 1)	370.0	265,100	Largest scale practicable at Talco site (FNI, 2013)
Talco Reservoir (Configuration 2)	370.0	382,800	Includes 2,000 cfs scalping flows from Sulphur River
George Parkhouse I	401.0	124,300	Scale from Site Protection Study (2008)
George Parkhouse II	410.0	124,200	Scale from Site Protection Study (2008)

Reservoir alternatives being evaluated as part of this study may be implemented individually or in combination, with a limit of two reservoirs in combination. However, all combinations of Marvin Nichols 1A (at any scale) with Talco, Configuration 2 (scalping from Sulphur River) were eliminated from consideration because the Talco diversion would actually be located within the Marvin Nichols reservoir. Pumping water from one impoundment to another provides no additional yield, at least in this case. Considering all other combinations results in a total of 60 possible alternatives — twelve standalone alternatives and 48 combination alternatives.

For the purposes of this evaluation, costs for the embankment and spillway components (capital and Operation and Maintenance), as well as the reservoir conflict costs, land costs and mitigation/permitting costs, were considered as the sum of these costs of the individual components. However, for the transmission system costs (including transmission Operation and Maintenance costs) and the carbon footprint analysis, the costs are not simply additive. Therefore, these costs were individually evaluated for all potential combination alternatives.

Cost estimates have been developed in six categories:

- Costs for the construction of the dam embankment and spillway
- Costs for relocations of facilities that would be inundated by the new (or larger) reservoir such as roads, bridges, pipelines, cemeteries, etc. ("Conflicts")
- Costs for the infrastructure (pipeline and pump stations) to transmit raw water from the newly-developed source to the users
- Annual Operation and Maintenance costs for the reservoir and transmission infrastructure, including pumping costs
- "Soft Costs" which includes Design, Engineering support during Construction, and permitting costs
- Land and mitigation costs

The costs include a 30 % allowance to cover engineering and contingencies for pipelines and a 35 % allowance to cover engineering and contingencies for other facilities, such as pump stations, dams, and reservoir conflicts. This report also includes an assessment of the carbon footprint associated with each alternative.

2.0 EMBANKMENT AND SPILLWAY COST ESTIMATES

A preliminary design and cost estimate has been developed for each of the alternative reservoir sites and conservation storage capacities. The design concept calls for the construction of a zoned earthen embankment dam with a gated concrete overflow spillway. With respect to the embankment and spillway, the two Talco configurations (with pumping and without) are identical. Wright Patman Lake is existing, and construction of a new embankment and/or spillway is not required. (Wright Patman reallocations do require other unique construction costs, which are discussed in the next chapter). These factors reduce the number of alternatives requiring cost estimates from the twelve alternatives shown in Table 1-1 to seven alternatives.

Embankment and spillway sizing was determined by incorporating geotechnical information, hydrologic modeling of the design storm for the upstream watershed, and hydraulic considerations of the spillway. All assumptions related to the geotechnical features of the dam and spillway were made from a desktop review of available geologic maps. No field borings were made as part of this analysis. Hydrologic modeling was performed using a combined HEC-HMS and HEC-RAS model for the Sulphur River Basin. The Probable Maximum Flood (PMF) requirements were established and modeled according to the regulations of the Texas Commission on Environmental Quality (TCEQ). (Note: These alternatives are conceptualized as water supply reservoirs only and do not include dedicated flood storage.) Wave runup calculations for freeboard were performed based on the U.S. Army Corps of Engineers (USACE) procedures. Hydraulic calculations were also performed for the shape and sizing of the ogee spillway crest, the discharge chute, and the stilling basin.

2.1 DESIGN STORM ANALYSIS

The PMF is defined as the greatest flood to be expected assuming complete coincidence of all factors that would produce the heaviest rainfall and maximum runoff. The Probable Maximum Precipitation (PMP) is theoretically the greatest depth of rainfall for a given duration that is physically possible over a given size storm area at a particular geographic location. The PMF model runs utilized HEC-HMS to generate runoff hydrographs for the subbasins contributing to each reservoir. HEC-RAS was used to route these hydrographs through the various stream reaches and the proposed reservoir with each given spillway configuration. The combined HEC-HMS and HEC-RAS models were adapted from a previous study of the Sulphur River Basin performed by FNI in June 2008.

Hydrometeorological Report No. 52 (HMR-52), developed by the U.S. Army Corps of Engineers, was used to determine the rainfall for each basin. PMP estimates were taken from Hydrometeorological Report No. 51 and distributed according to HMR-52 to obtain average rainfall depths over the various drainage areas. HMR-52 calculates rainfall depths for storm durations ranging from five minutes to seventy-two hours.

In January 2007, TCEQ released its Hydrologic and Hydraulic Guidelines for Dams in Texas. Through analysis of historical storm events in Texas, TCEQ has determined that a "front-end loaded" temporal distribution is more applicable to the type of storm event experienced across the state. This method places the greatest rainfall intensities at the beginning of the storm with the remainder of the rainfall tapering off toward the end of the storm. The modified analysis removes some of the conservatism associated with the temporal distribution. The modified distribution assumes the same depths found using the traditional PMP method but distributes these depths differently over the storm duration. The rainfall and time percentages are specified by TCEQ and vary according to the duration of the storm.

2.2 FREEBOARD CONSIDERATIONS

Each of the proposed reservoir alternatives was designed to maintain sufficient freeboard between the PMF elevation and the maximum embankment elevation. Wave runup calculations were performed for both Conservation Pool and PMF conditions at each reservoir location. This process involved determining the effective fetch length for each reservoir configuration, along with the design wind speed and duration, which are based on historical data and determined for the given fetch length. This process, along with the applicable charts and tables, is defined in the USACE Engineering Technical Letter 1110-2-221. This process produces the design wave height to calculate the wave runup, which is combined with the wind setup calculated from the average reservoir depth to obtain the total wave runup.

The calculated freeboard for each reservoir was then used to set an initial embankment height and subsequently the target PMF elevation. During the spillway sizing process, this target PMF elevation was the basis for the initial spillway gate configuration. In general, the initial assumptions were that the top of dam elevation would be set at the Conservation Pool elevation plus the Conservation Pool freeboard. Then, the target PMF elevation was set as the top of dam minus the PMF freeboard. An example calculation is shown below for the Marvin Nichols 1A, 328 alternative.

> Top of Dam = 328 feet-NGVD (Conservation Pool) + 14.4 feet (TCP Freeboard) = 342.4 feet-NGVD

Target PMF = 342.4 feet-NGVD (Top of Dam) – 7.1 (PMF Freeboard) = 335.3 feet-NGVD

For this alternative, the top of dam was rounded up to 343 feet-NGVD, and the final PMF elevation was calculated as 335 feet-NGVD. The embankment has sufficient height for a major wind event under Conservation Pool conditions, as well as the anticipated wave action during an extreme flood event, such as the PMF.

Adjustments to this rationale were allowed when the number of spillway gates became unreasonable or where an obvious cost savings was apparent. Detailed optimizations for each configuration were not performed due to the conceptual nature of this study.

2.3 SPILLWAY HYDRAULICS

The dimensions and configuration of the gated spillway was determined based on hydraulic calculations using methods from the U.S. Bureau of Reclamation publication, Design of Small Dams. The shape of the ogee spillway crest was determined from standard design charts based on design head and approach depth. The design head was set as the vertical distance from the spillway crest to the target PMF elevation. The crest elevation was set based on the selected spillway gate size, and the approach depth was determined based on generalized assumptions regarding the depth to competent foundation material. Limited iterations were necessary on a few alternatives to accommodate changes to the PMF elevation, the selected gate size, or the approach depth.

The chute slope downstream of the ogee crest was set to 1%, with a 3:1 slope transition from the chute into the stilling basin. Froude number calculations were performed at various reservoir elevations and spillway discharge values, accounting for spillway width and expected tailwater elevations. The goal was to design the stilling basin depth and length to produce and contain a hydraulic jump to dissipate energy before the flow reaches the discharge channel. The slope of the discharge channel downstream of the stilling basin ranged from 0.2% to 0.3% in order to transition flows to the approximate grade of the natural channel downstream.

The minimum height of the training walls on either side of the spillway from the ogee crest through the stilling basin area was calculated using Manning's equation to calculate depth of flow. PMF discharges were used for this calculation, and two feet were added to the normal depth for the minimum wall height. The walls were set at either the minimum height or the PMF tailwater elevation, whichever was higher.

2.4 EMBANKMENT AND SPILLWAY CONFIGURATION

The various quantities associated with these cost estimates are based on the embankment and spillway sizing processes and determined using available LiDAR topography data, aerial imagery, and geologic data. Quantities were calculated using a basic spreadsheet method. No three dimensional modeling of the proposed structures was performed. Unit costs were based on FNI experience and recent projects. Some of these costs were established based on ratios accounting for changes in scale or increases to account for inflation. Additional information is provided in Appendix A, Embankment and Spillway Technical Memorandum.

The following table provides the proposed embankment configurations for each reservoir alternative, including the Conservation Pool, PMF, and Top of Dam elevations.

Table 2-1 Embankment Elevations and Sizing

Reservoir Alternative	Conservation Pool (feet-NGVD)	PMF Elevation (feet-NGVD)	Top of Dam (feet-NGVD)	Maximum Height (feet)	Embankment Length (feet)
Marvin Nichols 1A	296.5	319.3	325.0	63	25,720
Marvin Nichols 1A	313.5	319.5	332.0	70	45,250
Marvin Nichols 1A	328	335.5	343.0	81	69,240
Talco Reservoir	350	355.9	362.0	72	40,680
Talco Reservoir	370	376.5	384.0	94	88,290
George Parkhouse I	401	407.0	413.0	71	23,690
George Parkhouse II	410	424.5	430.0	88	37,800

The following figures are provided for conceptual reference as to the configuration of the dam embankment and gated spillways. The figures are not to scale and are intended for reference purposes only. Specific details related to the geometry of each feature are provided in the individual line item cost descriptions contained in Appendix A.

Figure 2-1 depicts a typical embankment section, noting the various embankment zones and the soil cement liner along the upstream slope. Figure 2-2 represents the existing ground profile for a typical example, the George Parkhouse I reservoir site, which was developed along the dam alignment from available LiDAR topography data. The embankment profile was utilized in determining quantities for several line items. The embankment height from existing ground to the top of dam elevation was a key component in these calculations. Figures 2-5 through 2-12 at the end of this chapter represent the elevation profiles for the embankments of each reservoir site. Note that some alternatives are separated out between the main dam and saddle dam segments.

Figure 2-3 represents a typical cross section through the spillway, noting the ogee crest, Tainter gates, training walls, approach channel, and spillway bridge. Figure 2-4 shows the spillway profile for one of the Marvin Nichols 1A reservoir alternatives with the existing ground centerline and left and right offset profiles. Structural features including the ogee crest, spillway abutments, training walls, stilling basin, and approach and discharge channel are shown. The existing ground profiles were utilized for several line items, accounting for elevation variations by weighting the centerline profile with the left and right offset profiles. Figures 2-13 through 2-19 at the end of this chapter represent the spillway cross sections for each reservoir alternative.

Figure 2-1 Typical Dam Embankment Section

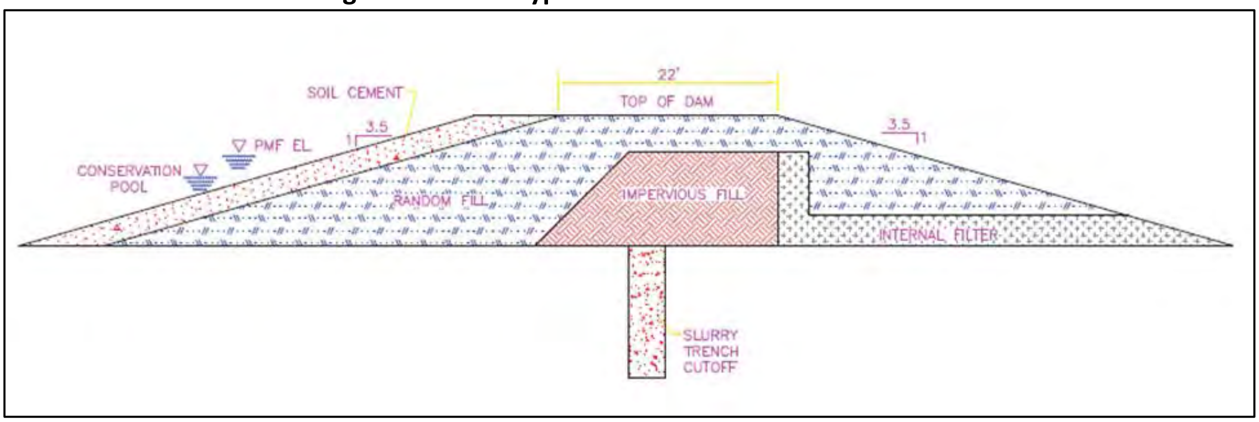


Figure 2-2 Typical Embankment Profile

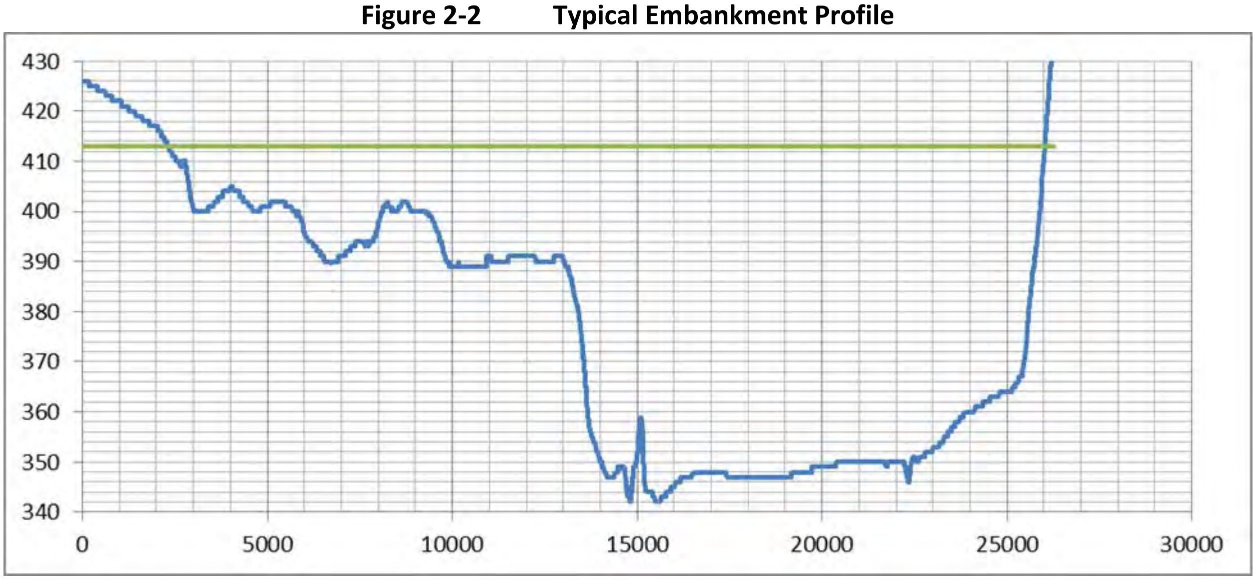


Figure 2-3 Typical Spillway Section

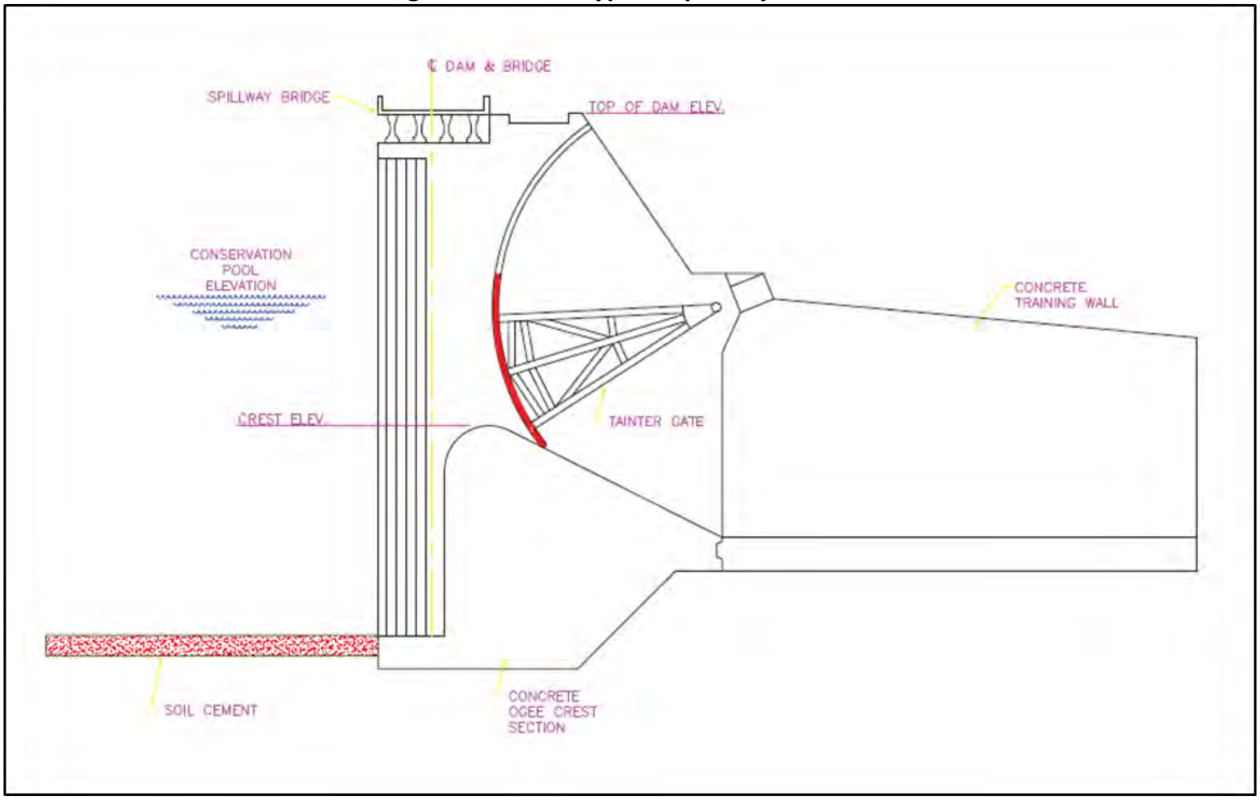
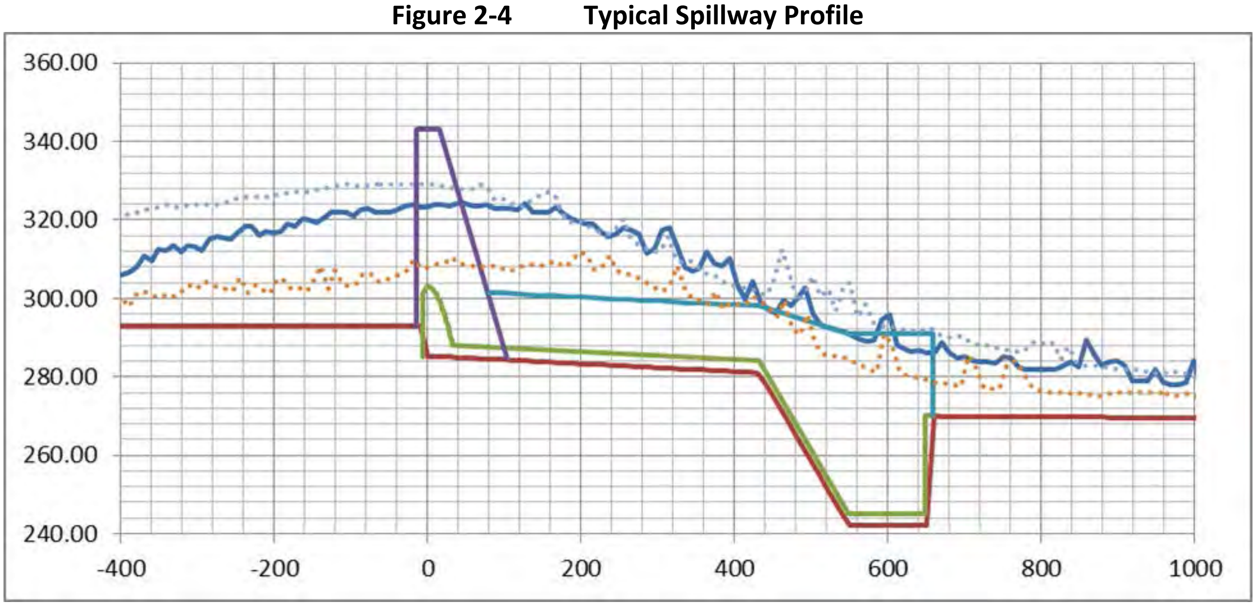


Figure 2-4 Typical Spillway Profile



2.5 GATED SPILLWAY DESIGN

The design concept for the reservoir alternatives is based on a gated spillway approach in order to maintain consistency among the proposed alternatives. As water supply reservoirs, these proposed alternatives are not intended to provide additional flood storage, which would require a significantly taller dam embankment. Also, a gated spillway provides greater discharge capacity than an uncontrolled spillway, which also reduces the required embankment height.

The Marvin Nichols 1A, 296.5 alternative was designed as an un-gated spillway because of several topographic and hydraulic concerns regarding the feasibility of a gated spillway. The smallest gate size considered was 30 feet wide by 20 feet tall. With gates this size, the spillway crest would need to be set at elevation 281.5 feet-NGVD. The average floodplain elevation downstream of the dam is approximately 275 feet-NGVD, which would not provide enough vertical distance to transition from the ogee crest to the stilling basin and back up to a discharge channel. Also, the PMF tailwater elevation is approximately 293.1 feet-NGVD, which would be well above the spillway crest, significantly limiting the discharge capacity. Therefore, a spillway crest at 281.5 feet-NGVD was deemed infeasible, and the proposed crest was raised to the conservation pool elevation of 296.5 feet-NGVD. At this elevation, an uncontrolled spillway is required.

The number and size of the large Tainter gates that will operate the spillway and control reservoir elevations were determined by both fitting the spillway in the natural topography and hydrologic modeling of the PMF requirements. Table 2-2 below summarizes the selected gate configuration for each reservoir alternative. No detailed structural design of the gates was performed.

Table 2-2 Spillway Gates and Preliminary Sizing

Reservoir Alternative	Conservation Pool (feet-NGVD)	Number of Gates	Height (feet)	Width (feet)	Total Spillway Width (feet)
Marvin Nichols 1A	296.5	0	---	---	900
Marvin Nichols 1A	313.5	20	20	30	752
Marvin Nichols 1A	328	10	30	40	490
Talco Reservoir	350	5	30	40	240
Talco Reservoir	370	4	30	40	190
George Parkhouse I	401	8	20	30	296
George Parkhouse II	410	8	20	30	296

2.6 SUMMARY OF EMBANKMENT AND SPILLWAY COSTS

The total cost for constructing the embankment and spillway components of each of the reservoir alternatives is summarized in Table 2-3 below. Individual cost estimates for each reservoir alternative are provided in Appendix A, along with a detailed explanation of each line item. Table 2-4 is provided as an example of the cost estimate from the Marvin Nichols 1A, 328 alternative. The line items shown in this table are representative of the other embankment and spillway estimates. Engineering services (design and construction phases) and contingencies are included at 35% of the estimated embankment and spillway cost; other key assumptions are documented in Appendix A.

As discussed in the introduction, forty-eight possible combination alternatives could be developed from the suite of stand-alone alternatives. For the purposes of this evaluation, costs for the embankment and spillway components of the combination alternatives were the sum of the costs of the individual components.

Table 2-3 Summary of Embankment and Spillway Cost Estimates

Reservoir Alternative	Conservation Pool Elevation (feet-NGVD)	Embankment & Spillway Cost	Engineering & Contingencies (35%)	Total Cost
Marvin Nichols 1A	296.5	$131,242,000	$45,934,700	$177,176,700
Marvin Nichols 1A	313.5	$174,832,000	$61,191,200	$236,023,200
Marvin Nichols 1A	328	$225,770,000	$79,019,500	$304,789,500
Talco Reservoir	350	$116,134,000	$40,646,900	$156,780,900
Talco Reservoir	370	$273,706,000	$95,797,100	$369,503,100
George Parkhouse I	401	$139,701,000	$48,895,350	$188,596,350
George Parkhouse II	410	$156,044,000	$54,615,400	$210,659,400

Table 2-4 Embankment and Spillway Cost Estimate – Marvin Nichols 1A (NP=328)

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Embankment and Spillway					
1	Mobilization	1	LS	$10,751,000.00	$10,751,000
2	Clearing and Grubbing	370	AC	$7,500.00	$2,775,000
3	Care of Water During Construction	1	LS	$2,102,000.00	$2,102,000
4	Excavation	1,042,300	CY	$3.00	$3,127,000
5	Fill (Core Compacted)	1,880,400	CY	$7.50	$14,103,000
6	Fill (Random Compacted)	8,689,300	CY	$7.00	$60,826,000
7	Soil Bentonite Slurry Trench	1,662,800	SF	$12.00	$19,954,000
8	Soil Cement	466,000	CY	$75.00	$34,950,000
9	Flex Road Base	35,100	CY	$60.00	$2,106,000
10	Sand Filter Drain	627,100	CY	$35.00	$21,949,000
11	Grassing	180	AC	$3,630.00	$654,000
12	Reinforced Concrete (Mass)	48,400	CY	$450.00	$21,780,000
13	Reinforced Concrete (Piers & Walls)	12,400	CY	$750.00	$9,300,000
14	Roller Compacted Concrete (RCC)	36,400	CY	$90.00	$3,276,000
15	Bridge (over Spillway)	9,800	SF	$50.00	$490,000
16	Bridge (to Outlet Works)	4,800	SF	$90.00	$432,000
17	Gates, Including Anchoring System	12,000	SF	$700.00	$8,400,000
18	Gate Hoist and Operating System	10	EA	$215,000.00	$2,150,000
19	Stop Gate and Lift Beam	8	EA	$67,000.00	$536,000
20	Low-Flow Outlet	1	LS	$3,622,000.00	$3,622,000
21	Barrier and Warning System	1	LS	$327,000.00	$327,000
22	Embankment Instrumentation	1	LS	$1,800,000.00	$1,800,000
23	Miscellaneous Internal Drainage	1	LS	$360,000.00	$360,000
				EMBANKMENT & SPILLWAY SUBTOTAL	**$225,770,000**
				ENGINEERING SERVICE & CONTIGENCY - 35%	**$79,020,000**
				EMBANKMENT & SPILLWAY TOTAL	**$304,790,000**

3.0 WRIGHT PATMAN REALLOCATION COSTS

3.1 OVERVIEW

Many Corps of Engineers reservoirs, including Wright Patman Lake, contain storage dedicated to municipal and industrial water supply. While this is not considered a "Federal" purpose, being viewed by the Corps as a state or local responsibility, the Corps can integrate water supply in reservoirs justified by Federal purposes such as navigation or hydropower. A non-Federal Sponsor is required to pay 100% of the marginal costs of reservoir construction associated with increasing reservoir size to accommodate conservation storage as well as a portion of the joint reservoir operations costs in return for a permanent right to a specified amount of storage in the reservoir. In a number of cases, the non-Federal Sponsor has requested an enlargement of their storage space within a Corps reservoir, generally displacing either flood protection or hydropower storage. This action, allowed under certain circumstances, is called a storage reallocation.

Wright Patman Lake is an existing Corps of Engineers reservoir, constructed in the late 1940's. Its authorized purposes include flood control, recreation, and water supply. The flood control pool at Wright Patman Lake is that portion of the impoundment from the top of the conservation pool, which currently ranges from elevation 220.6 to 227.0 feet NGVD (depending on the time of year), to elevation 259.5 feet NGVD. It contains over 2,000,000 acre-feet of storage volume. Theoretically, reallocation of almost any portion of this flood storage is possible. Earlier studies have estimated the potential new yield that could be developed from a variety of reallocation scenarios ranging from a very small reallocation, just slightly higher than the top of the Ultimate rule curve, to full reallocation of the flood pool to water supply storage (top of conservation pool at 259.5 feet NGVD). The largest reallocation evaluated generates a dependable yield of over 1,000,000 feet per year – a significantly higher yield than the identified long term water need for project participants. As a result, the range of reallocation scenarios studied in more detail was truncated at elevation 252.5 feet NGVD.

For purposes of this report, cost estimates were fully developed for three scenarios – a "small" reallocation yielding approximately 281,000 acre-feet per year (top of conservation pool at elevation 232.5 feet NGVD), a "medium" reallocation yielding approximately 593,000 acre-feet per year (top of conservation pool at elevation 242.5 feet NGVD), and a "large" reallocation yielding approximately 854,000 acre-feet per year (top of conservation pool at 252.5 feet NGVD).

While the cost estimates for these scenarios, by definition, do not include construction of a new embankment or spillway, other costs which are unique to the reallocation approach must be estimated. These costs generally fall into three categories, including required dam safety modifications, recreation facility relocations, and increased cost of storage. For this study, costs associated with Wright Patman Lake reallocation scenarios were developed by the Corps of Engineers and are discussed in more detail below.

3.2 DAM SAFETY MODIFICATIONS

In 2005, the Corps began an initiative to prioritize Corps-maintained and operated dams nationwide based on the risk presented. The Screening Portfolio Risk Analysis performed considered both project performance and the anticipated consequences of failure. Wright Patman Dam was screened in 2007, and as a result of this screening, was placed in Dam Safety Action (DSAC) Category III, High Priority. Projects in this classification have issues where the dam is significantly inadequate or the combination of life, economic, or environmental consequences with probability of failure is moderate to high. Current Corps policy, as defined in EC 1165-2-210, "Water Supply Storage and Risk Reduction Measures for Dam Safety," is that a reallocation that would require raising the conservation pool is not permitted while a project is classified DSAC I, II, or III.

Funds were received by the Fort Worth District in Fiscal Year 2012 to conduct a seepage study which would provide more detailed information than was utilized in the 2007 screening and classification of Wright Patman Dam. This study was completed in early 2014. In addition, during the spring of 2014, the Corps conducted a formal Periodic Assessment (PA) of Wright Patman Lake. The purpose of a Periodic Assessment is to review prior work and conduct a thorough on-site evaluation in order to formulate a recommendation with respect to maintaining or modifying the dam safety classification of a reservoir. In the case of Wright Patman Lake, this assessment was originally scheduled to occur in 2017 but was accelerated by the Corps in order to support the Sulphur Basin Feasibility Study.

In late April 2014, a cadre of Dam Safety experts from across the Corps assembled at Wright Patman to conduct the Periodic Assessment. Information from the seepage study, as well as a number of additional evaluations was utilized by the team. The formal results of this PA have not yet been released by the Corps; however, analyses conducted by the PA team provided a substantial body of information which has been used by the local office of the Corps to define the remedial actions which would reduce risk sufficiently that they could support ultimate modification of Wright Patman's Dam Safety Classification.

The Corps identified four type of actions that would likely be needed in order to satisfactorily reduce dam safety risks at Wright Patman Lake. Improvements are needed to the Emergency Action/Emergency Response Plan irrespective of any future activity. The conversion of 120,000 acre-feet of flood control storage to conservation storage authorized with the construction of Jim Chapman Lake (activation of the "ultimate" storage contract with the Corps of Engineers) would be facilitated by the construction of a seepage berm on the immediate downstream side of the embankment with concurrent extension of the existing relief wells. A more robust seepage berm would be expected to be required for a reallocation to elevation 232.5 feet NGVD, while reallocation to elevation 242.5 feet NGVD also requires widening of the emergency spillway in order to pass the design flood with the required level of freeboard. A slightly smaller reallocation (just under 242.5) would most likely not require a spillway modification but would require installation of a parapet wall at a specified location due to concerns related to the original construction circumstances associated with that particular embankment section. Reallocations at the scale of 252.5 would be expected to require a much larger spillway modification in addition to the parapet wall.

Preliminary cost estimates developed by the Corps for the structural measures described above are shown in Table 3-1 below.

Table 3-1 Potential Structural Measures Needed for Possible Future Reallocations

	Berm and Relief Wells	Extended Berm and Relief Wells	Spillway Modification	Parapet Wall	Total (Reallocation Costs only)
Ultimate Rule Curve	$5,000,000	N/A	N/A	N/A	$ 5,000,000
Reallocation 232.5	Not reallocation cost	$ 5,000,000	N/A	N/A	$ 5,000,000
Reallocation just below 242.5	Not reallocation cost	$ 5,000,000	N/A	$ 5,000,000	$ 10,000,000
Reallocation 242.5	Not reallocation cost	$ 5,000,000	$ 25,000,000	$ 10,000,000	$ 40,000,000
Reallocation 252.5	Not reallocation cost	$ 5,000,000	$ 50,000,000	$ 10,000,000	$ 65,000,000

3.3 RECREATION FACILITY RELOCATIONS

Recreation usage is an important consideration at Wright Patman Lake. A number of parks provide access to the water as well as camping and/or day use activities. Parks at Wright Patman Lake potentially affected by reallocation scenarios are shown in Figure 3-1.

Figure 3-1 Park Areas Potentially Impacted By Proposed Pool Rise at Lake Wright Patman

Depending on where specific facilities such as boat ramps, camp sites, and restrooms are currently located, they could be affected by the higher lake levels associated with a reallocation action. The Corps has made an assessment of the recreation facilities potentially affected by each of the three reallocation scenarios and has developed a cost estimate for the relocation or replacement of those facilities. Portions of thirteen parks would be affected as well as a number of roads which provide recreational access to Corps lands not within a developed park. Details of the Corps' estimates are contained in Appendix E, Recreation Facilities. Table 3-2 provides a summary of the costs for each scenario and includes a 20 % contingency factor.

Table 3-2 Estimated Cost of Recreation Facility Relocations

	Cost Estimate		
Facility Name	**Wright Patman 232.5**	**Wright Patman 242.5**	**Wright Patman 252.5**
Rocky Point Park	$1,401,500.00	$4,245,000.00	$19,021,000.00
Piney Point Park	$1,646,500.00	$2,738,575.00	$7,176,775.00
Spillway Park	$0.00	$0.00	$150,000.00
Elliott's Bluff Park	$3,049,750.00	$4,703,750.00	$8,007,750.00
Sportsman Cove	$1,278,125.00	$3,661,125.00	$4,388,125.00
North Shore Park	$1,845,500.00	$5,983,650.00	$7,049,150.00
Clear Springs Park	$2,413,400.00	$6,676,900.00	$10,691,650.00
Malden Campground	$565,600.00	$762,950.00	$7,461,750.00
Malden Day-Use	$46,000.00	$2,936,500.00	$2,936,500.00
Jackson Creek Park	$326,200.00	$457,200.00	$578,200.00
Overcup Park	$236,700.00	$381,200.00	$556,950.00
Herron Creek Park	$1,777,475.00	$1,777,475.00	$1,777,475.00
Thomas Lake Park	$420,000.00	$3,434,800.00	$3,434,800.00
Hunting Access Roads	$19,436,760.00	$29,396,320.00	$31,711,600.00
SUBTOTAL	$34,443,510.00	$67,155,445.00	$104,941,725.00
CONTIGENCY	$6,888,702	$13,431,089	$20,988,345
TOTAL	**$41,332,212**	**$80,586,534**	**$125,930,070**

3.4 COST OF STORAGE

As noted in the introduction, when water supply is added to a Corps reservoir, a non-Federal Sponsor must provide a portion of the reservoir construction costs. The terms of this agreement are specified in a contract between the non-Federal Sponsor and the Corps. Generally, the terms of the contract provide for 30-year or 50-year repayment of the storage costs at an interest rate established legislatively. In addition to the updated cost of storage, non-Federal Sponsors pay a prorated portion of the Corps' annual Operation and Maintenance (O&M) costs.

When a reallocation such as is envisioned at Wright Patman Lake occurs, the proportion of the reservoir's total storage volume dedicated to water supply increases. As a result, the sponsor's share of the reservoir construction and O&M costs increases commensurately. This results in the need to modify the storage contract between the non-Federal Sponsor and the Corps. For purposes of the contract modification, the value of the increased storage is established by Corps policy (ER 1105-2-100) as the highest of the following calculated values:

- The value of benefits (generally flood protection) foregone
- Revenues foregone (revenues lost to the Treasury as a result of reduced hydropower production)
- Estimated replacement costs of the storage
- Updated costs of the storage (initial construction costs updated to current values using the Corps of Engineers Civil Works Construction Cost Index System)

For Wright Patman Lake, analyses conducted by the Corps indicate that the updated cost of the initial storage is the appropriate metric for assessing the cost of storage for a Wright Patman reallocation. Because the proportion of the total reservoir costs attributable to the water supply purpose increases as the reallocation increases in size, as shown in Table 3-3, storage costs for a large reallocation can be substantially higher than for a smaller reallocation.

Table 3-3 Reallocated Storage Volume

Reallocation Alternative	Elevation (feet-NGVD)	Daily Average Storage Volume (acre-feet)	Reallocated Storage (Alternative Storage – Rule Curve Storage)	
			Interim Rule Curve	Ultimate Rule Curve
Avg Daily Elevation (Interim Rule Curve)	223.41	157,298		
Avg Daily Elevation (Ultimate Rule Curve)	226.56	237,660		
Alternative 1	232.50	457,770	300,342	220,110
Alternative 2	242.50	1,006,395	849,097	768,735
Alternative 3	252.50	1,816,145	1,658,847	1,578,485
Top of Flood Pool	259.50	2,571,4700		

The Corps' preliminary estimates for the storage costs for each of the reallocation scenarios were calculated using the approach described below and are shown in Table 3-4 below.

Table 3-4 Cost of Reallocated Storage under Interim and Ultimate Rule Curves

Reallocation Alternative	Interim Rule Curve		Ultimate Rule Curve	
	Reallocated Storage	Updated Cost of Reallocated Storage	Reallocated Storage	Updated Cost of Reallocated Storage
Alt. 1 (232.5 ft)	300,472	$62,892,386	220,110	$46,071,739
Alt. 2 (242.5 ft)	849,097	$177,726,127	768,735	$160,905,480
Alt. 3 (252.5 ft)	1,658,847	$347,216,437	1,578,485	$330,395,791

Note that the costs also vary depending on whether the volume being reallocated is compared to the Interim Rule curve or the Ultimate Rule curve. Based on guidance from the Corps, the estimates using the Ultimate Rule curve as the baseline have been carried forward in this analysis.

3.5 SUMMARY

The dam safety modifications, recreation facility relocations, and storage costs discussed above represent costs which are integral to a reallocation at Wright Patman Lake and must be included in project cost estimates for those alternatives. Note that these cost elements are unique to the reallocation approach and do not apply to the new reservoir alternatives. The total of these costs for each reallocation scenario are shown in Table 3-5 below.

Table 3-5 Wright Patman Reallocation Costs.

Cost Element	232.5 Reallocation	242.5 Reallocation	252.5 Reallocation
Dam Safety	$ 5,000,000	$ 40,000,000	$ 65,000,000
Recreation Facility Relocations	$ 41,332,212	$ 80,586,534	$ 125,930,070
Cost of Storage	$ 46,071,739	$ 160,905,480	$ 330,395,791
Total	**$ 92,403,951**	**$ 281,492,014**	**$ 521,325,861**

4.0 REAL ESTATE COSTS

Project cost estimates must include the real estate needed to construct the project. This section focuses on the real estate associated with the reservoir itself; costs for pipeline right-of-ways are addressed in Chapter 7, Transmission Costs. For the new reservoir alternatives, cost estimates were developed by SBG under this task order, while real estate costs associated with Wright Patman reallocations were developed by the Corps. Cost estimates discussed below do not include estimates for appraisal, title search, negotiations and other costs associated with the acquisition process, simply for the real estate itself. Each alternative is discussed in more detail below.

4.1 NEW RESERVOIR ALTERNATIVES

Estimates were developed for the seven alternatives shown in Table 4-1 below. Contour lines depicting the elevation of each alternative were overlain with digital parcel boundaries from the relevant taxing authority to determine the number of acres and parcels within each footprint. The exception to this methodology was Cass, Morris, and Hopkins County, where no digital land parcel information is available. For those alternatives partially located in Cass, Morris, or Hopkins County, average parcel size from adjacent counties was used to estimate the number of parcels within the relevant reservoir shapefile. Acreage shown below differs slightly from estimates in previous studies due to differences in source data for estimating contour elevation.

Table 4-1 Real Estate Requirements – New Reservoir Alternatives

Reservoir Alternative	Conservation Pool Elevation	Parcels Impacted	Acres Impacted
Talco*	350	707	24,138
Talco*	370	1,487	48,488
Parkhouse I	401	644	30,685
Parkhouse II	410	442	19,092
Marvin Nichols IA	296.5	271	20,256
Marvin Nichols IA	313.5	414	41,722
Marvin Nichols IA	328	875	66,102

* Talco Configurations 1 and 2 are the same; right of way for pipeline addressed in Chapter 7

Several assumptions were key to developing the land cost estimates. For example, if a parcel was partially within the reservoir footprint, the entire tract was included in the land cost. Additionally, average land costs per acre for the counties with digital parcel data were extrapolated to the counties without digital parcel data. Land costs have a 25% contingency added.

Structures within each reservoir footprint were estimated from 2013 ArcGIS aerial photographs. This information was combined with the parcel data, where available, to estimate structure value. An average structure value for each reservoir was developed in this fashion, and this average value was extrapolated to the counties without digital information. Structure values were adjusted by 50% to account for demolition, debris removal, plugging of septic systems and wells, and other contingencies.

Table 4-2 summarizes the estimated real estate costs for the new reservoir alternatives.

Table 4-2 Real Estate Estimates – New Reservoir Alternatives

Reservoir Alternative	Estimated Land Cost	Estimated Structure Cost	Total Real Estate Cost
Talco 350	$ 95,344,000	$ 13,400,000	$ 108,700,000
Talco 370	$ 160,205,000	$ 23,091,000	$ 183,300,000
Parkhouse I	$ 54,234,000	$ 8,303,000	$ 62,500,000
Parkhouse II	$ 16,217,000	$ 4,169,000	$ 20,400,000
Marvin Nichols IA 296.5	$ 39,908,000	$ 2,859,000	$ 42,800,000
Marvin Nichols IA 313.5	$ 69,062,000	$ 3,940,000	$ 73,000,000
Marvin Nichols IA 328	$ 133,822,000	$ 9,067,000	$ 143,000,000

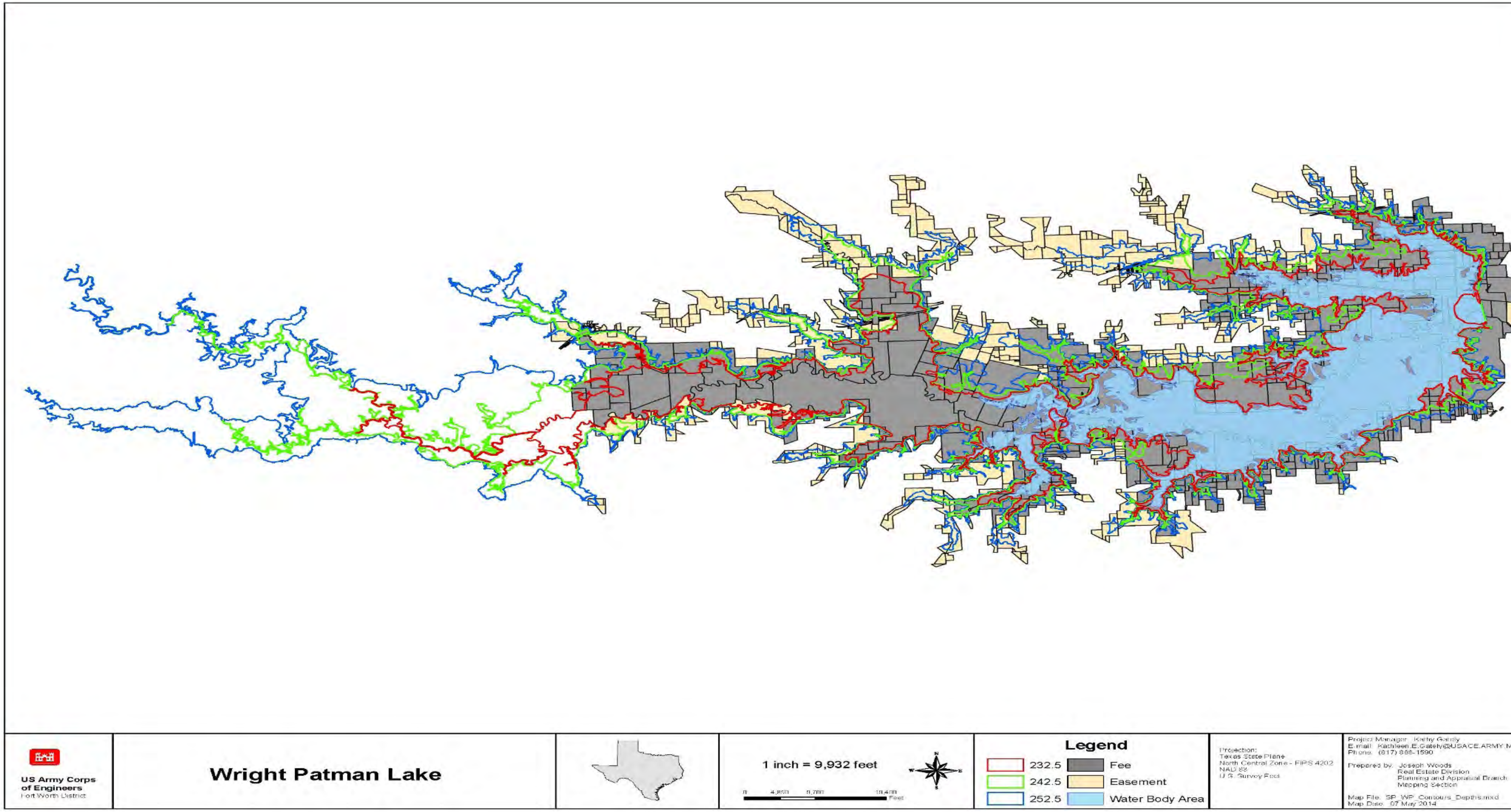
4.2 WRIGHT PATMAN REALLOCATION ALTERNATIVES

Not all of the land within the flood control pool (below elevation 259.5 feet NGVD) at Wright Patman Lake is owned by the Corps of Engineers. At the higher elevations within the flood pool, the Government originally purchased an easement restricting the construction of permanent structures but did not purchase the land, electing instead to leave the land in private ownership. Increasing the elevation of the conservation pool, would in some cases, increase the probability of long-term inundation of easement properties, necessitating a conversion of those easements to a fee title estate by the Government. The Corps of Engineers has estimated the number and extent of easement conversions required for each reallocation scenario. This information is depicted in Figure 4-1. (Note that the area in the upstream portion of the lake as depicted in this figure is the White Oak Creek Mitigation Area, already owned in fee by the Government.) Based on available tax information for Bowie and Cass Counties, estimates of the cost to acquire the fee interest in these properties are shown in Table 4-3. Because of the unique nature of the easement conversion, the Corps estimates are for acreage included within the specified contour elevation and do not include easement conversion of parcel remainders. Digital tax information is not available for Morris County, as previously noted; values for Morris County properties were estimated based on information from the Public Land Survey System and any available CADD files. The Corps estimates include a 25% contingency for land. No structures or structure contingencies are included, as the Corps owns an easement prohibiting the construction of permanent structures on these parcels.

Table 4-3 Real Estate Estimates – Wright Patman Alternatives

Reservoir Alternative	Acres Converted	Estimated Cost of Conversion
Wright Patman 232.5	7,126	$ 9,400,000
Wright Patman 242.5	21,145	$ 27,800,000
Wright Patman 252.5	46,824	$ 61,500,000

Figure 4-1 Wright Patman Lake



5.0 RESERVOIR CONFLICTS AND RELOCATION ESTIMATES

5.1 OVERVIEW

A significant portion of the cost of constructing a reservoir is relocation or purchase of the facilities and infrastructure that would be inundated or otherwise rendered unusable by the project. An analysis is required to inventory the facilities affected and assess whether those features should most appropriately be purchased and abandoned, raised in place, or relocated. Using available mapping, LiDAR, and aerial and satellite imagery, a planning-level assessment of the conflicts resolution required for each of the Sulphur River Basin Alternatives was performed. This analysis was supplemented in some instances, discussed in more detail below, by field verification of key parameters.

Alternatives evaluated in this portion of the analysis are shown in Table 3-1 below. Based on the spillway design discussed in Chapter 2, it was determined the conflicts assessment should include an additional five feet above the top of the normal conservation pool to address the potential impacts to facilities and infrastructure associated with a reservoir rises occurring during a flood event. This elevation is represented by the Temporary Flood Elevation in Table 5-1. Because the proposed new reservoirs would not have dedicated flood storage, this type of inundation would be occasional and temporary, and an operational plan to reduce the pool to normal elevations as quickly as possible is envisioned. Wright Patman Lake already has a flood easement in place for facilities and structures within the footprint of the contemplated reallocations, so consideration was given primarily to the conflicts resolution needed to address the permanent inundation of infrastructure and facilities associated with a given reallocation scenario. However, the roadway and bridge conflicts for Wright Patman were assumed to be raised in place to an elevation 10 feet above the conservation pool. This additional raise is intended to account for the effects of the modified flood storage pool at Wright Patman.

Table 5-1 Alternatives Evaluated for Conflicts Resolution

Reservoir Alternative	Conservation Pool (feet-NGVD)	Temporary Flood Elevation (feet-NGVD)
Wright Patman	232.5	242.5
Wright Patman	242.5	252.5
Wright Patman	252.5	262.5
Marvin Nichols 1A	296.5	301.5
Marvin Nichols 1A	313.5	318.5
Marvin Nichols 1A	328.0	333.0
Talco Reservoir	350.0	355.0
Talco Reservoir	370.0	375.0
George Parkhouse I	401.0	406.0
George Parkhouse II	410.0	415.0

5.2 COST ESTIMATING METHODOLOGY

Key categories of evaluation include roads and bridges, railroads, oil and gas pipelines/wells, power lines, public infrastructure, and cemeteries. Impacts to homes, commercial buildings, and other structures are to be estimated as part of the real estate costs and are not included as part of this analysis. Assumptions and methodology for estimating each category of required conflicts resolution are discussed below. Additional detail is provided in Appendix B, MTG Technical Report – Conflict Costs.

As with the embankment and spillway cost estimates, the conflict cost estimates for the combination alternatives were assumed to be additive with respect to the costs of their individual components. Differences between Talco Configuration 1 and Configuration 2 are captured in the transmission cost estimates discussed in Chapter Seven.

5.2.1 Roads and Bridges

Estimates of impacts to roads and bridges were estimated by superimposing the reservoir footprint over LiDAR data collected in 2006 by M7 Visual Intelligence/MTG and/or 2012 ArcGIS imagery to determine the extent of impact in each case. Federal Highways, U.S. Highways, and State Highways were all assumed to be raised in place to five feet above the normal conservation pool for the entire length of the roadway affected. Farm to Market (FM) roads were evaluated on an individual basis and were assumed to be raised in place in those instances where they appear to be the only artery connecting one side of the reservoir to the other without an extensive drive. A few FM roads, which appeared to serve structures or homes that would be purchased and abandoned, were considered to be abandoned in place, as were most County Roads. Figures 5-1 through 5-10 identify the elements of the road network within the footprint of each alternative that were assumed to require being raised in place versus abandonment. A short stretch of FM 1896 affected by the Talco alternatives is the only road section planned for relocation as part of this analysis.

In addition to the analysis based on mapping and imagery, a number of bridge elevations within the flood pool of Wright Patman Lake were field verified. The locations of these spot elevations are shown in Figure 3-1. Based on the surveyed elevations, a number of bridges that were planned to be raised in place based on LiDAR elevations were determined to be adequate in their current condition without raising under reallocation conditions. This assessment is discussed in more detail in Appendix B.

It should also be noted that the elevations assumed for all roadway conflicts, whether 5 feet above conservation pool or 10 feet, represent the roadway embankment elevation specifically. It is understood that the bridge openings may require additional clearance for boat traffic or other considerations. However, such additional clearance is not reflected in the current cost estimates.

Unit costs for embankment and pavement were based on information from the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA) indexed to 2013 price levels. Bridge replacement costs were estimated on a square foot basis using TxDOT costs.

5.2.2 Railroads

Impacts to railroads were estimated using the same methodology as roads and bridges. Only the Wright Patman Lake reallocation alternatives potentially affect a railroad embankment; there are no railroad impacts identified for any of the new reservoirs analyzed. Because railroad modifications are typically a very critical cost item, the existing elevation of the railroad embankments and bridges in the Wright Patman flood pool were field verified. Spot elevations at each of the Union Pacific Railroad crossings were surveyed to determine whether or not the embankment would need to be raised for a given reallocation scenario. These spot elevations are shown in Figure 5-1. Based on this elevation data, the minimum railroad embankment elevation in the Wright Patman flood pool is 262.6 feet-NGVD, which is at least ten feet above the highest Wright Patman reallocation scenario.

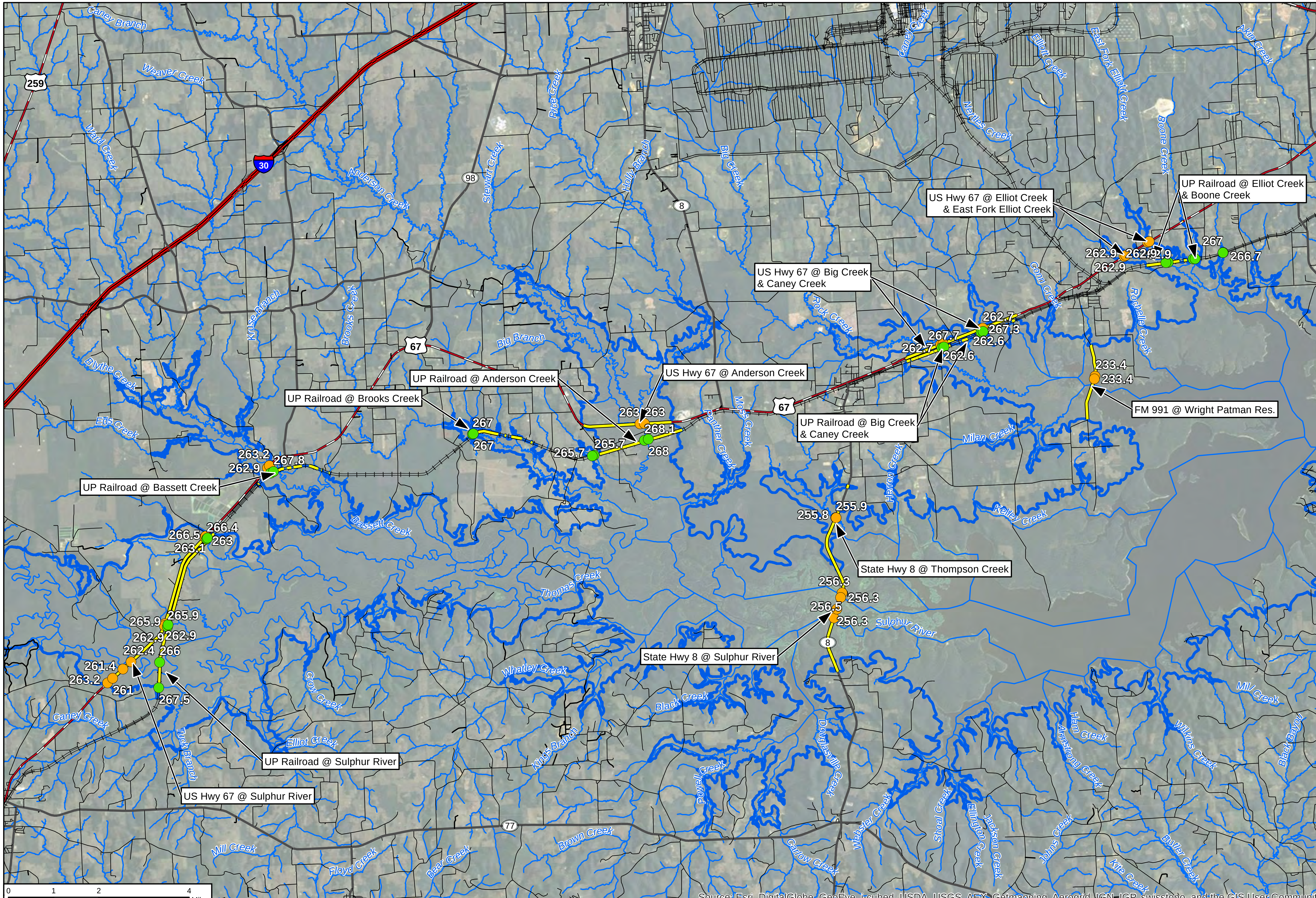


FIGURE 5-1

N W E S

SULPHUR BASIN COMPARITIVE ANALYSIS

BRIDGE SPOT ELEVATIONS

FREESE NICHOLS

4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT: XXX11111

FILE: BridgeSpotElevations_WP

DATUM & COORDINATE SYSTEM: NAD 1983 StatePlane Texas North Central FIPS 4202 Feet

DATE: April, 2014

PREPARED BY: JPM

5.2.3 Pipelines

Pipeline (oil and gas) impacts were estimated using GIS layers purchased from the Texas Railroad Commission (TRC). This data source is updated by the TRC on a regular basis and is current for the study area as of July 2013. Relocation costs per linear foot were also provided by the TRC and have been indexed from the 2008 values in their data base to 2013 levels based on changes in the Engineering News Record (ENR) Construction Cost Index between those years.

5.2.4 Oil and Gas Wells

The Texas Railroad Commission database discussed above also provided current information relative to the number of active and inactive wells and permitted locations not yet producing within the footprint of each alternative. Estimated costs to acquire and plug these features were indexed to 2013 values from similar estimates developed in a 2003 study for the Sulphur River Basin Authority (FNI, 2003). Collection systems internal to each well field were assumed to be 6” pipe and valued at $22 per linear foot for purchase and removal.

5.2.5 Powerlines

Power transmission lines impacted by each reservoir footprint were identified from 2012 ArcGIS imagery. Relocation costs per linear foot were estimated by indexing values obtained from the 2008 TWDB Site Protection Study to 2013 values using the Engineering News Record (ENR) construction cost index.

5.2.6 Public Water Systems

Several of the alternatives have the potential to affect public (municipal) water or wastewater infrastructure components as shown in Table 5-2 below. Estimates of the cost to mitigate these impacts were developed by extracting system descriptors from the data base on public water systems maintained by the Texas Commission on Environmental Quality (TCEQ) combined with cost estimates for similar systems developed by FNI as part of the 2011 Region C Regional Water Plan.

Table 5-2 Public Water Systems

Reservoir Alternative	Conservation Pool Elevation (feet-NGVD)	Public Water Wells	Raw Water Intake Structures	Wastewater Treatment Plants
Wright Patman	232.5	-	2	-
Wright Patman	242.5	-	2	-
Wright Patman	252.5	3	2	-
Marvin Nichols 1A	296.5	-	-	-
Marvin Nichols 1A	313.5	-	-	-
Marvin Nichols 1A	328	3	-	City of Talco
Talco Reservoir	350	-	-	-
Talco Reservoir	370	-	-	-
George Parkhouse I	401	-	-	-
George Parkhouse II	410	-	-	-

5.2.7 Cemeteries and State Historic Sites.

The number and location of cemeteries within the footprint of each alternative was obtained from the Texas Historical Commission (THC). Using the THC data base, an estimate of the number of graves within each cemetery was made. Unit costs for grave relocation were indexed from the 2008 TWDB report to 2013 prices.

In addition to cemeteries, two of the alternatives have the potential to affect designated State Historic Sites. The George Parkhouse I alternative affects a historic marker located near the Despain Bridge near the intersection of SH19 and SH154 near Cooper, Texas. The site currently consists only of a marker, as the original historic site was flooded by the construction of Jim Chapman Lake. The marker is within 300 feet of the potential reservoir's edge and was assumed to be relocated at a nominal cost. The George Parkhouse II alternative would affect the Leroy Nelson DeWitt State Historic Site located near FM1742 approximately 8 miles north of Cooper in Delta County. Relocation of the marker at this site was assumed at a nominal cost.

No comprehensive cultural resources surveys have been conducted for the Sulphur River Basin alternatives other than the records review discussed above and in the Comparative Environmental Assessment also performed under this contract. As a result, estimates to mitigate impacts to cultural or historic sites that have not yet been located are subject to significant uncertainty and require significant contingency. Costs for cultural resource survey and mitigation are estimated as part of the “soft cost” analysis being performed under separate contract, and are not addressed in this analysis.

5.3 SUMMARY OF RESERVOIR CONFLICTS COSTS

The results of the analysis described above are shown in Table 5-3. Appendix B contains the detailed spreadsheets for each individual alternative. Engineering services and contingencies estimated at 35% of the conflicts estimate have been added. As noted in the introduction, conflicts estimates for alternatives other than the Wright Patman reallocation scenarios include an additional 5 foot allowance for the temporary storage of floodwaters.

Table 5-3 Estimated Cost for Reservoir Conflicts and Relocations

Reservoir Alternative	Conservation Pool Elevation (feet-NGVD)	Estimated Conflict Cost	Engineering & Contingencies (35%)	Total Conflict Cost
Wright Patman	232.5	$23,256,655	$8,139,829	$31,396,484
Wright Patman	242.5	$47,530,714	$16,635,750	$64,166,464
Wright Patman	252.5	$114,070,736	$39,924,758	$153,995,494
Marvin Nichols 1A	296.5	$18,171,679	$6,360,088	$24,531,767
Marvin Nichols 1A	313.5	$45,190,393	$15,816,638	$61,007,031
Marvin Nichols 1A	328	$105,815,266	$37,035,343	$142,850,609
Talco Reservoir	350	$68,759,407	$24,065,792	$92,825,199
Talco Reservoir	370	$185,140,766	$64,799,268	$249,940,034
George Parkhouse I	401	$32,308,969	$11,308,139	$43,617,108
George Parkhouse II	410	$33,273,140	$11,645,599	$44,918,739

As can be seen from Table 5-3, the range of estimates for conflicts resolution varied widely between alternatives, ranging from a low of approximately $31 million for the Marvin Nichols 296.5 alternative to a high of almost $250 million for the larger Talco alternative. For comparative purposes, Table 5-4 portrays the estimated conflicts costs as a percentage of the estimated cost for embankment and spillway construction.

Table 5-4 Comparison of Conflicts Costs with Embankment & Spillway Costs

Reservoir Alternative	Conservation Pool Elevation (feet-NGVD)	Embankment & Spillway Estimate	Reservoir Conflicts Estimate	% of Embankment & Spillway Cost
Wright Patman	232.5	N/A	$31.4M	-
Wright Patman	242.5	N/A	$64.2M	-
Wright Patman	252.5	N/A	$154.0M	-
Marvin Nichols 1A	296.5	$177.2M	$24.5M	14%
Marvin Nichols 1A	313.5	$236.0M	$61.0M	26%
Marvin Nichols 1A	328	$304.8M	$142.8M	47%
Talco Reservoir	350	$156.8M	$92.8M	59%
Talco Reservoir	370	$369.5M	$249.9M	68%
George Parkhouse I	401	$188.6M	$43.6M	23%
George Parkhouse II	410	$210.7M	$45.0M	21%

The relatively high costs of the Talco alternative(s) are due primarily to impacts to oil and gas production facilities, bridge and road improvements, and a large powerline relocation. Required powerline relocations also significantly affect costs for the larger Wright Patman alternatives.

6.0 OTHER RESERVOIR COSTS

6.1 INTRODUCTION

In addition to the “hard” construction-type costs and real estate costs, there are additional significant costs associated with development of a water supply alternative. Engineering costs, including both design activities as well as engineering support during construction, can be significant. Other major costs include permitting and mitigation for natural and cultural resources. A comparative cost estimate for these items has been developed for the Sulphur River Basin alternatives and is discussed in more detail below.

6.2 ENGINEERING SUPPORT

For the Sulphur River Basin alternatives, design and engineering during construction (EDC) were estimated in relation to the estimated construction costs and included as part of the 35% contingency line item of the construction cost.

6.3 PERMITTING

Major water supply projects such as the alternatives under evaluation in the Sulphur River Basin require substantial effort for State and Federal permitting. A new water right is required from the State of Texas (TCEQ), and a Federal Section 404 (Clean Water Act) permit is required for the construction of a new reservoir. Reallocation alternatives at Wright Patman would also require review under Section 404 of the Clean Water Act; because reallocation would be a Federal (Corps of Engineers) action, the permitting and review process is slightly different from that for a non-Federal applicant but requires substantially the same information and public/stakeholder involvement. Because of the in-depth analysis and extensive review required for these permits, costs can be substantial. Detailed cost estimates cannot be developed until the specific alternatives to be permitted are identified, but for comparative purposes a reasonable estimate can be developed based on the scale of the project. (Larger projects generally having greater impact and a broader range of issues and, therefore, are more expensive to permit.) Based on SBG experience with similar projects, a value of 8% of the construction cost was used to estimate permitting costs.

6.4 MITIGATION

Mitigation would be expected to be required for both natural and cultural resources. Until site-specific assessments of cultural resource potential and habitat quality and quantity can be made, cost estimates are highly subjective. However, larger and more complex projects can reliably be predicted to have greater mitigation requirements than smaller or simpler projects, and reasonably valid comparisons between alternatives can be made on a "desktop" basis.

For purposes of estimating mitigation costs for aquatic resources (generally the most significant component of natural resources mitigation), data developed for the Environmental Evaluation Interim Report – Sulphur River Basin (FNI, 2013) with respect to the amount of "waters of the United States" was utilized. Minor modifications were made to the baseline assumptions considered in that prior report to ensure consistency with current assumptions for costing purposes. Waters of the United States are the aquatic resources subject to the jurisdiction of the U.S. Army Corps of Engineers under the Clean Water Act, Section 404, and can be comprised of open water and wetland types.

Using the Texas Parks and Wildlife Department (TPWD) Ecological Systems Classification data set as a basis, the acreage of streams, forested wetlands, shrub wetlands, and emergent wetlands within the normal conservation pool was estimated for each stand-alone alternative. For combination alternatives, the affected acreage for each component was simply summed. The total of all four vegetation categories represents an estimate of the potential amount of jurisdictional wetlands affected by each alternative. Similarly, acres of ephemeral/intermittent streams and perennial streams were estimated from the data set using an assumed 20-foot wide corridor for perennial streams and a 5-foot corridor for intermittent/ephemeral streams. No mitigation requirement for non-stream open water impacts was assumed, as a new or enlarged reservoir project would more than compensate for an open water habitat impacts. The estimated number of acres of stream and wetland impacts for each alternative is shown in Table 6-1. Percentage impacts to the White Oak Creek Mitigation Area at Wright Patman Lake are also shown in Table 6-1.

Table 6-1 Estimated Waters of the United States Impacts for each Alternative

Alternative ID	Alternative Description	Stream Acres	Forested Wetland Acres	Shrub Wetland Acres	Emergent Wetland Acres	TOTAL WATERS OF US	% WOCMA Impacted
1	Patman 232.5	114	12,118	42	251	12,525	4
2	Patman 242.5	223	17,936	111	566	18,836	21
3	Patman 252.5	344	30,573	174	1,006	32,097	58
4	MN296.5	120	10,613	829	589	12,151	0
5	MN313.5	198	17,678	1,270	930	20,076	0
6	MN328	266	20,581	1,414	1,269	23,530	0
7	Talco 350/config1	115	6,799	239	92	7,245	0
8	Talco 350/config2	115	6,799	239	92	7,245	0
9	Talco 370/config1	164	10,288	469	277	11,197	0
10	Talco 370/config2	164	10,288	469	277	11,197	0
11	PH1	52	5,577	282	440	6,350	0
12	PH2	34	1,144	28	93	1,299	0
13	Patman 232.5/MN296.5	234	22,731	871	840	24,676	4
14	Patman 242.5/MN296.5	343	28,549	940	1,155	30,987	21
15	Patman 252.5/MN296.5	464	41,186	1,003	1,595	44,248	58
16	Patman 232.5/MN313.5	312	29,796	1,312	1,181	32,601	4
17	Patman 242.5/MN313.5	421	35,614	1,381	1,496	38,912	21
18	Patman 252.5/MN313.5	542	48,251	1,444	1,936	52,173	58
19	Patman 232.5/MN328	380	32,699	1,456	1,520	36,055	4
20	Patman 242.5/MN328	489	38,517	1,525	1,835	42,366	21
21	Patman 252.5/MN328	610	51,154	1,588	2,275	55,627	58
22	Patman 232.5/PH1	166	17,695	324	691	18,875	4
23	Patman 242.5/PH1	275	23,513	393	1,006	25,187	21
24	Patman 252.5/PH1	396	36,150	456	1,446	38,447	58

Alternative ID	Alternative Description	Stream Acres	Forested Wetland Acres	Shrub Wetland Acres	Emergent Wetland Acres	TOTAL WATERS OF US	% WOCMA Impacted
25	Patman 232.5/PH2	148	13,262	70	344	13,824	4
26	Patman 242.5/PH2	257	19,080	139	659	20,135	21
27	Patman 252.5/PH2	378	31,717	202	1,099	33,396	58
28	Patman 232.5/Talco350-config1	229	18,917	281	343	19,770	4
29	Patman 242.5/Talco350-config1	338	24,735	350	658	26,081	21
30	Patman 252.5/Talco350-config1	459	37,372	413	1,098	39,342	58
31	Patman 232.5/Talco350-config2	229	18917	281	343	19,770	4
32	Patman 242.5/Talco350-config2	338	24735	350	658	26,081	21
33	Patman 252.5/Talco350-config2	459	37372	413	1098	39,342	58
34	Patman 232.5/Talco370-config1	277	22406	511	528	23,722	4
35	Patman 242.5/Talco370-config1	387	28224	580	843	30,034	21
36	Patman 252.5/Talco370-config1	508	40861	643	1283	43,294	58
37	Patman 232.5/Talco370-config2	277	22406	511	528	23,722	4
38	Patman 242.5/Talco370-config2	387	28224	580	843	30,034	21

Alternative ID	Alternative Description	Stream Acres	Forested Wetland Acres	Shrub Wetland Acres	Emergent Wetland Acres	TOTAL WATERS OF US	% WOCMA Impacted
39	Patman 252.5/Talco370-config2	508	40861	643	1283	43,294	58
40	MN296.5/Talco350-config1	235	17412	1068	681	19,396	0
41	MN313.5/Talco350-config1	313	24477	1509	1022	27,321	0
42	MN328/Talco350-config1	381	27380	1653	1361	30,775	0
43	MN296.5/Talco370-config1	284	20901	1298	866	23,349	0
44	MN313.5/Talco370-config1	362	27966	1739	1207	31,274	0
45	MN328/Talco370-config1	430	30869	1883	1546	34,728	0
46	MN296.5/PH1	172	16190	1111	1029	18,502	0
47	MN313.5/PH1	250	23255	1552	1370	26,427	0
48	MN328/PH1	318	26158	1696	1709	29,881	0
49	MN296.5/PH2	154	11757	857	682	13,451	0
50	MN313.5/PH2	232	18822	1298	1023	21,375	0
51	MN328/PH2	300	21725	1442	1362	24,830	0
52	Talco350-config1/PH1	167	12376	521	532	13,595	0
53	Talco350-config2/PH1	167	12376	521	532	13,595	0
54	Talco370-config1/PH1	216	15865	751	717	17,548	0
55	Talco370-config2/PH1	216	15865	751	717	17,548	0
56	Talco350-config1/PH2	149	7943	267	185	8,544	0
57	Talco350-config2/PH2	149	7943	267	185	8,544	0

Alternative ID	Alternative Description	Stream Acres	Forested Wetland Acres	Shrub Wetland Acres	Emergent Wetland Acres	TOTAL WATERS OF US	% WOCMA Impacted
58	Talco370-config1/PH2	198	11432	498	370	12,497	0
59	Talco370-config2/PH2	198	11432	498	370	12,497	0
60	PH1/PH2	86	6721	310	532	7,650	0

Other than basic ground-truthing of the classification, no field work was performed as a part of the comparative assessment, and as a result, no estimates were made of the quality of the habitat potentially impacted. For purposes of this cost estimate, all resources were assumed to be of high quality. Ephemeral streams were assumed to required mitigation on a 1:1 ratio, while perennial streams were assumed to require a 2:1 ratio. Wetlands (all categories) were assumed to require a 2:1 mitigation ratio. Stream mitigation was estimated to cost $100 per linear foot while land costs were assumed at $2,000 per acre. The cost to create, restore or enhance wetlands, regardless of type, was assumed to be $2,000 per acre in addition to the purchase price. Based on these assumptions, costs to mitigate waters of the United States are shown in Table 6-2. Mitigation for upland resources is not expected to be required. Mitigation cost estimates can, and will, be refined substantially once the preferred alternative/alternatives are identified and site-specific analysis can be performed.

Table 6-2 Estimated Mitigation Costs for Waters of the United States.

Alternative ID	Alternative Description	TOTAL WATERS OF US	Approximate Acres Needed for Mitigation	WOUS Costs
1	Patman 232.5	12,525	25,049	$157,266,600
2	Patman 242.5	18,836	37,672	$257,390,200
3	Patman 252.5	32,097	64,194	$422,359,800
4	MN296.5	12,151	24,302	$158,786,100
5	MN313.5	20,076	40,152	$265,283,900
6	MN328	23,530	47,060	$329,842,050
7	Talco 350/config1	7,245	14,490	$118,931,300
8	Talco 350/config2	7,245	14,490	$118,931,300
9	Talco 370/config1	11,197	22,395	$180,178,470
10	Talco 370/config2	11,197	22,395	$180,178,470
11	PH1	6,350	12,701	$95,767,300
12	PH2	1,299	2,599	$39,682,700
13	Patman 232.5/MN296.5	24,676	49,352	$316,052,700
14	Patman 242.5/MN296.5	30,987	61,975	$416,176,300
15	Patman 252.5/MN296.5	44,248	88,496	$581,145,900
16	Patman 232.5/MN313.5	32,601	65,201	$422,550,500
17	Patman 242.5/MN313.5	38,912	77,824	$522,674,100
18	Patman 252.5/MN313.5	52,173	104,346	$687,643,700
19	Patman 232.5/MN328	36,055	72,110	$487,108,650
20	Patman 242.5/MN328	42,366	84,733	$587,232,250
21	Patman 252.5/MN328	55,627	111,254	$752,201,850
22	Patman 232.5/PH1	18,875	37,750	$253,033,900
23	Patman 242.5/PH1	25,187	50,373	$353,157,500
24	Patman 252.5/PH1	38,447	76,895	$518,127,100
25	Patman 232.5/PH2	13,824	27,648	$196,949,300
26	Patman 242.5/PH2	20,135	40,271	$297,072,900
27	Patman 252.5/PH2	33,396	66,793	$462,042,500
28	Patman 232.5/Talco350-config1	19,770	39,539	$276,197,900
29	Patman 242.5/Talco350-config1	26,081	52,162	$376,321,500
30	Patman 252.5/Talco350-config1	39,342	78,684	$541,291,100
31	Patman 232.5/Talco350-config2	19,770	39,539	$276,197,900
32	Patman 242.5/Talco350-config2	26,081	52,162	$376,321,500

Alternative ID	Alternative Description	TOTAL WATERS OF US	Approximate Acres Needed for Mitigation	WOUS Costs
33	Patman 252.5/Talco350-config2	39,342	78,684	$541,291,100
34	Patman 232.5/Talco370-config1	23,722	47,444	$337,445,070
35	Patman 242.5/Talco370-config1	30,034	60,067	$437,568,670
36	Patman 252.5/Talco370-config1	43,294	86,589	$602,538,270
37	Patman 232.5/Talco370-config2	23,722	47,444	$337,445,070
38	Patman 242.5/Talco370-config2	30,034	60,067	$437,568,670
39	Patman 252.5/Talco370-config2	43,294	86,589	$602,538,270
40	MN296.5/Talco350-config1	19,396	38,792	$277,717,400
41	MN313.5/Talco350-config1	27,321	54,642	$384,215,200
42	MN328/Talco350-config1	30,775	61,550	$448,773,350
43	MN296.5/Talco370-config1	23,349	46,697	$338,964,570
44	MN313.5/Talco370-config1	31,274	62,547	$445,462,370
45	MN328/Talco370-config1	34,728	69,455	$510,020,520
46	MN296.5/PH1	18,502	37,003	$254,553,400
47	MN313.5/PH1	26,427	52,853	$361,051,200
48	MN328/PH1	29,881	59,761	$425,609,350
49	MN296.5/PH2	13,451	26,901	$198,468,800
50	MN313.5/PH2	21,375	42,751	$304,966,600
51	MN328/PH2	24,830	49,659	$369,524,750
52	Talco350-config1/PH1	13,595	27,191	$214,698,600
53	Talco350-config2/PH1	13,595	27,191	$214,698,600
54	Talco370-config1/PH1	17,548	35,096	$275,945,770
55	Talco370-config2/PH1	17,548	35,096	$275,945,770
56	Talco350-config1/PH2	8,544	17,089	$158,614,000
57	Talco350-config2/PH2	8,544	17,089	$158,614,000
58	Talco370-config1/PH2	12,497	24,994	$219,861,170
59	Talco370-config2/PH2	12,497	24,994	$219,861,170
60	PH1/PH2	7,650	15,300	$135,450,000

Mitigation of inundation effects on cultural resources can also be a significant cost. This item is particularly difficult to estimate, as the nature and extent of the impacts is largely unknown until site-specific surveys are conducted. These surveys are highly labor intensive and expensive and are generally not performed until the geographic extent of possible impacts is fairly precisely defined. For screening purposes, cultural resource mitigation cost estimates again drew on the comparative impact assessment performed in 2012.

As part of that study, a records search was performed. However, only a fraction of the land area potentially affected by the alternative project sites has been previously surveyed for cultural resources, and previously-surveyed acreage is disproportionately associated with Wright Patman Lake. In order to assess the probability and extent of cultural resource impacts across all alternatives, a predictive tool was developed. This tool was based on geomorphic setting, slope aspect, soils, land cover, and distance to a water source, these variables being major influences on the behavioral patterns of ancient peoples as well as early settlers. Using GIS technology, the footprint of each reservoir alternative was subdivided into categories representing the likelihood of encountering significant cultural resources. Table 6-3 presents the “high probability” acreage for each standalone alternative as well as the % of the alternative footprint that could be identified to have been previously surveyed for cultural resources.

Table 6-3 High Probability Cultural Resources Acreage by Alternative

Reservoir Alternative	Cultural Resources		
	High Probability Acreage	Previous CRM Survey	% covered by previous survey
Wright Patman 232.5	5,292	3,657	18.2%
Wright Patman 242.5	13,952	8,733	20.8%
Wright Patman 252.5	25,957	11,796	17.0%
Marvin Nichols 296.5	13,904	757	3.7%
Marvin Nichols 313.5	25,809	837	2.0%
Marvin Nichols328	35,209	892	1.3%
Talco Reservoir 350	12,728	269	1.1%
Talco Reservoir 370	23,555	390	0.8%
Parkhouse I	16,358	0	0.0%
Parkhouse II	7,048	120	0.8%

Based on a combination of the high probability acreage and its previously-surveyed percentage, cost estimates were developed for each stand-alone alternative as shown in Table 6-4.For combination alternatives, the estimates for the appropriate stand-alone alternative were summed.

Table 6-4 Estimated Mitigation Costs for Cultural Resources

Reservoir Alternative	Estimated Mitigation Cost
Wright Patman 232.5	$1,550,000
Wright Patman 242.5	$3,470,000
Wright Patman 252.5	$6,610,000
Marvin Nichols 296.5	$2,500,000
Marvin Nichols 313.5	$4,920,000
Marvin Nichols328	$7,130,000
Talco Reservoir 350	$2,520,000
Talco Reservoir 370	$4,350,000
Parkhouse I	$2,920,000
Parkhouse II	$1,890,000

7.0 TRANSMISSION SYSTEM COST ESTIMATES

7.1 OVERVIEW

The transmission facilities required to convey the yield of the various Sulphur River Basin alternatives to the desired delivery locations are an important component of the overall cost estimate of each option. All twelve alternatives identified in Table 1-1 were evaluated as standalone alternatives in addition to the 48 possible combination alternatives. Cost estimates were developed for each alternative based on a common set of delivery assumptions, discussed in more detail below. Because each combination alternative embodies a unique scenario for the source and quantity of water transmitted, the number, location, and size of pipeline segments and pump stations are unique to that alternative as well. Unlike the embankment and spillway cost estimates discussed in Chapter 2 and the conflicts cost estimates discussed in Chapter 5, transmission cost estimates for combination alternatives are not simply additive and were estimated individually. To facilitate this effort, a transmission "costing model" was created containing the overall transmission costs and associated hydraulic calculations. This costing model has been developed specifically to analyze the Sulphur River Basin alternatives but is based on the assumptions and methods from prior studies. The costing model performs hydraulic calculations and associated transmission facility cost analysis for each Sulphur River Basin Reservoir alternative.

It is important to emphasize that the goal of the analysis is to differentiate the cost for each of the various sources and combinations. Therefore, the analysis did not fine-tune the configurations of the transmission system for each alternative. This planning level study of the transmission system should provide relative cost differences for each of the alternatives. Unless otherwise noted, the costing methodology used is consistent with the Texas Water Development Board's (TWDB) regional planning guidelines for Region C.

7.2 ROUTE SELECTION

Various factors were considered when selecting pipeline routes from the Sulphur River Basin reservoirs to the distribution locations. Considering a route location that would be compatible with the multiple source alternatives was a major influence. More specifically, lake pump stations (LPS) were located at the downstream side at the base of the reservoir dams near the channel bottom and reservoir minimum elevations. This choice allows for pumping approximately the full capacity of the reservoir as requested by the JCPD members. The pipeline route best suited for this LPS configuration runs north of Wright Patman, between Marvin Nichols and Talco and south of the George Parkhouse reservoirs. A pipeline route alongside the north of Wright Patman originating from the pump station at the base of the dam is significantly shorter than a route running along the south side of the reservoir starting at the same location.

This pipeline route running near and between the dam sites was selected as the base route to analyze. The base route is common to all of the alternatives, except those with George Parkhouse I in operation; the base route crosses the reservoir footprint for George Parkhouse I. As a result, alternatives including the George Parkhouse I component feature a slightly different alignment. The base pipeline route was designed to stay north of Chapman Lake and continue west on a straight line path before it bends slightly southwest near Ray Roberts Lake to ultimately deliver to Lake Bridgeport. Reasons for selection of this northern base route (in contrast to the existing Chapman Lake System "southern" route) include:

- Based on the location of intake LPS at the reservoir dams, the preferred pipeline route runs between the source reservoirs and north of Chapman Lake
- The northern base route is located nearer to potential Sulphur River Basin local users (such as Texarkana and Clarksville) who will be allocated 20% of the Sulphur River Basin yields
- The route was estimated to be the least expensive route
- The existing Chapman Lake pipeline ROW does not appear wide enough for additional Sulphur River Basin parallel pipelines (up to three new parallel pipelines may be required)
- It is anticipated that the Denton, Frisco, and McKinney area will experience significant development northward by 2040 and the base route mostly avoids these growing areas
- The base route is located on primarily rural land
- The base route runs next to one of NTMWD's delivery locations (North Water Treatment Plant at Leonard)
- The base route avoids running through the middle of Denton to deliver water to Lake Bridgeport
- The base route runs just south of Lake Ray Roberts allowing convenient delivery of DWU, UTRWD and Irving water
- The base route runs across the Elm Fork Trinity River allowing for another distribution point for DWU, Irving and UTRWD
- The base route is independent of the existing transmission systems allowing for greater flexibility, pumping operations, and Operation and Maintenance procedures

The Sulphur River Basin water delivery locations requested by each JCPD member are listed in Table 7-1. TRWD has the longest distribution distance of any Owner from any of the five sources to Lake Bridgeport. This extra pipeline distance results in a higher a higher unit cost for TRWD than for the other JCPD Owners.

Table 7-1 Delivery Locations for Each JCPD Member

	TRWD	DWU	NTMWD	UTRWD	Irving	SRBA
Delivery Location	Lake Bridgeport	Trinity River and Lake Ray Roberts	NWTP & Wylie WTP	Trinity River And Lake Ray Roberts	*Trinity River and Lake Ray Roberts	Unspecified

*Irving prefers to use the existing Chapman Lake pipeline to transmit a portion of their water from the Sulphur River Basin to Lewisville Lake if feasible

Irving has the option of utilizing the existing Chapman system to deliver a portion of their Sulphur River Basin yields to Lewisville Lake. The remaining portion of Irving's Sulphur River Basin yield along with DWU and UTRWD yields will be distributed to the Elm Fork Trinity River just below Lake Ray Roberts as well as through a branch line leading to Lake Ray Roberts. NTMWD has requested delivering half of their Sulphur River Basin yield to their North WTP in Leonard and the other half to the existing Wylie WTP. The proposed northern base route runs approximately 1.7 miles south of the assumed future terminal storage reservoir (TSR) at the North WTP. Assumptions related to incorporation of the existing Chapman Lake Transmission System are discussed in detail in Appendix C, Transmission Facility Hydraulics and Cost Analysis.

The base route for the proposed pipeline and delivery points is shown in Figure 7-1. As previously mentioned, alternatives containing the George Parkhouse I component represent the only deviation from the base route. This case requires an alternate route that diverges from the base route east of the dam site, runs south of the reservoir, and connects back to the base route at BPS #2 as shown in Figure 7-2. For the single case of the George Parkhouse I and II reservoirs in combination, an alternate George Parkhouse II extension pipeline was routed from the George Parkhouse II LPS directly to the George Parkhouse I LPS, also shown in Figure 7-2. Additional detail concerning route selection and development of routes is found in Appendix C.

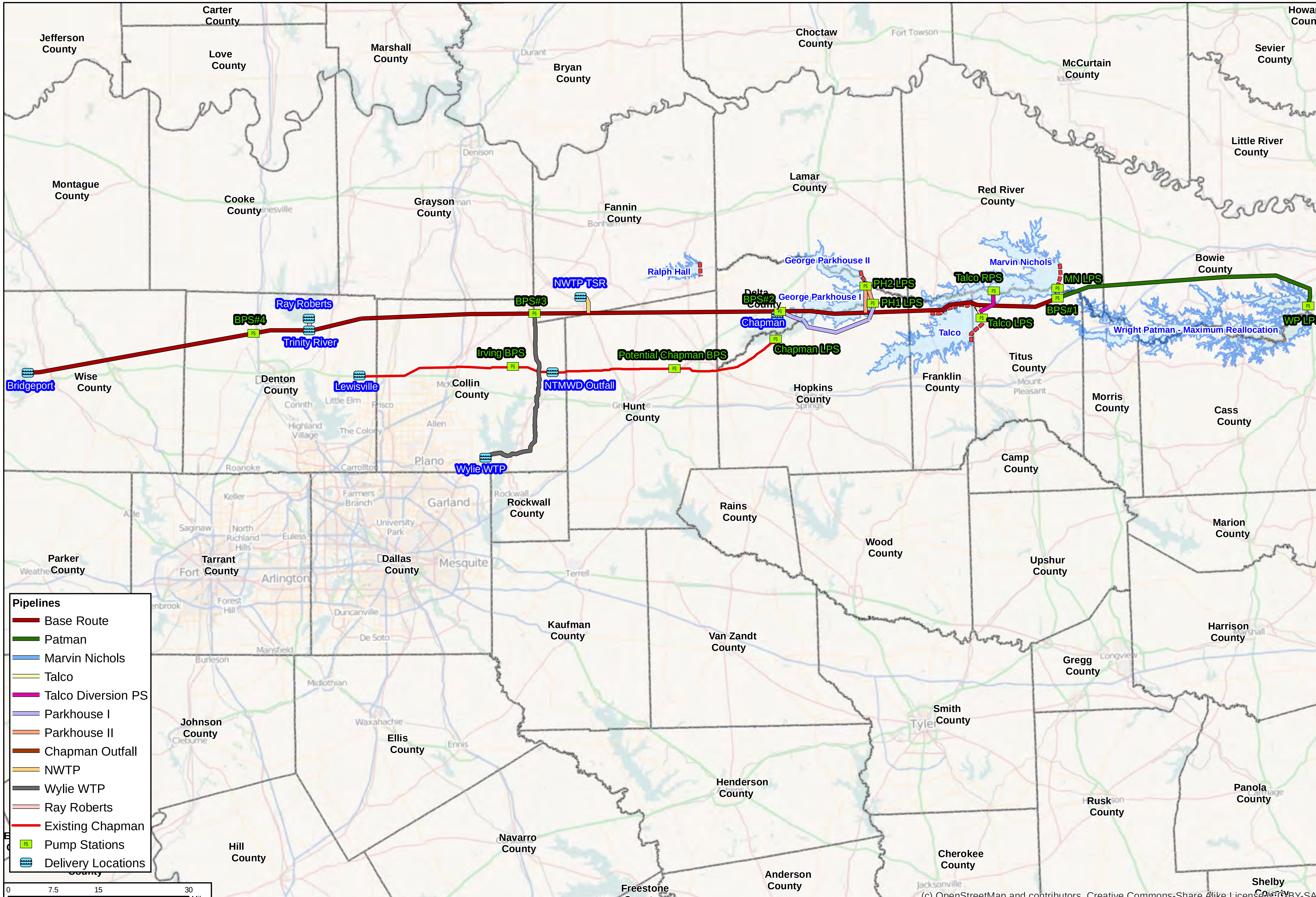


FIGURE 7-1

SULPHUR BASIN COMPARITIVE ANALYSIS

PROPOSED OVERALL TRANSMISSION SYSTEM

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE H:\PIPES_PUMPS\FINAL_EXHIBITS
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY 02150

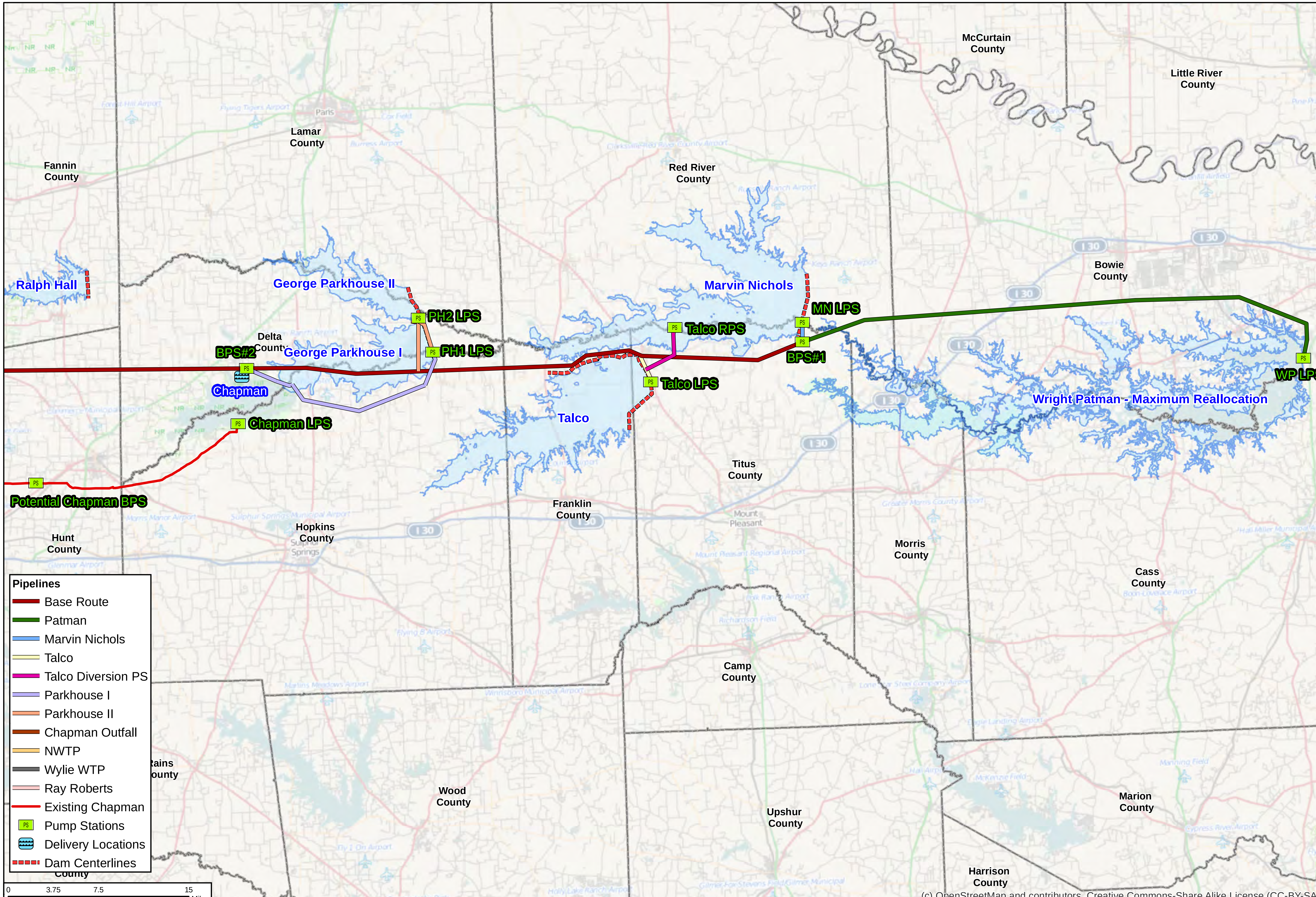


FIGURE 7-2

SULPHUR BASIN COMPARITIVE ANALYSIS

PROPOSED TRANSMISSION SYSTEM - EAST SECTION

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE H:\PIPES_PUMPS\FINAL_EXHIBITS
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY 02150

7.3 COST MODEL STRUCTURE

The cost model has three primary components. The first component utilizes the pipeline route and corresponding ground profiles (from GIS) to develop the hydraulic grade lines (HGL). The cost model performs the HGL calculations for the base pipeline route from the furthest east source to Lake Bridgeport. The flow reaches must be defined at each HGL control point to allow for automatic pipeline sizing calculations of segments as the flow changes along the base route. After the base route HGL calculations are performed, the model sizes additional pump stations and branch pipeline diameters that either tie-in to or diverge from the base route. Because base route HGL values are already calculated, the sub HGL calculation worksheets link to the base route values for points connecting to and diverging from the base route.

The second component utilizes the hydraulic grade lines and key input parameters to size pipeline segments and pump stations. Key assumptions and selection of input parameters for the hydraulic calculations are discussed in detail in Appendix C. After completion of sizing the pipelines and pump stations in the calculations on the individual HGL worksheets, the “Pipeline Summary” and “Pump Station Summary” worksheets link to the separate calculations and summarize the facility information. The pipeline summary separates each pipeline segment where a change in flow, pipe size or ownership occurs. The pipeline summary also contains information about the discharge structures required at each distribution location. The discharge structure summary table includes the location, size and unit cost of the structure. Discharge structure costs are based on the standard unit cost methodology except for cases discharging into water treatment plants (North WTP and Wylie WTP). For the WTP discharge structures the base unit costs were doubled to account for the flow control valves that will be required into the existing facilities.

The pump station summary also links to the locations in the individual HGL worksheets where the pump station sizing calculations are performed. The summary includes all LPS, BPS and pump station storage tanks/reservoirs including those for the existing Chapman system. The sizes of storage tanks/reservoirs are calculated on the summary worksheet based on the storage time that is defined at the top of the summary table. A six hour storage time at peak flow was assumed in this study.

Thirdly, the model develops costs for each scenario and apportions those costs to the various JCPD members, based on the project ownership distribution as specified in the JCPD inter-local contract. This distribution is shown in Table 7-2 below.

Table 7-2 Ownership Distribution among JCPD Members

Ownership Component	% Ownership						
	TRWD	NTMWD	DWU	UTRWD	Irving	SRBA	Total
All Raw Water	23.918%	23.918%	23.358%	4.807%	4.000%	20.000%	100.000%
Metroplex JCPD Sections	29.897%	29.897%	29.197%	6.009%	5.000%	0.000%	100.000%

FNI asked the JCPD participants to provide the water delivery dates required for the Sulphur River Basin yields to determine feasibility of project phasing. Based on the results and further discussions with the Owners, each of their yield percentage requirements by year are summarized in Table 7-3 below.

Table 7-3 Requested Water Delivery Schedule

	TRWD	DWU	NTMWD	UTRWD	Irving	SRBA
2020	0%	0%	0%	0%	0%	0%
2030	0%	0%	0%	0%	100%	100%
2040	100%	0%	50%	50%	100%	100%
2050	100%	30%	100%	100%	100%	100%
2060	100%	100%	100%	100%	100%	100%

As seen in Table 7-3, the requested delivery schedule requires that approximately half of the yield be delivered by 2040 and the full yield by 2060. This allows some flexibility for pipeline phasing, and the pipelines have been designed to transmit the total yield evenly between two parallel pipelines where two are required. The second of the two pipelines could be constructed at a later time (by 2050) to reduce costs before the full yield is required.

The costing methodology is consistent with the TWDB regional planning guidelines for Region C. In general, unit costs were taken from the TWDB's Costing Tool, developed in 2012; however, a number of the alternatives require transmission facilities that are larger than those listed in the TWDB's Costing Tool. Where required, unit cost values were extrapolated to account for larger facilities. All unit costs have been indexed to November 2013 dollars.

All transmission facility components are compiled and summarized on the "Cost Summary" worksheet. Required cost data input parameters include:

- Debt Service Rate (5.5%)
- Debt Payment Period (40 years)
- Electric Cost ($0.07 per kWh)
- Pipeline Engineering and Contingencies (30%)
- Pump Station Engineering and Contingencies (35%)

Values for cost data input parameters used in this analysis are shown within the parentheses above.

The cost summary references the pipeline and pump station summaries as well as the unit costs and Owners' Share worksheets to perform the following cost procedures:

- Separates each transmission component by changes in ownership and capacity
- Assigns unit costs to each component based on type and size
- Calculates initial construction costs
- Adds engineering and contingencies
- Adds permitting and mitigation
- Lists the Owner's percentage of costs below each component
- Calculates each Owner's separate component costs
- Summarizes capital pipeline costs and separates by Owner
- Summarizes capital pump station costs and separates by Owner
- Summarizes capital pipeline and pump station construction costs (first costs) and separates by Owner
- Calculates JCPD Owners' interest during construction
- Calculates annual debt service costs
- Calculates annual electricity costs
- Calculates annual Operation and Maintenance costs
- Calculates total annual costs during and after debt service and separates by Owner
- Calculates total unit costs during and after debt service and separates by Owner

Each Sulphur River Basin alternative has its own cost summary output file that includes both total costs and costs separated between JCPD Owners. An example of the entire output for a single alternative in which each transmission component cost is separated is included in Appendix C.

7.4 SUMMARY OF TRANSMISSION SYSTEM COSTS

The total estimated transmission cost for each of the sixty alternatives is summarized in Table 7-4. Cost results are based on the total capital and annual costs and assume constructing each Sulphur River Basin alternative in one phase. As discussed previously, only about half of the total yield is required by 2040 with the remaining half not required until 2060. These delivery dates may allow construction phasing of the transmission system which would reduce initial capital costs.

The majority of the Sulphur River Basin alternatives result in total yields that are too large to be conveyed through one 120-inch diameter pipeline and therefore two parallel pipelines are required for a portion of the route. Nine of the alternatives had flows that resulted in three parallel pipelines required for a portion of the base pipeline route. The large flow values associated with the TalcoConfig2 diversion pump station result in the need for two 120-inch diameter pipelines to fill the reservoir when diverting 1,000 CFS and four 120-inch diameter pipelines if diverting 2,000 CFS. Large discharge structures are also required for the water diverted from the Sulphur River to the Talco Reservoir depending on the number of pipelines (either two or four).

When including interest during construction, transmission total costs range from approximately $864 million (ID12 – Parkhouse II standalone) up to $6.75 billion (ID21 – Wright Patman at TCP 252.5 and Marvin Nichols at TCP 328). Total costs are a reflection of multiple factors including pipe lengths, the number of pump stations and parallel pipelines required, and sizes of components such as pipe diameters. All Wright Patman options have high total costs because they require pumping large yields at longer distances than other sources. The proposed base pipeline route from Wright Patman to Lake Bridgeport is approximately 218 miles long. On the other hand, the standalone route from Parkhouse II to Lake Bridgeport is only approximately 145 miles, resulting in the lowest total transmission capital costs of any of the alternatives.

Unit cost values give a better representation of the cost effectiveness of each alternative by showing how much the option costs compared to how much water is made available. Transmission unit cost values during debt service range from approximately $1.72 to $2.65 per 1000 gallons delivered. The alternative with the lowest transmission unit costs during debt service was found to be Talco Configuration 1 at TCP of 370 feet combined with either Marvin Nichols at TCP 328 (ID 45) or Parkhouse 2 (ID 58). Note that the yields shown in Table 7-4 represent the total predicted yield of the project, while unit costs are based on the 80% of the projected yield to be transmitted to the Metroplex. Estimated yields do not include an allowance for anticipated eFlow requirements. Environmental flow requirements would be expected to reduce yields for all alternatives and result in higher actual unit costs than those shown in Table 7-4.

The two smallest yield alternatives in the ten lowest unit costs were Talco Configuration 1 at TCP of 370 in combination with Parkhouse I and Parkhouse II (ID 54 and 58). These options resulted in Metroplex JCPD Owner yield totals of 309,344 and 307,912 acre-feet per year, respectively. The three alternatives with Marvin Nichols at TCP of 328 feet in combination with Wright Patman at various TCP values (ID 19, 20, 21) had similar unit costs and had the lowest unit costs of any option with Wright Patman as a source.

Costs associated with transmission components are shown to play a significant part in the overall costs of each option, but other factors must be considered when determining the optimal or preferred Sulphur River Basin alternative. These transmission cost values will be incorporated with environmental impact data and reservoir costs to assist in the selection of the Sulphur River Basin reservoir source or sources to implement in the future.

Table 7-4 Transmission System Cost Estimates

Table 4-4. Overall Transmission Cost Summary Results

SOURCE INFORMATION		YIELD SUMMARY	TRANSMISSION FIRST COSTS				TRANSMISSION ANNUAL COSTS				TRANSMISSION UNIT COSTS				Cost Rankings	
											Per Acre-ft		Per 1,000 Gallons		1 = Least Expensive	
Alternative ID	Alternative Description	Total Yield (AFY)	Pipelines (Before Interest)	Pump Station (Before Interest)	Total (Before Interest)	Total (After Interest)	Debt Service	O&M	Electricity	Total	During Debt Service	After Debt Service	During Debt Service	After Debt Service	During Debt Service	After Debt Service
1	Patman 232.5	281,000	$1,444,112,000	$385,793,000	$1,829,905,000	$2,272,138,000	$141,600,000	$21,468,000	$30,795,000	$193,863,000	$862	$232	$2.65	$0.71	60	60
2	Patman 242.5	592,700	$2,683,930,000	$630,200,000	$3,314,130,000	$4,115,056,000	$256,452,000	$38,112,000	$69,000,000	$363,564,000	$767	$226	$2.35	$0.69	58	59
3	Patman 252.5	854,400	$3,689,963,000	$791,961,000	$4,481,924,000	$5,565,071,000	$346,816,000	$50,854,000	$95,704,000	$493,374,000	$722	$214	$2.22	$0.66	51	56
4	MN296.5	200,000	$884,629,000	$260,241,000	$1,144,870,000	$1,421,551,000	$88,592,000	$13,622,000	$17,318,000	$119,532,000	$747	$193	$2.29	$0.59	57	30
5	MN313.5	400,000	$1,406,061,000	$377,798,000	$1,783,859,000	$2,214,964,000	$138,037,000	$20,983,000	$35,168,000	$194,188,000	$607	$175	$1.86	$0.54	14	20
6	MN328	590,000	$2,111,305,000	$473,979,000	$2,585,284,000	$3,210,070,000	$200,053,000	$29,497,000	$51,980,000	$281,530,000	$596	$173	$1.83	$0.53	12	15
7	Talco 350/config1	169,600	$701,704,000	$236,935,000	$938,639,000	$1,165,480,000	$72,633,000	$11,451,000	$14,046,000	$98,130,000	$723	$188	$2.22	$0.58	52	24
8	Talco 350/config2	217,100	$953,931,000	$323,263,000	$1,277,194,000	$1,585,855,000	$98,831,000	$15,651,000	$22,424,000	$136,906,000	$788	$219	$2.42	$0.67	59	58
9	Talco 370/config1	265,100	$950,422,000	$291,637,000	$1,242,059,000	$1,542,227,000	$96,113,000	$14,931,000	$22,208,000	$133,252,000	$628	$175	$1.93	$0.54	20	17
10	Talco 370/config2	382,800	$1,441,065,000	$443,196,000	$1,884,261,000	$2,339,632,000	$145,808,000	$22,745,000	$41,550,000	$210,103,000	$686	$210	$2.11	$0.64	36	54
11	PH1	124,300	$516,137,000	$183,493,000	$699,630,000	$868,710,000	$54,138,000	$8,592,000	$8,967,000	$71,697,000	$721	$177	$2.21	$0.54	50	22
12	PH2	124,200	$514,206,000	$182,052,000	$696,258,000	$864,523,000	$53,876,000	$8,543,000	$8,857,000	$71,276,000	$717	$175	$2.20	$0.54	47	18
13	Patman 232.5/MN296.5	446,200	$1,708,483,000	$507,792,000	$2,216,275,000	$2,751,882,000	$171,498,000	$26,571,000	$45,014,000	$243,083,000	$681	$201	$2.09	$0.62	32	38
14	Patman 242.5/MN296.5	625,200	$2,540,049,000	$632,113,000	$3,172,162,000	$3,938,778,000	$245,466,000	$36,863,000	$64,739,000	$347,068,000	$694	$203	$2.13	$0.62	39	44
15	Patman 252.5/MN296.5	872,000	$3,520,313,000	$809,612,000	$4,329,925,000	$5,376,338,000	$335,056,000	$49,689,000	$93,282,000	$478,027,000	$685	$205	$2.10	$0.63	35	46
16	Patman 232.5/MN313.5	627,950	$2,451,827,000	$602,635,000	$3,054,462,000	$3,792,634,000	$236,359,000	$35,404,000	$59,090,000	$330,853,000	$659	$188	$2.02	$0.58	27	25
17	Patman 242.5/MN313.5	804,950	$3,090,144,000	$736,476,000	$3,826,620,000	$4,751,399,000	$296,109,000	$44,169,000	$80,554,000	$420,832,000	$654	$194	$2.01	$0.59	25	31
18	Patman 252.5/MN313.5	999,650	$4,040,159,000	$873,719,000	$4,913,878,000	$6,101,415,000	$380,242,000	$55,796,000	$102,341,000	$538,379,000	$673	$198	$2.07	$0.61	30	36
19	Patman 232.5/MN328	806,600	$2,951,005,000	$709,910,000	$3,660,915,000	$4,545,648,000	$283,286,000	$42,311,000	$76,637,000	$402,234,000	$623	$184	$1.91	$0.57	18	23
20	Patman 242.5/MN328	990,500	$3,683,014,000	$855,931,000	$4,538,945,000	$5,635,872,000	$351,229,000	$52,164,000	$99,888,000	$503,281,000	$635	$192	$1.95	$0.59	22	27
21	Patman 252.5/MN328	1,184,550	$4,451,346,000	$986,600,000	$5,437,946,000	$6,752,134,000	$420,795,000	$62,037,000	$120,369,000	$603,201,000	$637	$192	$1.95	$0.59	23	28
22	Patman 232.5/PH1	395,140	$1,659,839,000	$473,374,000	$2,133,213,000	$2,648,747,000	$165,072,000	$25,367,000	$38,706,000	$229,145,000	$725	$203	$2.22	$0.62	53	42
23	Patman 242.5/PH1	687,540	$3,015,712,000	$681,479,000	$3,697,191,000	$4,590,691,000	$286,094,000	$42,247,000	$72,292,000	$400,633,000	$728	$208	$2.24	$0.64	54	53
24	Patman 252.5/PH1	943,630	$4,068,623,000	$834,463,000	$4,903,086,000	$6,088,015,000	$379,408,000	$55,214,000	$98,019,000	$532,641,000	$706	$203	$2.17	$0.62	44	43
25	Patman 232.5/PH2	400,300	$1,664,073,000	$468,842,000	$2,132,915,000	$2,648,377,000	$165,048,000	$25,306,000	$38,680,000	$229,034,000	$715	$200	$2.19	$0.61	45	37
26	Patman 242.5/PH2	658,750	$2,861,955,000	$641,217,000	$3,503,172,000	$4,349,784,000	$271,081,000	$39,978,000	$66,447,000	$377,506,000	$716	$202	$2.20	$0.62	46	41
27	Patman 252.5/PH2	903,400	$3,664,098,000	$832,286,000	$4,496,384,000	$5,583,025,000	$347,936,000	$51,500,000	$96,705,000	$496,141,000	$686	$205	$2.11	$0.63	37	47
28	Patman 232.5/Talco350-config1	447,010	$1,785,522,000	$509,193,000	$2,294,715,000	$2,849,279,000	$177,569,000	$27,305,000	$44,889,000	$249,763,000	$698	$202	$2.14	$0.62	40	39
29	Patman 242.5/Talco350-config1	713,240	$3,088,501,000	$691,234,000	$3,779,735,000	$4,693,184,000	$292,481,000	$43,129,000	$74,309,000	$409,919,000	$718	$206	$2.20	$0.63	48	48
30	Patman 252.5/Talco350-config1	943,670	$3,998,537,000	$848,690,000	$4,847,227,000	$6,018,656,000	$375,085,000	$54,876,000	$99,678,000	$529,639,000	$702	$205	$2.15	$0.63	43	45
31	Patman 232.5/Talco350-config2	497,550	$2,111,056,000	$596,229,000	$2,707,285,000	$3,361,555,000	$209,493,000	$32,156,000	$54,340,000	$295,989,000	$744	$217	$2.28	$0.67	56	57
32	Patman 242.5/Talco350-config2	721,750	$3,164,577,000	$741,259,000	$3,905,836,000	$4,849,758,000	$302,238,000	$44,923,000	$77,813,000	$424,974,000	$736	$213	$2.26	$0.65	55	55
33	Patman 252.5/Talco350-config2	941,650	$4,115,661,000	$875,469,000	$4,991,130,000	$6,197,335,000	$386,219,000	$56,531,000	$99,565,000	$542,315,000	$720	$207	$2.21	$0.64	49	50
34	Patman 232.5/Talco370-config1	536,900	$2,164,669,000	$549,945,000	$2,714,614,000	$3,370,655,000	$210,061,000	$31,633,000	$51,728,000	$293,422,000	$683	$194	$2.10	$0.60	33	32
35	Patman 242.5/Talco370-config1	803,130	$3,318,570,000	$728,972,000	$4,047,542,000	$5,025,711,000	$313,203,000	$46,067,000	$80,718,000	$439,988,000	$685	$197	$2.10	$0.61	34	35
36	Patman 252.5/Talco370-config1	1,033,560	$4,148,245,000	$909,154,000	$5,057,399,000	$6,279,621,000	$391,348,000	$57,577,000	$109,365,000	$558,290,000	$675	$202	$2.07	$0.62	31	40
37	Patman 232.5/Talco370-config2	653,830	$2,638,112,000	$684,664,000	$3,322,776,000	$4,125,790,000	$257,120,000	$38,913,000	$69,873,000	$365,906,000	$700	$208	$2.15	$0.64	41	51
38	Patman 242.5/Talco370-config2	869,430	$3,598,108,000	$834,566,000	$4,432,674,000	$5,503,918,000	$343,006,000	$50,936,000	$93,824,000	$487,766,000	$701	$208	$2.15	$0.64	42	52
39	Patman 252.5/Talco370-config2	1,079,130	$4,443,529,000	$973,481,000	$5,417,010,000	$6,726,138,000	$419,175,000	$61,684,000	$116,291,000	$597,150,000	$692	$206	$2.12	$0.63	38	49
40	MN296.5/Talco350-config1	365,460	$1,286,216,000	$389,661,000	$1,675,877,000	$2,080,886,000	$129,682,000	$20,148,000	$31,220,000	$181,050,000	$619	$176	$1.90	$0.54	17	21
41	MN313.5/Talco350-config1	566,820	$1,970,990,000	$495,524,000	$2,466,514,000	$3,062,596,000	$190,863,000	$28,701,000	$49,362,000	$268,926,000	$593	$172	$1.82	$0.53	10	14
42	MN328/Talco350-config1	751,620	$2,557,863,000	$597,798,000	$3,155,661,000	$3,918,290,000	$244,190,000	$36,286,000	$66,572,000	$347,048,000	$577	$171	$1.77	$0.52	6	12
43	MN296.5/Talco370-config1	460,350	$1,580,021,000	$435,965,000	$2,015,986,000	$2,503,180,000	$155,999,000	$23,836,000	$39,107,000	$218,942,000	$594	$171	$1.82	$0.52	11	11
44	MN313.5/Talco370-config1	661,710	$2,164,882,000	$543,042,000	$2,707,924,000	$3,362,348,000	$209,542,000	$31,519,000	$57,442,000	$298,503,000	$564	$168	$1.73	$0.52	3	6
45	MN328/Talco370-config1	846,510	$2,790,490,000	$641,844,000	$3,432,334,000	$4,261,826,000	$265,599,000	$39,384,000	$74,490,000	$379,473,000	$560	$168	$1.72	$0.52	1	7
46	MN296.5/PH1	314,500	$1,127,937,000	$352,792,000	$1,480,729,000	$1,838,577,000	$114,581,000	$17,884,000	$26,039,000	$158,504,000	$630	$175	$1.93	$0.54	21	16
47	MN313.5/PH1	502,890	$1,719,890,000	$456,290,000	$2,176,180,000	$2,702,097,000	$168,396,000	$25,551,000	$43,376,000	$237,323,000	$590	$171	$1.81	$0.53	9	13
48	MN328/PH1	681,410	$2,379,011,000	$550,936,000	$2,929,947,000	$3,638,027,000	$226,723,000	$33,613,000	$59,501,000	$319,837,000	$587	$171	$1.80	$0.52	8	10
49	MN296.5/PH2	310,650	$1,096,087,000	$350,974,000	$1,447,061,000	$1,796,772,000	$111,976,000	$17,552,000	$25,975,000	$155,503,000	$626	$175	$1.92	$0.54	19	19
50	MN313.5/PH2	465,930	$1,525,307,000	$436,028,000	$1,961,335,000	$2,435,331,000	$151,770,000	$23,345,000	$39,962,000	$215,077,000	$577	$170	$1.77	$0.52	5	9
51	MN328/PH2	644,960	$2,234,463,000	$515,120,000	$2,749,583,000	$3,414,075,000	$212,767,000	$31,524,000	$53,922,000	$298,213,000	$578	$166	$1.77	$0.51	7	4
52	Talco350-config1/PH1	292,750	$998,183,000	$336,283,000	$1,334,466,000	$1,656,966,000	$103,263,000	$16,347,000	$23,390,000	$143,000,000	$611	$170	$1.87	$0.52	16	8
53	Talco350-config2/PH1	337,170	$1,228,895,000	$417,315,000	$1,646,210,000	$2,044,050,000	$127,386,000	$20,236,000	$31,297,000	$178,919,000	$663	$191	$2.04	$0.59	28	26
54	Talco370-config1/PH1	386,680	$1,210,513,000	$386,575,000	$1,597,088,000	$1,983,057,000	$123,586,000	$19,398,000	$31,695,000	$174,679,000	$565	$165	$1.73	$0.51	4	3
55	Talco370-config2/PH1	486,980	$1,790,734,000	$516,897,000	$2,307,631,000	$2,865,316,000	$178,568,000	$27,535,000	$48,989,000	$255,092,000	$655	$196	$2.01	$0.60	26	34
56	Talco350-config1/PH2	292,660	$991,149,000	$331,349,000	$1,322,498,000	$1,642,106,000	$102,337,000	$16,174,000	$23,013,000	$141,524,000	$604	$167	$1.86	$0.51	13	5
57	Talco350-config2/PH2	322,330	$1,163,603,000	$408,744,000	$1,572,347,000	$1,952,336,000	$121,670,000	$19,450,000	$30,352,000	$171,472,000	$665	$193	$2.04	$0.59	29	29
58	Talco370-config1/PH2	384,890	$1,201,047,000	$381,193,000	$1,582,240,000	$1,964,620,000	$122,436,000	$19,192,000	$31,022,000	$172,650,000	$561	$163	$1.72	$0.50	2	2
59	Talco370-config2/PH2	462,180	$1,644,327,000	$501,140,000	$2,145,467,000	$2,663,963,000	$166,020,000	$25,868,000	$46,422,000	$238,310,000	$645	$196	$1.98	$0.60	24	33
60	PH1/PH2	236,410	$805,586,000	$286,302,000	$1,091,888,000	$1,355,765,000	$84,492,000	$13,500,000	$17,259,000	$115,251,000	$609	$163	$1.87	$0.50	15	1

Red Highlight = Cases that require 3 parallel pipelines for a portion of the main route

•Talco Config2 pumps water from the Sulphur River to supply the reservoir. This alternative would divert MN supply and therefore cannot be in combination with MN.

•Cases where Metroplex JCPO Owners Yield > 1000 CFS require three pipelines for a portion of the main route. All Talco370 Config2 cases require 4 pipelines from the diversion pump station at the Sulphur River to Talco Reservoir

•Before and after interest specified in the transmission first costs refers to the interest accrued during the project construction period

8.0 OPERATION AND MAINTENANCE COSTS

Annual costs have been estimate for each of the sixty alternatives. Operation and Maintenance costs for the infrastructure (embankment and spillway and transmission system, including pump stations and pipelines) are estimated as a percent of construction cost, absent better information. Pumping costs were estimated directly based on the configuration of the overall transmission system for each alternative.

8.1 RESERVOIR OPERATION AND MAINTENANCE

Annual Operation and Maintenance for the reservoir (exclusive of any recreation or land stewardship activities) generally focuses on the embankment and spillway. Typical activities associated with the embankment would include mowing and other vegetation maintenance, surface slide repair, erosion control replacements, and access road maintenance or repair. Spillway Operation and Maintenance typically includes any labor required for gate operations and testing, painting, structural inspections, electrical maintenance and repair, and other activities needed to ensure that all components are fully functional and continue to perform in accordance with design parameters. In general, the cost of these activities is directly related to the size of the embankment and the spillway. Based on FNI experience in the operation of water supply reservoirs for estimating reservoir Operation and Maintenance in regional water planning, the cost estimates developed for this analysis include 1.8% of the estimated embankment and spillway construction cost (exclusive of permitting and Engineering Services costs) annually. Reservoir Operation and Maintenance costs for the combination alternatives were assumed to be the sum of the Operation and Maintenance costs of the individual components.

8.2 TRANSMISSION SYSTEM OPERATION AND MAINTENANCE

The cost model discussed in Chapter 7 estimates required pipe segment lengths and sizes, the number and location of Booster pump stations needed, and the horsepower required to move the yield of each alternative from the source(s) to the designated delivery locations. As with the reservoir itself, annual Operation and Maintenance costs are generally a function of pipeline length and the number and size of pumps/pump stations involved. Based on FNI experience in the operation of large raw water transmission systems, and consistent with Texas Water Development Board guidance for estimating reservoir Operation and Maintenance in regional water planning, the cost estimates developed for this analysis includes 1.0% of the estimated pipeline construction costs and 2.5% of the pump/pump station costs (exclusive of permitting and Engineering Services costs) annually for Operation and Maintenance. This does not include the cost of power for pumping, which is discussed in Section 8.3 below. Because the transmission system for each combination alternative was modeled individually, the Operation and Maintenance estimate for that alternative is likewise unique and not necessarily additive of the Operation and Maintenance costs of the stand-alone components.

8.3 ANNUAL PUMPING COSTS

As noted above, horsepower requirements for each of the sixty stand-alone or combination alternatives were calculated by the transmission cost model. Based on a user-input cost for electricity, the model also estimates annual pumping costs. TWDB guidelines for the current round of regional water planning specify an electricity cost of $0.09 per kilowatt hour unless better assumptions can be documented and justified. In order to develop a consensus value to use for the cost of electricity in the 2016 Regional Water Plan, FNI queried four major raw water suppliers (TRWD, DWU, UTRWD, and NTMWD) as to their current electricity contracts and desired rates for that analysis. All four entities have current contracts for electricity at rates substantially less than $0.09 per kilowatt hour; current rates for these suppliers range from $0.04787 per kilowatt hour to $0.07 per kilowatt hour. The consensus estimate for Region C planning purposes was $0.07 per kilowatt hour, and that same value was used in this analysis. Table 8-1 shows the estimated annual Operation and Maintenance costs for each standalone alternative.

Table 8-1 Annual Operation & Maintenance Costs

Reservoir Alternative	Conservation Pool Elevation (feet-NGVD)	Reservoir O&M Cost ($M/yr)	Transmission O&M Cost ($M/yr)	Pumping Costs ($M/yr)	Total Annual O&M Cost ($M/yr)
Wright Patman	232.5	*	21.5	30.8	52.3*
Wright Patman	242.5	*	38.1	69.0	107.1*
Wright Patman	252.5	*	50.8	95.7	146.5*
Marvin Nichols 1A	296.5	3.2	13.6	17.3	34.1
Marvin Nichols 1A	313.5	4.2	21.0	35.2	60.4
Marvin Nichols 1A	328	5.5	29.5	52.0	87.0
Talco (Config 1)	350	2.8	11.4	14.0	28.2
Talco (Config 2)	350	2.8	15.6	22.4	40.8
Talco (Config 1)	370	6.6	14.9	22.2	43.7
Talco (Config 2)	370	6.6	22.7	41.6	70.9
George Parkhouse I	401	3.4	8.6	9.0	21.0
George Parkhouse II	410	3.8	8.5	8.9	21.2

* estimate does not include reservoir Operation and Maintenance component of Wright Patman costs

9.0 CARBON FOOTPRINT ANALYSIS

9.1 INTRODUCTION

A carbon footprint analysis was performed to compare the carbon emissions from each of the 60 alternatives assessed as part of the Sulphur River Basin Comparative Analysis. A carbon footprint is an inventory of the greenhouse gas (GHG) emissions caused by an organization, event, or product over a giver period of time and is often expressed in terms of carbon dioxide equivalents (CO_2e). The greenhouse gases included in this carbon analysis are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The analysis provides information on the carbon emissions associated with moving different amounts of water various distances. This carbon analysis includes the embodied emissions of the key materials used for the pipelines, pump stations, and dams, as well as, the change in atmospheric carbon due to the reservoir inundation, and the emissions associated with transmitting the water from each source to the users over the life of each project.

The embodied energy (carbon) of a building material is representative of the total primary energy consumed (carbon released) over its life cycle, including extraction, manufacturing, and transportation. (Hammond and Jones, 2008). The embodied emission coefficients for major building materials included in pipelines, pump stations and reservoir embankments have been estimated by researchers and are available on line. Coefficients for this analysis were obtained from the University of Bath's Inventory of Carbon and Energy (ICE) database, Version 2.0.

The lake inundation analysis considers the amount of greenhouse gases that are currently being removed by existing vegetation within each reservoir site in addition to the greenhouse gases emitted by the reservoir surface over a 100 year lifetime. This variable is largely a function of the size of the reservoir footprint and the type of vegetation inundated. The net change in Greenhouse Gases (GHG) is derived from estimates of CO_2, CH_4, and N_2O uptake from the existing land cover over the project life (future carbon sequestration foregone) added to the flux from the reservoir surface resulting from decomposing biomass within the reservoir (current carbon sequestration).

The emissions associated with pumping the water from point A to point B, or power generation emissions, are associated with generating the electricity needed to power the pumps. They are calculated using the kilowatt hours at average flow for all of the pump stations along the pipeline route.

The total carbon footprint for a given alternative is the sum of the embodied emissions, the inundation emissions and the power generation emissions for that alternative. A detailed explanation of the methodology and input data is contained in Appendix D, Carbon Footprint Analysis.

9.2 KEY ASSUMPTIONS

A 100-year period was determined to be representative of the project life for a large-scale water project and was selected to assess the carbon emissions for each alternative. The 100-year period is assumed to start after construction is complete and water is being moved from point A to point B.

Because this analysis is for comparative purposes only and is not intended to calculate exact amounts of carbon emissions, several simplifying assumptions were made.

- The emissions from transporting the construction materials from the factory gate to the project site, as well as the emissions due to construction, were not included. It was assumed these emissions would be similar for each alternative and would be minimal when compared to the embodied, inundation, and operational emissions.
- Emissions associated with operation and maintenance activities (including the replacement of parts, driving, etc.) over the 100 year life of each alternative were not considered. At this point in the planning process it would be difficult to accurately quantify these emissions and they will likely be negligible relative to the other emissions considered in this analysis.
- Where the transmission analysis assumes the upgrade of an existing pump station (rather than construction of a new pump station), only the net increase in emissions from upgrades to existing pump stations was included.
- Phasing of the construction of the infrastructure is an option and would change the total amount of operation emissions over the 100 year life of each alternative, but detailed evaluation of project phasing is outside of the scope of this analysis and was not considered herein.

9.3 EMBODIED EMISSIONS

Estimates of the total Embodied Emissions associated with the materials in the pipes, pump stations, and embankment for each alternative are shown in Figure 9-1. Figure 9-2 shows the embodied emissions on a unit basis, per 1,000 gallons of yield. As can be seen in Figure 9-1, the embodied emissions associated with the embankment for the Wright Patman scenarios are negligible. This is because the embankment is already constructed and no enlargement is anticipated. (Depending on the results of the dam safety analysis, spillway modifications may be required to implement the Wright Patman reallocation alternatives. This is unknown as of the time of this analysis and would be expected to have a very minor effect on the overall estimation of embodied emissions.)

The majority of the embodied emissions are due to the pipelines and embankment. On average, the embodied emissions from the pipelines account for 56 % of the total embodied emissions, the dams account for 44 %, and the emissions from the pump stations account for less than one percent. As would be expected, the total embodied emissions are generally a function of the scale of the project. Figure 9-2 indicates that there is little variation in the unit embodied emissions between alternatives associated with the pipeline materials; almost all the variability is associated with the embodied emissions of the embankment materials. In general, the alternatives with smaller yields have significantly higher emissions embodied in the embankment than the alternatives with greater yields.

Figure 9-1 Total Embodied Emissions for Pipelines, Pump Stations, and Dams

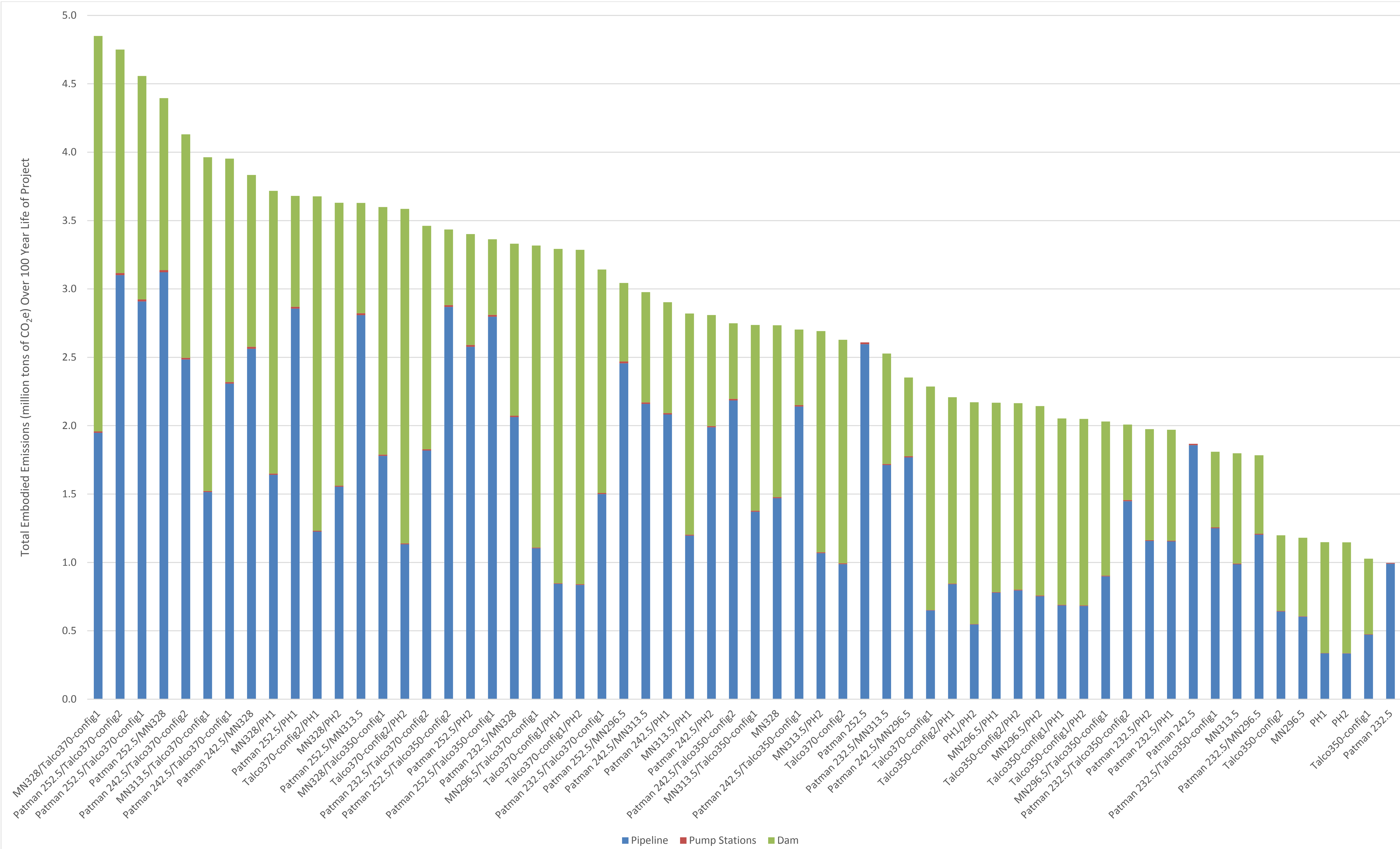
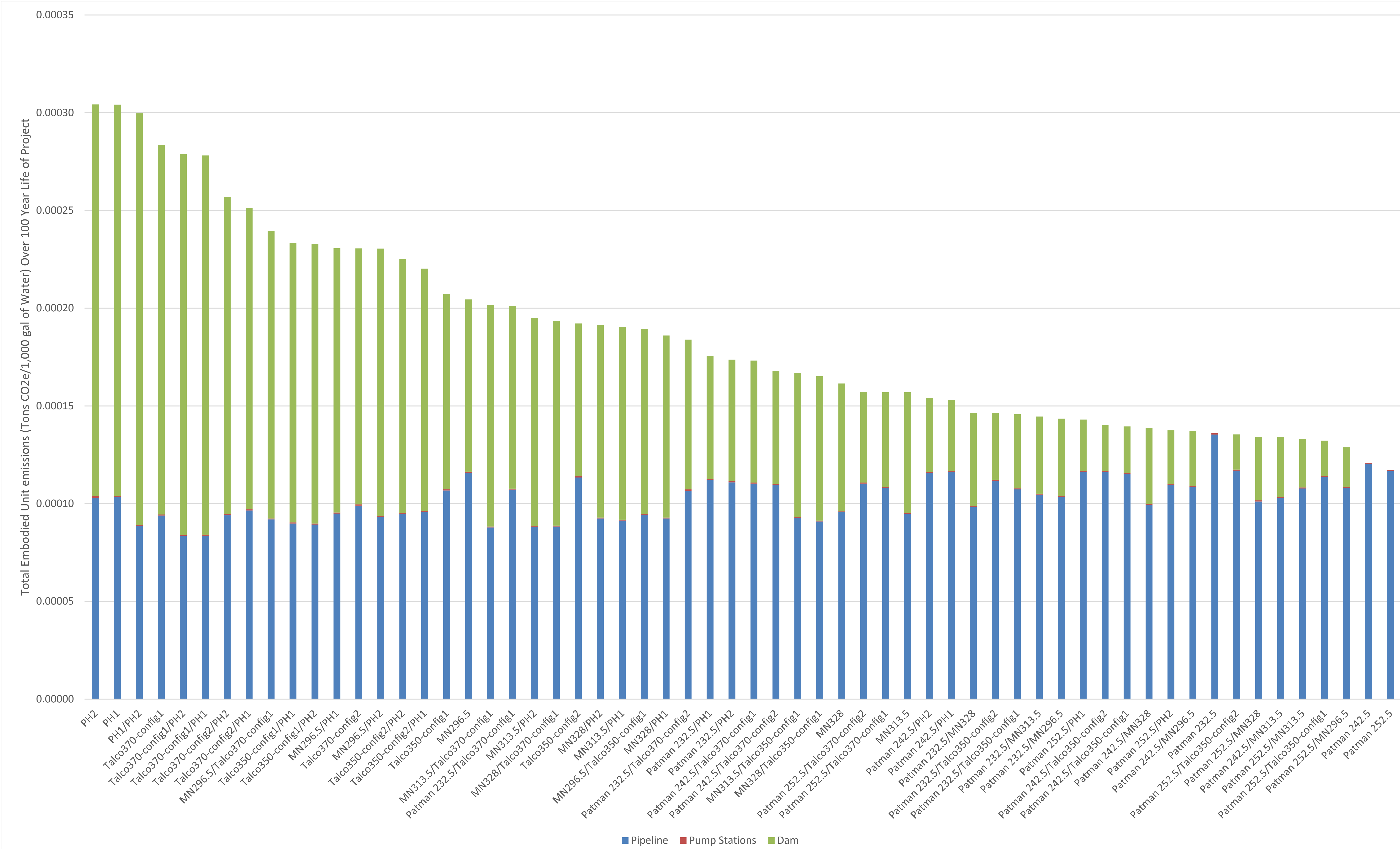


Figure 9-2 Unit Embodied Emissions for Pipelines, Pump Stations, and Dams



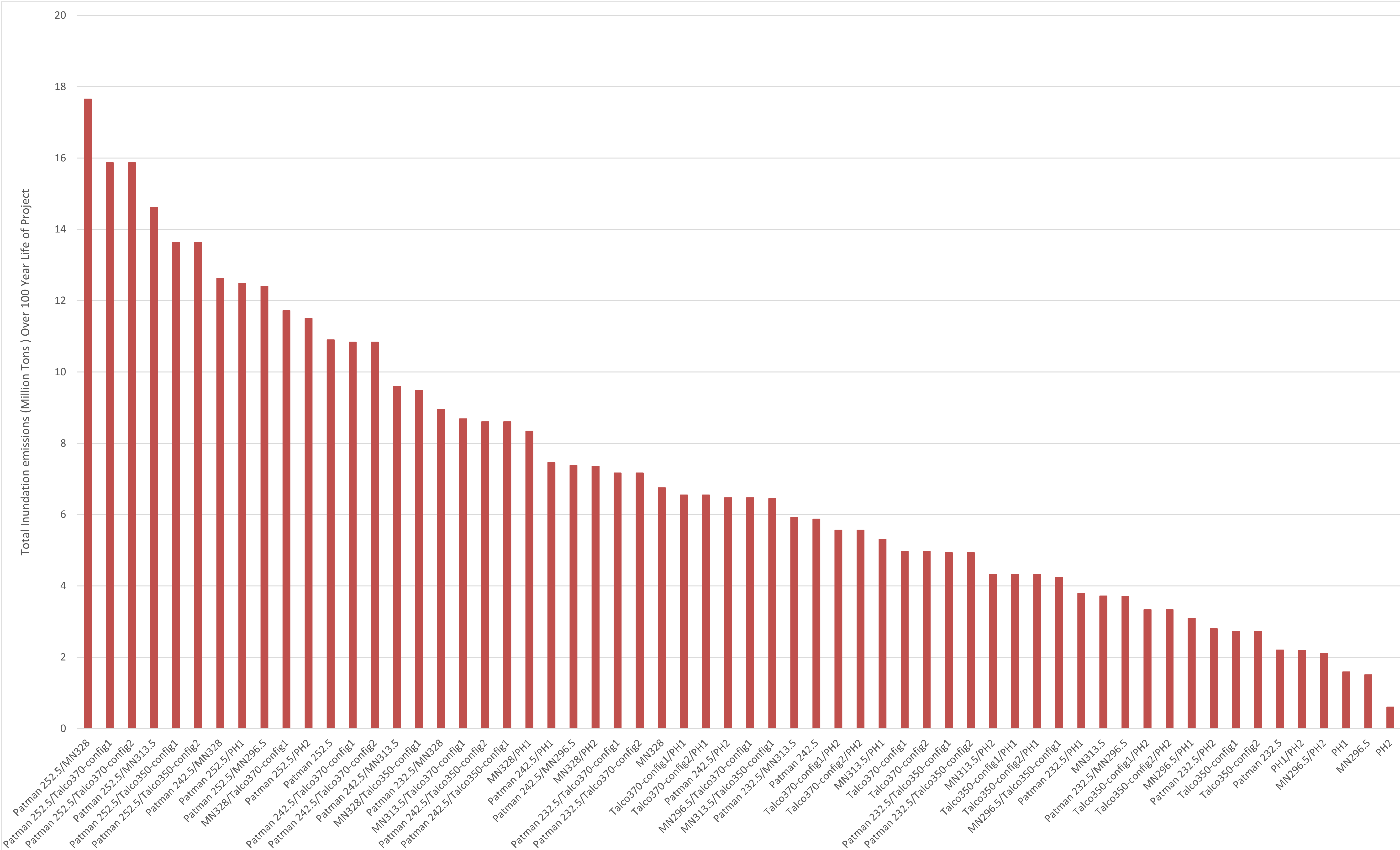
9.4 INUNDATION EMISSIONS

Over the 100 year life of the reservoir the total inundation CO_2e emissions for all sixty alternatives range from 600 thousand tons CO_2e to 17.7 million tons CO_2e. On a unit emissions basis (tons of CO_2e per 1,000 gallons of water), the emissions range from 0.00015 to 0.00057. The CO_2e emissions from the reservoirs throughout the 100 year lifetime are included in Table 9-1. For the Wright Patman alternatives, only the new area to be inundated is included in this analysis. The inundation emissions for the combination alternatives are the sum of the inundation emissions of the relevant components. In general, inundation emissions are largely a function of the area to be inundated, with some variability associated with the type of vegetation inundated. (Reservoirs inundating large areas of forest and wetlands will have higher emissions because those land types have higher biomass emission rates.) The Wright Patman 252.5 alternative has the largest area of wetland and forested area being inundated which would explain why alternatives involving Wright Patman 252.5 have the largest inundation emissions. Parkhouse II has the smallest area of wetland and forested area being inundated, hence many of the alternatives including Parkhouse II have lower total inundation emissions.

Table 9-1 Total Lake Inundation Emissions Over 100 Year Life of Project

Reservoir Alternative	Conservation Pool Elevation (feet-NGVD)	Total Yield (acre-ft/yr)	Lake Inundation Emissions (Tons CO_2e)	Unit Emissions (Tons CO_2e/1000 Gallons of Water)
Wright Patman	232.5	281,000	2,200,868	0.0002404
Wright Patman	242.5	592,700	5,872,308	0.0003041
Wright Patman	252.5	854,400	10,899,648	0.0003915
Marvin Nichols 1A	296.5	200,000	1,506,410	0.0002312
Marvin Nichols 1A	313.5	400,000	3,719,535	0.0002854
Marvin Nichols 1A	328	590,000	6,753,683	0.0003513
Talco (Config 1)	350	169,600	2,730,125	0.0004940
Talco (Config 2)	350	217,100	2,730,125	0.0003859
Talco (Config 1)	370	265,100	4,965,882	0.0005749
Talco (Config 2)	370	382,800	4,965,882	0.0003981
George Parkhouse I	401	124,300	1,586,792	0.0003918
George Parkhouse II	410	124,200	601,078	0.0001485

Figure 9-3 Total Inundation Emissions Over 100-Year Life of Project



9.5 POWER GENERATION EMISSIONS

The emissions associated with pumping the water from point A to point B, or power generation emissions, were calculated using the kilowatt hours at average flow for all of the pump stations along the pipeline route as calculated for the transmission cost estimates. Where the transmission analysis indicated a need for an upgrade to an existing pump station (rather than a new pump station), only the emissions from the increase in kilowatt hours used were included. The annual carbon dioxide equivalent emissions for each of the 60 alternatives were then calculated by multiplying the electricity use at average flow by the eGRID CO_2e emission rate for the ERCOT subregion, which includes nearly all of Texas. There is a direct correlation between the yield for an alternative and the amount of power generation emissions. Figure 9-4 shows the total power generation emissions, Figure 9-5 shows the unit emissions (emissions per 1,000 gallons of supply), and Figure 9-6 shows the unit emissions per mile of pipeline. Total power generation emissions vary significantly, based on both project scale and distance pumped. When controlling for project scale by estimating transmission emissions per 1,000 gallons of water yielded, Figure 9-5 indicates that variability is almost completely a function of distance pumped; the alternatives with the shortest pipeline length have lower per unit emissions than alternatives with longer pipeline length. When controlling for both scale and pipeline length (Figure 9-6), almost all the variability between alternatives is eliminated. The exception would be the Talco Configuration 2 alternatives and the Wright Patman reallocation alternatives, each of which require an extra booster pump station.

Figure 9-4 Total Power Generation Emissions

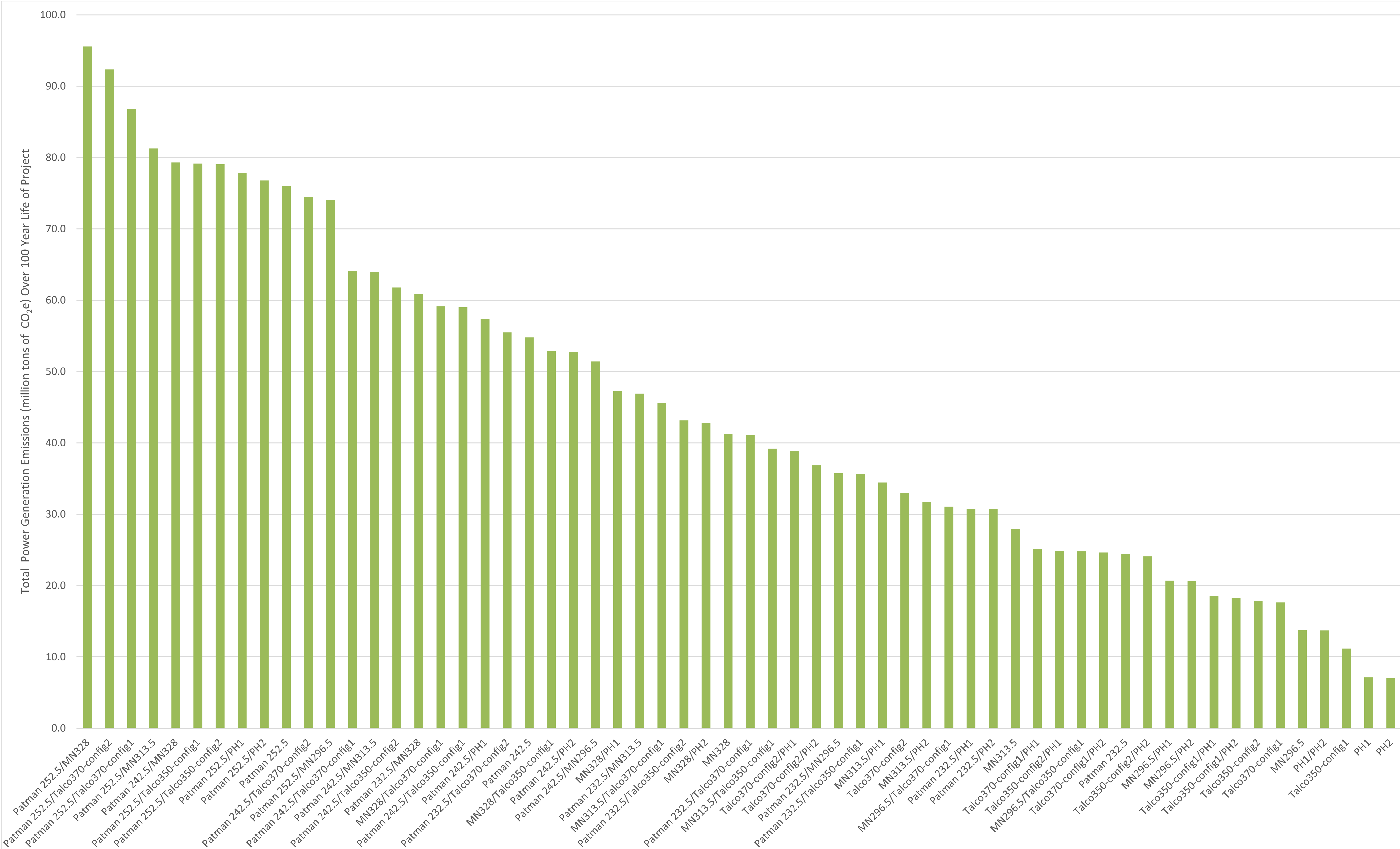


Figure 9-5 Unit Power Generation Emissions Over 100-Year Life of Project

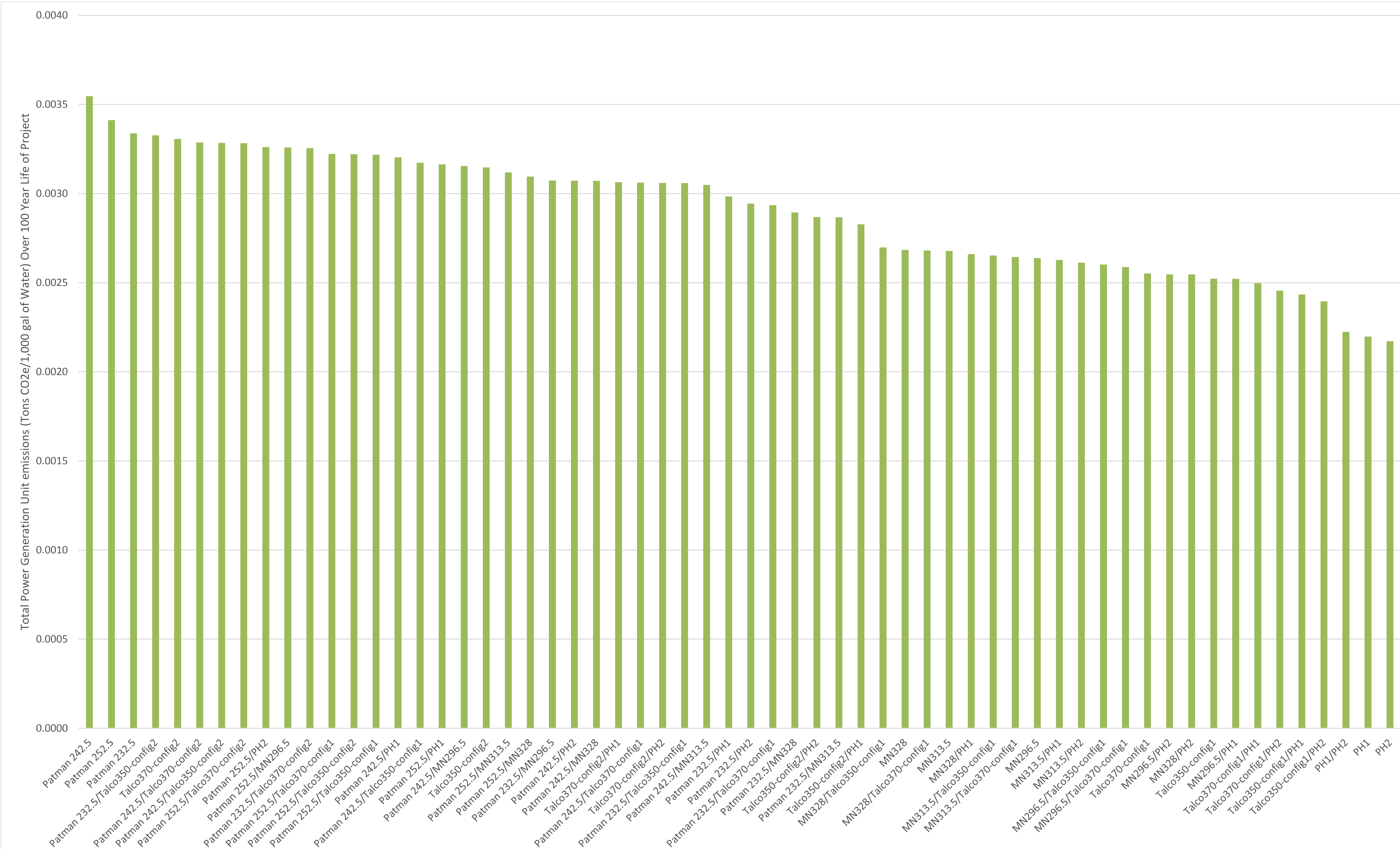
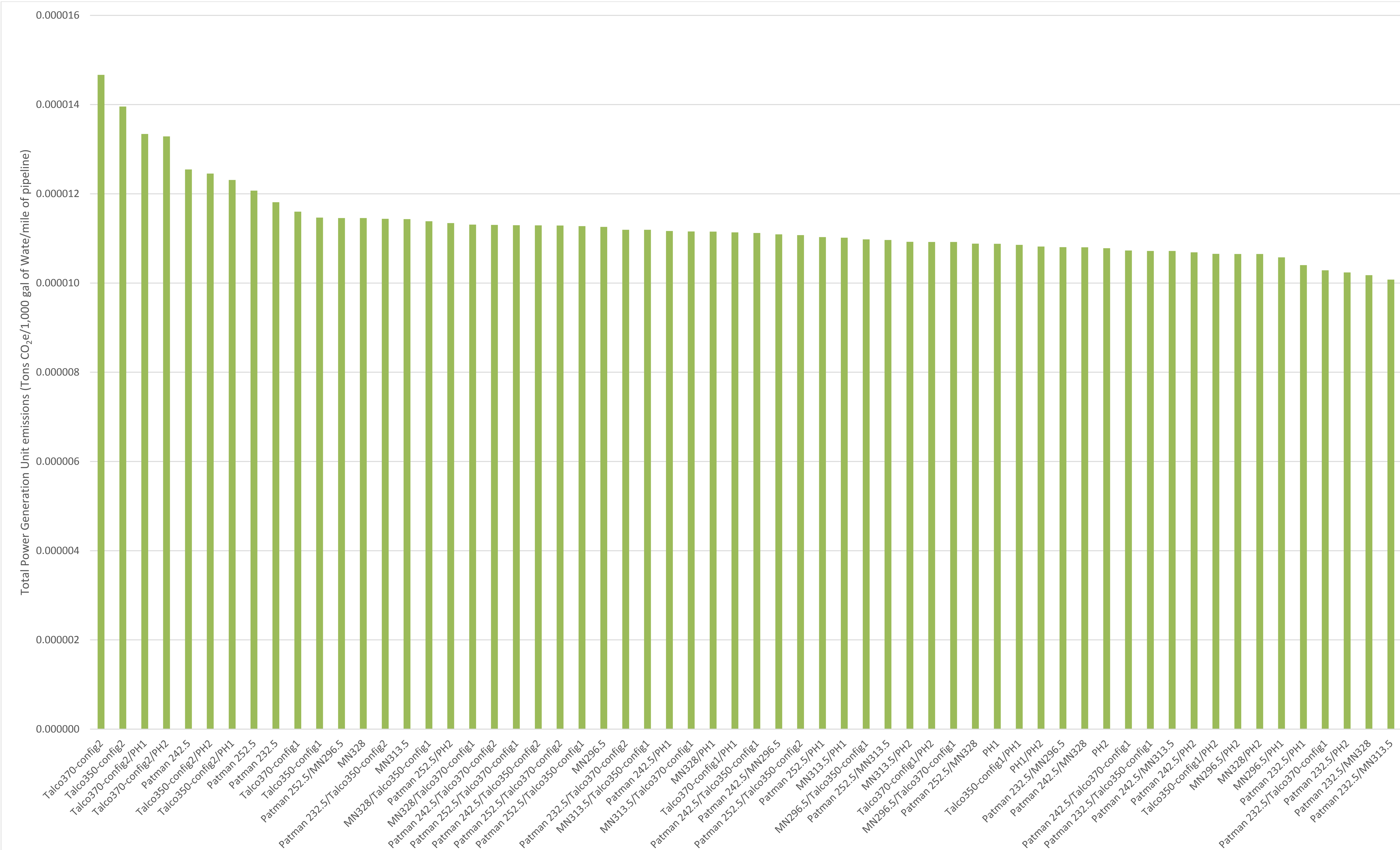


Figure 9-6 Unit Power Generation Emissions per Mile of Pipeline



9.6 SUMMARY OF CARBON FOOTPRINT ANALYSIS

Figure 9-7 portrays the total Carbon Dioxide equivalent emissions for each alternative over the project life. Total carbon emissions are substantially dominated by the power generation emissions which can comprise up to 88 % of the total emissions, depending on the alternative, and on average account for 81 % of the total emissions. As shown in Figure 9-7, the alternative with the lowest total emissions is the Parkhouse II Alternative, which also has the smallest project yield. The Wright Patman 252.5/Marvin Nichols 328 alternative has the highest total emissions. It is logical that the Wright Patman 252.5/Marvin Nichols 328 alternative would have the highest total emissions because it is the largest alternative in terms of supply.

The carbon dioxide equivalent emissions were also considered on a unit of water basis (amount of CO_2e/1,000 gallons of water) to eliminate the variability introduced by the different supply amounts. The unit emissions for each of the 60 alternatives are presented in Figure 9-8. The average unit emissions for the 60 alternatives is 0.0035 CO_2e/1,000 gallons of water.

Figure 9-7 Total Carbon Dioxide Equivalent Emissions Over 100-Year Life of Project

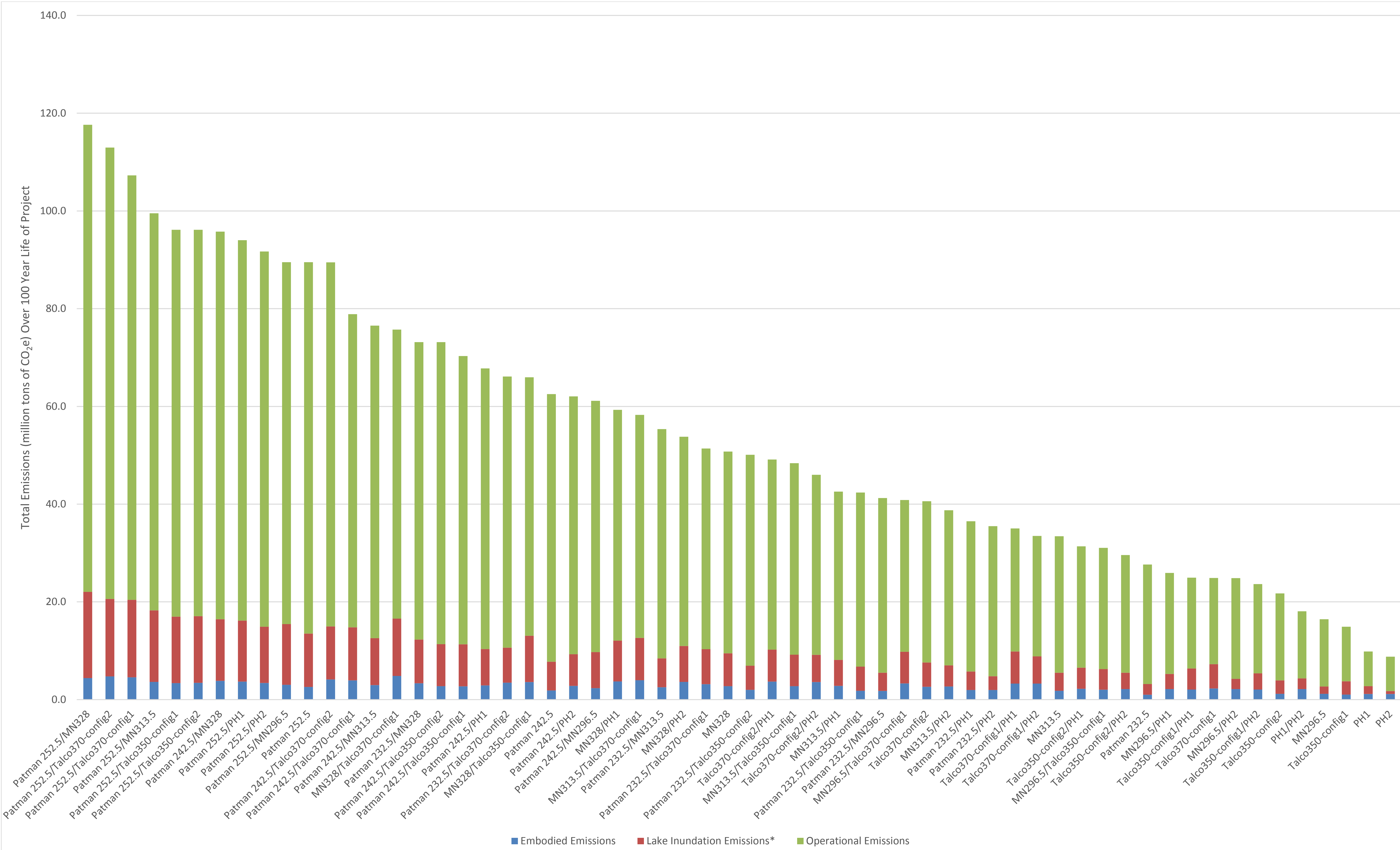
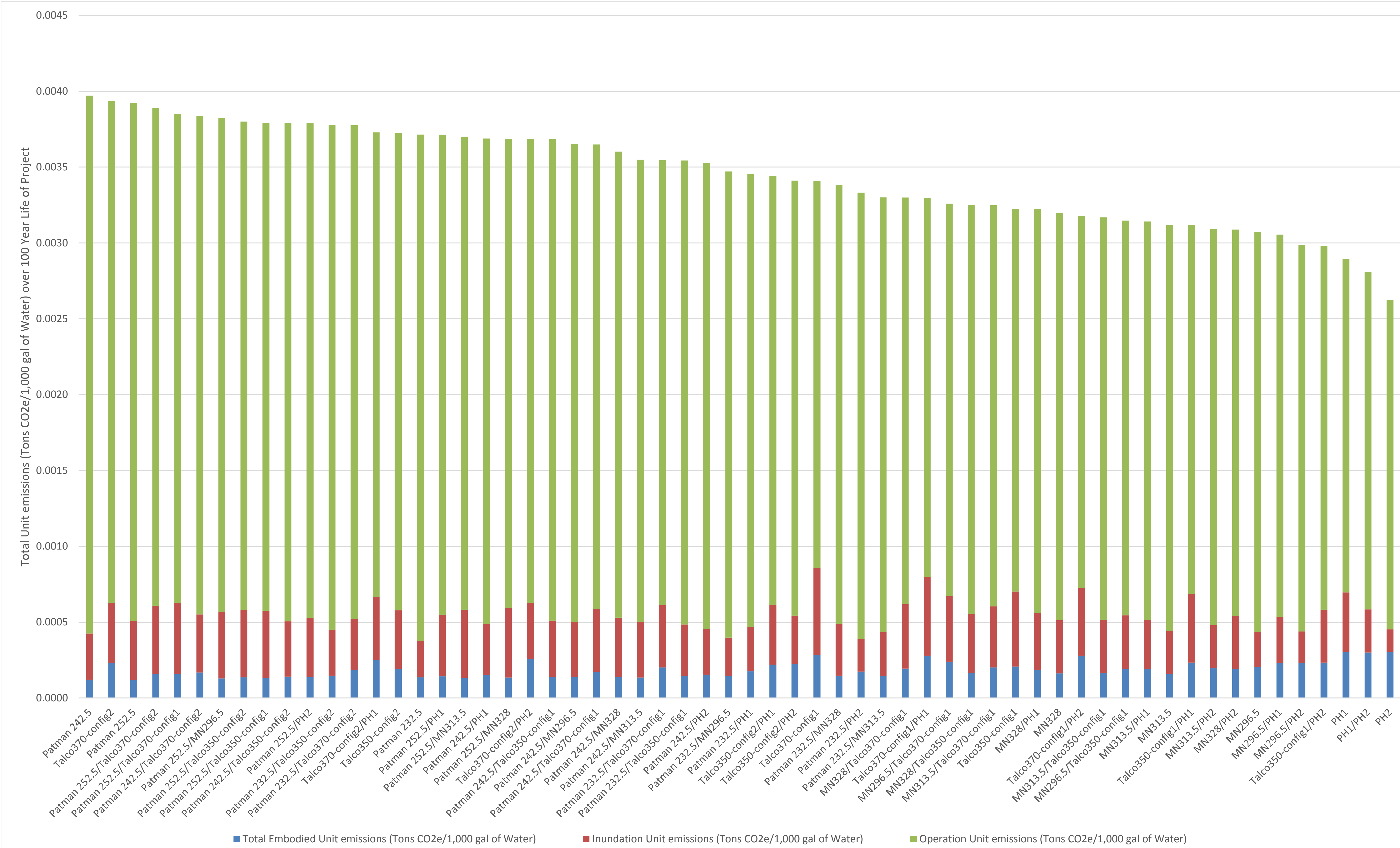


Figure 9-8 Total Unit Emissions Over 100-Year Life of Project



10.0 COST ROLLUP

10.1 CAPITAL COSTS

Previous chapters detail the development of costs for embankment and spillway construction, other reallocation activities, conflicts resolution, real estate, transmission, and operations and maintenance for all alternatives under evaluation in the Sulphur River Basin Feasibility Study. This chapter portrays comprehensive cost estimates for the alternatives and describes the process of converting these total costs to unit costs of water under several different scenarios.

Consistent with TWDB guidance on Regional Water Planning, Interest During Construction (IDC) has been added to the estimated capital costs for the reservoirs as well as for the transmission systems. Construction periods range from 6-84 months depending primarily on the scale of the embankment and the length of the required pipeline segments. In accordance with TWDB guidelines, IDC is calculated as the total of interest accrued at the end of the construction period using a 6 % annual interest rate on total borrowed funds, less a 4 % rate of return on investment of unspent funds.

Total capital costs for the alternatives for both the reservoir component and the transmission system are shown in Table 10-1.

Table 10-1 Estimated Capital Costs – All Alternatives

		CAPITAL COSTS											
		Reservoir							Transmission				Total Capital Cost
Alternative ID	Alternative Description	Dam and spillway	Land	Conflicts	Mitigation	Permitting	Total	Total Incl IDC	Pipelines	PumpStations	Total	Total incl IDC	
1	Patman 232.5	$ 92,403,951	$ 9,400,000	$ 31,396,484	$ 158,816,600	$ 7,392,316	$ 299,409,351	$ 335,838,487	$1,444,112,000	$385,704,000	$1,829,816,000	**$2,272,027,633**	**$ 2,607,866,120**
2	Patman 242.5	$ 281,492,014	$ 27,800,000	$ 64,166,464	$ 260,860,200	$ 22,519,361	$ 656,838,039	$ 736,755,523	$2,683,930,000	$630,111,000	$3,314,041,000	**$4,114,945,288**	**$ 4,851,700,812**
3	Patman 252.5	$ 521,325,861	$ 61,500,000	$ 153,995,494	$ 428,969,800	$ 41,706,069	$ 1,207,497,224	$ 1,354,413,411	$3,689,963,000	$791,872,000	$4,481,835,000	**$5,564,960,064**	**$ 6,919,373,476**
4	MN296.5	$ 177,177,000	$ 42,766,431	$ 24,531,767	$ 161,286,100	$ 14,174,160	$ 419,935,458	$ 471,029,005	$884,629,000	$260,152,000	$1,144,781,000	**$1,421,440,224**	**$ 1,892,469,229**
5	MN313.5	$ 236,023,000	$ 73,001,776	$ 61,007,031	$ 270,203,900	$ 18,881,840	$ 659,117,547	$ 739,312,379	$1,406,061,000	$377,709,000	$1,783,770,000	**$2,214,853,696**	**$ 2,954,166,075**
6	MN328	$ 304,790,000	$ 142,889,057	$ 142,850,609	$ 336,972,050	$ 24,383,200	$ 951,884,916	$ 1,067,700,754	$2,111,305,000	$473,890,000	$2,585,195,000	**$3,209,959,076**	**$ 4,277,659,829**
7	Talco 350/config1	$ 156,781,000	$ 108,744,494	$ 92,825,199	$ 121,451,300	$ 12,542,480	$ 492,344,473	$ 552,248,025	$701,704,000	$236,846,000	$938,550,000	**$1,165,369,379**	**$ 1,717,617,404**
8	Talco 350/config2	$ 156,781,000	$ 108,744,494	$ 92,825,199	$ 121,451,300	$ 12,542,480	$ 492,344,473	$ 552,248,025	$953,931,000	$323,174,000	$1,277,105,000	**$1,585,742,965**	**$ 2,137,990,990**
9	Talco 370/config1	$ 369,503,000	$ 183,297,904	$ 249,940,034	$ 184,528,470	$ 29,560,240	$ 1,016,829,648	$ 1,140,547,311	$950,422,000	$291,548,000	$1,241,970,000	**$1,542,116,890**	**$ 2,682,664,201**
10	Talco 370/config2	$ 369,503,000	$ 183,297,904	$ 249,940,034	$ 184,528,470	$ 29,560,240	$ 1,016,829,648	$ 1,140,547,311	$1,441,065,000	$443,107,000	$1,884,172,000	**$2,339,519,847**	**$ 3,480,067,159**
11	PH1	$ 188,596,000	$ 62,537,183	$ 43,617,108	$ 98,687,300	$ 15,087,680	$ 408,525,271	$ 458,230,541	$516,137,000	$183,404,000	$699,541,000	**$868,599,073**	**$ 1,326,829,614**
12	PH2	$ 210,659,000	$ 20,385,741	$ 44,918,739	$ 41,572,700	$ 16,852,720	$ 334,388,900	$ 375,073,997	$514,206,000	$181,963,000	$696,169,000	**$864,412,162**	**$ 1,239,486,160**
13	Patman 232.5/MN296.5	$ 269,580,951	$ 52,166,431	$ 55,928,251	$ 320,102,700	$ 21,566,476	$ 719,344,809	$ 806,867,492	$1,708,483,000	$507,792,000	$2,216,275,000	**$2,751,882,179**	**$ 3,558,749,671**
14	Patman 242.5/MN296.5	$ 458,669,014	$ 70,566,431	$ 88,698,231	$ 422,146,300	$ 36,693,521	$ 1,076,773,497	$ 1,207,784,529	$2,540,049,000	$632,113,000	$3,172,162,000	**$3,938,778,391**	**$ 5,146,562,919**
15	Patman 252.5/MN296.5	$ 698,502,861	$ 104,266,431	$ 178,527,261	$ 590,255,900	$ 55,880,229	$ 1,627,432,682	$ 1,825,442,416	$3,520,313,000	$809,612,000	$4,329,925,000	**$5,376,337,975**	**$ 7,201,780,391**
16	Patman 232.5/MN313.5	$ 328,426,951	$ 82,401,776	$ 92,403,515	$ 429,020,500	$ 26,274,156	$ 958,526,898	$ 1,075,150,866	$2,451,827,000	$602,635,000	$3,054,462,000	**$3,792,633,832**	**$ 4,867,784,697**
17	Patman 242.5/MN313.5	$ 517,515,014	$ 100,801,776	$ 125,173,495	$ 531,064,100	$ 41,401,201	$ 1,315,955,586	$ 1,476,067,902	$3,090,144,000	$736,476,000	$3,826,620,000	**$4,751,399,255**	**$ 6,227,467,158**
18	Patman 252.5/MN313.5	$ 757,348,861	$ 134,501,776	$ 215,002,525	$ 699,173,700	$ 60,587,909	$ 1,866,614,771	$ 2,093,725,790	$4,040,159,000	$873,719,000	$4,913,878,000	**$6,101,414,896**	**$ 8,195,140,686**
19	Patman 232.5/MN328	$ 397,193,951	$ 152,289,057	$ 174,247,093	$ 495,788,650	$ 31,775,516	$ 1,251,294,267	$ 1,403,539,241	$2,951,005,000	$709,910,000	$3,660,915,000	**$4,545,648,328**	**$ 5,949,187,569**
20	Patman 242.5/MN328	$ 586,282,014	$ 170,689,057	$ 207,017,073	$ 597,832,250	$ 46,902,561	$ 1,608,722,955	$ 1,804,456,277	$3,683,014,000	$855,931,000	$4,538,945,000	**$5,635,871,838**	**$ 7,440,328,115**
21	Patman 252.5/MN328	$ 826,115,861	$ 204,389,057	$ 296,846,103	$ 765,941,850	$ 66,089,269	$ 2,159,382,140	$ 2,422,114,165	$4,451,346,000	$986,600,000	$5,437,946,000	**$6,752,134,410**	**$ 9,174,248,575**
22	Patman 232.5/PH1	$ 280,999,951	$ 71,937,183	$ 75,013,592	$ 257,503,900	$ 22,479,996	$ 707,934,622	$ 794,069,028	$1,659,839,000	$473,374,000	$2,133,213,000	**$2,648,746,586**	**$ 3,442,815,613**
23	Patman 242.5/PH1	$ 470,088,014	$ 90,337,183	$ 107,783,572	$ 359,547,500	$ 37,607,041	$ 1,065,363,310	$ 1,194,986,064	$3,015,712,000	$681,479,000	$3,697,191,000	**$4,590,691,149**	**$ 5,785,677,213**
24	Patman 252.5/PH1	$ 709,921,861	$ 124,037,183	$ 197,612,602	$ 527,657,100	$ 56,793,749	$ 1,616,022,495	$ 1,812,643,952	$4,068,623,000	$834,463,000	$4,903,086,000	**$6,088,014,794**	**$ 7,900,658,745**
25	Patman 232.5/PH2	$ 303,062,951	$ 29,785,741	$ 76,315,223	$ 200,389,300	$ 24,245,036	$ 633,798,251	$ 710,912,484	$1,664,073,000	$468,842,000	$2,132,915,000	**$2,648,376,568**	**$ 3,359,289,052**
26	Patman 242.5/PH2	$ 492,151,014	$ 48,185,741	$ 109,085,203	$ 302,432,900	$ 39,372,081	$ 991,226,939	$ 1,111,829,521	$2,861,955,000	$641,217,000	$3,503,172,000	**$4,349,783,577**	**$ 5,461,613,098**
27	Patman 252.5/PH2	$ 731,984,861	$ 81,885,741	$ 198,914,233	$ 470,542,500	$ 58,558,789	$ 1,541,886,124	$ 1,729,487,409	$3,664,098,000	$832,286,000	$4,496,384,000	**$5,583,025,121**	**$ 7,312,512,530**
28	Patman 232.5/Talco350-config1	$ 249,184,951	$ 118,144,494	$ 124,221,683	$ 280,267,900	$ 19,934,796	$ 791,753,824	$ 888,086,512	$1,785,522,000	$509,193,000	$2,294,715,000	**$2,849,278,774**	**$ 3,737,365,286**
29	Patman 242.5/Talco350-config1	$ 438,273,014	$ 136,544,494	$ 156,991,663	$ 382,311,500	$ 35,061,841	$ 1,149,182,512	$ 1,289,003,548	$3,088,501,000	$691,234,000	$3,779,735,000	**$4,693,183,557**	**$ 5,982,187,106**
30	Patman 252.5/Talco350-config1	$ 678,106,861	$ 170,244,494	$ 246,820,693	$ 550,421,100	$ 54,248,549	$ 1,699,841,697	$ 1,906,661,436	$3,998,537,000	$848,690,000	$4,847,227,000	**$6,018,656,349**	**$ 7,925,317,785**
31	Patman 232.5/Talco350-config2	$ 249,184,951	$ 118,144,494	$ 124,221,683	$ 280,267,900	$ 19,934,796	$ 791,753,824	$ 888,086,512	$2,111,056,000	$596,229,000	$2,707,285,000	**$3,361,554,566**	**$ 4,249,641,078**
32	Patman 242.5/Talco350-config2	$ 438,273,014	$ 136,544,494	$ 156,991,663	$ 382,311,500	$ 35,061,841	$ 1,149,182,512	$ 1,289,003,548	$3,164,577,000	$741,259,000	$3,905,836,000	**$4,849,759,386**	**$ 6,138,762,934**
33	Patman 252.5/Talco350-config2	$ 678,106,861	$ 170,244,494	$ 246,820,693	$ 550,421,100	$ 54,248,549	$ 1,699,841,697	$ 1,906,661,436	$4,115,661,000	$875,469,000	$4,991,130,000	**$6,197,336,387**	**$ 8,103,997,823**
34	Patman 232.5/Talco370-config1	$ 461,906,951	$ 192,697,904	$ 281,336,518	$ 343,345,070	$ 36,952,556	$ 1,316,238,999	$ 1,476,385,798	$2,164,669,000	$549,945,000	$2,714,614,000	**$3,370,654,765**	**$ 4,847,040,563**
35	Patman 242.5/Talco370-config1	$ 650,995,014	$ 211,097,904	$ 314,106,498	$ 445,388,670	$ 52,079,601	$ 1,673,667,687	$ 1,877,302,835	$3,318,570,000	$728,972,000	$4,047,542,000	**$5,025,711,475**	**$ 6,903,014,310**
36	Patman 252.5/Talco370-config1	$ 890,828,861	$ 244,797,904	$ 403,935,528	$ 613,498,270	$ 71,266,309	$ 2,224,326,872	$ 2,494,960,722	$4,148,245,000	$909,154,000	$5,057,399,000	**$6,279,620,616**	**$ 8,774,581,339**
37	Patman 232.5/Talco370-config2	$ 461,906,951	$ 192,697,904	$ 281,336,518	$ 343,345,070	$ 36,952,556	$ 1,316,238,999	$ 1,476,385,798	$2,638,112,000	$684,664,000	$3,322,776,000	**$4,125,791,276**	**$ 5,602,177,074**
38	Patman 242.5/Talco370-config2	$ 650,995,014	$ 211,097,904	$ 314,106,498	$ 445,388,670	$ 52,079,601	$ 1,673,667,687	$ 1,877,302,835	$3,598,108,000	$834,566,000	$4,432,674,000	**$5,503,918,326**	**$ 7,381,221,160**
39	Patman 252.5/Talco370-config2	$ 890,828,861	$ 244,797,904	$ 403,935,528	$ 613,498,270	$ 71,266,309	$ 2,224,326,872	$ 2,494,960,722	$4,443,529,000	$973,481,000	$5,417,010,000	**$6,726,138,807**	**$ 9,221,099,529**
40	MN296.5/Talco350-config1	$ 333,958,000	$ 151,510,925	$ 117,356,966	$ 282,737,400	$ 26,716,640	$ 912,279,931	$ 1,023,277,030	$1,286,216,000	$389,572,000	$1,675,788,000	**$2,080,775,686**	**$ 3,104,052,716**
41	MN313.5/Talco350-config1	$ 392,804,000	$ 181,746,270	$ 153,832,230	$ 391,655,200	$ 31,424,320	$ 1,151,462,020	$ 1,291,560,404	$1,970,990,000	$495,435,000	$2,466,425,000	**$3,062,485,930**	**$ 4,354,046,334**
42	MN328/Talco350-config1	$ 461,571,000	$ 251,633,551	$ 235,675,808	$ 458,423,350	$ 36,925,680	$ 1,444,229,389	$ 1,619,948,779	$2,557,863,000	$597,709,000	$3,155,572,000	**$3,918,179,085**	**$ 5,538,127,864**
43	MN296.5/Talco370-config1	$ 546,680,000	$ 226,064,335	$ 274,471,801	$ 345,814,570	$ 43,734,400	$ 1,436,765,106	$ 1,611,576,316	$1,580,021,000	$435,876,000	$2,015,897,000	**$2,503,078,828**	**$ 4,114,655,144**
44	MN313.5/Talco370-config1	$ 605,526,000	$ 256,299,680	$ 310,947,065	$ 454,732,370	$ 48,442,080	$ 1,675,947,195	$ 1,879,859,690	$2,164,882,000	$542,953,000	$2,707,835,000	**$3,362,237,484**	**$ 5,242,097,175**
45	MN328/Talco370-config1	$ 674,293,000	$ 326,186,961	$ 392,790,643	$ 521,500,520	$ 53,943,440	$ 1,968,714,564	$ 2,208,248,065	$2,790,490,000	$641,755,000	$3,432,245,000	**$4,261,715,649**	**$ 6,469,963,714**
46	MN296.5/PH1	$ 365,773,000	$ 105,303,614	$ 68,148,875	$ 259,973,400	$ 29,261,840	$ 828,460,729	$ 929,259,546	$1,127,937,000	$352,703,000	$1,480,640,000	**$1,838,466,269**	**$ 2,767,725,815**
47	MN313.5/PH1	$ 424,619,000	$ 135,538,959	$ 104,624,139	$ 368,891,200	$ 33,969,520	$ 1,067,642,818	$ 1,197,542,920	$1,719,890,000	$456,201,000	$2,176,091,000	**$2,701,986,912**	**$ 3,899,529,832**
48	MN328/PH1	$ 493,386,000	$ 205,426,240	$ 186,467,717	$ 435,659,350	$ 39,470,880	$ 1,360,410,187	$ 1,525,931,294	$2,379,011,000	$550,847,000	$2,929,858,000	**$3,637,916,783**	**$ 5,163,848,077**
49	MN296.5/PH2	$ 387,836,000	$ 63,152,172	$ 69,450,506	$ 202,858,800	$ 31,026,880	$ 754,324,358	$ 846,103,003	$1,096,087,000	$350,885,000	$1,446,972,000	**$1,796,661,723**	**$ 2,642,764,726**
50	MN313.5/PH2	$ 446,682,000	$ 93,387,517	$ 105,925,770	$ 311,776,600	$ 35,734,560	$ 993,506,447	$ 1,114,386,376	$1,525,307,000	$435,939,000	$1,961,246,000	**$2,435,220,321**	**$ 3,549,606,697**
51	MN328/PH2	$ 515,449,000	$ 163,274,798	$ 187,769,348	$ 378,544,750	$ 41,235,920	$ 1,286,273,816	$ 1,442,774,751	$2,234,463,000	$515,031,000	$2,749,494,000	**$3,413,964,215**	**$ 4,856,738,966**
52	Talco350-config1/PH1	$ 345,377,000	$ 171,281,677	$ 136,442,307	$ 220,138,600	$ 27,630,160	$ 900,869,744	$ 1,010,478,566	$998,183,000	$336,194,000	$1,334,377,000	**$1,656,855,890**	**$ 2,667,334,455**
53	Talco350-config2/PH1	$ 367,440,000	$ 129,130,235	$ 137,743,938	$ 220,138,600	$ 29,395,200	$ 883,847,973	$ 991,385,756	$1,228,895,000	$417,226,000	$1,646,121,000	**$2,043,939,062**	**$ 3,035,324,818**
54	Talco370-config1/PH1	$ 558,099,000	$ 245,835,087	$ 293,557,142	$ 283,215,770	$ 44,647,920	$ 1,425,354,919	$ 1,598,777,852	$1,210,513,000	$386,486,000	$1,596,999,000	**$1,982,945,748**	**$ 3,581,723,600**
55	Talco370-config2/PH1	$ 580,162,000	$ 203,683,645	$ 294,858,773	$ 283,215,770	$ 46,412,960	$ 1,408,333,148	$ 1,579,685,042	$1,790,734,000	$516,808,000	$2,307,542,000	**$2,865,205,675**	**$ 4,444,890,717**
56	Talco350-config1/PH2	$ 367,440,000	$ 129,130,235	$ 137,743,938	$ 163,024,000	$ 29,395,200	$ 826,733,373	$ 927,322,022	$991,149,000	$331,260,000	$1,322,409,000	**$1,641,995,583**	**$ 2,569,317,606**
57	Talco350-config2/PH2	$ 426,361,951	$ 160,910,925	$ 148,753,450	$ 163,024,000	$ 34,108,956	$ 933,159,282	$ 1,046,696,772	$1,163,603,000	$408,655,000	$1,572,258,000	**$1,952,225,591**	**$ 2,998,922,363**
58	Talco370-config1/PH2	$ 580,162,000	$ 203,683,645	$ 294,858,773	$ 224,271,170	$ 46,412,960	$ 1,349,388,548	$ 1,513,568,653	$1,201,047,000	$381,104,000	$1,582,151,000	**$1,964,509,432**	**$ 3,478,078,085**
59	Talco370-config2/PH2	$ 639,083,951	$ 235,464,335	$ 305,868,285	$ 224,271,170	$ 51,126,716	$ 1,455,814,457	$ 1,632,943,402	$1,644,327,000	$501,051,000	$2,145,378,000	**$2,663,851,501**	**$ 4,296,794,903**
60	PH1/PH2	$ 399,255,000	$ 82,922,924	$ 88,535,847	$ 140,260,000	$ 31,940,400	$ 742,914,171	$ 833,304,538	$805,586,000	$286,213,000	$1,091,799,000	**$1,355,654,064**	**$ 2,188,958,603**

Embankment and spillway costs for the new reservoirs range from approximately $157 million to over $870 million. Not surprisingly, these costs are determined largely by the scale of the project, with alternatives yielding less than 200,000 acre-feet per year on the low end of the range, and alternatives yielding over 1,000,000 acre-feet per year on the high end of the range. Estimates for conflicts resolution varied widely between alternatives, ranging from a low of approximately $25 million for the Marvin Nichols 296.5 alternative to a high of almost $250 million for the Talco 370 alternative. Conflicts costs as a percentage of embankment and spillway cost range from 14% to as much as 68%. Total reservoir costs range from $408 million for Parkhouse I to $2.2 billion for the Wright Patman 252.5 reallocation in combination with the Talco 370 alternative.

Transmission costs dominate the total costs, and economies of scale are largely absent in transmission facilities. For even the smallest alternative (Parkhouse II), the estimated cost of the transmission system is more than twice the estimate of the reservoir cost. For larger alternatives, estimated transmission costs approach 3-4 times the current estimate of the reservoir cost. Comparing the transmission costs for different scales of reservoir at the same location provides additional information. For example, the Talco – Configuration 1 reservoir with a conservation pool of 350 feet-NGVD yields approximately 170,000 acre-ft per year. The larger scale (370 feet-NGVD) increases the yield by approximately 95,000 acre-ft per year. The estimated transmission cost for the larger scale is more than $300 million greater than the transmission cost for the smaller scale, resulting in a cost of approximately $3,900 per acre-foot of increased yield. Similarly, the marginal cost of the transmission system for increasing the yield from approximately 200,000 acre-feet per year (Marvin Nichols 1A, 296.5) to 400,000 acre-feet per year (Marvin Nichols 1A, 313.5) is almost $4,000 per acre-ft of increased yield while the cost increase for the next increment of yield (600,000 acre-feet/yr) at this location is almost $5,000 per acre-ft of increased yield.

Transmission costs are also particularly sensitive to the distance pumped. For example, both the Wright Patman 242.5 reallocation and the Marvin Nichols 328 alternatives yield approximately 600,000 acre-feet per year. However, the transmission costs for the Wright Patman alternative are estimated at $4.1 billion in contrast to $3.2 billion for the Marvin Nichols alternative, a difference equal to more than 1.5 times the cost of the reservoir construction.

10.2 ANNUAL COSTS

Table 10-2 Estimated Annual Costs – All Alternatives

		ANNUAL COSTS						
		Reservoir		Transmission			Total Annual Cost	Total Annual Cost
Alternative ID	Alternative Description	Debt Service	O&M	Debt Service	O&M	Electricity	During Debt Service	After Debt Service
1	Patman 232.5	$20,930,000	1,663,271	$141,600,000	$21,468,000	$30,795,000	$ 216,456,271	$ 53,926,271
2	Patman 242.5	$45,915,000	5,066,856	$256,452,000	$38,112,000	$69,000,000	$ 414,545,856	$ 112,178,856
3	Patman 252.5	$84,408,000	9,383,865	$346,816,000	$50,854,000	$95,704,000	$ 587,165,865	$ 155,941,865
4	MN296.5	$29,355,000	3,189,186	$88,592,000	$13,622,000	$17,318,000	$ 152,076,186	$ 34,129,186
5	MN313.5	$46,074,000	4,248,414	$138,037,000	$20,983,000	$35,168,000	$ 244,510,414	$ 60,399,414
6	MN328	$66,539,000	5,486,220	$200,053,000	$29,497,000	$51,980,000	$ 353,555,220	$ 86,963,220
7	Talco 350/config1	$34,416,000	2,822,058	$72,633,000	$11,451,000	$14,046,000	$ 135,368,058	$ 28,319,058
8	Talco 350/config2	$34,416,000	2,822,058	$98,831,000	$15,651,000	$22,424,000	$ 174,144,058	$ 40,897,058
9	Talco 370/config1	$71,079,000	6,651,054	$96,113,000	$14,931,000	$22,208,000	$ 210,982,054	$ 43,790,054
10	Talco 370/config2	$71,079,000	6,651,054	$145,808,000	$22,745,000	$41,550,000	$ 287,833,054	$ 70,946,054
11	PH1	$28,557,000	3,394,728	$54,138,000	$8,592,000	$8,967,000	$ 103,648,728	$ 20,953,728
12	PH2	$23,375,000	3,791,862	$53,876,000	$8,543,000	$8,857,000	$ 98,442,862	$ 21,191,862
13	Patman 232.5/MN296.5	$50,284,000	4,852,457	$171,498,000	$26,571,000	$45,014,000	$ 298,219,457	$ 76,437,457
14	Patman 242.5/MN296.5	$75,270,000	8,256,042	$245,466,000	$36,863,000	$64,739,000	$ 430,594,042	$ 109,858,042
15	Patman 252.5/MN296.5	$113,762,000	12,573,051	$335,056,000	$49,689,000	$93,282,000	$ 604,362,051	$ 155,544,051
16	Patman 232.5/MN313.5	$67,004,000	5,911,685	$236,359,000	$35,404,000	$59,090,000	$ 403,768,685	$ 100,405,685
17	Patman 242.5/MN313.5	$91,989,000	9,315,270	$296,109,000	$44,169,000	$80,554,000	$ 522,136,270	$ 134,038,270
18	Patman 252.5/MN313.5	$130,482,000	13,632,279	$380,242,000	$55,796,000	$102,341,000	$ 682,493,279	$ 171,769,279
19	Patman 232.5/MN328	$87,469,000	7,149,491	$283,286,000	$42,311,000	$76,637,000	$ 496,852,491	$ 126,097,491
20	Patman 242.5/MN328	$112,454,000	10,553,076	$351,229,000	$52,164,000	$99,888,000	$ 626,288,076	$ 162,605,076
21	Patman 252.5/MN328	$150,947,000	14,870,085	$420,795,000	$62,037,000	$120,369,000	$ 769,018,085	$ 197,276,085
22	Patman 232.5/PH1	$49,487,000	5,057,999	$165,072,000	$25,367,000	$38,706,000	$ 283,689,999	$ 69,130,999
23	Patman 242.5/PH1	$74,472,000	8,461,584	$286,094,000	$42,247,000	$72,292,000	$ 483,566,584	$ 123,000,584
24	Patman 252.5/PH1	$112,965,000	12,778,593	$379,408,000	$55,214,000	$98,019,000	$ 658,384,593	$ 166,011,593
25	Patman 232.5/PH2	$44,304,000	5,455,133	$165,048,000	$25,306,000	$38,680,000	$ 278,793,133	$ 69,441,133
26	Patman 242.5/PH2	$69,290,000	8,858,718	$271,081,000	$39,978,000	$66,447,000	$ 455,654,718	$ 115,283,718
27	Patman 252.5/PH2	$107,782,000	13,175,727	$347,936,000	$51,500,000	$96,705,000	$ 617,098,727	$ 161,380,727
28	Patman 232.5/Talco350-config1	$55,346,000	4,485,329	$177,569,000	$27,305,000	$44,889,000	$ 309,594,329	$ 76,679,329
29	Patman 242.5/Talco350-config1	$80,331,000	7,888,914	$292,481,000	$43,129,000	$74,309,000	$ 498,138,914	$ 125,326,914
30	Patman 252.5/Talco350-config1	$118,824,000	12,205,923	$375,085,000	$54,876,000	$99,678,000	$ 660,668,923	$ 166,759,923
31	Patman 232.5/Talco350-config2	$55,346,000	4,485,329	$209,493,000	$32,156,000	$54,340,000	$ 355,820,329	$ 90,981,329
32	Patman 242.5/Talco350-config2	$80,331,000	7,888,914	$302,238,000	$44,923,000	$77,813,000	$ 513,193,914	$ 130,624,914
33	Patman 252.5/Talco350-config2	$118,824,000	12,205,923	$386,219,000	$56,531,000	$99,565,000	$ 673,344,923	$ 168,301,923
34	Patman 232.5/Talco370-config1	$92,009,000	8,314,325	$210,061,000	$31,633,000	$51,728,000	$ 393,745,325	$ 91,675,325
35	Patman 242.5/Talco370-config1	$116,994,000	11,717,910	$313,203,000	$46,067,000	$80,718,000	$ 568,699,910	$ 138,502,910
36	Patman 252.5/Talco370-config1	$155,487,000	16,034,919	$391,348,000	$57,577,000	$109,365,000	$ 729,811,919	$ 182,976,919
37	Patman 232.5/Talco370-config2	$92,009,000	8,314,325	$257,120,000	$38,913,000	$69,873,000	$ 466,229,325	$ 117,100,325
38	Patman 242.5/Talco370-config2	$116,994,000	11,717,910	$343,006,000	$50,936,000	$93,824,000	$ 616,477,910	$ 156,477,910
39	Patman 252.5/Talco370-config2	$155,487,000	16,034,919	$419,175,000	$61,684,000	$116,291,000	$ 768,671,919	$ 194,009,919
40	MN296.5/Talco350-config1	$63,771,000	6,011,244	$129,682,000	$20,148,000	$31,220,000	$ 250,832,244	$ 57,379,244
41	MN313.5/Talco350-config1	$80,490,000	7,070,472	$190,863,000	$28,701,000	$49,362,000	$ 356,486,472	$ 85,133,472
42	MN328/Talco350-config1	$100,956,000	8,308,278	$244,190,000	$36,286,000	$66,572,000	$ 456,312,278	$ 111,166,278
43	MN296.5/Talco370-config1	$100,434,000	9,840,240	$155,999,000	$23,836,000	$39,107,000	$ 329,216,240	$ 72,783,240
44	MN313.5/Talco370-config1	$117,154,000	10,899,468	$209,542,000	$31,519,000	$57,442,000	$ 426,556,468	$ 99,860,468
45	MN328/Talco370-config1	$137,619,000	12,137,274	$265,599,000	$39,384,000	$74,490,000	$ 529,229,274	$ 126,011,274
46	MN296.5/PH1	$57,912,000	6,583,914	$114,581,000	$17,884,000	$26,039,000	$ 222,999,914	$ 50,506,914
47	MN313.5/PH1	$74,631,000	7,643,142	$168,396,000	$25,551,000	$43,376,000	$ 319,597,142	$ 76,570,142
48	MN328/PH1	$95,097,000	8,880,948	$226,723,000	$33,613,000	$59,501,000	$ 423,814,948	$ 101,994,948
49	MN296.5/PH2	$52,729,000	6,981,048	$111,976,000	$17,552,000	$25,975,000	$ 215,213,048	$ 50,508,048
50	MN313.5/PH2	$69,449,000	8,040,276	$151,770,000	$23,345,000	$39,962,000	$ 292,566,276	$ 71,347,276
51	MN328/PH2	$89,914,000	9,278,082	$212,767,000	$31,524,000	$53,922,000	$ 397,405,082	$ 94,724,082
52	Talco350-config1/PH1	$62,973,000	6,216,786	$103,263,000	$16,347,000	$23,390,000	$ 212,189,786	$ 45,953,786
53	Talco350-config2/PH1	$61,784,000	6,613,920	$127,386,000	$20,236,000	$31,297,000	$ 247,316,920	$ 58,146,920
54	Talco370-config1/PH1	$99,636,000	10,045,782	$123,586,000	$19,398,000	$31,695,000	$ 284,360,782	$ 61,138,782
55	Talco370-config2/PH1	$98,447,000	10,442,916	$178,568,000	$27,535,000	$48,989,000	$ 363,981,916	$ 86,966,916
56	Talco350-config1/PH2	$57,791,000	6,613,920	$102,337,000	$16,174,000	$23,013,000	$ 205,928,920	$ 45,800,920
57	Talco350-config2/PH2	$65,231,000	7,674,515	$121,670,000	$19,450,000	$30,352,000	$ 244,377,515	$ 57,476,515
58	Talco370-config1/PH2	$94,326,000	10,442,916	$122,436,000	$19,192,000	$31,022,000	$ 277,418,916	$ 60,656,916
59	Talco370-config2/PH2	$101,766,000	11,503,511	$166,020,000	$25,868,000	$46,422,000	$ 351,579,511	$ 83,793,511
60	PH1/PH2	$51,932,000	7,186,590	$84,492,000	$13,500,000	$17,259,000	$ 174,369,590	$ 37,945,590

Annual costs are comprised of the debt service on the reservoir and transmission components of the project, the estimated Operations and Maintenance costs for both the reservoir and transmission components of the project and the pumping costs. Consistent with TWDB guidelines for regional water planning, debt service was calculated using a 40 year repayment period and a 5.5% interest rate. Electricity costs were assumed to be $.07 per kilowatt hour. Table 10-2 portrays the annual cost of each alternative both during and after debt service on the capital costs.

10.3 UNIT COSTS

Cost per unit of water is a function of both the costs and the yield. Table 10-3 presents a variety of information relative to unit costs. Both cost per acre-foot of yield as well as per 1,000 gallons are displayed. In each case, the unit cost is shown both during and after debt service. In addition, unit costs are presented based on two different yield scenarios. The first set of unit costs are developed based on 100% of the dependable yield as identified by the updated WAM modeling (FNI, 2014). Those yields do not reflect the impact of eFlow requirements expected to be imposed during the permitting process. The second set of unit costs is based on yields net of an estimated eFlow requirement developed using the Lyons approach. This reduces yield by 1-22% depending on the alternative.

Table 10-3 Unit Cost of Water – All Alternatives

		100 % Yield UNIT COSTS				UNIT COSTS NET OF LYONS			
		Per Acre-ft		Per 1,000 Gallons		Per Acre-ft		Per 1,000 Gallons	
Alternative ID	Alternative Description	During Debt Service	After Debt Service	During Debt Service	After Debt Service	During Debt Service	After Debt Service	During Debt Service	After Debt Service
1	Patman 232.5	$ 770.31	$ 191.91	$ 2.37	$ 0.59	$ 981.28	$ 244.47	$ 3.01	$ 0.75
2	Patman 242.5	$ 699.42	$ 189.27	$ 2.15	$ 0.58	$ 874.27	$ 236.58	$ 2.69	$ 0.73
3	Patman 252.5	$ 687.23	$ 182.52	$ 2.11	$ 0.56	$ 827.98	$ 219.90	$ 2.54	$ 0.68
4	MN296.5	$ 760.38	$ 170.65	$ 2.34	$ 0.52	$ 784.71	$ 176.11	$ 2.41	$ 0.54
5	MN313.5	$ 611.28	$ 151.00	$ 1.88	$ 0.46	$ 630.83	$ 155.83	$ 1.94	$ 0.48
6	MN328	$ 599.25	$ 147.40	$ 1.84	$ 0.45	$ 618.42	$ 152.11	$ 1.90	$ 0.47
7	Talco 350/config1	$ 798.16	$ 166.98	$ 2.45	$ 0.51	$ 798.24	$ 166.99	$ 2.45	$ 0.51
8	Talco 350/config2	$ 802.14	$ 188.38	$ 2.46	$ 0.58	$ 802.22	$ 188.40	$ 2.46	$ 0.58
9	Talco 370/config1	$ 795.86	$ 165.18	$ 2.44	$ 0.51	$ 795.94	$ 165.20	$ 2.44	$ 0.51
10	Talco 370/config2	$ 751.91	$ 185.33	$ 2.31	$ 0.57	$ 751.99	$ 185.35	$ 2.31	$ 0.57
11	PH1	$ 833.86	$ 168.57	$ 2.56	$ 0.52	$ 873.15	$ 176.52	$ 2.68	$ 0.54
12	PH2	$ 792.62	$ 170.63	$ 2.43	$ 0.52	$ 811.27	$ 174.64	$ 2.49	$ 0.54
13	Patman 232.5/MN296.5	$ 668.35	$ 171.31	$ 2.05	$ 0.53	$ 742.03	$ 190.19	$ 2.28	$ 0.58
14	Patman 242.5/MN296.5	$ 688.73	$ 175.72	$ 2.12	$ 0.54	$ 786.36	$ 200.62	$ 2.42	$ 0.62
15	Patman 252.5/MN296.5	$ 693.08	$ 178.38	$ 2.13	$ 0.55	$ 792.33	$ 203.92	$ 2.43	$ 0.63
16	Patman 232.5/MN313.5	$ 642.99	$ 159.89	$ 1.97	$ 0.49	$ 697.06	$ 173.34	$ 2.14	$ 0.53
17	Patman 242.5/MN313.5	$ 648.66	$ 166.52	$ 1.99	$ 0.51	$ 721.95	$ 185.33	$ 2.22	$ 0.57
18	Patman 252.5/MN313.5	$ 682.73	$ 171.83	$ 2.10	$ 0.53	$ 762.64	$ 191.94	$ 2.34	$ 0.59
19	Patman 232.5/MN328	$ 615.98	$ 156.33	$ 1.89	$ 0.48	$ 659.28	$ 167.32	$ 2.02	$ 0.51
20	Patman 242.5/MN328	$ 632.29	$ 164.16	$ 1.94	$ 0.50	$ 693.54	$ 180.07	$ 2.13	$ 0.55
21	Patman 252.5/MN328	$ 649.21	$ 166.54	$ 1.99	$ 0.51	$ 715.92	$ 183.66	$ 2.20	$ 0.56
22	Patman 232.5/PH1	$ 717.95	$ 174.95	$ 2.20	$ 0.54	$ 852.87	$ 207.83	$ 2.62	$ 0.64
23	Patman 242.5/PH1	$ 703.33	$ 178.90	$ 2.16	$ 0.55	$ 847.62	$ 215.60	$ 2.60	$ 0.66
24	Patman 252.5/PH1	$ 697.71	$ 175.93	$ 2.14	$ 0.54	$ 823.27	$ 207.59	$ 2.53	$ 0.64
25	Patman 232.5/PH2	$ 696.46	$ 173.47	$ 2.14	$ 0.53	$ 819.51	$ 204.12	$ 2.52	$ 0.63
26	Patman 242.5/PH2	$ 691.70	$ 175.00	$ 2.12	$ 0.54	$ 827.06	$ 209.25	$ 2.54	$ 0.64
27	Patman 252.5/PH2	$ 683.08	$ 178.64	$ 2.10	$ 0.55	$ 801.74	$ 209.67	$ 2.46	$ 0.64
28	Patman 232.5/Talco350-config1	$ 692.59	$ 171.54	$ 2.13	$ 0.53	$ 794.22	$ 196.71	$ 2.44	$ 0.60
29	Patman 242.5/Talco350-config1	$ 698.42	$ 175.71	$ 2.15	$ 0.54	$ 820.95	$ 206.54	$ 2.52	$ 0.63
30	Patman 252.5/Talco350-config1	$ 700.11	$ 176.71	$ 2.15	$ 0.54	$ 811.63	$ 204.86	$ 2.49	$ 0.63
31	Patman 232.5/Talco350-config2	$ 715.14	$ 182.86	$ 2.20	$ 0.56	$ 801.45	$ 204.93	$ 2.46	$ 0.63
32	Patman 242.5/Talco350-config2	$ 711.04	$ 180.98	$ 2.18	$ 0.56	$ 818.41	$ 208.31	$ 2.51	$ 0.64
33	Patman 252.5/Talco350-config2	$ 715.07	$ 178.73	$ 2.20	$ 0.55	$ 817.38	$ 204.30	$ 2.51	$ 0.63
34	Patman 232.5/Talco370-config1	$ 733.37	$ 170.75	$ 2.25	$ 0.52	$ 820.83	$ 191.11	$ 2.52	$ 0.59
35	Patman 242.5/Talco370-config1	$ 708.10	$ 172.45	$ 2.17	$ 0.53	$ 816.32	$ 198.81	$ 2.51	$ 0.61
36	Patman 252.5/Talco370-config1	$ 706.11	$ 177.04	$ 2.17	$ 0.54	$ 807.41	$ 202.43	$ 2.48	$ 0.62
37	Patman 232.5/Talco370-config2	$ 713.07	$ 179.10	$ 2.19	$ 0.55	$ 773.51	$ 194.28	$ 2.38	$ 0.60
38	Patman 242.5/Talco370-config2	$ 709.06	$ 179.98	$ 2.18	$ 0.55	$ 791.59	$ 200.92	$ 2.43	$ 0.62
39	Patman 252.5/Talco370-config2	$ 712.31	$ 179.78	$ 2.19	$ 0.55	$ 795.37	$ 200.75	$ 2.44	$ 0.62
40	MN296.5/Talco350-config1	$ 686.35	$ 157.01	$ 2.11	$ 0.48	$ 698.05	$ 159.68	$ 2.14	$ 0.49
41	MN313.5/Talco350-config1	$ 628.92	$ 150.19	$ 1.93	$ 0.46	$ 642.95	$ 153.54	$ 1.97	$ 0.47
42	MN328/Talco350-config1	$ 607.11	$ 147.90	$ 1.86	$ 0.45	$ 622.08	$ 151.55	$ 1.91	$ 0.47
43	MN296.5/Talco370-config1	$ 715.14	$ 158.10	$ 2.20	$ 0.49	$ 724.80	$ 160.24	$ 2.23	$ 0.49
44	MN313.5/Talco370-config1	$ 644.63	$ 150.91	$ 1.98	$ 0.46	$ 656.91	$ 153.79	$ 2.02	$ 0.47
45	MN328/Talco370-config1	$ 625.19	$ 148.86	$ 1.92	$ 0.46	$ 638.85	$ 152.11	$ 1.96	$ 0.47
46	MN296.5/PH1	$ 709.06	$ 160.59	$ 2.18	$ 0.49	$ 735.95	$ 166.68	$ 2.26	$ 0.51
47	MN313.5/PH1	$ 635.52	$ 152.26	$ 1.95	$ 0.47	$ 658.20	$ 157.69	$ 2.02	$ 0.48
48	MN328/PH1	$ 621.97	$ 149.68	$ 1.91	$ 0.46	$ 643.56	$ 154.88	$ 1.98	$ 0.48
49	MN296.5/PH2	$ 692.78	$ 162.59	$ 2.13	$ 0.50	$ 712.59	$ 167.24	$ 2.19	$ 0.51
50	MN313.5/PH2	$ 627.92	$ 153.13	$ 1.93	$ 0.47	$ 646.58	$ 157.68	$ 1.99	$ 0.48
51	MN328/PH2	$ 616.17	$ 146.87	$ 1.89	$ 0.45	$ 634.87	$ 151.33	$ 1.95	$ 0.46
52	Talco350-config1/PH1	$ 724.82	$ 156.97	$ 2.23	$ 0.48	$ 738.98	$ 160.04	$ 2.27	$ 0.49
53	Talco350-config2/PH1	$ 733.51	$ 172.46	$ 2.25	$ 0.53	$ 745.93	$ 175.38	$ 2.29	$ 0.54
54	Talco370-config1/PH1	$ 735.39	$ 158.11	$ 2.26	$ 0.49	$ 746.24	$ 160.44	$ 2.29	$ 0.49
55	Talco370-config2/PH1	$ 747.43	$ 178.58	$ 2.30	$ 0.55	$ 756.17	$ 180.67	$ 2.32	$ 0.55
56	Talco350-config1/PH2	$ 703.65	$ 156.50	$ 2.16	$ 0.48	$ 710.62	$ 158.05	$ 2.18	$ 0.49
57	Talco350-config2/PH2	$ 758.16	$ 178.32	$ 2.33	$ 0.55	$ 764.99	$ 179.92	$ 2.35	$ 0.55
58	Talco370-config1/PH2	$ 720.77	$ 157.60	$ 2.21	$ 0.48	$ 726.21	$ 158.78	$ 2.23	$ 0.49
59	Talco370-config2/PH2	$ 760.70	$ 181.30	$ 2.34	$ 0.56	$ 765.49	$ 182.44	$ 2.35	$ 0.56
60	PH1/PH2	$ 737.57	$ 160.51	$ 2.27	$ 0.49	$ 763.98	$ 166.25	$ 2.35	$ 0.51

A third set of yields reflects the contractual relationship between the Metroplex members of the Joint Committee for Program Development (JCPD) and the Sulphur River Basin Authority wherein 20% of project yields would be dedicated to in-basin needs at no cost to the Authority. Table 10-4 shows the unit cost to the Metroplex JCPD members for based on their anticipated portion of the yield as well as the commensurate yield made available to in-Basin users.

10.4 EVALUATION

Figure 10-1 portrays all 60 alternatives in terms of their total capital costs, which range from $1.2 billion to over $10 billion. Not surprisingly, the variation is largely explained by the scale (yield) of the project and the distance water must be transported. Figure 10-2 ranks the alternatives based on total annual cost after debt service. Minor variations in ranking can be observed but the ranking of alternatives is substantially the same.

Table 10-4

					UNIT COSTS			
		Lyons Yield	Metroplex JCPD Yield	SRBA Yield	Per Acre-ft		Per 1,000 Gallons	
Alternative ID	Alternative Description	ac-ft/yr	ac-ft/yr	ac-ft/yr	During Debt Service	After Debt Service	During Debt Service	After Debt Service
1	Patman 232.5	220,585	176,468	44,117	$ 1,226.60	$ 305.59	$ 3.77	$ 0.94
2	Patman 242.5	474,160	379,328	94,832	$ 1,092.84	$ 295.73	$ 3.36	$ 0.91
3	Patman 252.5	709,152	567,322	141,830	$ 1,034.98	$ 274.87	$ 3.18	$ 0.84
4	MN296.5	193,800	155,040	38,760	$ 980.88	$ 220.13	$ 3.01	$ 0.68
5	MN313.5	387,600	310,080	77,520	$ 788.54	$ 194.79	$ 2.42	$ 0.60
6	MN328	571,710	457,368	114,342	$ 773.02	$ 190.14	$ 2.37	$ 0.58
7	Talco 350/config1	169,583	135,666	33,917	$ 997.80	$ 208.74	$ 3.06	$ 0.64
8	Talco 350/config2	217,078	173,663	43,416	$ 1,002.77	$ 235.50	$ 3.08	$ 0.72
9	Talco 370/config1	265,073	212,059	53,015	$ 994.92	$ 206.50	$ 3.06	$ 0.63
10	Talco 370/config2	382,762	306,209	76,552	$ 939.99	$ 231.69	$ 2.89	$ 0.71
11	PH1	118,707	94,965	23,741	$ 1,091.44	$ 220.65	$ 3.35	$ 0.68
12	PH2	121,343	97,075	24,269	$ 1,014.09	$ 218.30	$ 3.11	$ 0.67
13	Patman 232.5/MN296.5	401,897	321,518	80,379	$ 927.54	$ 237.74	$ 2.85	$ 0.73
14	Patman 242.5/MN296.5	547,581	438,065	109,516	$ 982.95	$ 250.78	$ 3.02	$ 0.77
15	Patman 252.5/MN296.5	762,763	610,211	152,553	$ 990.42	$ 254.90	$ 3.04	$ 0.78
16	Patman 232.5/MN313.5	579,246	463,397	115,849	$ 871.32	$ 216.67	$ 2.68	$ 0.67
17	Patman 242.5/MN313.5	723,229	578,584	144,646	$ 902.44	$ 231.67	$ 2.77	$ 0.71
18	Patman 252.5/MN313.5	894,907	715,926	178,981	$ 953.30	$ 239.93	$ 2.93	$ 0.74
19	Patman 232.5/MN328	753,627	602,902	150,725	$ 824.10	$ 209.15	$ 2.53	$ 0.64
20	Patman 242.5/MN328	903,027	722,422	180,605	$ 866.93	$ 225.08	$ 2.66	$ 0.69
21	Patman 252.5/MN328	1,074,166	859,333	214,833	$ 894.90	$ 229.57	$ 2.75	$ 0.71
22	Patman 232.5/PH1	332,632	266,105	66,526	$ 1,066.08	$ 259.79	$ 3.27	$ 0.80
23	Patman 242.5/PH1	570,498	456,399	114,100	$ 1,059.53	$ 269.50	$ 3.25	$ 0.83
24	Patman 252.5/PH1	799,717	639,773	159,943	$ 1,029.09	$ 259.49	$ 3.16	$ 0.80
25	Patman 232.5/PH2	340,194	272,155	68,039	$ 1,024.39	$ 255.15	$ 3.15	$ 0.78
26	Patman 242.5/PH2	550,930	440,744	110,186	$ 1,033.83	$ 261.57	$ 3.18	$ 0.80
27	Patman 252.5/PH2	769,696	615,757	153,939	$ 1,002.18	$ 262.09	$ 3.08	$ 0.80
28	Patman 232.5/Talco350-config1	389,810	311,848	77,962	$ 992.77	$ 245.89	$ 3.05	$ 0.76
29	Patman 242.5/Talco350-config1	606,784	485,427	121,357	$ 1,026.19	$ 258.18	$ 3.15	$ 0.79
30	Patman 252.5/Talco350-config1	814,006	651,205	162,801	$ 1,014.53	$ 256.08	$ 3.12	$ 0.79
31	Patman 232.5/Talco350-config2	443,969	355,175	88,794	$ 1,001.82	$ 256.16	$ 3.08	$ 0.79
32	Patman 242.5/Talco350-config2	627,065	501,652	125,413	$ 1,023.01	$ 260.39	$ 3.14	$ 0.80
33	Patman 252.5/Talco350-config2	823,781	659,025	164,756	$ 1,021.73	$ 255.38	$ 3.14	$ 0.78
34	Patman 232.5/Talco370-config1	479,692	383,753	95,938	$ 1,026.04	$ 238.89	$ 3.15	$ 0.73
35	Patman 242.5/Talco370-config1	696,665	557,332	139,333	$ 1,020.40	$ 248.51	$ 3.13	$ 0.76
36	Patman 252.5/Talco370-config1	903,888	723,110	180,778	$ 1,009.27	$ 253.04	$ 3.10	$ 0.78
37	Patman 232.5/Talco370-config2	602,747	482,198	120,549	$ 966.88	$ 242.85	$ 2.97	$ 0.75
38	Patman 242.5/Talco370-config2	778,788	623,031	155,758	$ 989.48	$ 251.16	$ 3.04	$ 0.77
39	Patman 252.5/Talco370-config2	966,429	773,143	193,286	$ 994.22	$ 250.94	$ 3.05	$ 0.77
40	MN296.5/Talco350-config1	359,335	287,468	71,867	$ 872.56	$ 199.60	$ 2.68	$ 0.61
41	MN313.5/Talco350-config1	554,453	443,562	110,891	$ 803.69	$ 191.93	$ 2.47	$ 0.59
42	MN328/Talco350-config1	733,524	586,819	146,705	$ 777.60	$ 189.44	$ 2.39	$ 0.58
43	MN296.5/Talco370-config1	454,216	363,373	90,843	$ 906.00	$ 200.30	$ 2.78	$ 0.62
44	MN313.5/Talco370-config1	649,334	519,467	129,867	$ 821.14	$ 192.24	$ 2.52	$ 0.59
45	MN328/Talco370-config1	828,405	662,724	165,681	$ 798.57	$ 190.14	$ 2.45	$ 0.58
46	MN296.5/PH1	303,010	242,408	60,602	$ 919.94	$ 208.35	$ 2.83	$ 0.64
47	MN313.5/PH1	485,560	388,448	97,112	$ 822.75	$ 197.12	$ 2.53	$ 0.61
48	MN328/PH1	658,546	526,837	131,709	$ 804.45	$ 193.60	$ 2.47	$ 0.59
49	MN296.5/PH2	302,014	241,611	60,403	$ 890.74	$ 209.05	$ 2.74	$ 0.64
50	MN313.5/PH2	452,480	361,984	90,496	$ 808.23	$ 197.10	$ 2.48	$ 0.61
51	MN328/PH2	625,960	500,768	125,192	$ 793.59	$ 189.16	$ 2.44	$ 0.58
52	Talco350-config1/PH1	287,139	229,711	57,428	$ 923.72	$ 200.05	$ 2.84	$ 0.61
53	Talco350-config2/PH1	331,554	265,243	66,311	$ 932.41	$ 219.22	$ 2.86	$ 0.67
54	Talco370-config1/PH1	381,059	304,847	76,212	$ 932.80	$ 200.56	$ 2.86	$ 0.62
55	Talco370-config2/PH1	481,349	385,079	96,270	$ 945.21	$ 225.84	$ 2.90	$ 0.69
56	Talco350-config1/PH2	289,786	231,829	57,957	$ 888.28	$ 197.56	$ 2.73	$ 0.61
57	Talco350-config2/PH2	319,453	255,562	63,891	$ 956.23	$ 224.90	$ 2.94	$ 0.69
58	Talco370-config1/PH2	382,007	305,605	76,401	$ 907.77	$ 198.48	$ 2.79	$ 0.61
59	Talco370-config2/PH2	459,289	367,431	91,858	$ 956.86	$ 228.05	$ 2.94	$ 0.70
60	PH1/PH2	228,238	182,590	45,648	$ 954.98	$ 207.82	$ 2.93	$ 0.64

Figure 10-1 Total Capital Costs

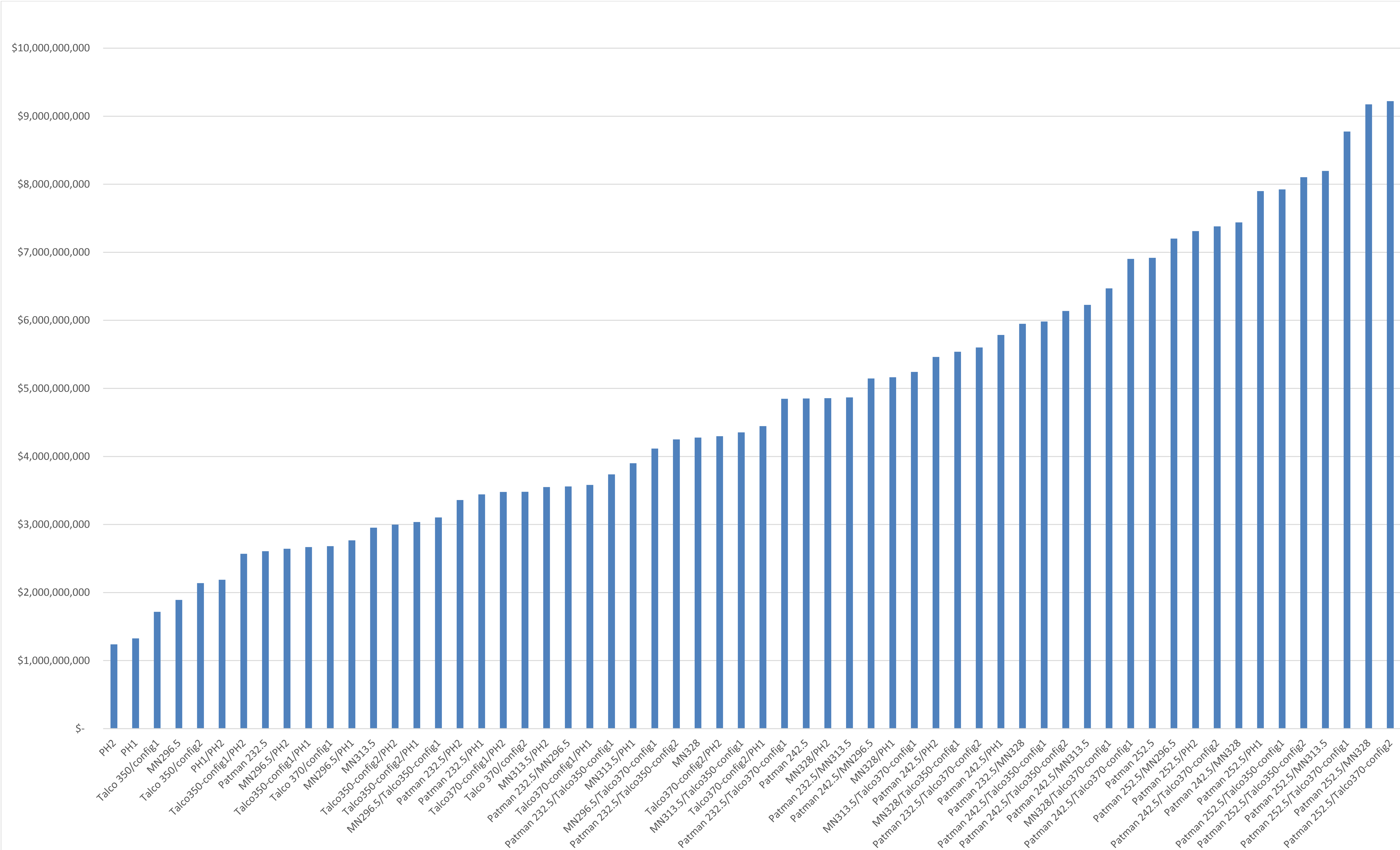
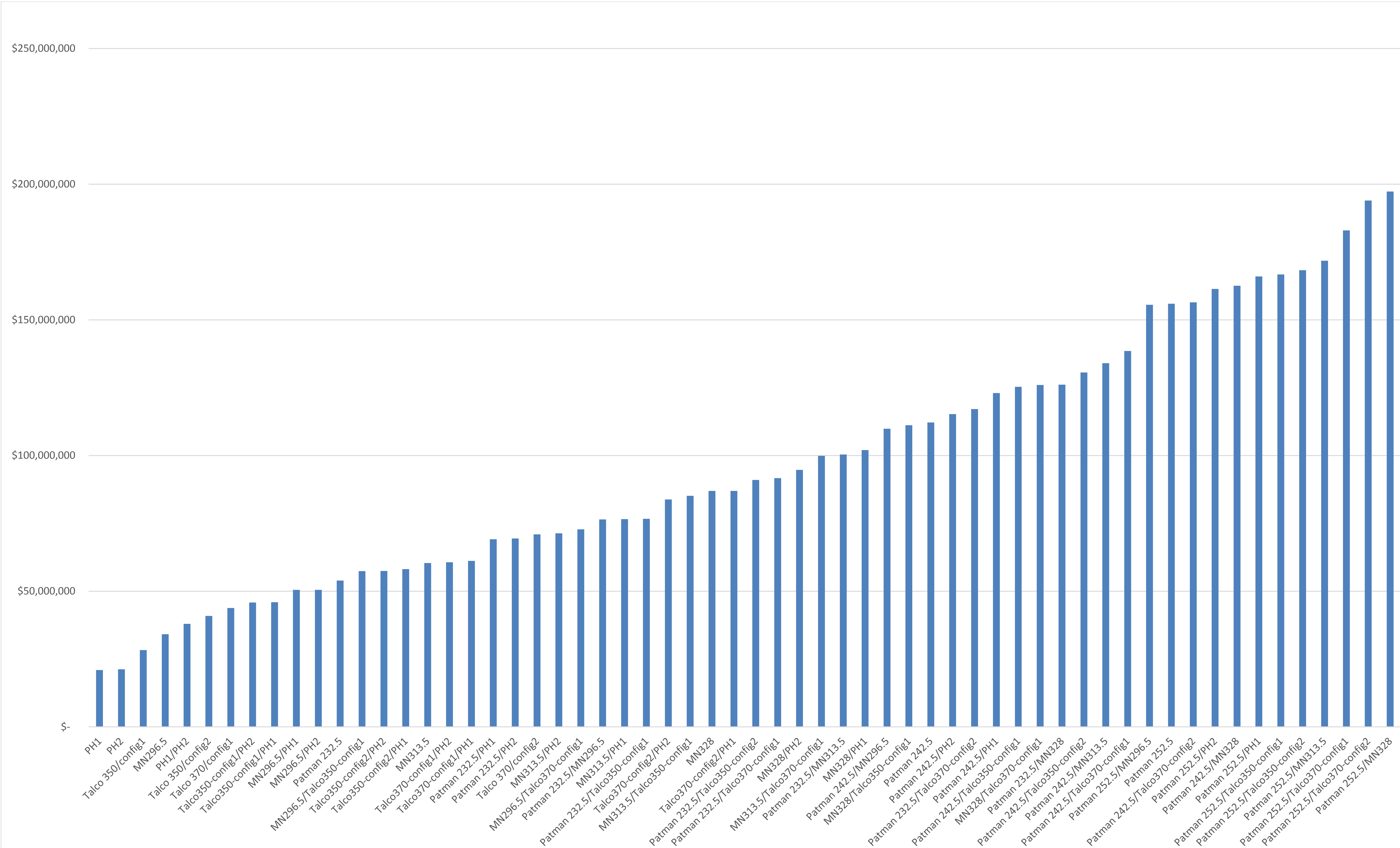


Figure 10-2 Total Annual Costs After Debt Service



Figures 10-3 through 10-8 portray the alternatives based on unit cost of water, during and after debt service, using each of the three sets of unit cost estimates discussed in Section 10.3 above. Conclusions are highly dependent on whether one focuses on unit costs during or after debt service. The cheapest alternatives in Figures 10-3 and 10-5 (during debt service) are highlighted in yellow. Those same alternatives are also highlighted in yellow on Figures 10-4 and 10-6 (after debt service) and while they cluster near the "lower unit cost" end of the continuum, they do not uniformly comprise the lowest cost group. Similarly, assessment of unit costs for the Talco Configuration 1 versus Configuration 2 question depends on whether or not the debt service has been retired (see rankings highlighted in green in Figures 10-3 through 10-6). For the Talco 370 alternative, the scalping infrastructure associated with Configuration 2 appears to be justified during the debt service period; Configuration 2 has lower unit costs than Configuration 1. After debt service is retired, unit costs for that configuration are consistently higher than for the configuration without it. At the smaller scale (350), Configuration 2 results in more expensive water across the board.

Figure 10-3 Unit Costs based on 100% Yield During Debt Service

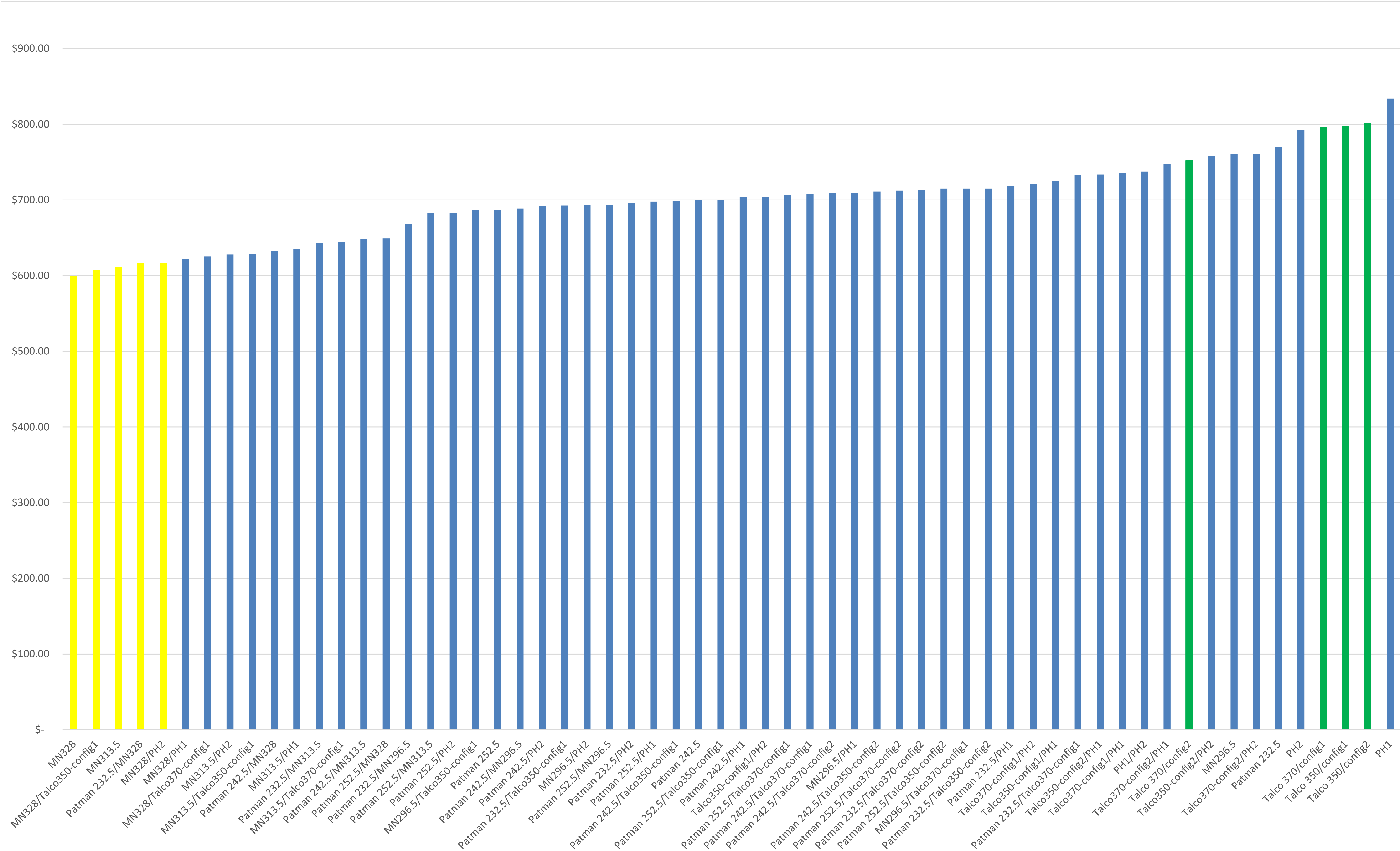


Figure 10-4 Unit Costs based on 100% Yield After Debt Service

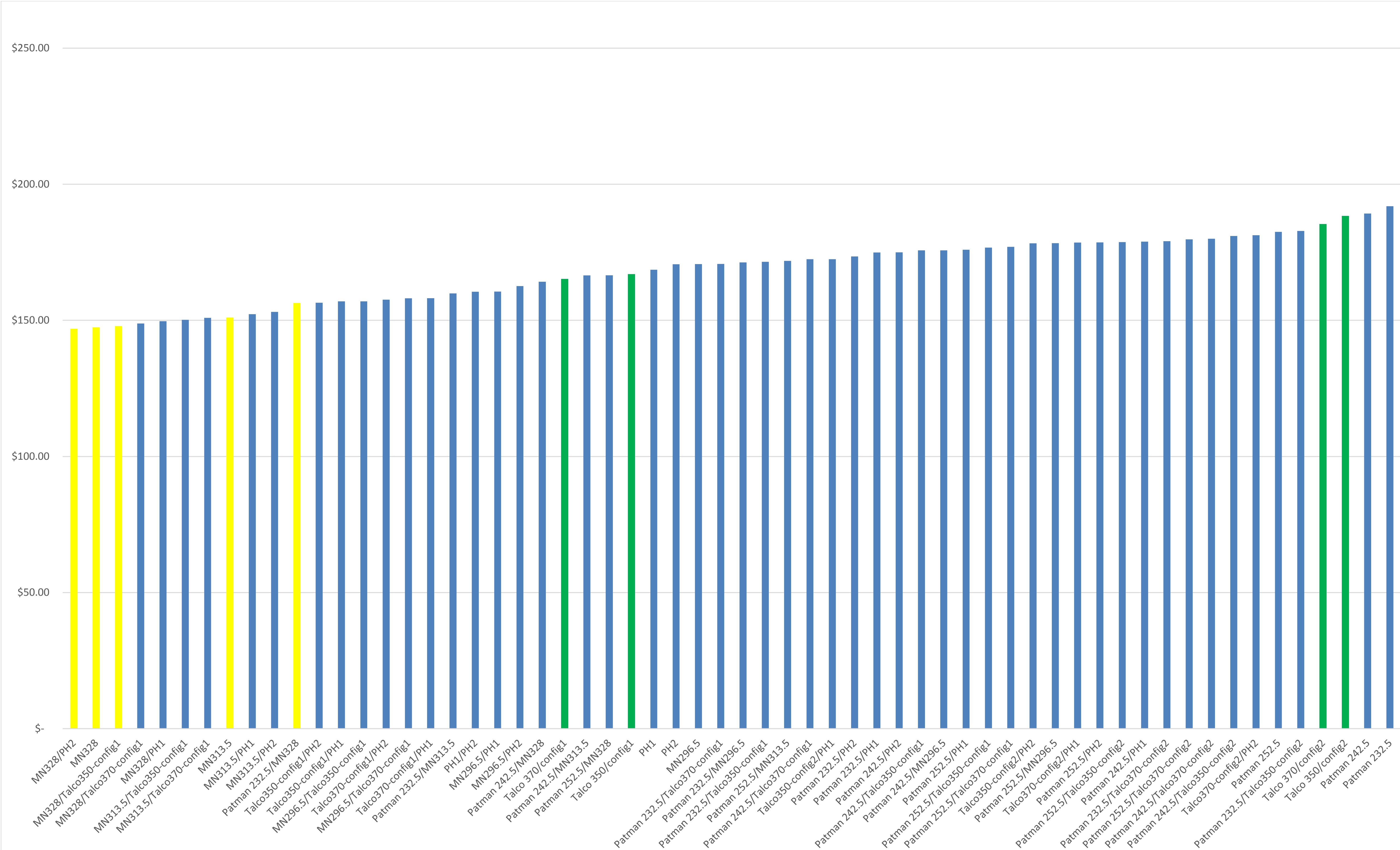


Figure 10-5 Unit Costs based on Lyons During Debt Service

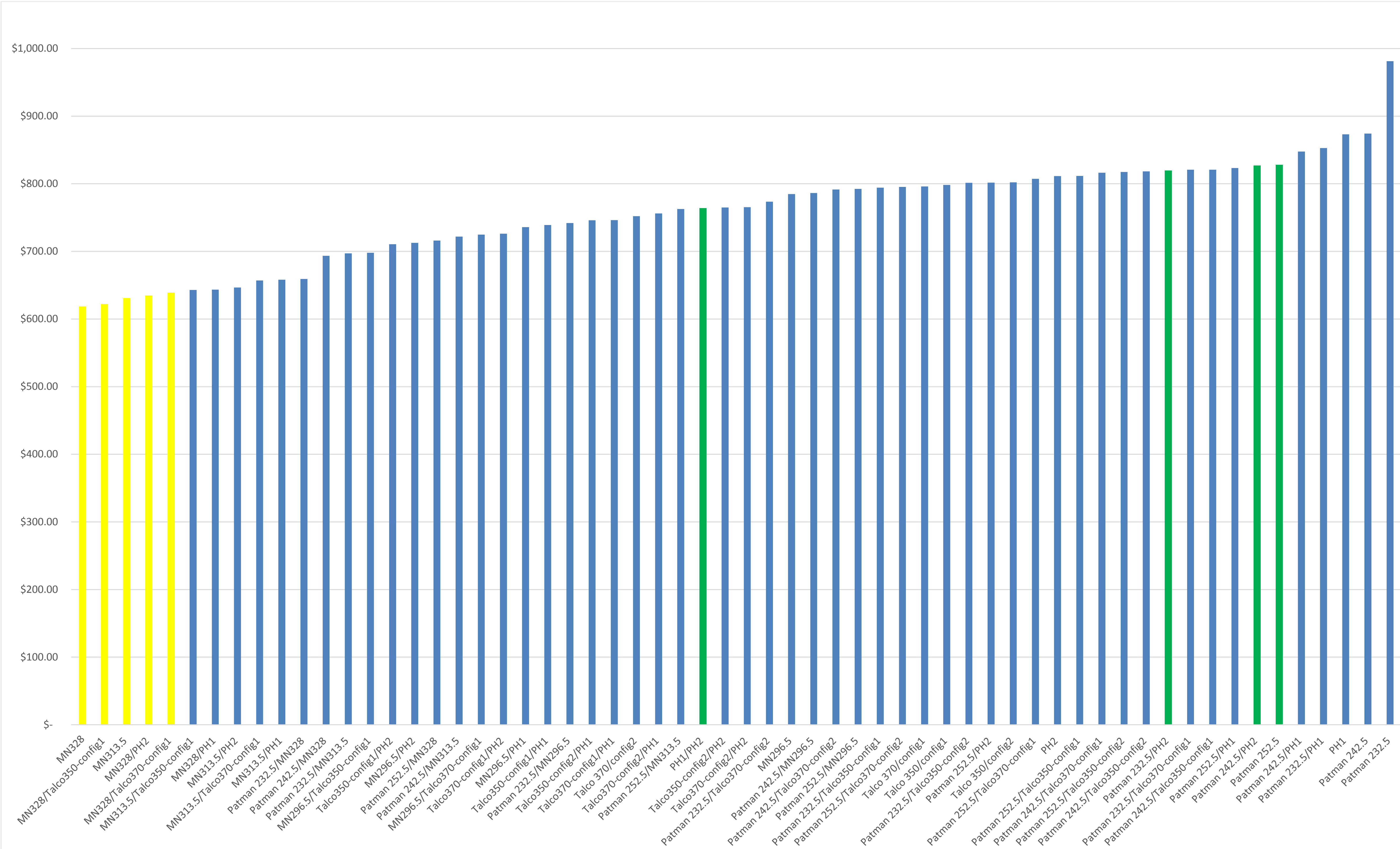
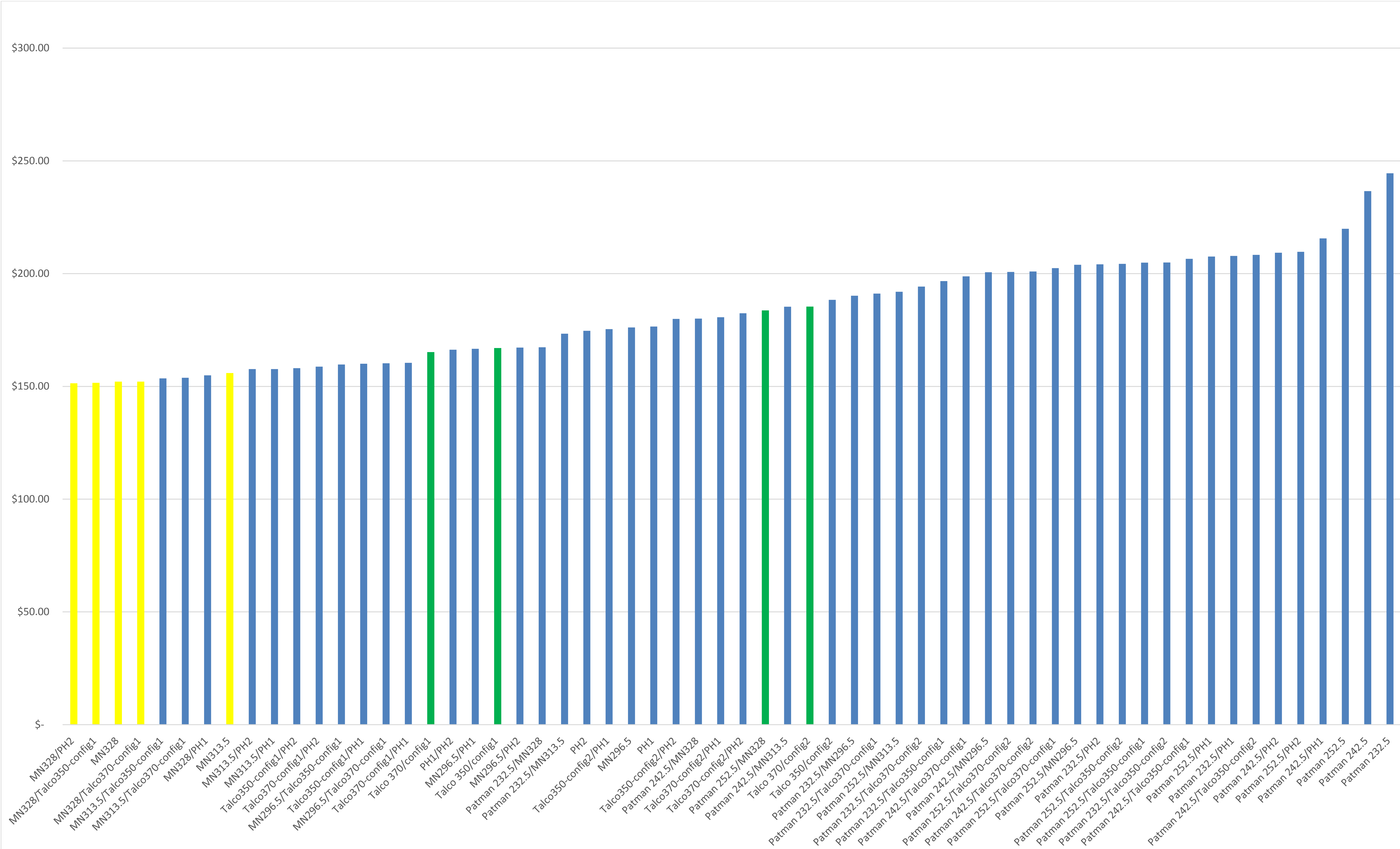


Figure 10-6 Unit Costs based on Lyons After Debt Service



Comparison of unit costs is likewise highly sensitive to eFlow reductions in yield. In the absence of site-specific data, the Lyons approach is the methodology endorsed by the Texas Commission on Environmental Quality (TCEQ) for estimating in-stream flow requirements. The Lyons approach depends heavily on historical daily gage data. Preliminary assessment of likely eFlow requirements using the Lyons approach results in substantially higher flow requirements on a percentage basis for Wright Patman reallocation alternatives than for the new reservoir alternatives, primarily as a result of conservative assumptions necessitated by lack of stream gage information prior to construction of Wright Patman. This can be seen by comparing the cheapest alternatives in Figures 10-3 and 10-4 to the cheapest alternatives in Figures 10-5 and 10-6. Once the eFlow reduction is figured into the unit cost estimates, the Wright Patman alternatives are pushed towards the higher end of the cost continuum.

Figures 10-7 and 10-8 indicate that the unit costs based on 80% of the Lyons net yields are identical in rank to that of the 100% Lyons yields. As expected, unit costs are higher based on the smaller across-the-board yield estimates.

It may be helpful to compare alternatives that have been grouped according to similar yields. Figures 10-9 through 10-13 compare subgroups of alternatives based on the 100% yields . These figures indicate that the Parkhouse alternatives, individually or in combination with each other, as well as the smaller Talco scale and the smallest Marvin Nichols scale yield substantially less than the defined project need. Likewise, the group of alternatives yielding over 1,000,000 acre-feet per year provide substantially more yield than the defined yield and are likely not permittable for that reason. Focusing on the group of alternatives that yield between 500,000 and 1,000,000 acre-feet per year results reduces number of alternatives to 29. Four of those alternatives include the Talco Configuration 2 components. Based on the previous discussion, the cost-effective contribution of the Configuration 2 infrastructure is suspect, potentially reducing the number of alternatives in the appropriate range to 25.

Figure 10-7 Unit Costs based on 80% of Lyons During Debt Service

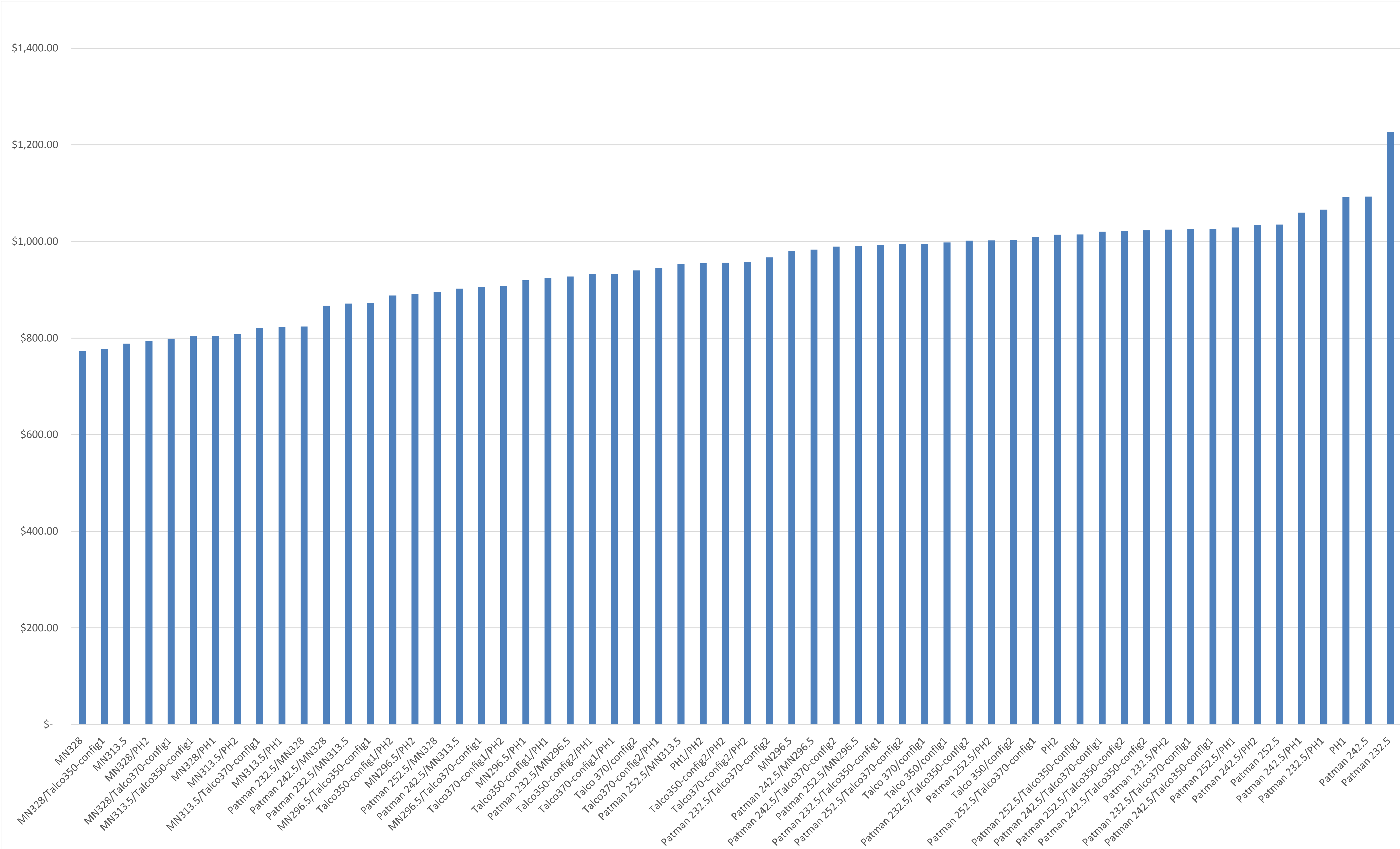


Figure 10-8 Unit Costs based on 80% of Lyons After Debt Service

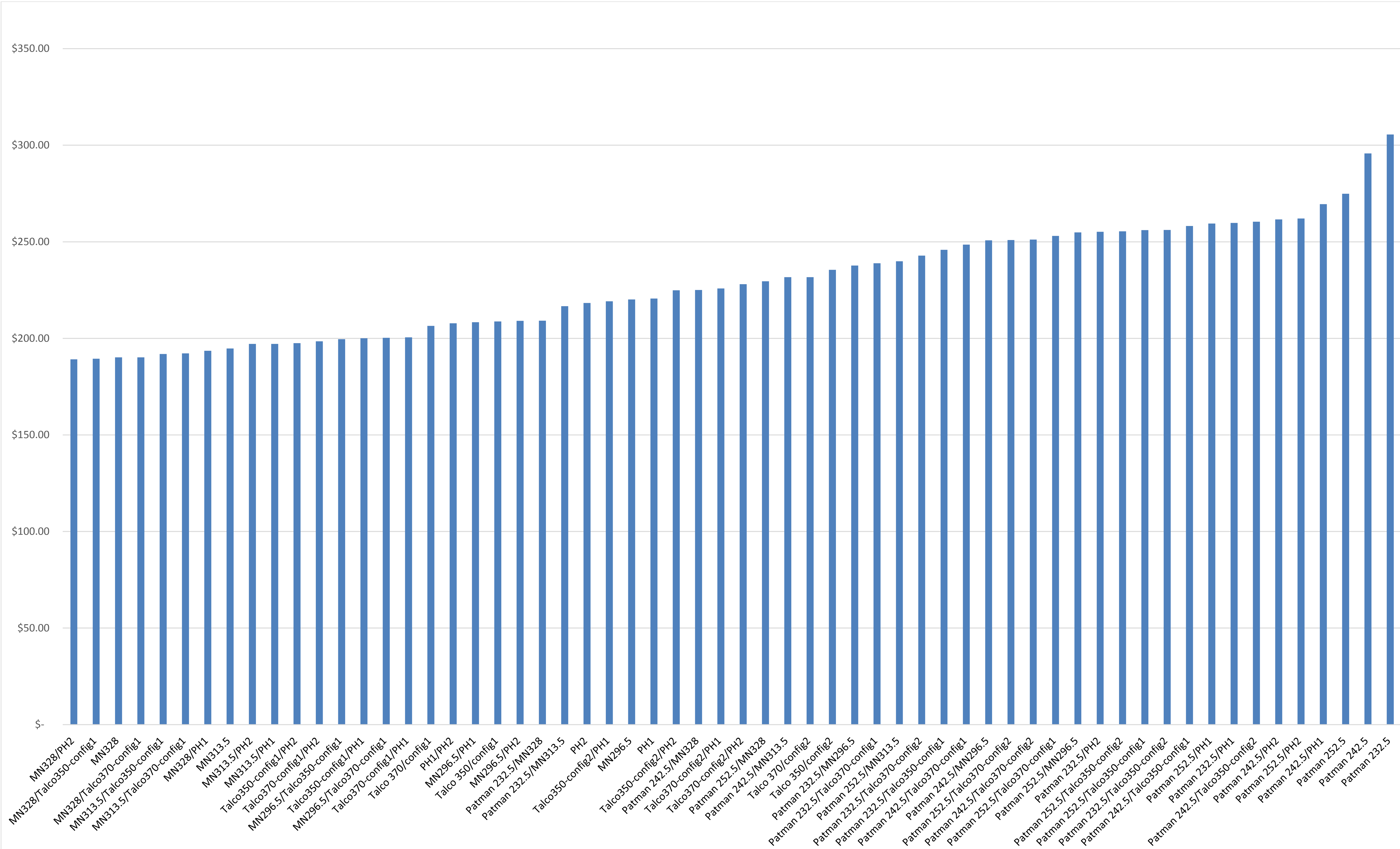
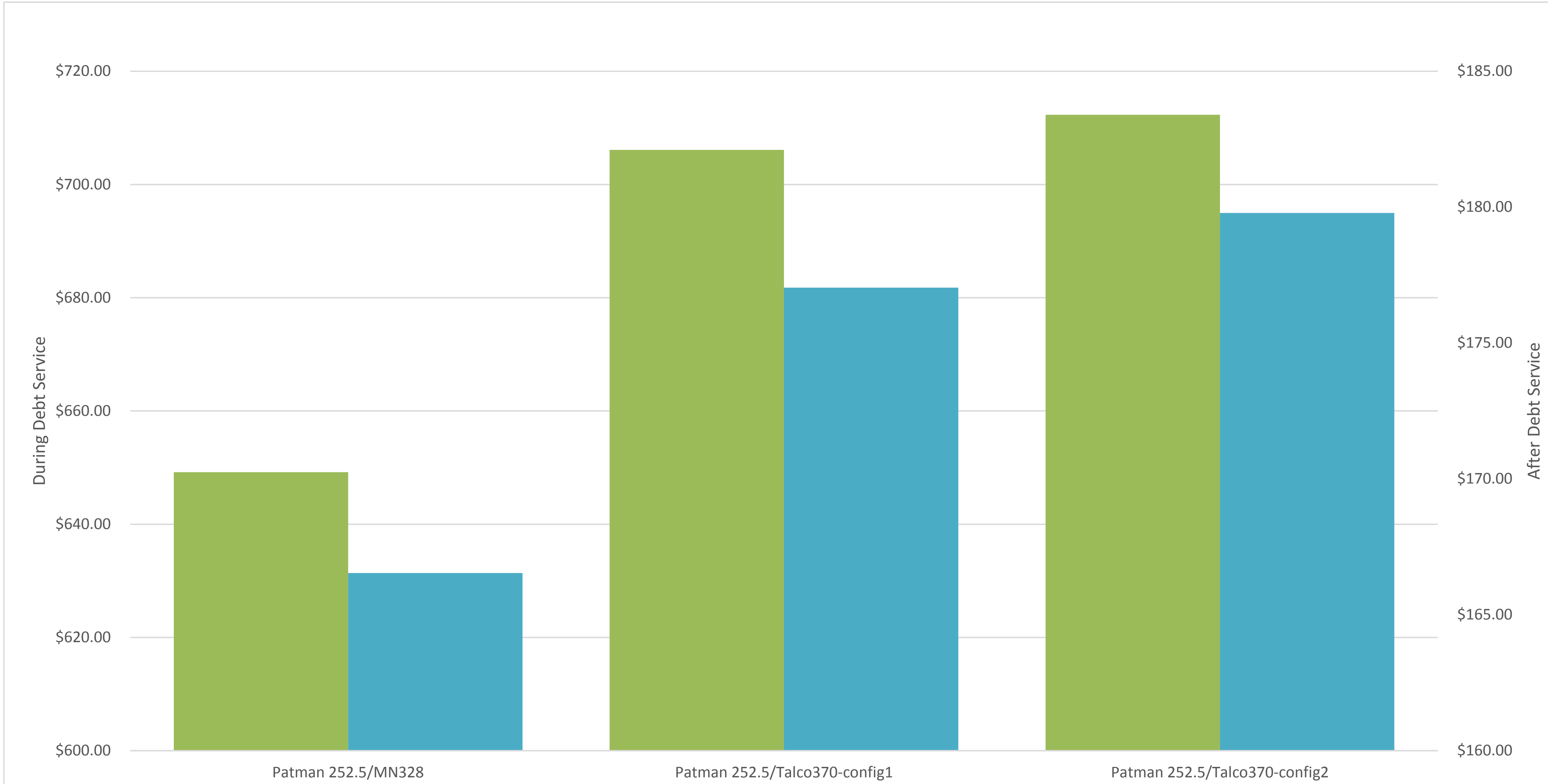
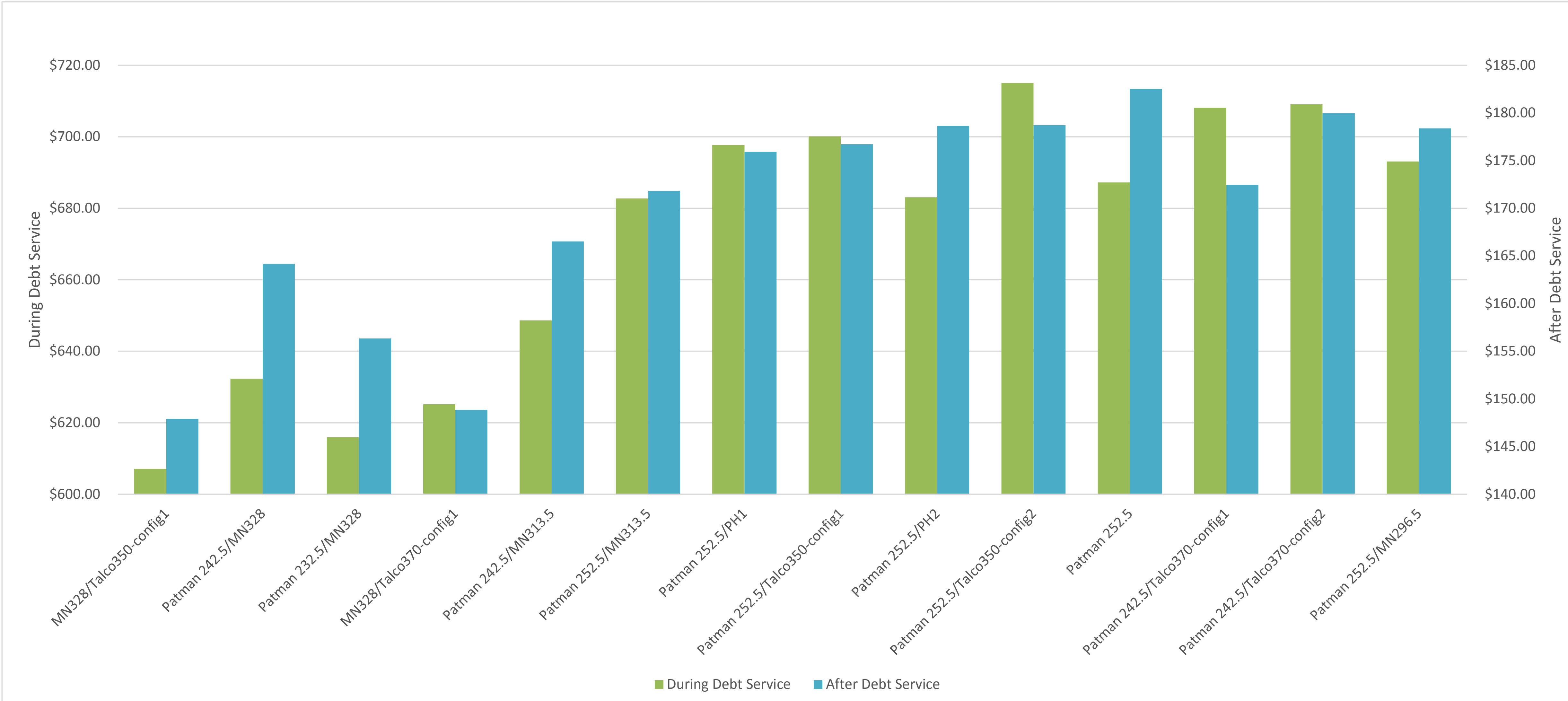


Figure 10-9 Unit Costs of 100% Alternatives Yielding Over a Million Ac-Ft/Yr



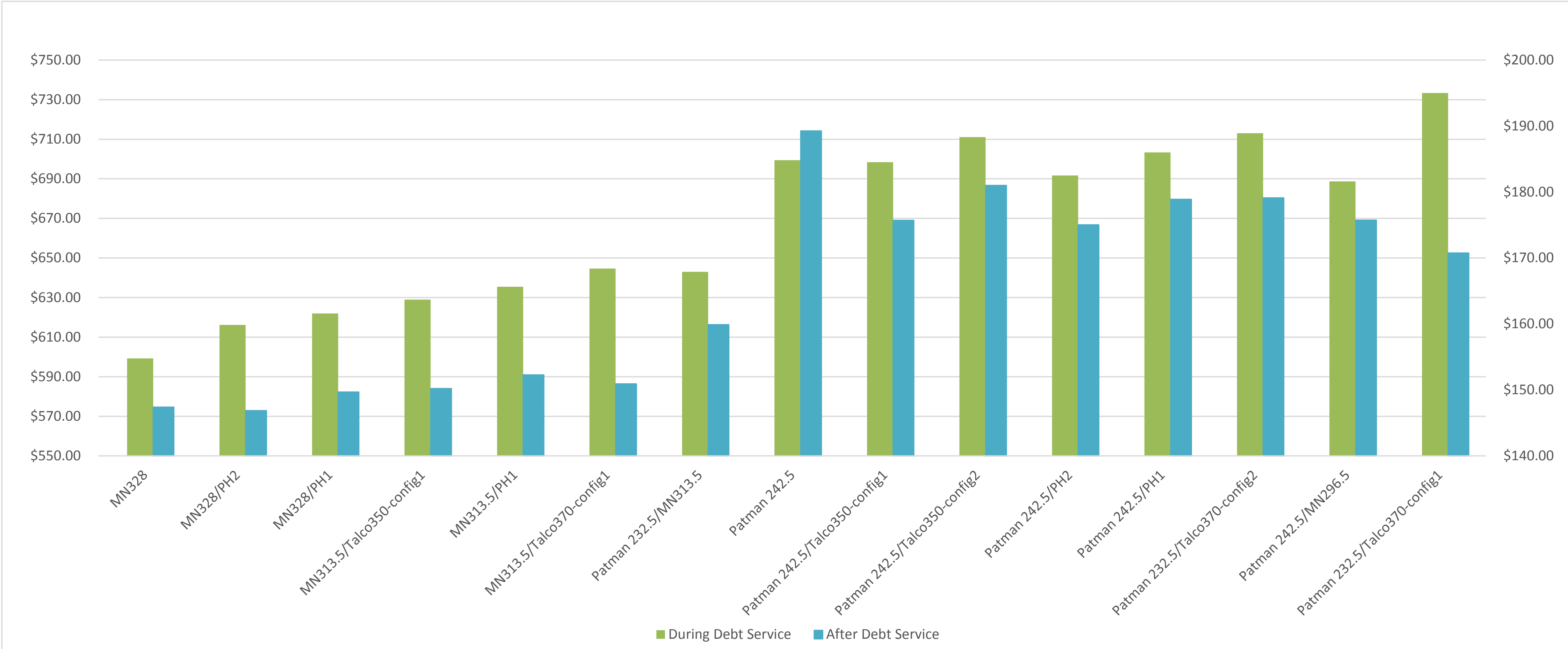
Alternative ID	Alternative Description	YIELD	Per Acre-ft	
		ac-ft/yr	During Debt Service	After Debt Service
21	Patman 252.5/MN328	1,184,550	$649.21	$166.54
39	Patman 252.5/Talco370-config2	1,079,130	$712.31	$179.78
36	Patman 252.5/Talco370-config1	1,033,560	$706.11	$177.04

Figure 10-10 Unit Costs of 100% Alternatives Yielding from 750k to 1 Million



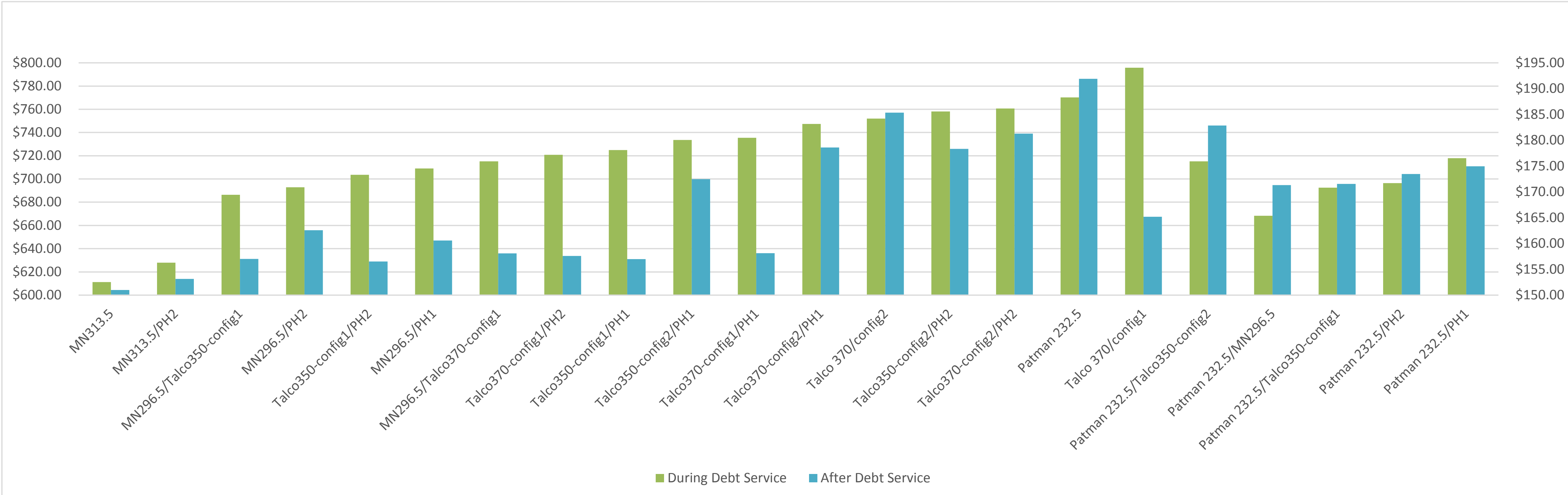
Alternative ID	Alternative Description	YIELD	Per Acre-ft	
		ac-ft/yr	During Debt Service	After Debt Service
42	MN328/Talco350-config1	751,620	$607.11	$147.90
20	Patman 242.5/MN328	990,500	$632.29	$164.16
19	Patman 232.5/MN328	806,600	$615.98	$156.33
45	MN328/Talco370-config1	846,510	$625.19	$148.86
17	Patman 242.5/MN313.5	804,950	$648.66	$166.52
18	Patman 252.5/MN313.5	999,650	$682.73	$171.83
24	Patman 252.5/PH1	943,630	$697.71	$175.93
30	Patman 252.5/Talco350-config1	943,670	$700.11	$176.71
27	Patman 252.5/PH2	903,400	$683.08	$178.64
33	Patman 252.5/Talco350-config2	941,650	$715.07	$178.73
3	Patman 252.5	854,400	$687.23	$182.52
35	Patman 242.5/Talco370-config1	803,130	$708.10	$172.45
38	Patman 242.5/Talco370-config2	869,430	$709.06	$179.98
15	Patman 252.5/MN296.5	872,000	$693.08	$178.38

Figure 10-11 Unit Costs of 100% Yield Alternatives Yielding From 500k to 750k



Alternative ID	Alternative Description	YIELD	Per Acre-ft	
		ac-ft/yr	During Debt Service	After Debt Service
6	MN328	590,000	$599.25	$147.40
51	MN328/PH2	644,960	$616.17	$146.87
48	MN328/PH1	681,410	$621.97	$149.68
41	MN313.5/Talco350-config1	566,820	$628.92	$150.19
47	MN313.5/PH1	502,890	$635.52	$152.26
44	MN313.5/Talco370-config1	661,710	$644.63	$150.91
16	Patman 232.5/MN313.5	627,950	$642.99	$159.89
2	Patman 242.5	592,700	$699.42	$189.27
29	Patman 242.5/Talco350-config1	713,240	$698.42	$175.71
32	Patman 242.5/Talco350-config2	721,750	$711.04	$180.98
26	Patman 242.5/PH2	658,750	$691.70	$175.00
23	Patman 242.5/PH1	687,540	$703.33	$178.90
37	Patman 232.5/Talco370-config2	653,830	$713.07	$179.10
14	Patman 242.5/MN296.5	625,200	$688.73	$175.72
34	Patman 232.5/Talco370-config1	536,900	$733.37	$170.75

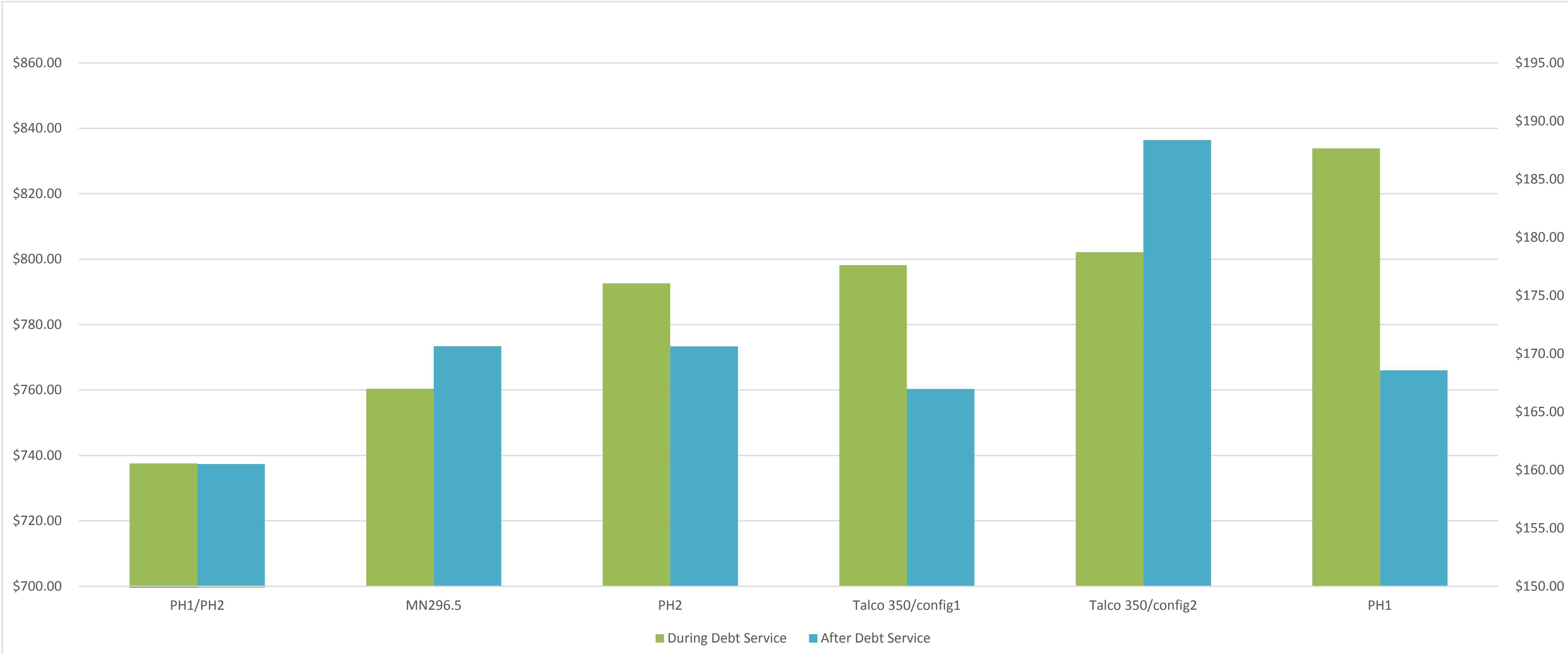
Figure 10-12 Unit Costs of 100% Yield Alternatives Yielding From 250k to 500k



Alternative ID	Alternative Description	YIELD	Per Acre-ft	
		ac-ft/yr	During Debt Service	After Debt Service
5	MN313.5	400,000	$611.28	$151.00
50	MN313.5/PH2	465,930	$627.92	$153.13
40	MN296.5/Talco350-config1	365,460	$686.35	$157.01
49	MN296.5/PH2	310,650	$692.78	$162.59
56	Talco350-config1/PH2	292,660	$703.65	$156.50
46	MN296.5/PH1	314,500	$709.06	$160.59
43	MN296.5/Talco370-config1	460,350	$715.14	$158.10
58	Talco370-config1/PH2	384,890	$720.77	$157.60
52	Talco350-config1/PH1	292,750	$724.82	$156.97
53	Talco350-config2/PH1	337,170	$733.51	$172.46
54	Talco370-config1/PH1	386,680	$735.39	$158.11
55	Talco370-config2/PH1	486,980	$747.43	$178.58
10	Talco 370/config2	382,800	$751.91	$185.33
57	Talco350-config2/PH2	322,330	$758.16	$178.32
59	Talco370-config2/PH2	462,180	$760.70	$181.30
1	Patman 232.5	281,000	$770.31	$191.91
9	Talco 370/config1	265,100	$795.86	$165.18
31	Patman 232.5/Talco350-config2	497,550	$715.14	$182.86
13	Patman 232.5/MN296.5	446,200	$668.35	$171.31
28	Patman 232.5/Talco350-config1	447,010	$692.59	$171.54
25	Patman 232.5/PH2	400,300	$696.46	$173.47
22	Patman 232.5/PH1	395,140	$717.95	$174.95

Figure 10-12

Figure 10-13 Unit Costs of 100% Alternatives Yielding Under 250k



Alternative ID	Alternative Description	YIELD	Per Acre-ft	
ac-ft/yr	During Debt Service	After Debt Service		
60	PH1/PH2	236,410	$738	$161
4	MN296.5	200,000	$760	$171
12	PH2	124,200	$793	$171
7	Talco 350/config1	169,600	$798	$167
8	Talco 350/config2	217,100	$802	$188
11	PH1	124,300	$834	$169

Unit costs for this subset of alternatives range from $599.25 per acre-foot to $733.37 per acre-foot (during debt service) or from $146.87 per acre-foot to $189.27 per acre-foot after debt service. Within this range, 12 alternatives cluster together, having unit costs under $650 per acre-foot during debt service.

After debt service, there was no clear cluster of unit costs. Instead, the costs were distributed more evenly with no large price jumps. Generally speaking, though, the most cost effective 12 alternatives with debt service are also the least expensive after debt service.

Evaluation of this group of seven alternatives indicates that they are comprised of some combination of the following components:

- Marvin Nichols 328
- Marvin Nichols 313.5
- Wright Patman 232.5
- Wright Patman 242.5
- Talco 350 – Configuration 1
- Talco 370 – Configuration 1
- Parkhouse I
- Parkhouse II

The only stand-alone alternative appearing in the select group is Marvin Nichols 328, and the two Parkhouse alternatives appear only in combination with Marvin Nichols 328 or 313.5. None of the Talco Configuration 2, Patman 252.5 or Marvin Nichols 296.5 alternatives made it into this most cost effective subset.

In general, the larger Marvin Nichols scales, the smaller Wright Patman scales, and the Talco Configuration 1 alternatives appear to merit further consideration, at least on the basis of unit costs.

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APPENDIX A
EMBANKMENT & SPILLWAY COST ESTIMATES

MEMORANDUM

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TO: Becky Griffith

CC: File

FROM: Patrick Miles, P.E.

SUBJECT: Sulphur Basin Comparative Analysis
Dam and Spillway Cost Estimate
Quantity Estimation and Cost Assumptions

DATE: April 28, 2014

PROJECT: UFH12387

The purpose of this memorandum is to document the procedures and assumptions made in developing preliminary cost estimates for seven reservoir alternatives as part of the Sulphur Basin Comparative Analysis project. These cost estimates account for the construction of a zoned earthen embankment dam with a gated concrete overflow spillway. It should be understood that these estimates are intended for conceptual screening purposes only. Several generalizing assumptions have been made for both item quantities and unit costs.

Embankment and spillway sizing was determined incorporating geotechnical information, hydrologic modeling of the upstream watershed, and hydraulic considerations of the spillway. All assumptions related to the geotechnical features of the dam and spillway were made from a desktop review of available geologic maps. No field borings were made as part of this analysis. Hydrologic modeling was performed using a combined HEC-HMS and HEC-RAS model for the Sulphur River Basin. The Probable Maximum Flood (PMF) requirements were established and modeled according to the regulations of the Texas Commission on Environmental Quality (TCEQ). Wave runup calculations for freeboard were performed based on the U.S. Army Corps of Engineers (USACE) processes. Hydraulic calculations for the shape and sizing of the spillway were based on methods from the U.S. Bureau of Reclamation publication, *Design of Small Dams*.

Design Storm Analysis

The Probable Maximum Flood (PMF) is defined as the greatest flood to be expected, and the Probable Maximum Precipitation (PMP) is theoretically the greatest depth of rainfall for a given duration that is physically possible over a given size storm area at a particular geographic location. The PMF model runs utilized HEC-HMS to generate runoff hydrographs for the subbasins contributing to each reservoir. HEC-RAS was used to route these hydrographs through the various stream reaches and the proposed reservoir with each given spillway configuration. The combined HEC-HMS and HEC-RAS was adapted from a previous study of the Sulphur River Basin performed by FNI in June 2008.[1]

Hydrometeorological Report No. 52 (HMR-52),[2] developed by the U.S. Army Corps of Engineers, was used to determine the rainfall for each basin. PMP estimates were taken from Hydrometeorological Report No. 51[3] and distributed according to HMR-52 to obtain average rainfall depths over the various drainage areas. HMR-52 calculates rainfall depths for storm durations ranging from five minutes to seventy-two hours.

In January 2007, TCEQ released its Hydrologic and Hydraulic Guidelines for Dams in Texas.[4] Through analysis of historical storm events in Texas, TCEQ has determined that a "front-end loaded" temporal distribution is more applicable to the type of storm event experienced across the state. This method places the greatest rainfall intensities at the beginning of the storm with the remainder of the rainfall tapering off toward the end of the storm. The modified analysis removes some of the conservatism associated with the temporal distribution. The modified distribution assumes the same depths found using the traditional PMP method but distributes these depths differently over the storm duration. The rainfall and time percentages are specified by TCEQ and vary according to the duration of the storm.

Freeboard Considerations

Each of the proposed reservoir alternatives was designed to maintain sufficient freeboard between the PMF elevation and the maximum embankment elevation. Wave runup calculations were performed for both Normal Pool and PMF conditions at each reservoir location. This process involved determining the effective fetch length for each reservoir configuration, along with the design wind speed and duration, which are based on historical data and determined for the given fetch length. This process, along with the applicable charts and tables is defined in the USACE Engineering Technical Letter 1110-2-221.[5] This process produces the design wave height to calculate the wave runup, which is combined with the wind setup calculated from the average reservoir depth to obtain the total wave runup. The total wave runup calculations under Normal Pool conditions assume the full design wind speed, producing large runup, while the calculations under PMF conditions allow for the use of a percentage of the design wind speed, producing lesser runup. This reduction factor ranges from 20% to 50% depending on the nature of the PMF reservoir stage hydrograph relative to the rainfall hydrograph. If the reservoir reaches the peak PMF elevation before the contributing storm has diminished, the wind speeds are assumed to be higher. Whereas, if the reservoir elevation rises slowly and the peak occurs after the storm has diminished, the wind speeds are assumed to be lower.

The calculated freeboard for each reservoir was then used to set an initial embankment height and subsequently the target PMF elevation. During the spillway sizing process, this target PMF elevation was the basis for the initial spillway gate configuration. In general, the initial assumptions were that the top of dam elevation would be set at Normal Pool plus the Normal Pool freeboard. Then, the target PMF elevation was set as the top of dam minus the PMF freeboard. An example calculation is shown below for the Marvin Nichols 1A, Normal Pool 328 alternative.

Top of Dam = 328 ft-msl (Normal Pool) + 14.4 feet (NP Freeboard) = 342.4 ft-msl

Target PMF = 342.4 ft-msl (Top of Dam) – 7.1 (PMF Freeboard) = 335.3 ft-msl

For this alternative, the top of dam was rounded up to 343 ft-msl, and the final PMF elevation was calculated as 335.5 ft-msl. The embankment has sufficient height for a major wind event under normal pool conditions, as well as the anticipated wave action during an extreme flood event, such as the PMF.

Adjustments to this rationale were allowed when the number of spillway gates became unreasonable or where an obvious cost savings was apparent. Detailed optimizations for each configuration were not performed due to the conceptual nature of this study.

Spillway Hydraulics

The dimensions and configuration of the gated spillway was determined based on hydraulic calculations using methods from the U.S. Bureau of Reclamation publication, *Design of Small Dams*.[6] The shape of the ogee spillway crest was determined from standard design charts based on design head and approach depth. The design head was set as the vertical distance from the spillway crest to the target PMF elevation. The crest elevation was set based on the selected spillway gate size, and the approach depth was determined based on generalized assumptions regarding the depth to competent foundation material. Limited iterations were necessary on a few alternatives to accommodate changes to the PMF elevation, the selected gate size, or the approach depth.

The chute slope downstream of the ogee crest was set to 1%, with a 3:1 slope transition from the chute into the stilling basin. Froude number calculations were performed at various reservoir elevations and spillway discharge values, accounting for spillway width and expected tailwater elevations. The goal was to design the stilling basin depth and length to produce and contain a hydraulic jump to dissipate energy before the outflow reaches the discharge channel. The slope of the discharge channel downstream of the stilling basin ranged from 0.2% to 0.3% in order to transition flows to the approximate grade of the natural channel downstream.

The minimum height of the training walls on either side of the spillway from the ogee crest through the stilling basin area was calculated using Manning's equation to calculate depth of flow. PMF discharges were used for this calculation, and two feet were added to the normal depth for the minimum wall height. The walls were set at either the minimum height or the PMF tailwater elevation, whichever was higher.

Embankment and Spillway Configuration

The various quantities associated with these cost estimates were based on the embankment and spillway sizing process and determined using available LiDAR topography data, aerial imagery, and geologic data. Quantities were calculated using a basic spreadsheet method. No three dimensional modeling of the proposed structures was performed. Unit costs were based on FNI experience and recent projects. Some of these costs were established based on ratios accounting for changes in scale or increases to account for inflation.

The following table provides the proposed embankment configurations for each reservoir alternative, including the Normal Pool, PMF, and Top of Dam elevations.

Table A-1 – Embankment Elevations

Reservoir Site	Normal Pool (ft-msl)	PMF Elevation (ft-msl)	Top of Dam (ft-msl)	Maximum Height (feet)
Marvin Nichols 1A	328	335.5	343.0	81
Marvin Nichols 1A	313.5	319.5	332.0	70
Marvin Nichols 1A	296.5	319.3	325.0	63
George Parkhouse I	401	407.0	413.0	71
George Parkhouse II	410	424.5	430.0	88
Talco Reservoir	370	376.5	384.0	94
Talco Reservoir	350	355.9	362.0	72

The following figures are provided for conceptual reference as to the configuration of the dam embankment and gated spillways. The figures are not to scale and are intended for reference purposes only. Further details regarding the geometry of each feature are provided in the line item descriptions to follow.

Figure A-1 depicts a typical embankment section, noting the various embankment zones and the soil cement liner along the upstream slope. Figure A-2 represents the existing ground profile for the George Parkhouse I reservoir site, which was cut along the dam alignment from available LiDAR topography data. The embankment profile was utilized in determining quantities for several line items. The embankment height from existing ground to the top of dam elevation was a key component in these calculations.

On the following page, Figure A-3 represents a typical cross section through the spillway, noting the ogee crest, Tainter gates, training walls, approach channel, and spillway bridge. Figure A-4 shows the spillway profile for one of the Marvin Nichols 1A reservoir alternatives with the existing ground centerline and left and right offset profiles. Structural features including the ogee crest, spillway abutments, training walls, stilling basin, and approach and discharge channel are shown. The existing ground profiles were utilized for several line items, accounting for elevation variations by weighting the centerline profile with the left and right offset profiles.

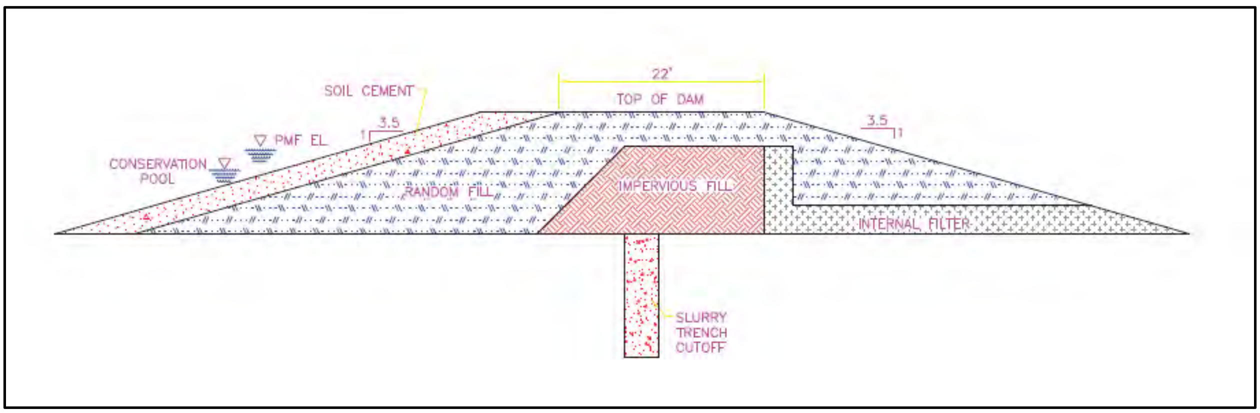


Figure A-1 – Typical Dam Embankment Section

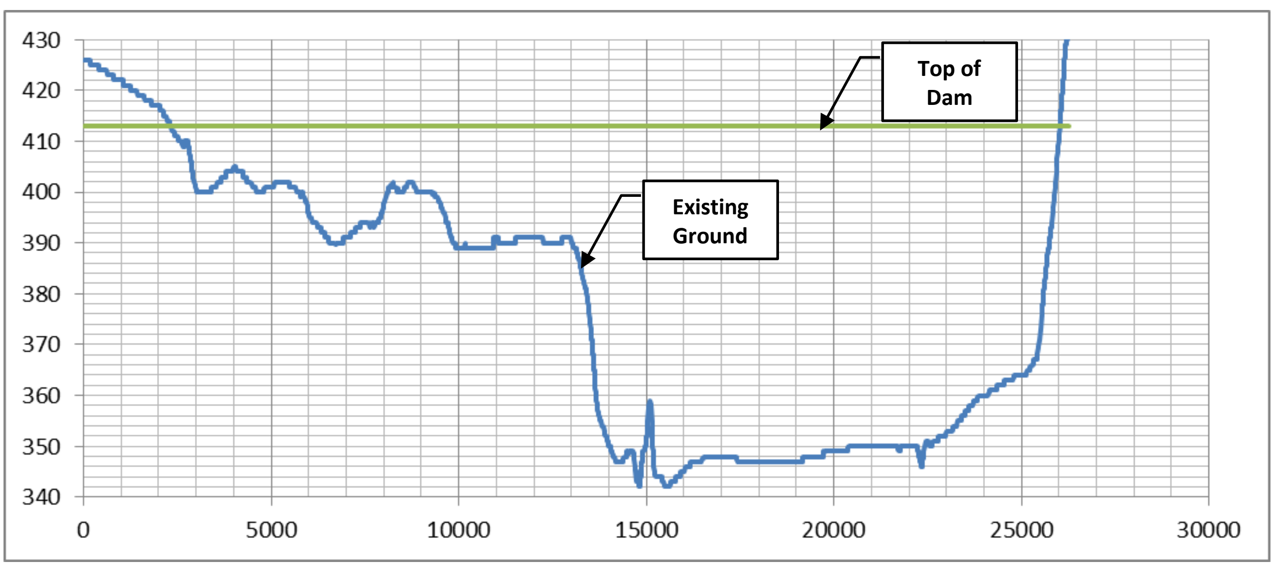


Figure A-2 – Typical Embankment Profile

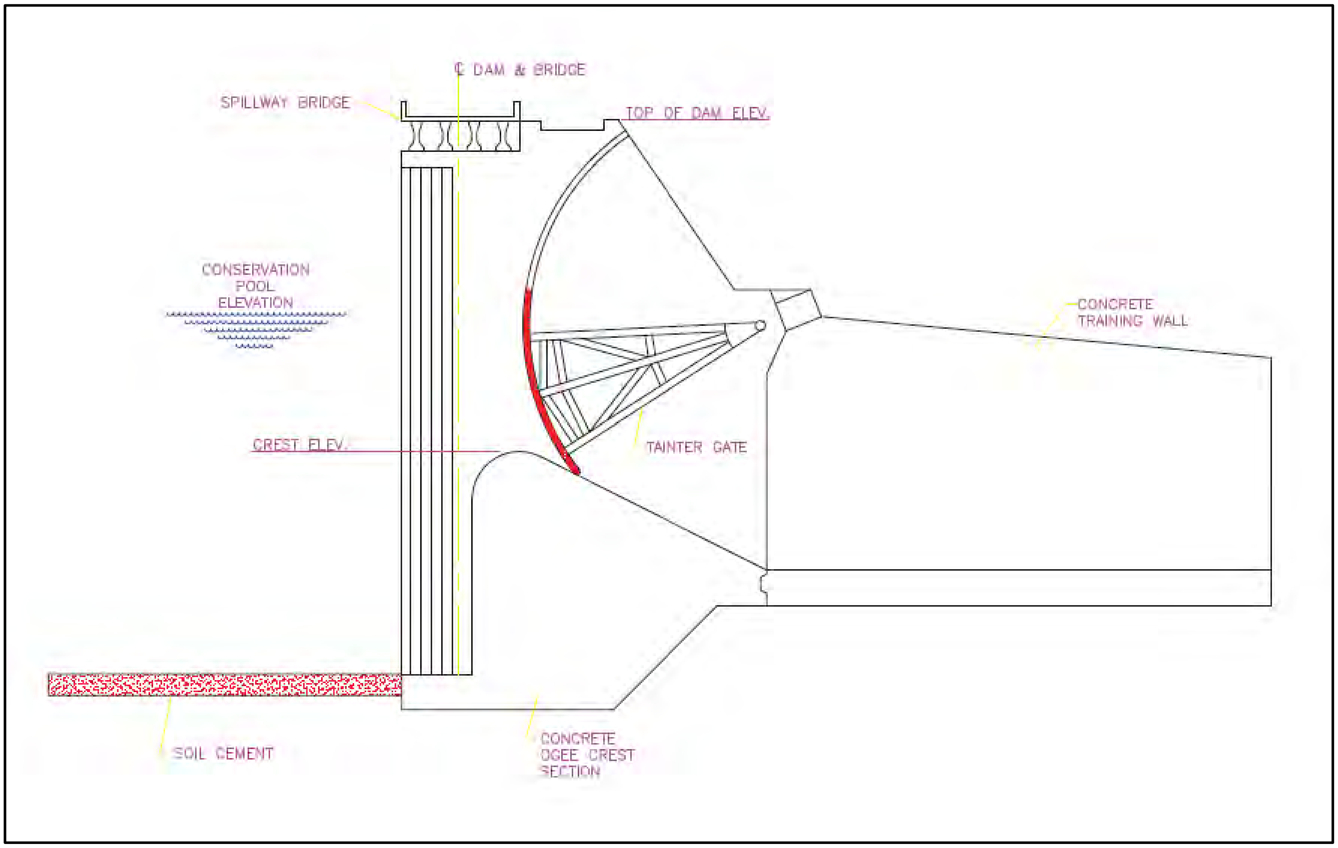


Figure A-3 – Typical Spillway Section

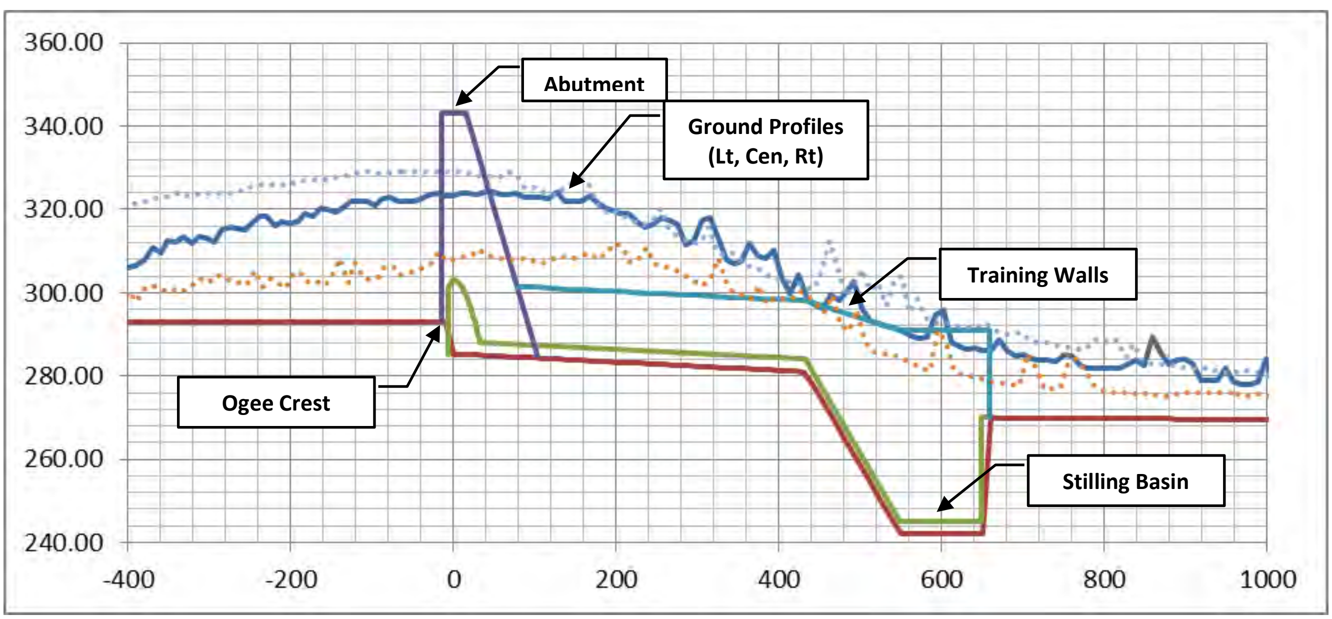


Figure A-4 – Typical Spillway Profile

The remainder of this memorandum provides specific detail concerning each line item in the cost estimate and how both the quantities and unit costs were determined. The cost estimates for each reservoir alternative are attached for reference, along with detailed figures of the elevation profiles for the embankment and spillway sections of each of the proposed reservoir alternatives.

Item 1 – Mobilization

Mobilization costs were simply assumed as 5% of the subtotal of all other costs. This lump sum unit cost thus varied significantly between the various alternatives.

Item 2 – Clearing and Grubbing

Quantities: The dam footprint was calculated by determining the incremental widths along the length of the dam based on the embankment height above the existing ground profile. A buffer of 20% was added to the dam footprint to account for the clearing of additional work areas.

Unit Cost: A unit cost of $7,500 per acre was assumed based on recent FNI experience developing a planning-level cost estimate for the Ringgold Reservoir.

Item 3 – Care of Water During Construction

Care of Water costs were simply assumed as 1% of the subtotal of all other costs. This lump sum unit cost thus varied significantly between the various alternatives.

Item 4 – Excavation

The “Excavation” line item represents the excavation required for the spillway area. It extends from the approach channel through the crest and chute section and the stilling basin and the full length of the discharge channel to the natural creek bed.

Quantities: Quantities were calculated from the spillway profiles with left, center, and right depths. The centerline depth was used for the middle 50% of the spillway, and the left and right depths were used for the respective 25% sections. Side slopes of 3:1 were also applied to the left and right profiles.

Unit Cost: A unit cost of $3.00 per cubic yard was applied to the spillway excavation based on past FNI experience with this type of excavation and generalized assumptions from the desktop geotechnical review.

Item 5 – Fill (Core Compacted)

This line item represents the portion of the zoned embankment labeled “Impervious Fill” in Figure 1. This is the impervious core of the embankment intended to limit seepage through the embankment. The impervious core exists wherever the embankment is taller than five feet.

Quantities: The impervious core is 15 feet wide at the top with a 1:1 upstream slope and a vertical downstream slope. The dimensions of this segment were calculated at frequent intervals based on the embankment height at that location, and an average end area method was utilized to calculate the incremental volumes, which were then summed for the total.

Unit Cost: A unit cost of $7.50 per cubic yard was applied to the impervious core material based on past FNI experience with this type of compacted fill and generalized assumptions about the geotechnical properties of available soil nearby. For the Marvin Nichols 1A (Normal Pool=296.5) alternative, the unit cost was reduced to $7.00 based on the greater depth of cut for the spillway. A cut/fill quantity balance was performed for the Marvin Nichols (Normal Pool=296.5) alternative, such that all spillway excavation materials are intended to be used as embankment fill. It is also assumed that the deeper cut will provide greater quantities of select material to be used for the impervious fill section of the embankment.

Item 6 – Fill (Random Compacted)

This line item represents the portion of the zoned embankment labeled "Random Fill" in Figure 1. This is the majority of the embankment fill used to create the dam.

Quantities: The overall dam dimensions account for a top width of 22 feet and upstream and downstream side slopes of 3.5:1. This line item was calculated by subtracting the impervious core and sand filter drain from the total embankment section. Similar to the process described for the impervious core, the embankment area was computed at frequent intervals based on the embankment height. The incremental areas for the impervious core and sand filter drain were then subtracted, and the incremental volumes were calculated and summed for the total.

Unit Cost: Unit costs ranging from $5.00 to $7.00 per cubic yard were applied to the random fill based on past FNI experience with this type of compacted fill and generalized assumptions about the geotechnical properties of the available soil nearby. The costs were adjusted for each alternative based on the volume of soil available from the excavation of the spillway area. Alternatives with greater volumes of spillway excavation were given higher unit costs for random fill because the spillway excavation would be a required borrow source. Typically, embankment fill borrow sources would be located near the embankment site and involve shorter haul distances. The percentage of fill coming from the spillway excavation area factors in to the total cut/fill cost, which is reflected in the random fill unit cost.

Item 7 – Soil Bentonite Slurry Trench

This line item represents the "Slurry Cutoff Trench" shown in Figure 1. A trench will be excavated below the embankment and lined with bentonite slurry to prevent the development of a seepage path below the dam. The dimensions stated below were developed based on generalized assumptions from the available geotechnical data. Further detailed design will be necessary for determining the final configuration.

Quantities: The slurry trench was limited to those portions of the embankment where the natural ground is at or below the Normal Pool elevation plus two feet. The purpose of the slurry trench is to prevent active seepage paths forming below the embankment foundation, and the trench is, therefore, not necessary where the dam is not regularly impounding water. The depth of the slurry trench was set as the minimum of either the height of the dam or 25 feet. This depth was again calculated at frequent intervals, along with the incremental surface area, which was then summed for the total.

Unit Cost: A unit cost of $12.00 per square foot was applied to the slurry trench based on past FNI experience with this type of material.

<u>Item 8 – Soil Cement</u>

This line item represents all soil cement used for the project including the upstream slope protection, a 250-foot long portion of the spillway discharge channel, and the slopes behind the spillway training walls.

<u>Quantities</u>: The quantities for the three volumes of soil cement were calculated by a unique process for each feature as described below:

Slope Protection - A two-foot thick layer of soil cement is planned for protecting the upstream slope of the dam from erosion caused by wave action and water level fluctuation. The soil cement layer will extend the full height of the embankment from the upstream toe to the crest of the dam. Any embankment with discernible height will be protected with the soil cement layer. These dimensions were calculated at frequent intervals, and an incremental volume was computed based on an average end area method. The incremental volumes were then summed for the total.

Discharge Channel - The spillway discharge channel will be protected with an 18-inch thick layer of soil cement for 250 feet downstream of the stilling basin, which is shown in Figure 4. The discharge channel will be protected up to the natural ground and the limits of excavation. As described previously, the discharge channel will be excavated to the same width as the spillway, which is determined by the size and number of gates, and will have excavated 3:1 side slopes. The same left, center, and right profiles were utilized to calculate the slope lengths and bottom width at frequent intervals. These lengths were multiplied by the soil cement thickness to compute incremental volumes, which were then summed for the total.

Training Wall Slopes - The training walls along the spillway discharge chute, shown in Figures 3 and 4, will be free-standing vertical walls. The excavated surface behind these walls will be protected with an 18-inch layer of soil cement. A horizontal offset of ten feet was applied behind the walls, and the soil cement protection will extend from the base of the wall up along the slope to the height of the wall. These dimensions were calculated at frequent intervals to determine incremental volumes by an average end area method. The incremental volumes were then summed for the total.

<u>Unit Cost</u>: A unit cost of $75 per cubic yard was applied to the placement of all soil cement based on past FNI experience with this type of material.

<u>Item 9 – Flex Road Base</u>

This line item represents the flex base roadway along the crest of the dam. The roadway runs the full length of the embankment.

<u>Quantities</u>: The road is assumed to be 8 inches and 22 feet wide with tapered sides at a 2:1 slope. The volume of flex base material was calculated as the area of this typical section times the length of embankment, which was determined as the total length of all segments with any discernable height.

<u>Unit Cost</u>: A unit cost of $60 per cubic yard was applied to the flex road base based on past FNI experience with this type of material.

Item 10 – Sand Filter Drain

This line item represents the portion of the zoned embankment labeled “Internal Filter” in Figure 1. This is the portion of the embankment intended to collect and transfer any seepage that does occur downstream of the impervious core. The filter drain exists wherever there is an impervious core, which corresponds to where the embankment is taller than five feet.

Quantities: The L-shaped sand filter has a vertical arm is three feet thick and the same height as the impervious core, which is defined as the embankment height minus five feet of cover. The horizontal arm is also three feet thick and extends from the downstream face of the impervious core to the downstream toe with a ten foot buffer.

Unit Cost: A unit cost of $35 per cubic yard was applied to the sand filter drain based on past FNI experience with this type of material.

Item 11 – Grassing

This line item represents the seeded grass cover for the downstream slope of the embankment. The full slope from the crest of the dam to the downstream toe will be grassed.

Quantities: The downstream slope length was calculated based on the embankment height at frequent intervals. The slope lengths were averaged to determine incremental areas, which were then summed for the total.

Unit Cost: A unit cost of $3,630 per acre was applied to this line item based on a recent FNI project for modifications to North Lake Dam.

Item 12 – Reinforced Concrete (Mass)

This line item represents the reinforced concrete of the larger features, which will be placed in large mass sections. These features include the ogee spillway crest, the spillway discharge chute, and the stilling basin.

Quantities: The quantities for the three volumes of concrete were calculated by a unique process as described for each feature below:

Ogee Crest - The shape of the ogee crest is defined by specific equations dependent on design head and approach depth. The equations defined in *Design of Small Dams* were utilized for each reservoir alternative. The area under the curve of the ogee crest was multiplied by the spillway width to determine the total volume of concrete for the ogee crest.

Discharge Chute - The discharge chute extends from the end of the ogee crest to the beginning of the stilling basin. This quantity represents only the floor of the chute. The training walls are addressed in a separate line item. The chute length was set to best fit with the natural topography, and the slope transitions from 1% to 3:1 just before the stilling basin. The total chute length was multiplied by the spillway width and a floor thickness of three feet to determine the total volume of concrete.

Stilling Basin - The depth and length of the stilling basin were sized to contain the maximum hydraulic jump expected from the spillway discharge. The stilling basin is also three feet thick, and the end sill was set to 10 feet wide. Multiplied by the spillway width, these dimensions determine the total volume of concrete.

Unit Cost: A unit cost of $450 per cubic yard was applied to the mass sections of reinforced concrete based on past FNI experience with this type of material. The mass concrete sections will require less detailed form work and reinforcing than the concrete for the piers and walls, resulting in a lower unit cost for this line item.

Item 13 – Reinforced Concrete (Piers & Walls)

This line item represents the reinforced concrete of the remaining structural features, including the spillway piers, training walls, and abutment faces.

Quantities: The quantities for the three volumes of concrete were calculated by a unique process as described for each feature below:

Spillway Piers – The spillway piers extend from the base of the ogee spillway to the top of dam elevation to support a bridge across the spillway. They have a top width of 30 feet, and the base is as wide as the ogee spillway crest is long. Each pier is assumed to be 10 feet thick. These dimensions were multiplied by the number of piers, which corresponds to the number of gates minus one, for the total volume of concrete. For the Marvin Nichols 1A, Normal Pool 296.5 alternative, there are no spillway gates. Five foot thick piers were assumed at 100-foot spans for this alternative.

Training Walls – The minimum height of the training wall was determined by normal depth calculations for the PMF discharge or by the PMF tailwater elevation. The walls have a minimum thickness of 18 inches or the wall height divided by 10. For quantity estimation purposes, a generalized footing was assumed with a length of 75% of the wall height. Incremental cross-sectional areas were calculated at frequent intervals, and the incremental volumes were summed for the total volume of concrete.

Abutment Face - The majority of the spillway abutments will be constructed using roller compacted concrete, as described in the following line item. However, the abutment face exposed to the spillway will have a two-foot thick layer of reinforced concrete. The area of the abutment face, as defined in the following section, was multiplied by the thickness to determine the total volume of concrete necessary for each abutment face.

Unit Cost: A unit cost of $750 per cubic yard was applied to the reinforced concrete for piers and walls based on past FNI experience with this type of material. The mass concrete sections will require less detailed form work and reinforcing than the concrete for the piers and walls, resulting in a higher unit cost for this line item.

Item 14 – Roller Compacted Concrete (RCC)

This line item represents the large masses of roller compacted concrete (RCC) that will serve as the spillway abutments. These features are constructed into the embankment to integrate the embankment and spillway structures.

Quantities: The abutments have a cross-sectional area as tall as the height from the approach channel to the top of dam elevation, with a vertical upstream face and a 1.5:1 downstream face. The top width is 30 feet and the base extends from the end of the approach channel to the point where the abutment intersects the slope of the discharge chute. The length of the abutment going into the embankment was set as three times the height of the abutment. These dimensions were combined to determine the total volume of RCC for each of the two abutments.

Unit Cost: A unit cost of $90 per cubic yard was applied to the RCC for the abutments based on past FNI experience with this type of material.

Item 15 – Bridge (over Spillway)

This line item represents the bridge over the spillway. This bridge will sit on top of the spillway piers described previously and will serve as the primary access across the dam, as well as for operation of the spillway gates. No detailed structural design of these bridges was performed at this time.

Quantities: The length of the bridge is equal to the spillway width, and a bridge width of 20 feet was assumed.

Unit Cost: A unit cost of $50 per square foot was applied to the spillway bridge based on past FNI experience with this type of structure. The unit cost for this bridge does not include the piers, as they have been accounted for previously with Item 13.

Item 16 – Bridge (to Outlet Works)

This line item represents the bridge extending from the crest of the dam to the outlet works tower, which will serve as the primary access for operation of the outlet works. The outlet works tower will be located roughly near the upstream toe of the embankment.

Quantities: The length of this bridge was determined as the horizontal distance from the upstream toe to the dam crest, minus 50 feet. The assumed embankment side slopes of 3.5:1 were multiplied by the maximum height of the embankment, and 50 feet were subtracted to determine this length. A bridge width of 20 feet was also assumed.

Unit Cost: A unit cost of $90 per square foot was applied to the outlet works bridge based on past FNI experience with this type of structure. The unit cost for this bridge does include the piers, which were assumed at reasonable span lengths though a detailed pier design was not performed.

Item 17 – Gates, Including Anchor System

This line item represents the large Tainter gates that will operate the spillway and control the reservoir elevations. The number and size of the gates was determined by both fitting the spillway in the natural topography and hydrologic modeling of the PMF requirements. The table below summarizes the selected gate configuration for each reservoir alternative. The Marvin Nichols 1A, Normal Pool 296.5 alternative was designed as an un-gated spillway because of several topographic and hydraulic concerns regarding the feasibility of a gated spillway. No detailed structural design of the gates was performed at this time.

Reservoir Site	Normal Pool (ft-msl)	Number of Gates	Height (feet)	Width (feet)
Marvin Nichols 1A	328	10	30	40
Marvin Nichols 1A	313.5	20	20	30
Marvin Nichols 1A	296.5	0	0	0
George Parkhouse I	401	8	20	30
George Parkhouse II	410	8	20	30
Talco Reservoir	370	4	30	40
Talco Reservoir	350	5	30	40

Quantities: As is typical for cost estimates for these type of gates, the costs were determined based on the total square footage of the gate surface, which was simply calculated as the gate height times the gate width, times the total number of gates.

Unit Cost: A unit cost of $700 per square foot was applied to the spillway gates based on FNI experience on a recent project involving the replacement of spillway gates at Lake Fork Dam. This unit cost is intended to account for all features of the gates, including structural frame, trunnion arms, anchor system, etc. However, the Lake Fork project did not include the replacement of the anchor system. The unit cost was increased by 10% to account for these additional costs. An average of the submitted bid tabs was utilized to determine the unit cost.

Item 18 – Gate Hoist and Operating System

This line item represents the hoists that will be used to lift each gate in order to operate the spillway. It was assumed that each gate would have a dedicated, automatic hoist.

Quantities: The number of gate hoists simply corresponds to the number of gates, as mentioned in the previous line item.

Unit Cost: A unit cost of $215,000 per hoist was applied to the gate hoist based on FNI experience on a recent project involving the installation of automatic gate hoists at Lake Buchanan Dam. An average of the submitted bid tabs was utilized to determine the unit cost.

Item 19 – Stop Gate and Lift Beam

This line item represents the stop logs and lift beam system that will be used to service the spillway gates as needed. Only one set of stop logs was assumed for the whole spillway. No detailed structural design of the stop logs was performed at this time.

Quantities: The number of stop logs was determined based on the gate height, with the stop logs being about four feet tall each. The stop log width was accounted for in two different unit costs.

Unit Cost: A unit cost of either $50,000 or $67,000, depending on gate width, was applied to the stop logs based on FNI experience with the Lake Fork Gate Replacement project. The average costs from the submitted bid tabs was used as a ratio based on the Lake Fork gate sizes compared with the proposed reservoir alternatives

Item 20 – Low-Flow Outlet

This line item represents the low-flow outlet intake tower and conduit. The gated tower will be located inside the reservoir near the upstream toe of the embankment. A conduit will extend from the tower through the embankment to pass required low flows and potentially serve as the intake tower for the water supply facilities as well. No actual design for these features was performed. Rather, the lump sum cost was determined based on a ratio of the embankment height compared with the recently compiled cost estimate for the Lower Bois d'Arc Reservoir. This ratio was then applied to the lump sum cost listed in the Lower Bois d'Arc cost estimate for each of the various reservoir alternatives.

Item 21 – Barrier and Warning System

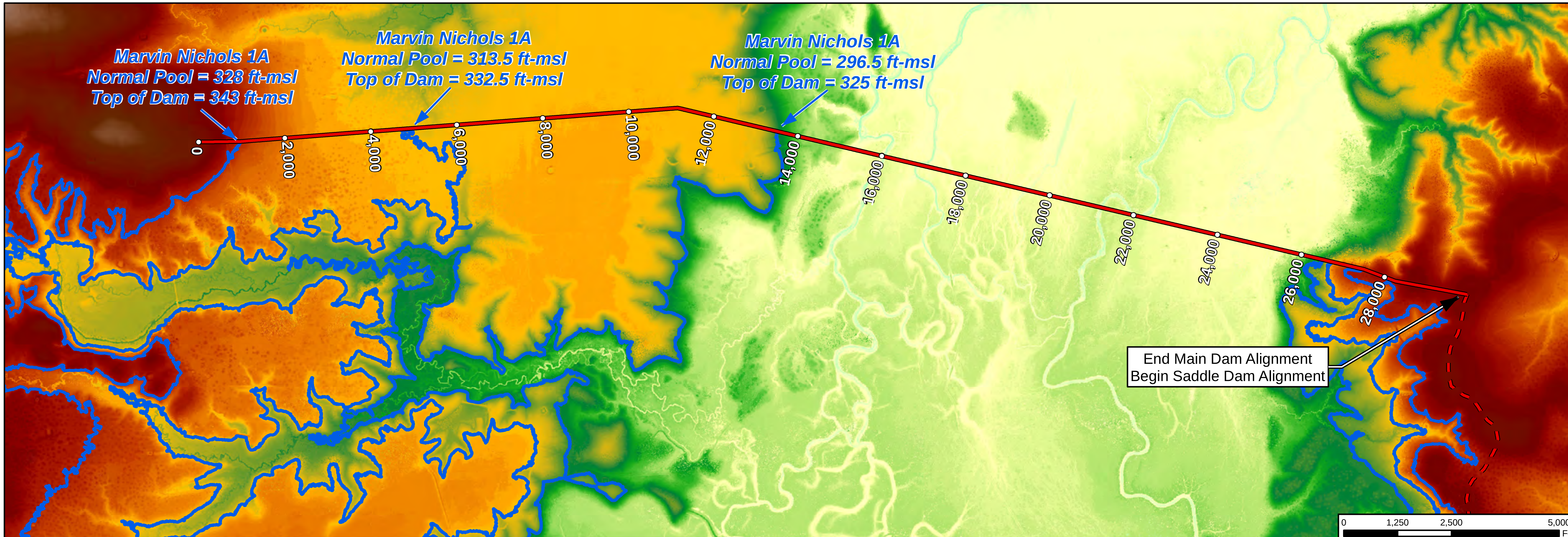
This line item represents the barrier and warning system in front of the spillway, including buoys, anchors, signage, etc. No actual design for these features was performed. Rather, the lump sum cost was determined based on a ratio of the spillway width compared with the recently compiled cost estimate for the Lower Bois d'Arc Reservoir. This ratio was then applied to the lump sum cost listed in the Lower Bois d'Arc cost estimate for each of the various reservoir alternatives.

Item 22 – Embankment Instrumentation

This line item represents any necessary instrumentation, such as piezometers or survey monuments, included with the embankment. No actual design for these features was performed. Rather, the lump sum cost was determined based on a ratio of the dam length compared with the recently compiled cost estimate for the Lower Bois d'Arc Reservoir. This ratio was then applied to the lump sum cost listed in the Lower Bois d'Arc cost estimate for each of the various reservoir alternatives.

Item 23 – Miscellaneous Internal Drainage

This line item represents any necessary internal drainage features in addition to the sand filter drain, such as pipes, outlets, valves, etc. No actual design for these features was performed. Rather, the lump sum cost was determined based on a ratio of the dam length compared with the recently compiled cost estimate for the Lower Bois d'Arc Reservoir. This ratio was then applied to the lump sum cost listed in the Lower Bois d'Arc cost estimate for each of the various reservoir alternatives.



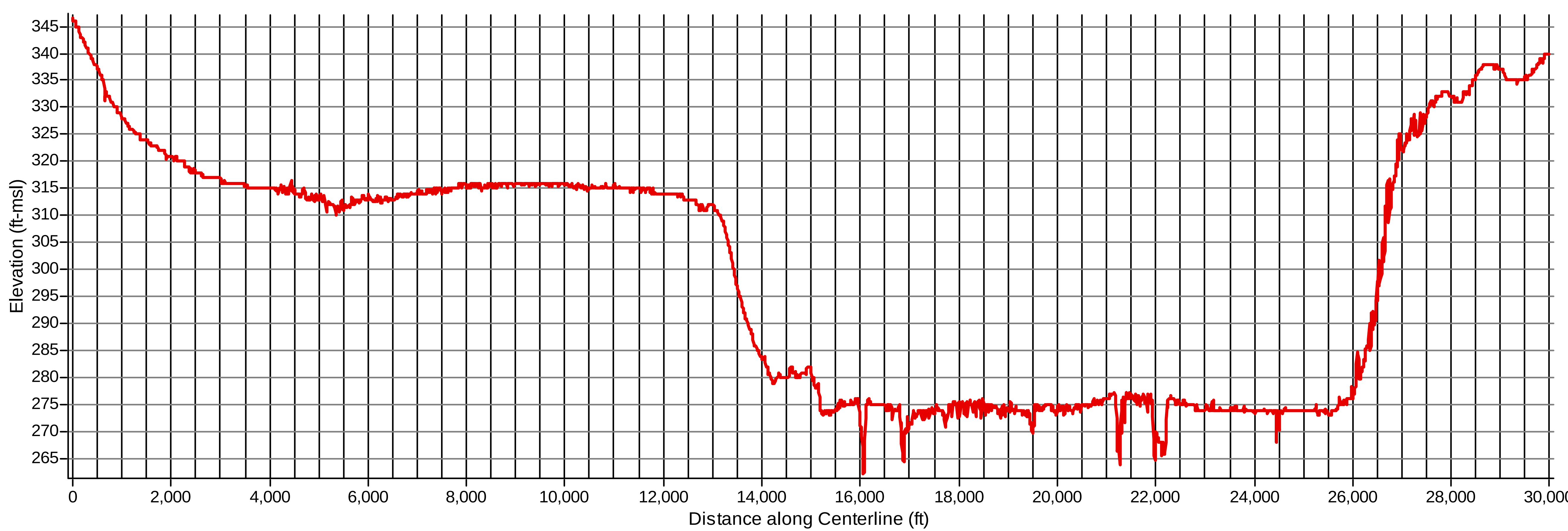


FIGURE A-5

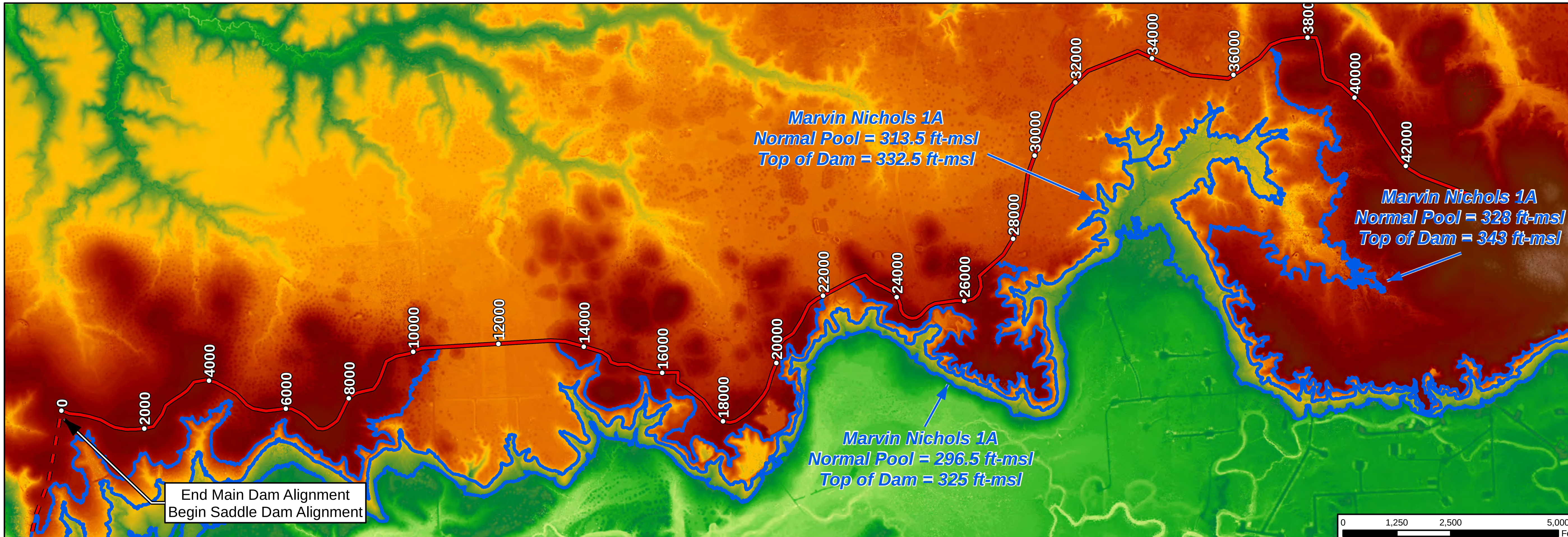
N E S W

MARVIN NICHOLS 1A RESERVOIR SITE

ELEVATION PROFILE - MAIN DAM

FREESE AND NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT	UFH12387
FILE	Plan&Profile_MN1A-Main
DATUM & COORDINATE SYSTEM	NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE	April, 2014
PREPARED BY	JPM



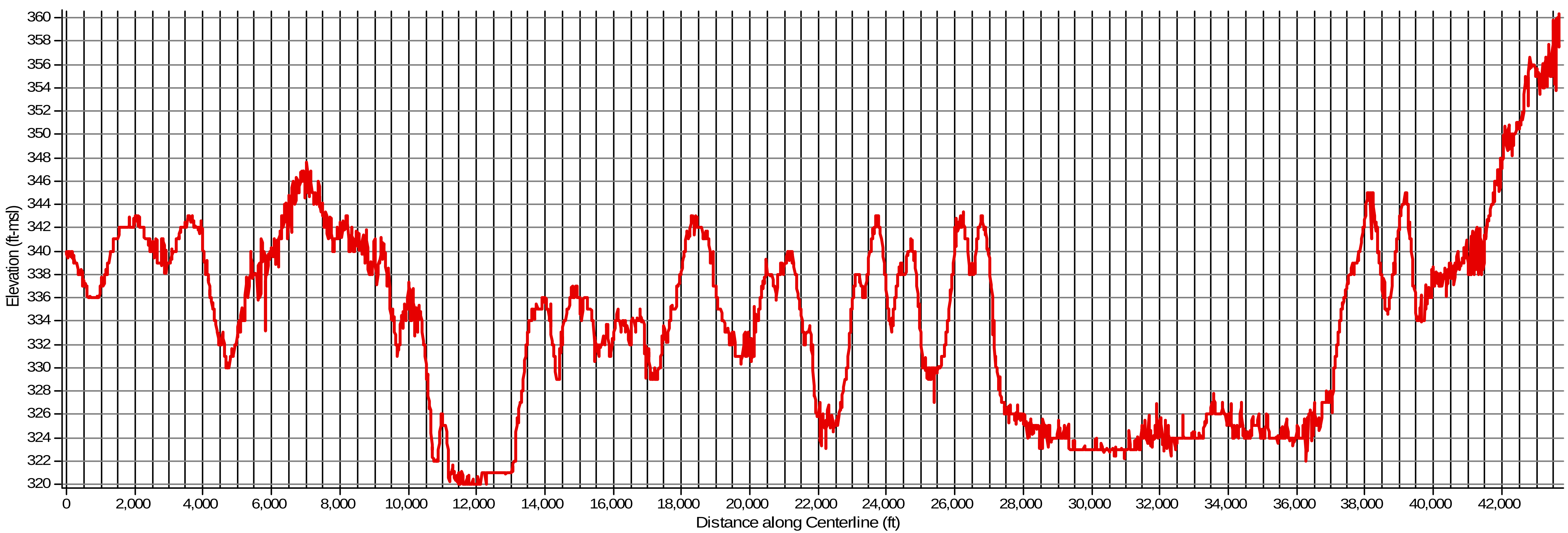


FIGURE A-6

S E W N

MARVIN NICHOLS 1A RESERVOIR SITE

ELEVATION PROFILE - SADDLE DAM

FREESE AND NICHOLS

4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387

FILE Plan&Profile_MN1A-Saddle

DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas Central FIPS 4203 Feet

DATE April, 2014

PREPARED BY JPM

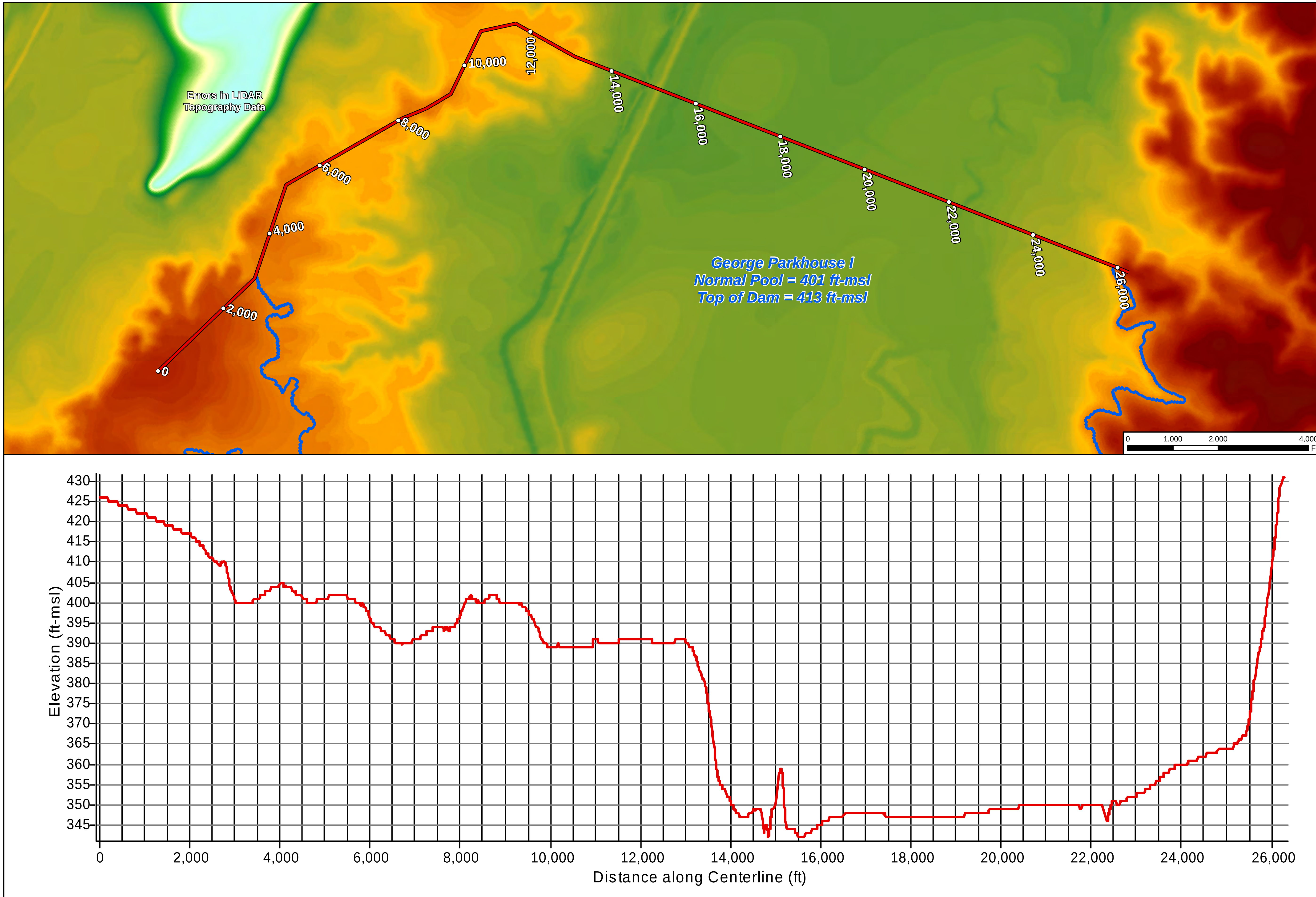


FIGURE A-7

N E S W

GEORGE PARKHOUSE I RESERVOIR SITE

ELEVATION PROFILE

FREESE AND NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387

FILE Plan&Profile_PH1

DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas Central FIPS 4203 Feet

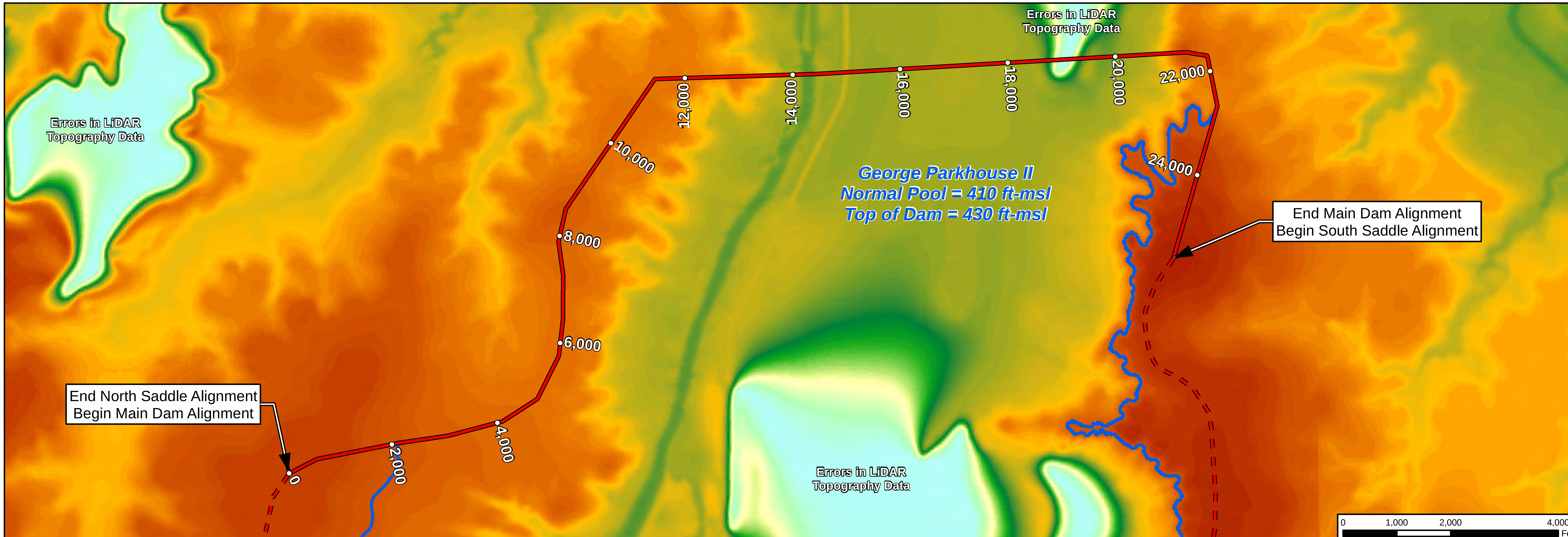
DATE April, 2014

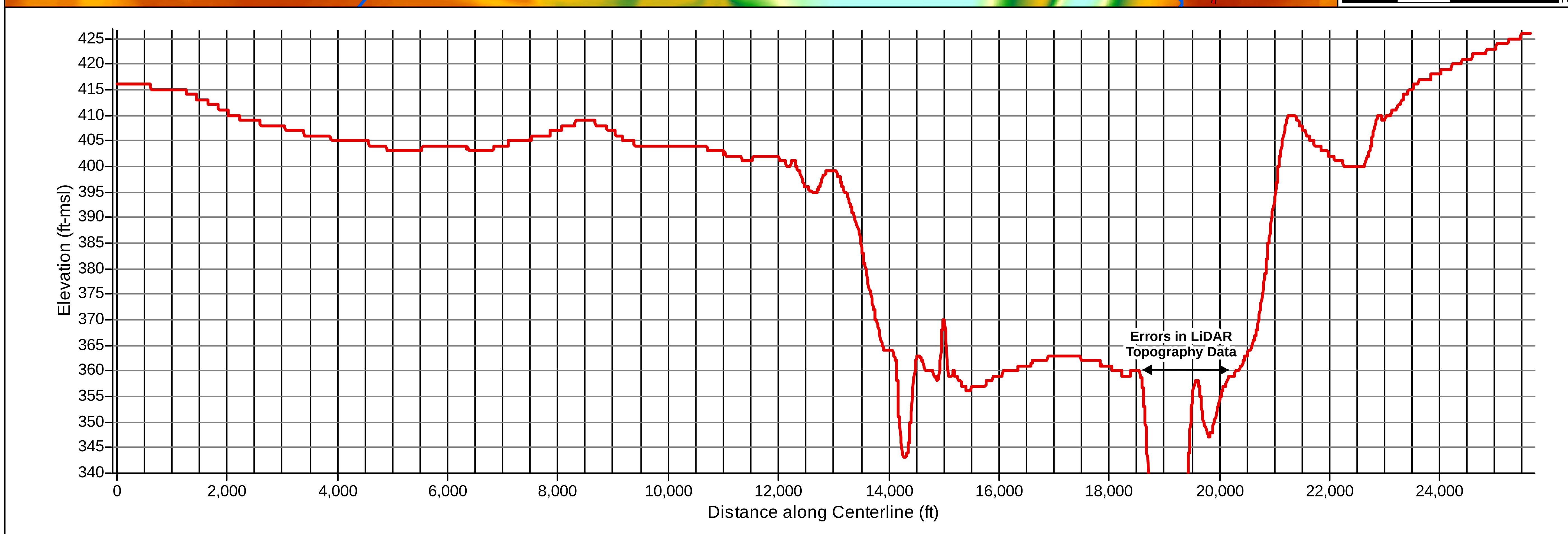
PREPARED BY JPM

GEORGE PARKHOUSE II RESERVOIR SITE

ELEVATION PROFILE - MAIN DAM

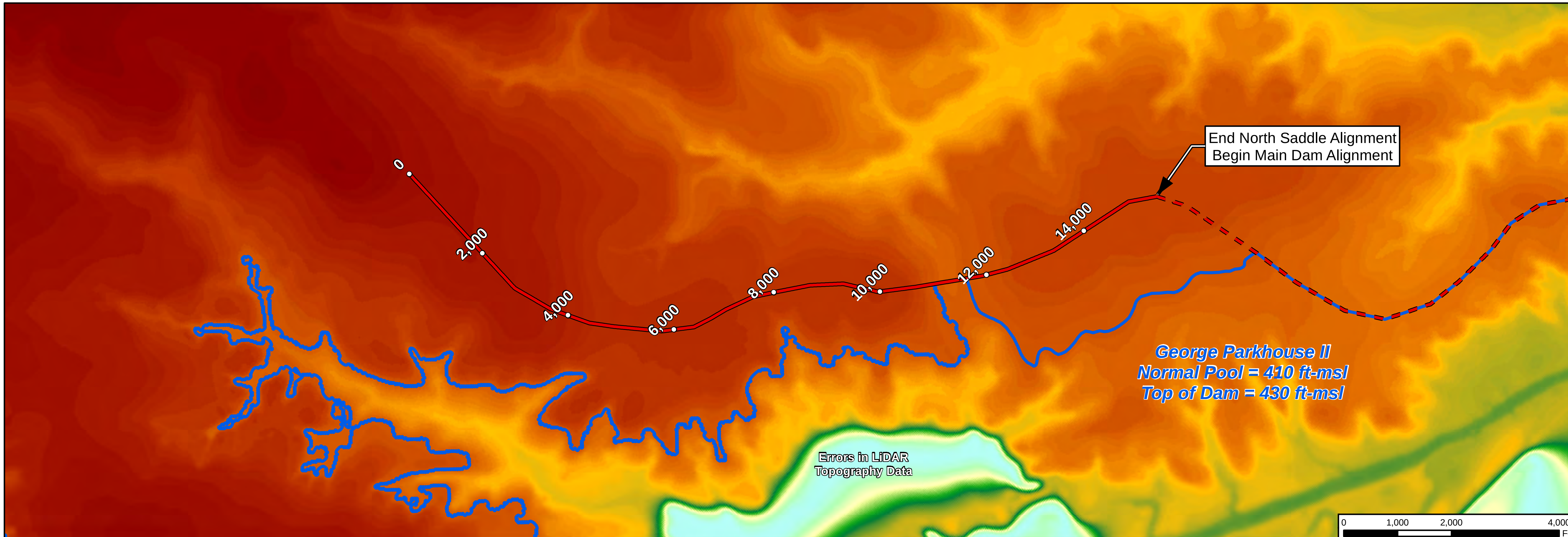
FIGURE A-8





FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT: UFH12387
FILE: Plan&Profile_PH2-Main
DATUM & COORDINATE SYSTEM: NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE: April, 2014
PREPARED BY: JPM



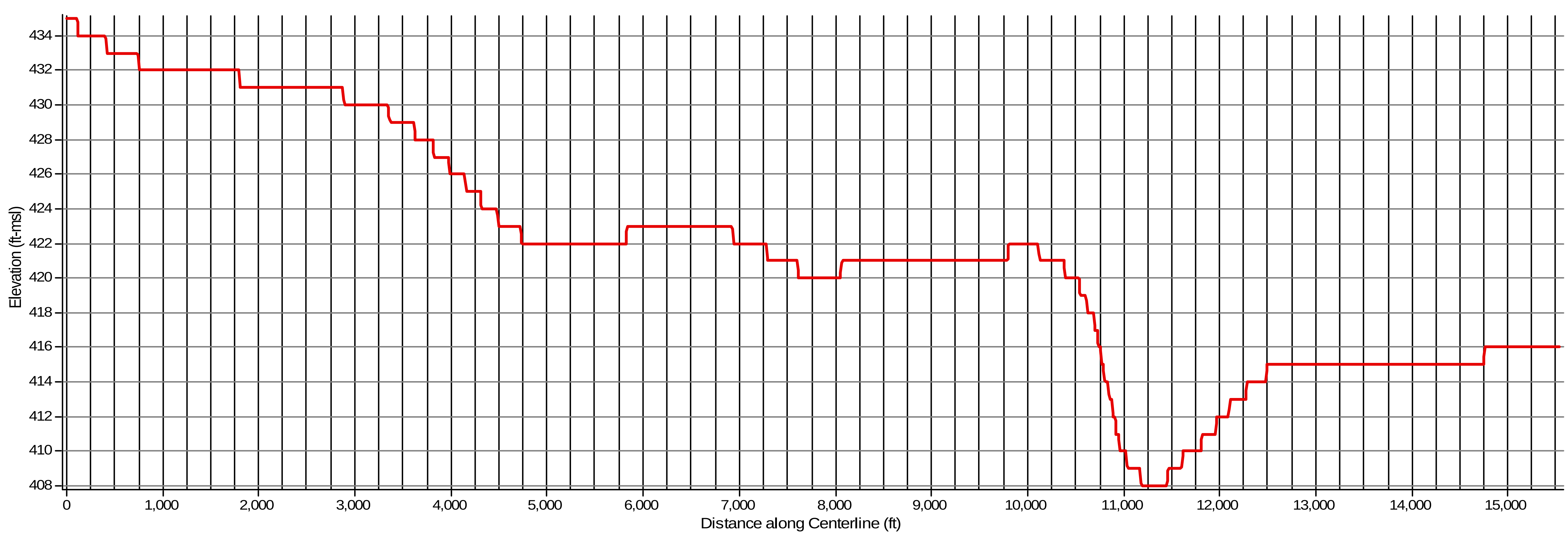


FIGURE A-9

GEORGE PARKHOUSE II RESERVOIR SITE

ELEVATION PROFILE - NORTH SADDLE

FREESE NICHOLS

4055 International Plaza
Suite 200
Fort Worth, TX 76109

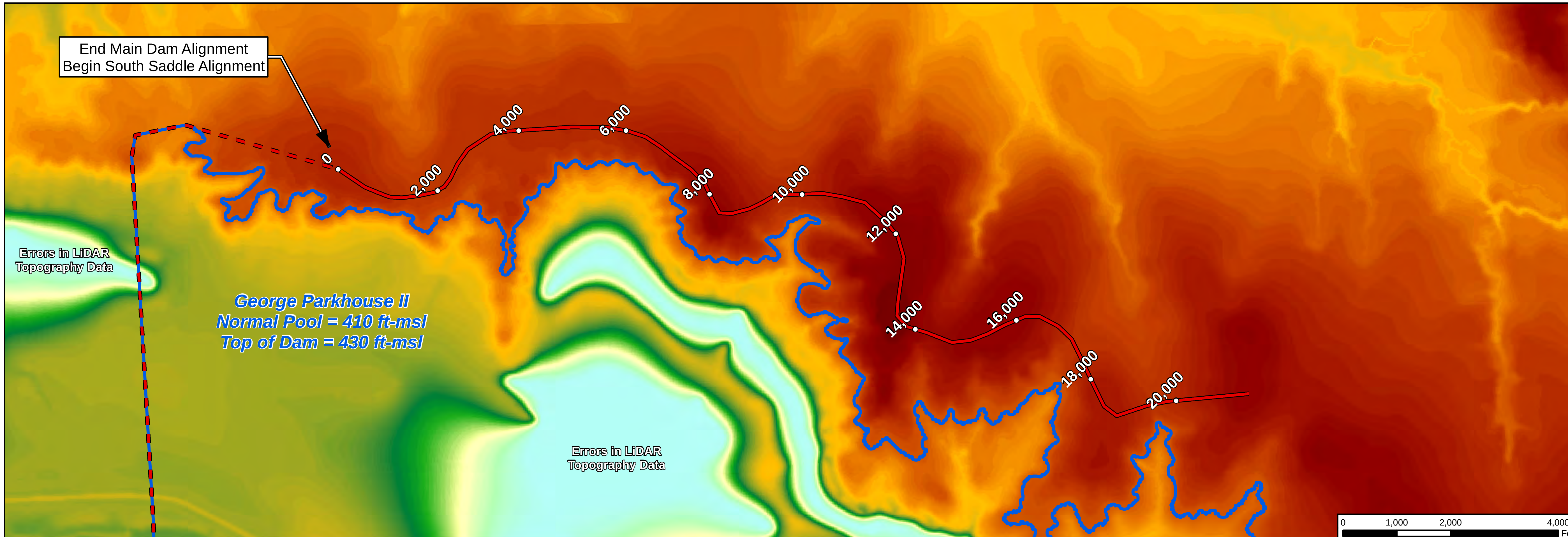
FNI PROJECT UFH12387

FILE Plan&Profile_PH2-NorthSaddle

DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas Central FIPS 4203 Feet

DATE April, 2014

PREPARED BY JPM



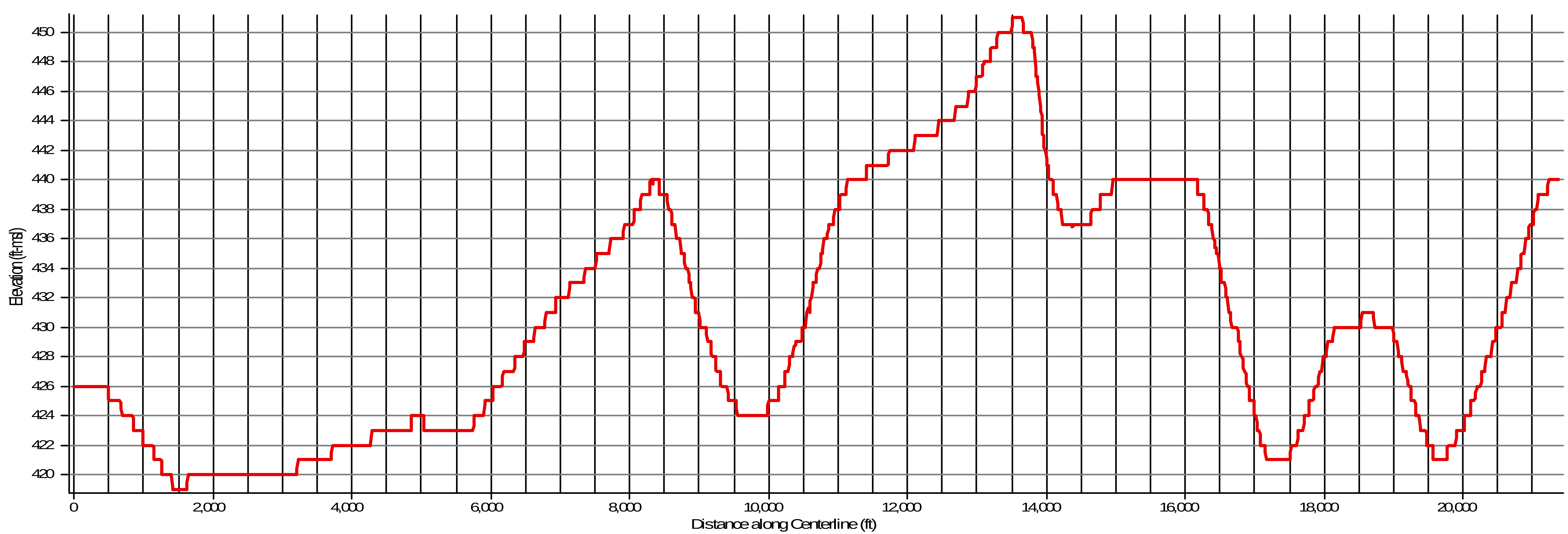


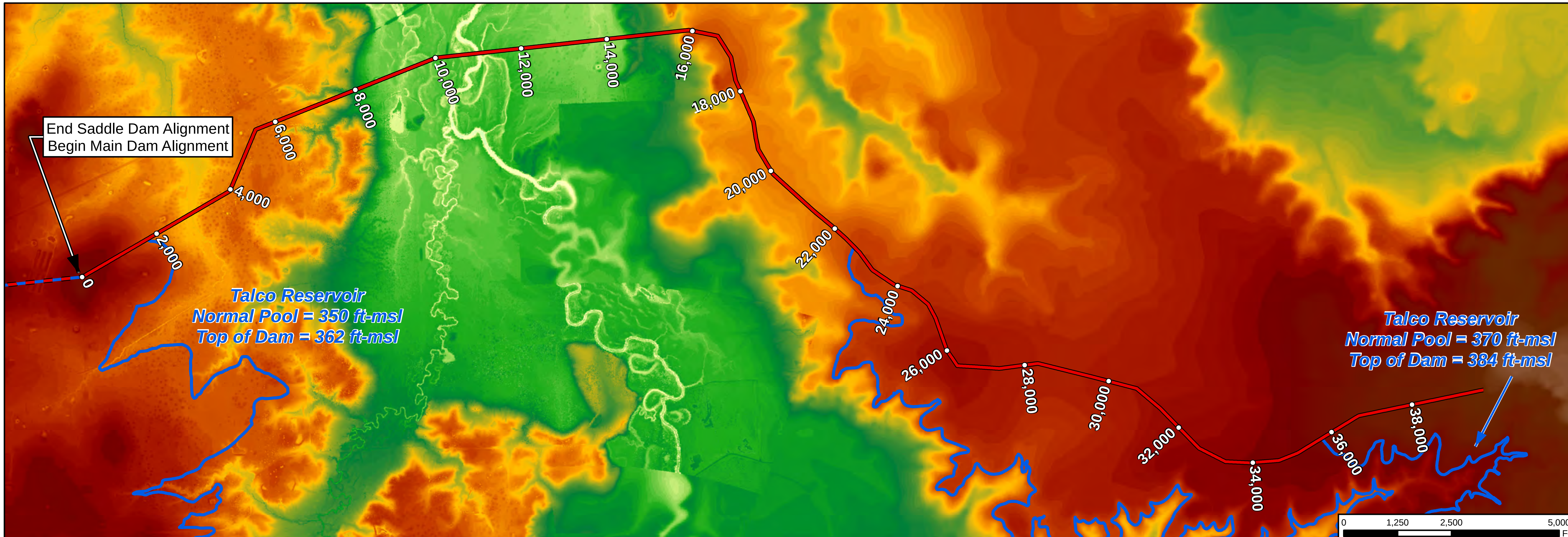
FIGURE B-10

S E W N

GEORGE PARKHOUSE II RESERVOIR SITE
ELEVATION PROFILE - SOUTH SADDLE

FREESE AND NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE Plan&Profile_PH2-SouthSaddle
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE April, 2014
PREPARED BY JPM



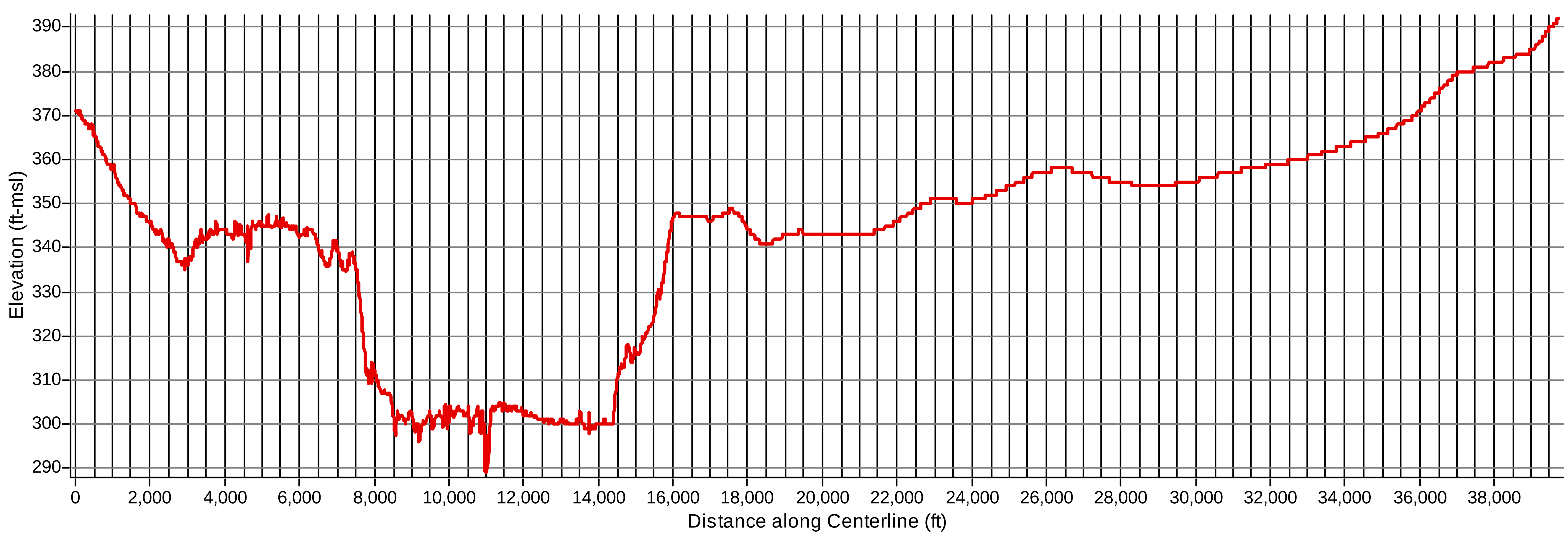


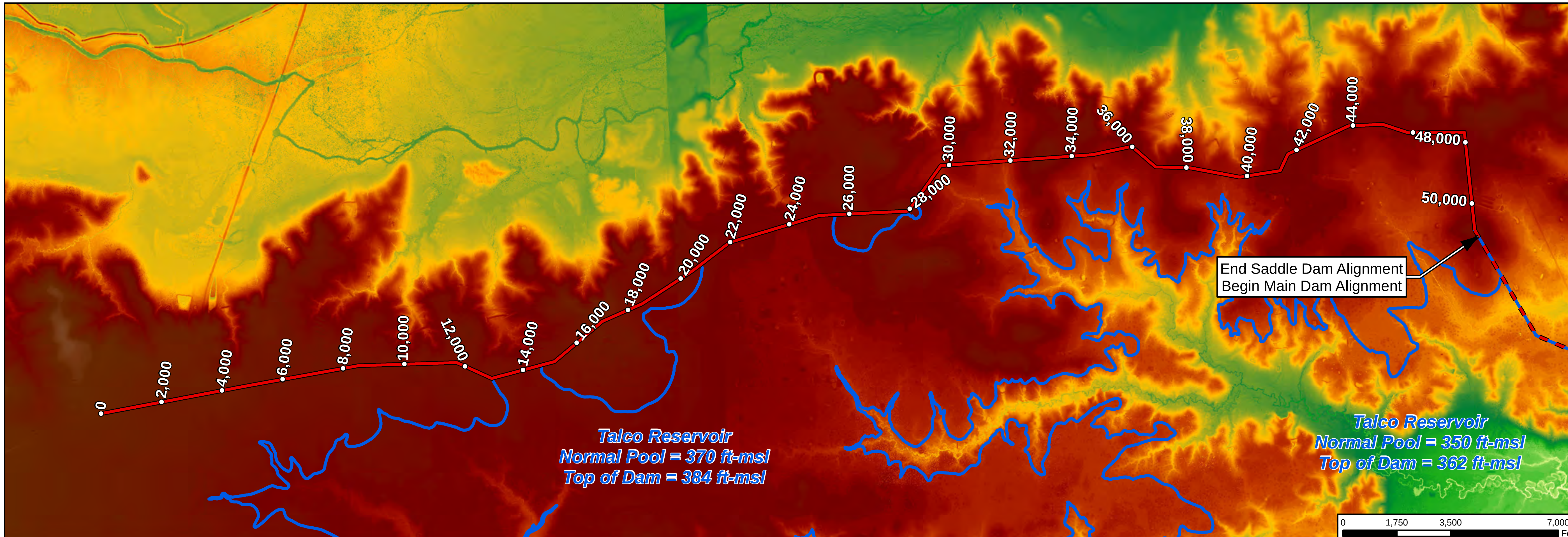
FIGURE A-11

TALCO RESERVOIR SITE

ELEVATION PROFILE - MAIN DAM

FREESE AND NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE Plan&Profile_Talco-Main
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE April, 2014
PREPARED BY JPM



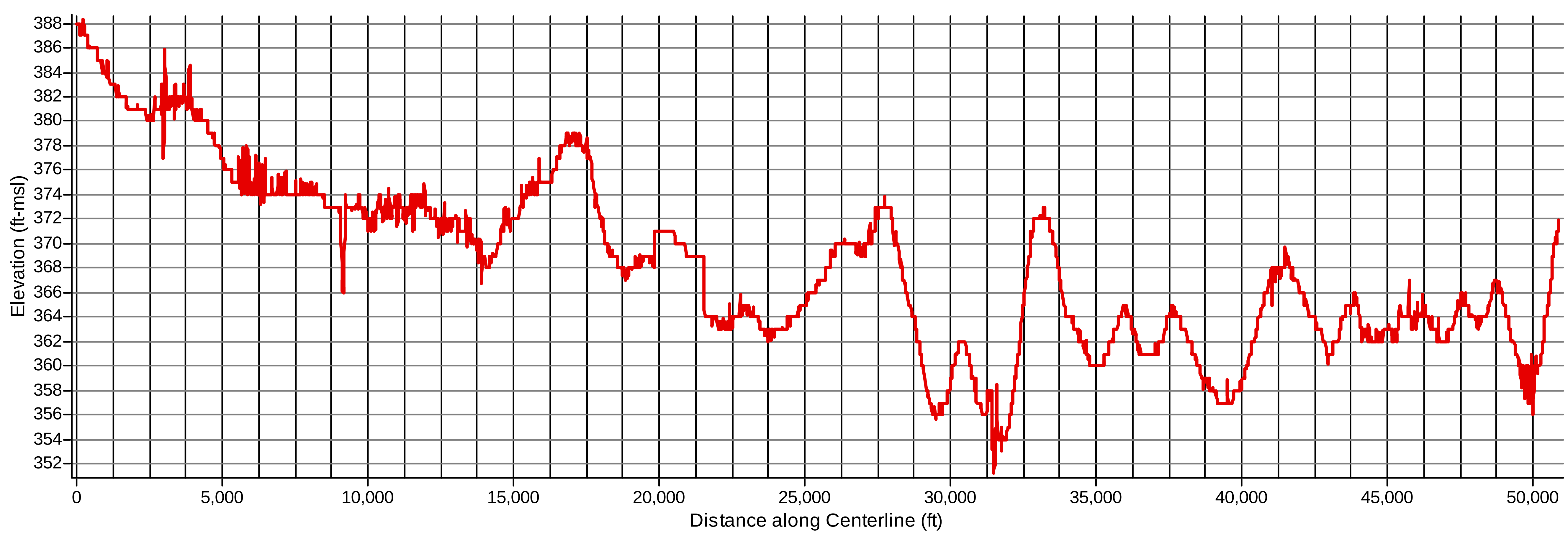


FIGURE A-12

N S W E

TALCO RESERVOIR SITE

ELEVATION PROFILE - SADDLE DAM

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

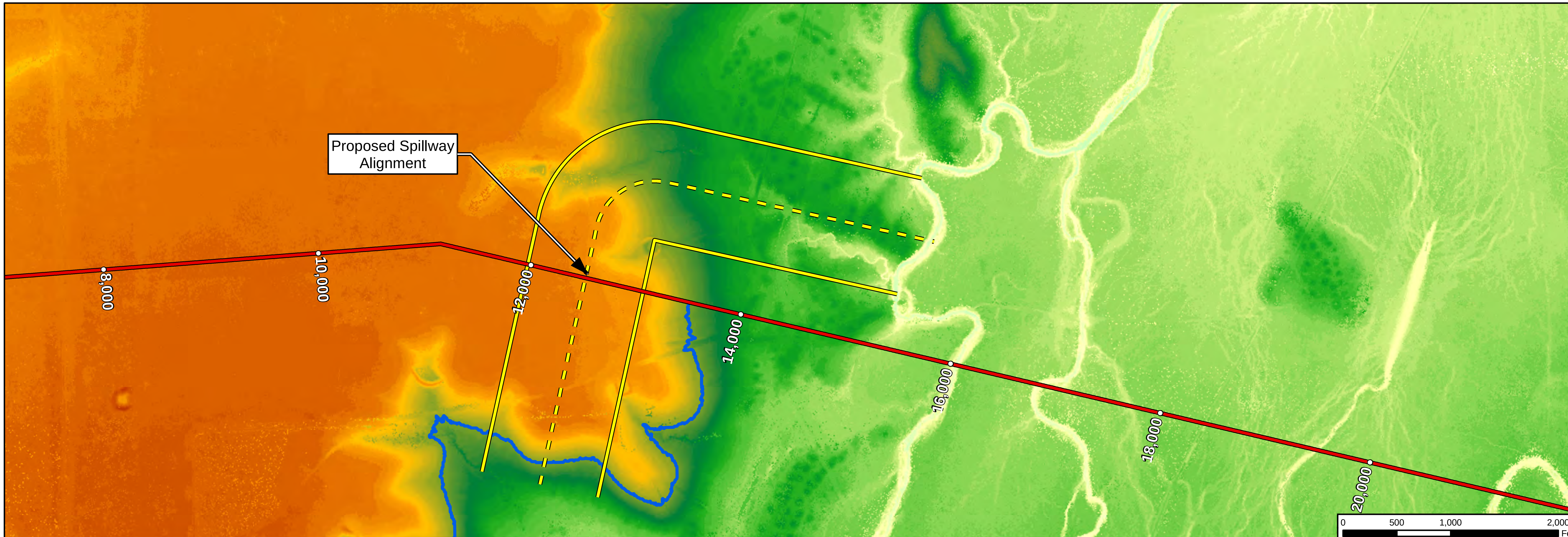
FNI PROJECT UFH12387

FILE Plan&Profile_Talco-Saddle

DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas Central FIPS 4203 Feet

DATE April, 2014

PREPARED BY JPM



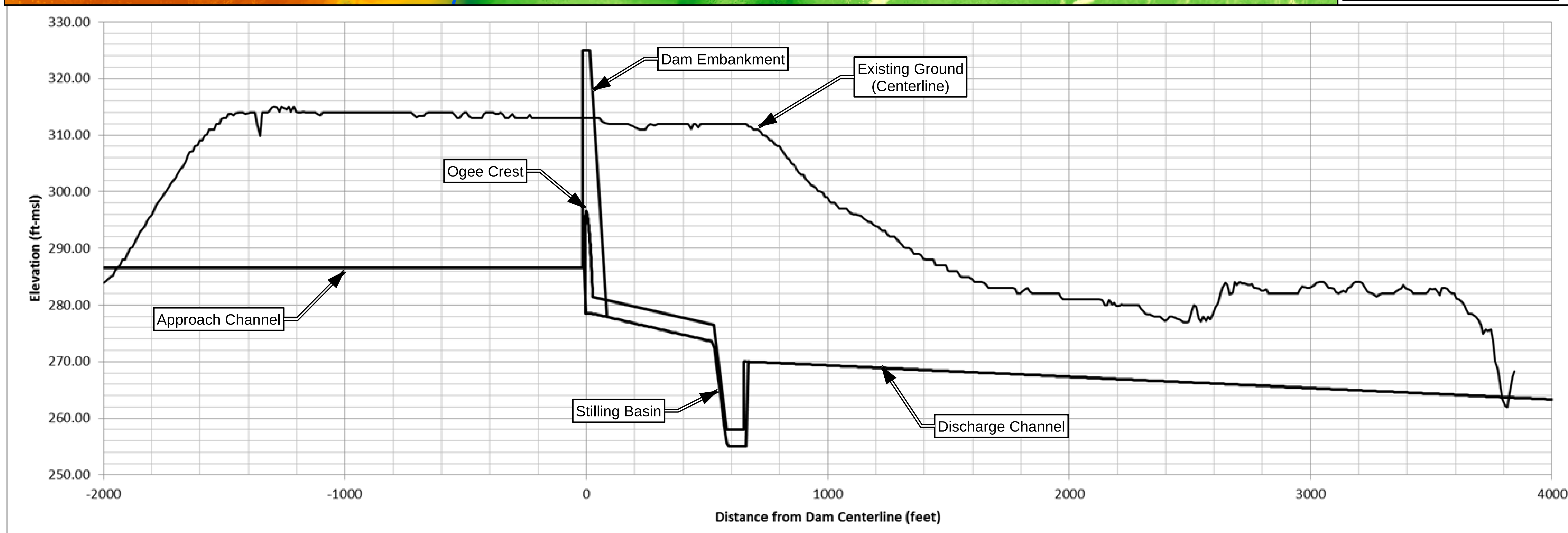


FIGURE A-13

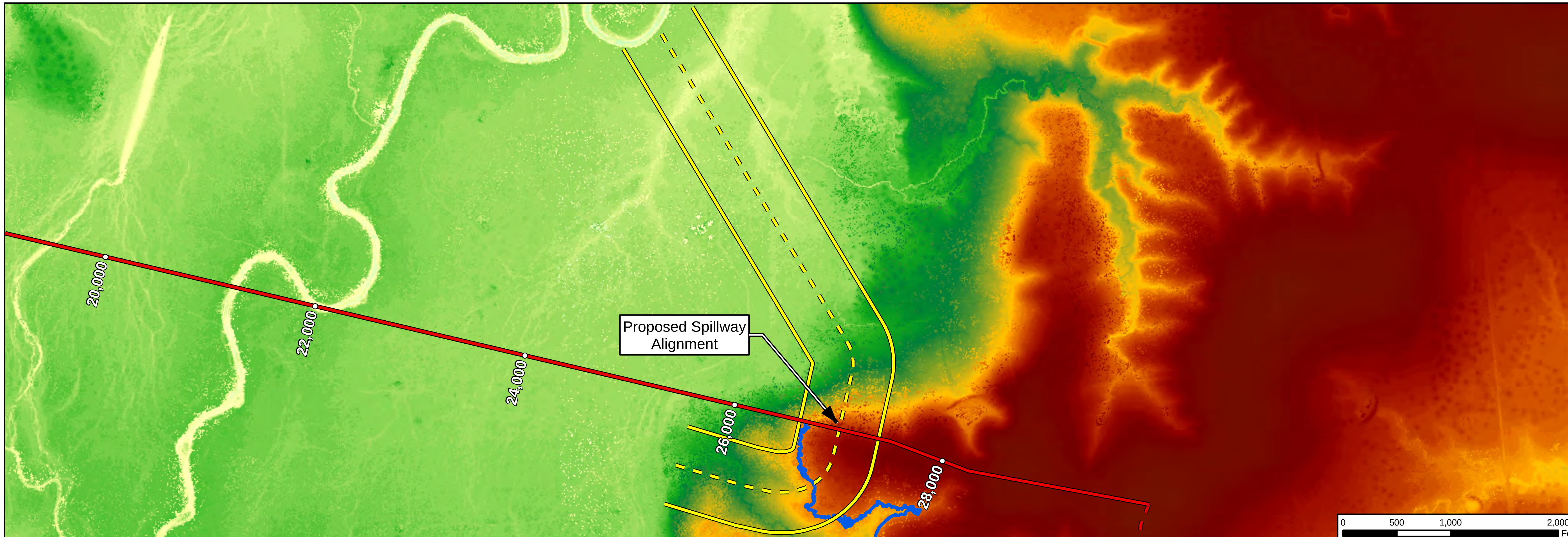
N E S W

MARVIN NICHOLS 1A RESERVOIR SITE

SPILLWAY PROFILE - NP = 296.5

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT: UFH12387
FILE: Plan&Profile_MN1A-296_5
DATUM & COORDINATE SYSTEM: NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE: April, 2014
PREPARED BY: JPM



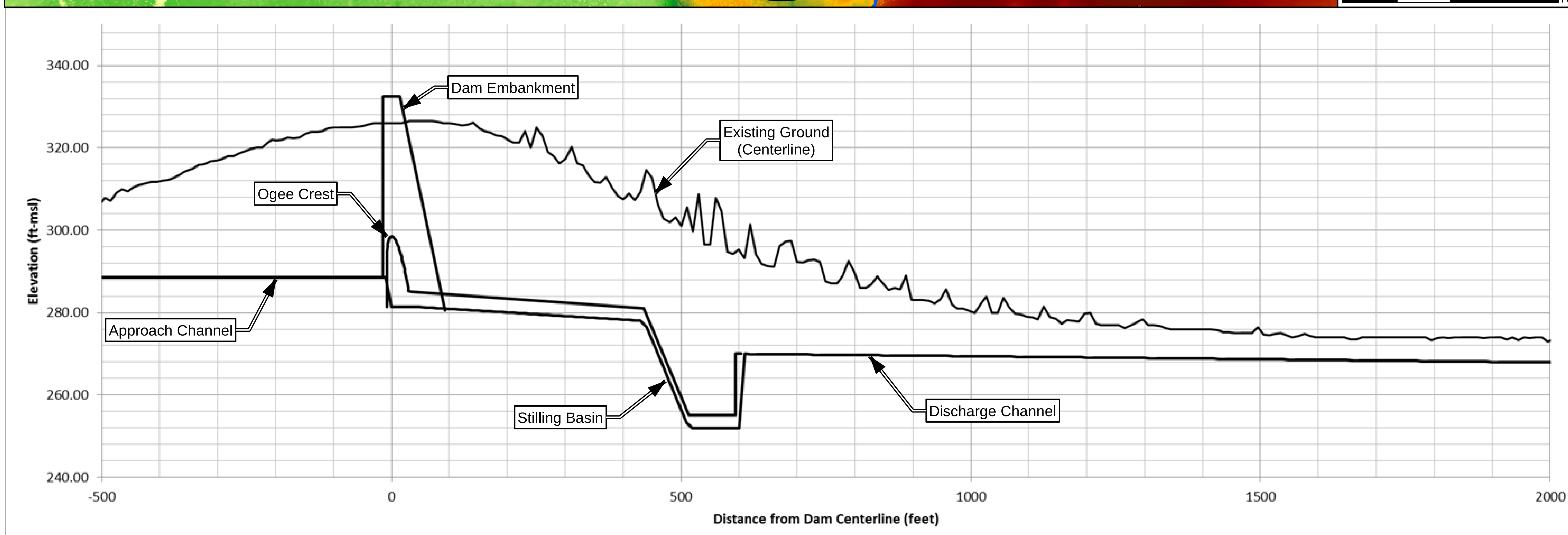


FIGURE A-14

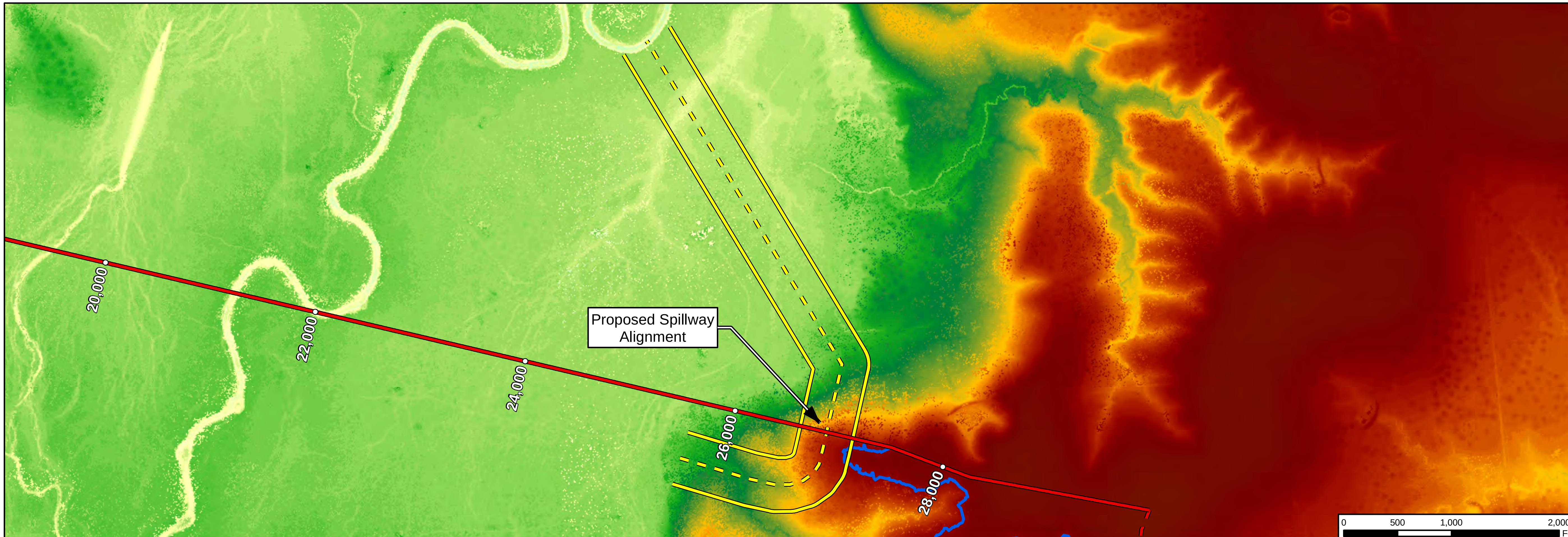
N E S W

MARVIN NICHOLS 1A RESERVOIR SITE

SPILLWAY PROFILE - NP = 313.5

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT: UFH12387
FILE: Plan&Profile_MN1A-313_5
DATUM & COORDINATE SYSTEM: NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE: April, 2014
PREPARED BY: JPM



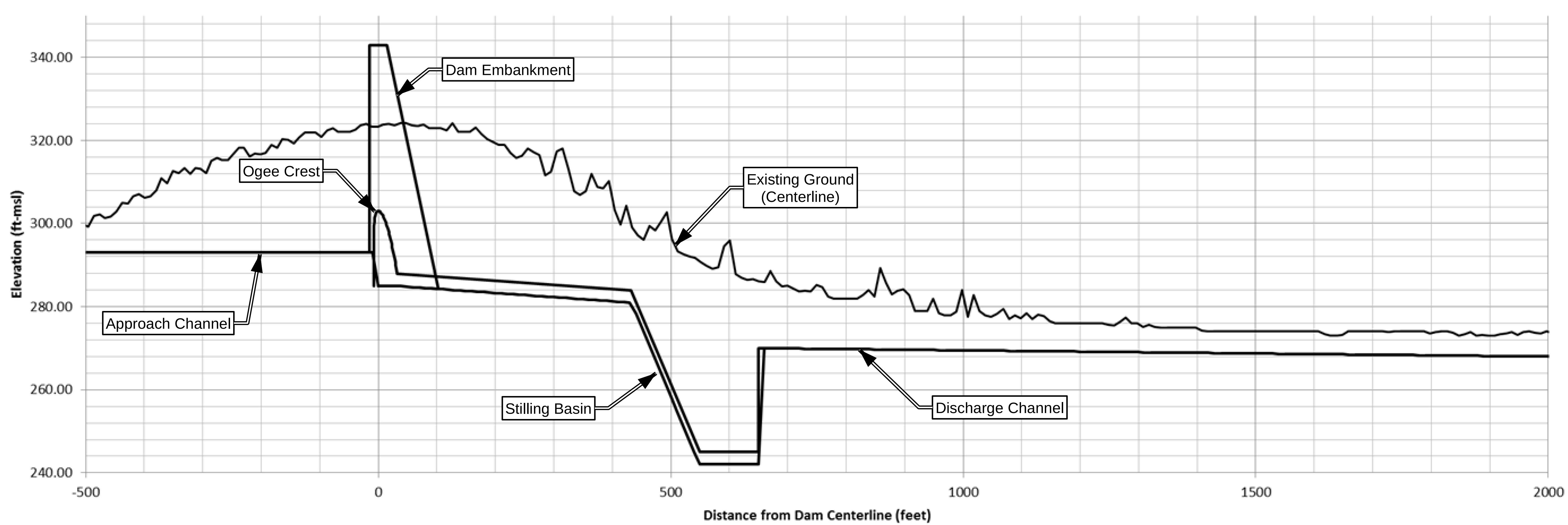


FIGURE A-15

N E S W

MARVIN NICHOLS 1A RESERVOIR SITE

SPILLWAY PROFILE - NP = 328

FREESE AND NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT	UFH12387
FILE	Plan&Profile_MN1A-328
DATUM & COORDINATE SYSTEM	NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE	April, 2014
PREPARED BY	JPM

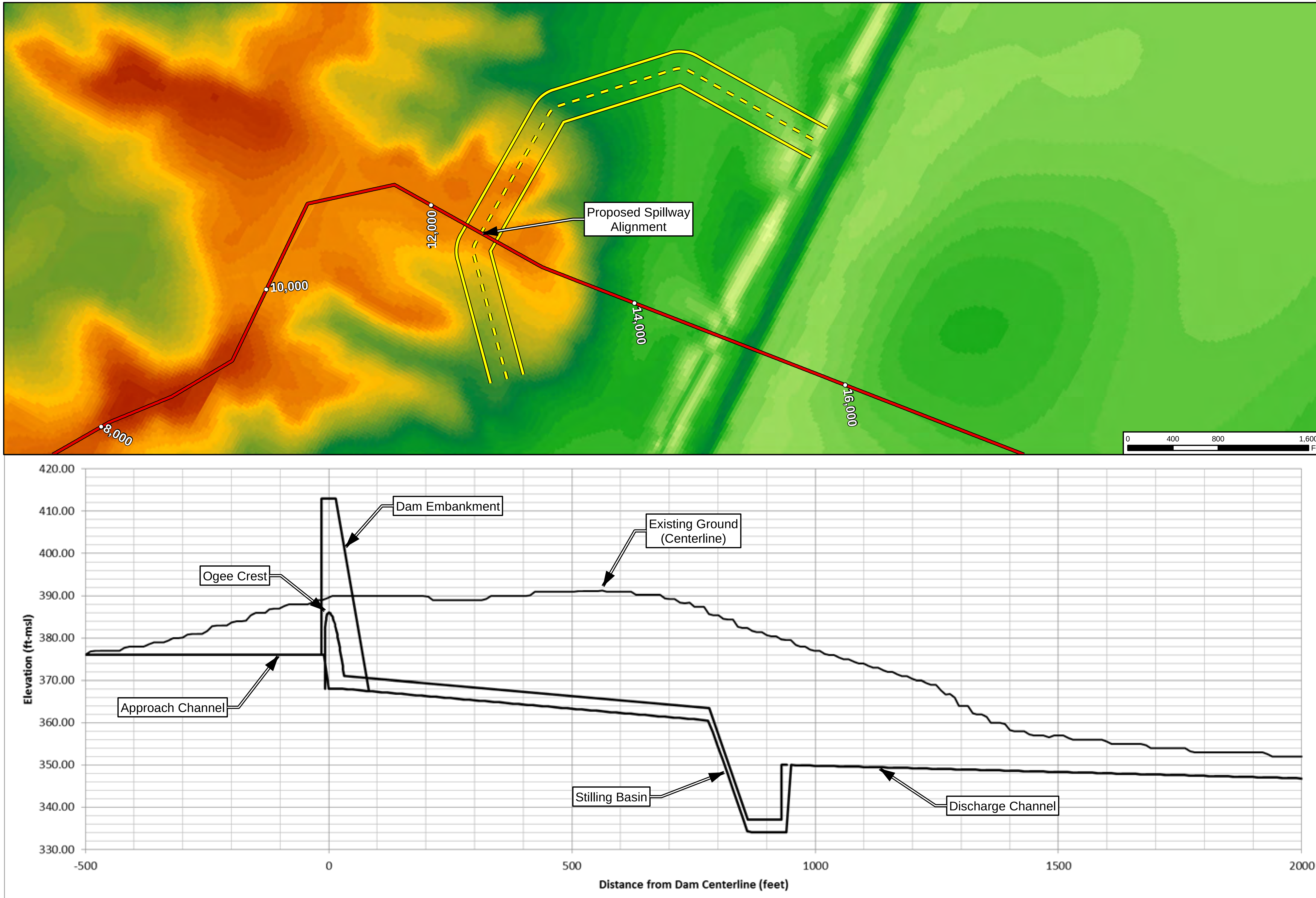


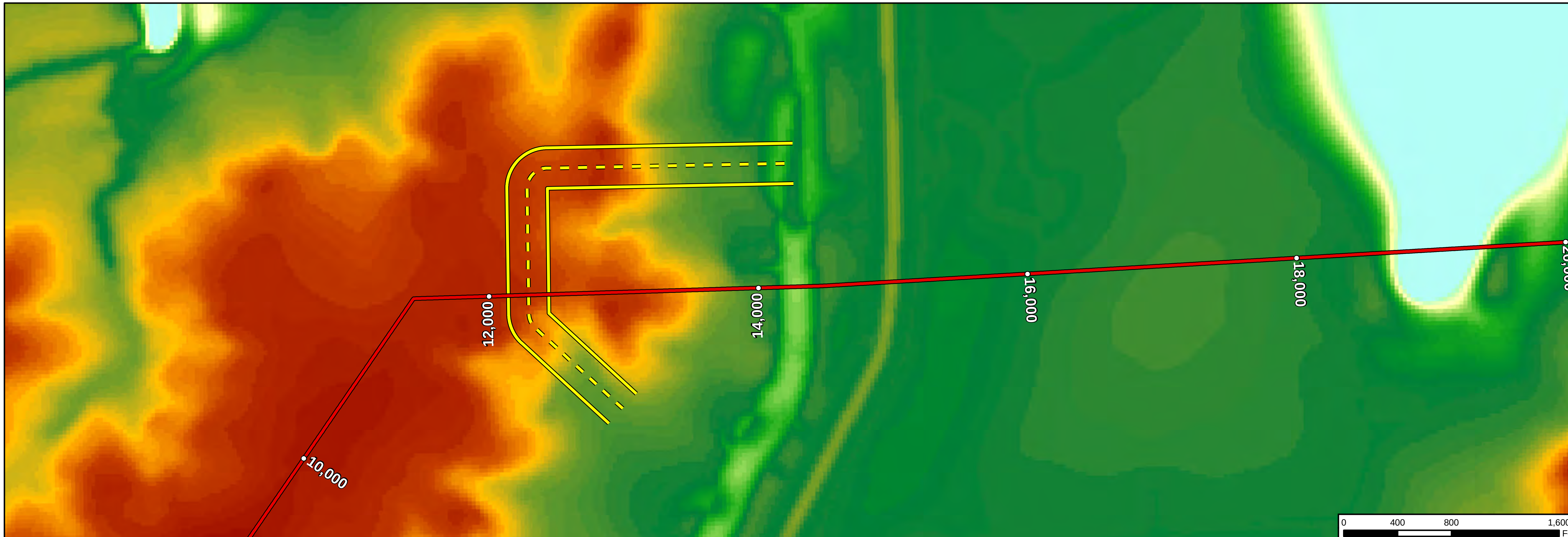
FIGURE A-16

GEORGE PARKHOUSE I RESERVOIR SITE

SPILLWAY PROFILE - NP = 401

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT	UFH12387
FILE	Plan&Profile_PH1-401
DATUM & COORDINATE SYSTEM	NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE	April, 2014
PREPARED BY	JPM



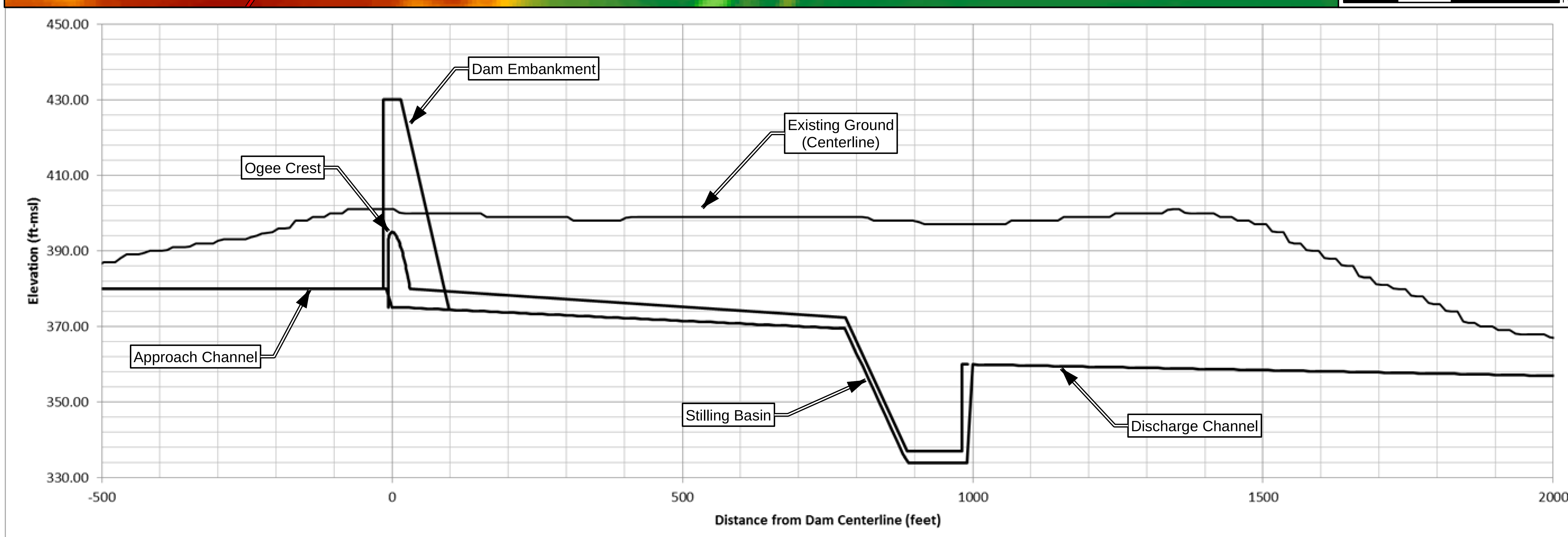


FIGURE A-17

GEORGE PARKHOUSE II RESERVOIR SITE

SPILLWAY PROFILE - NP = 410

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT: UFH12387
FILE: Plan&Profile_PH2-410
DATUM & COORDINATE SYSTEM: NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE: April, 2014
PREPARED BY: JPM

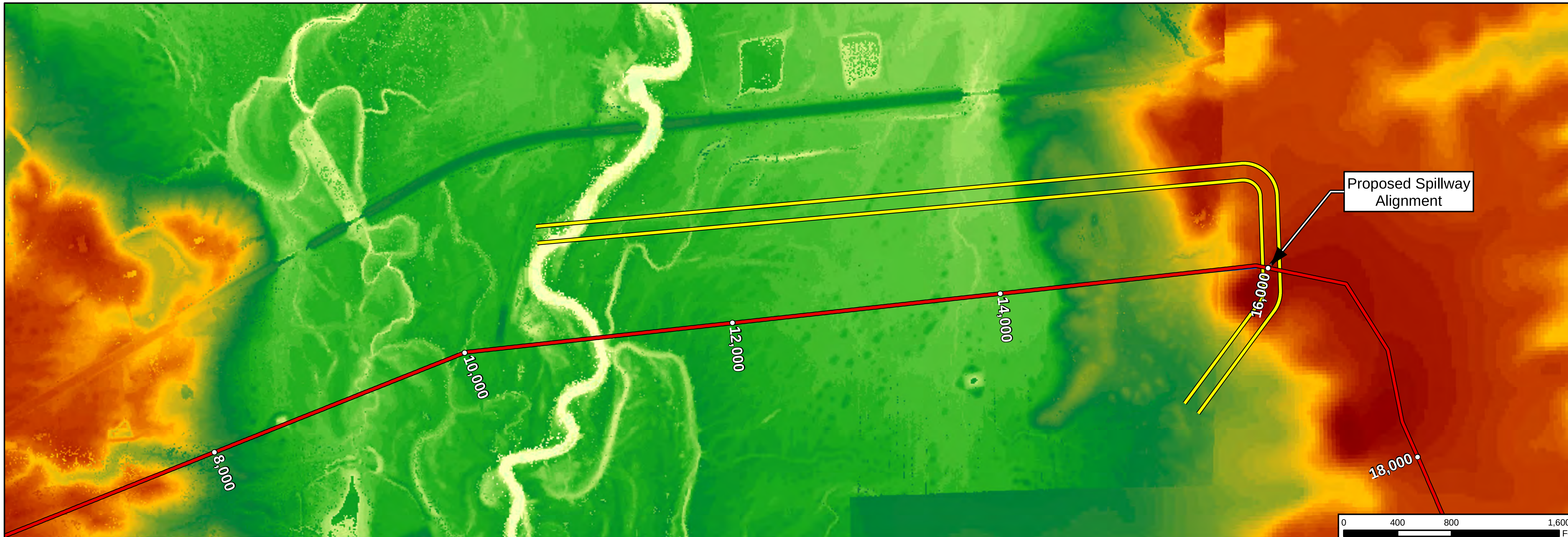


FIGURE A-18

TALCO RESERVOIR SITE

SPILLWAY PROFILE - NP = 350

FREESE NICHOLS

4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE Plan&Profile_Talco-350
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE April, 2014
PREPARED BY JPM

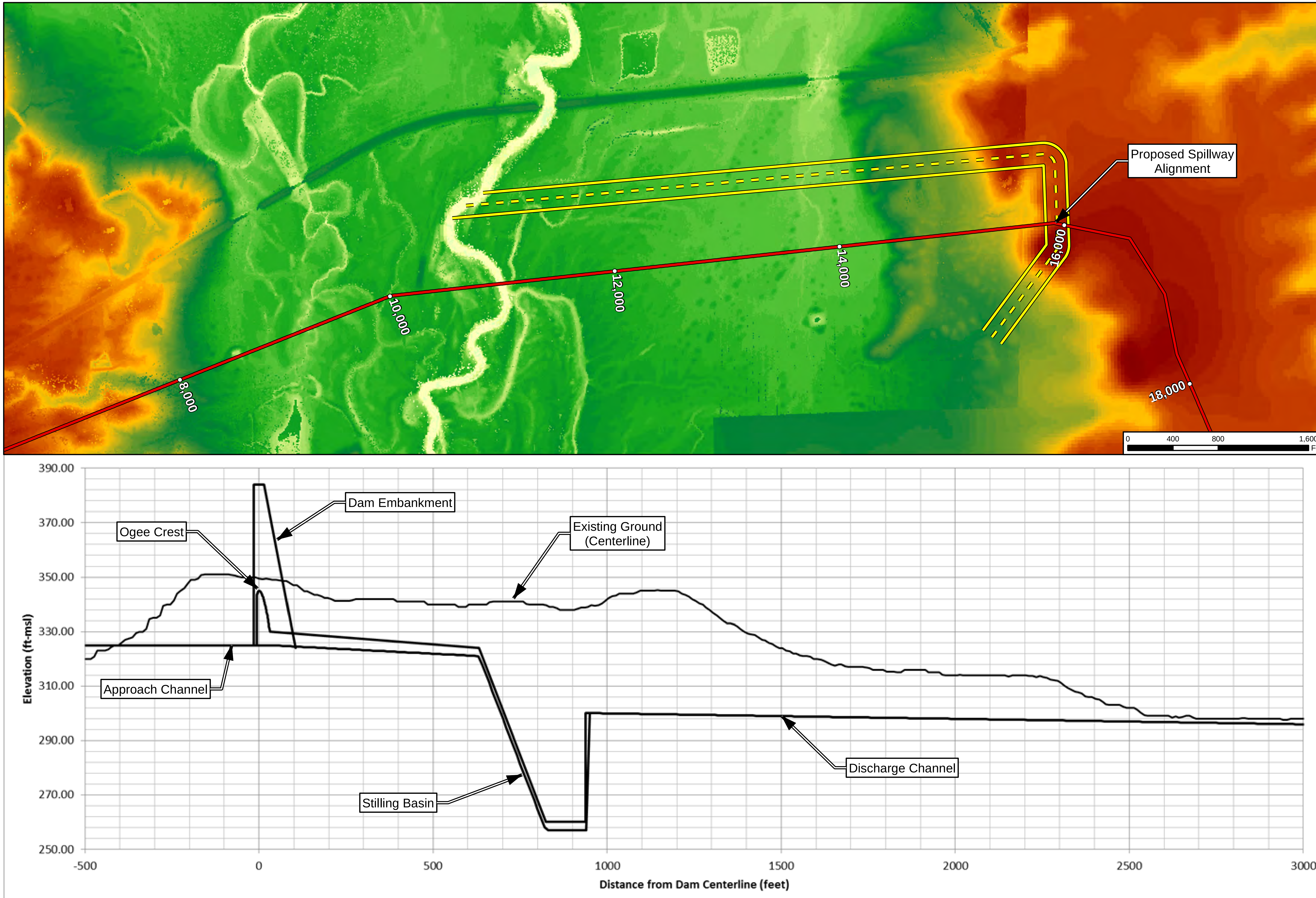


FIGURE A-19

TALCO RESERVOIR SITE

SPILLWAY PROFILE - NP = 370

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT	UFH12387
FILE	Plan&Profile_Talco-370
DATUM & COORDINATE SYSTEM	NAD 1983 StatePlane Texas Central FIPS 4203 Feet
DATE	April, 2014
PREPARED BY	JPM

Sulphur Basin Comparitive Analysis
Marvin Nichols 1A
Normal Pool - 328 ft-msl

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OPINION OF PROBABLE CONSTRUCTION COSTS

January 14, 2014

ESTIMATOR	CHECKED BY	ACCOUNT NO
JPM	JLR	UFH12387

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Dam and Spillway					
1	Mobilization	1	LS	$10,751,000.00	$10,751,000.00
2	Clearing and Grubbing	370	AC	$7,500.00	$2,775,000.00
3	Care of Water During Construction	1	LS	$2,102,000.00	$2,102,000.00
4	Excavation	1,042,300	CY	$3.00	$3,127,000.00
5	Fill (Core Compacted)	1,880,400	CY	$7.50	$14,103,000.00
6	Fill (Random Compacted)	8,689,300	CY	$7.00	$60,826,000.00
7	Soil Bentonite Slurry Trench	1,662,800	SF	$12.00	$19,954,000.00
8	Soil Cement	466,000	CY	$75.00	$34,950,000.00
9	Flex Road Base	35,100	CY	$60.00	$2,106,000.00
10	Sand Filter Drain	627,100	CY	$35.00	$21,949,000.00
11	Grassing	180	AC	$3,630.00	$654,000.00
12	Reinforced Concrete (Mass)	48,400	CY	$450.00	$21,780,000.00
13	Reinforced Concrete (Piers & Walls)	12,400	CY	$750.00	$9,300,000.00
14	Roller Compacted Concrete (RCC)	36,400	CY	$90.00	$3,276,000.00
15	Bridge (over Spillway)	9,800	SF	$50.00	$490,000.00
16	Bridge (to Outlet Works)	4,800	SF	$90.00	$432,000.00
17	Gates, Including Anchoring System	12,000	SF	$700.00	$8,400,000.00
18	Gate Hoist and Operating System	10	EA	$215,000.00	$2,150,000.00
19	Stop Gate and Lift Beam	8	EA	$67,000.00	$536,000.00
20	Low-Flow Outlet	1	LS	$3,622,000.00	$3,622,000.00
21	Barrier and Warning System	1	LS	$327,000.00	$327,000.00
22	Embankment Instrumentation	1	LS	$1,800,000.00	$1,800,000.00
23	Miscellaneous Internal Drainage	1	LS	$360,000.00	$360,000.00
				EMBANKMENT & SPILLWAY SUBTOTAL	**$225,770,000**
				ENGINEERING SERVICE & CONTIGENCY - 35%	**$79,020,000**
				EMBANKMENT & SPILLWAY TOTAL	**$304,790,000**

Notes:

Sulphur Basin Comparitive Analysis
Marvin Nichols 1A
Normal Pool - 313.5 ft-msl

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OPINION OF PROBABLE CONSTRUCTION COSTS

January 14, 2014

ESTIMATOR	CHECKED BY	ACCOUNT NO
JPM	JLR	UFH12387

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Dam and Spillway					
1	Mobilization	1	LS	$8,326,000.00	$8,326,000.00
2	Clearing and Grubbing	240	AC	$7,500.00	$1,800,000.00
3	Care of Water During Construction	1	LS	$1,631,000.00	$1,631,000.00
4	Excavation	1,885,600	CY	$3.00	$5,657,000.00
5	Fill (Core Compacted)	1,182,600	CY	$7.50	$8,870,000.00
6	Fill (Random Compacted)	5,424,900	CY	$6.50	$35,262,000.00
7	Soil Bentonite Slurry Trench	1,062,900	SF	$12.00	$12,755,000.00
8	Soil Cement	308,600	CY	$75.00	$23,145,000.00
9	Flex Road Base	22,800	CY	$60.00	$1,368,000.00
10	Sand Filter Drain	403,000	CY	$35.00	$14,105,000.00
11	Grassing	110	AC	$3,630.00	$400,000.00
12	Reinforced Concrete (Mass)	68,600	CY	$450.00	$30,870,000.00
13	Reinforced Concrete (Piers & Walls)	12,900	CY	$750.00	$9,675,000.00
14	Roller Compacted Concrete (RCC)	26,300	CY	$90.00	$2,367,000.00
15	Bridge (over Spillway)	15,100	SF	$50.00	$755,000.00
16	Bridge (to Outlet Works)	4,000	SF	$90.00	$360,000.00
17	Gates, Including Anchoring System	12,000	SF	$700.00	$8,400,000.00
18	Gate Hoist and Operating System	20	EA	$215,000.00	$4,300,000.00
19	Stop Gate and Lift Beam	5	EA	$50,000.00	$250,000.00
20	Low-Flow Outlet	1	LS	$3,155,000.00	$3,155,000.00
21	Barrier and Warning System	1	LS	$502,000.00	$502,000.00
22	Embankment Instrumentation	1	LS	$732,000.00	$732,000.00
23	Miscellaneous Internal Drainage	1	LS	$147,000.00	$147,000.00
				EMBANKMENT & SPILLWAY SUBTOTAL	**$174,832,000**
				ENGINEERING SERVICE & CONTIGENCY - 35%	**$61,191,000**
				EMBANKMENT & SPILLWAY TOTAL	**$236,023,000**

Notes:

Sulphur Basin Comparitive Analysis
Marvin Nichols 1A
Normal Pool - 296.5 ft-msl

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OPINION OF PROBABLE CONSTRUCTION COSTS

January 14, 2014

ESTIMATOR	CHECKED BY	ACCOUNT NO
JPM	JLR	UFH12387

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Dam and Spillway					
1	Mobilization	1	LS	$6,250,000.00	$6,250,000.00
2	Clearing and Grubbing	170	AC	$7,500.00	$1,275,000.00
3	Care of Water During Construction	1	LS	$1,225,000.00	$1,225,000.00
4	Excavation	3,651,000	CY	$3.00	$10,953,000.00
5	Fill (Core Compacted)	837,700	CY	$7.00	$5,864,000.00
6	Fill (Random Compacted)	3,779,000	CY	$5.00	$18,895,000.00
7	Soil Bentonite Slurry Trench	907,400	SF	$12.00	$10,889,000.00
8	Soil Cement	224,200	CY	$75.00	$16,815,000.00
9	Flex Road Base	12,700	CY	$60.00	$762,000.00
10	Sand Filter Drain	292,900	CY	$35.00	$10,252,000.00
11	Grassing	70	AC	$3,630.00	$255,000.00
12	Reinforced Concrete (Mass)	81,600	CY	$450.00	$36,720,000.00
13	Reinforced Concrete (Piers & Walls)	5,400	CY	$750.00	$4,050,000.00
14	Roller Compacted Concrete (RCC)	18,800	CY	$90.00	$1,692,000.00
15	Bridge (over Spillway)	18,000	SF	$50.00	$900,000.00
16	Bridge (to Outlet Works)	3,500	SF	$90.00	$315,000.00
17	Gates, Including Anchoring System	0	SF	$0.00	$0.00
18	Gate Hoist and Operating System	0	EA	$0.00	$0.00
19	Stop Gate and Lift Beam	0	EA	$0.00	$0.00
20	Low-Flow Outlet	1	LS	$2,822,000.00	$2,822,000.00
21	Barrier and Warning System	1	LS	$600,000.00	$600,000.00
22	Embankment Instrumentation	1	LS	$590,000.00	$590,000.00
23	Miscellaneous Internal Drainage	1	LS	$118,000.00	$118,000.00
	EMBANKMENT & SPILLWAY SUBTOTAL				**$131,242,000**
	ENGINEERING SERVICE & CONTIGENCY - 35%				**$45,935,000**
	EMBANKMENT & SPILLWAY TOTAL				**$177,177,000**

Notes:

Sulphur Basin Comparitive Analysis
George Parkhouse I
Normal Pool - 401 ft-msl

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January 14, 2014

ESTIMATOR	CHECKED BY	ACCOUNT NO
JPM	JLR	UFH12387

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Dam and Spillway					
1	Mobilization	1	LS	$6,653,000.00	$6,653,000.00
2	Clearing and Grubbing	200	AC	$7,500.00	$1,500,000.00
3	Care of Water During Construction	1	LS	$1,303,000.00	$1,303,000.00
4	Excavation	563,200	CY	$3.00	$1,690,000.00
5	Fill (Core Compacted)	1,223,300	CY	$7.50	$9,175,000.00
6	Fill (Random Compacted)	5,662,500	CY	$7.00	$39,638,000.00
7	Soil Bentonite Slurry Trench	1,016,600	SF	$12.00	$12,200,000.00
8	Soil Cement	263,700	CY	$75.00	$19,778,000.00
9	Flex Road Base	12,000	CY	$60.00	$720,000.00
10	Sand Filter Drain	385,600	CY	$35.00	$13,496,000.00
11	Grassing	80	AC	$3,630.00	$291,000.00
12	Reinforced Concrete (Mass)	37,100	CY	$450.00	$16,695,000.00
13	Reinforced Concrete (Piers & Walls)	6,100	CY	$750.00	$4,575,000.00
14	Roller Compacted Concrete (RCC)	17,000	CY	$90.00	$1,530,000.00
15	Bridge (over Spillway)	6,000	SF	$50.00	$300,000.00
16	Bridge (to Outlet Works)	4,000	SF	$90.00	$360,000.00
17	Gates, Including Anchoring System	4,800	SF	$700.00	$3,360,000.00
18	Gate Hoist and Operating System	8	EA	$215,000.00	$1,720,000.00
19	Stop Gate and Lift Beam	5	EA	$50,000.00	$250,000.00
20	Low-Flow Outlet	1	LS	$3,156,000.00	$3,156,000.00
21	Barrier and Warning System	1	LS	$198,000.00	$198,000.00
22	Embankment Instrumentation	1	LS	$927,000.00	$927,000.00
23	Miscellaneous Internal Drainage	1	LS	$186,000.00	$186,000.00
				EMBANKMENT & SPILLWAY SUBTOTAL	**$139,701,000**
				ENGINEERING SERVICE & CONTIGENCY - 35%	**$48,895,000**
				EMBANKMENT & SPILLWAY TOTAL	**$188,596,000**

Notes:

Sulphur Basin Comparitive Analysis
George Parkhouse II
Normal Pool - 410 ft-msl

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ESTIMATOR	CHECKED BY	ACCOUNT NO
JPM	JLR	UFH12387

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Dam and Spillway					
1	Mobilization	1	LS	$7,431,000.00	$7,431,000.00
2	Clearing and Grubbing	250	AC	$7,500.00	$1,875,000.00
3	Care of Water During Construction	1	LS	$1,453,000.00	$1,453,000.00
4	Excavation	840,900	CY	$3.00	$2,523,000.00
5	Fill (Core Compacted)	1,193,800	CY	$7.50	$8,954,000.00
6	Fill (Random Compacted)	5,518,900	CY	$7.00	$38,633,000.00
7	Soil Bentonite Slurry Trench	1,000,800	SF	$12.00	$12,010,000.00
8	Soil Cement	314,300	CY	$75.00	$23,573,000.00
9	Flex Road Base	24,700	CY	$60.00	$1,482,000.00
10	Sand Filter Drain	403,500	CY	$35.00	$14,123,000.00
11	Grassing	120	AC	$3,630.00	$436,000.00
12	Reinforced Concrete (Mass)	48,700	CY	$450.00	$21,915,000.00
13	Reinforced Concrete (Piers & Walls)	9,400	CY	$750.00	$7,050,000.00
14	Roller Compacted Concrete (RCC)	36,400	CY	$90.00	$3,276,000.00
15	Bridge (over Spillway)	6,000	SF	$50.00	$300,000.00
16	Bridge (to Outlet Works)	5,100	SF	$90.00	$459,000.00
17	Gates, Including Anchoring System	4,800	SF	$700.00	$3,360,000.00
18	Gate Hoist and Operating System	8	EA	$215,000.00	$1,720,000.00
19	Stop Gate and Lift Beam	5	EA	$50,000.00	$250,000.00
20	Low-Flow Outlet	1	LS	$3,867,000.00	$3,867,000.00
21	Barrier and Warning System	1	LS	$198,000.00	$198,000.00
22	Embankment Instrumentation	1	LS	$963,000.00	$963,000.00
23	Miscellaneous Internal Drainage	1	LS	$193,000.00	$193,000.00
				EMBANKMENT & SPILLWAY SUBTOTAL	**$156,044,000**
				ENGINEERING SERVICE & CONTIGENCY - 35%	**$54,615,000**
				EMBANKMENT & SPILLWAY TOTAL	**$210,659,000**

Notes:

Sulphur Basin Comparitive Analysis
Talco Reservoir
Normal Pool - 370 ft-msl

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OPINION OF PROBABLE CONSTRUCTION COSTS

January 14, 2014

ESTIMATOR	CHECKED BY	ACCOUNT NO
JPM	JLR	UFH12387

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Dam and Spillway					
1	Mobilization	1	LS	$13,034,000.00	$13,034,000.00
2	Clearing and Grubbing	510	AC	$7,500.00	$3,825,000.00
3	Care of Water During Construction	1	LS	$2,544,000.00	$2,544,000.00
4	Excavation	946,100	CY	$3.00	$2,839,000.00
5	Fill (Core Compacted)	2,494,100	CY	$7.50	$18,706,000.00
6	Fill (Random Compacted)	11,269,800	CY	$7.00	$78,889,000.00
7	Soil Bentonite Slurry Trench	2,459,000	SF	$12.00	$29,508,000.00
8	Soil Cement	651,200	CY	$75.00	$48,840,000.00
9	Flex Road Base	45,000	CY	$60.00	$2,700,000.00
10	Sand Filter Drain	878,600	CY	$35.00	$30,751,000.00
11	Grassing	270	AC	$3,630.00	$981,000.00
12	Reinforced Concrete (Mass)	30,600	CY	$450.00	$13,770,000.00
13	Reinforced Concrete (Piers & Walls)	11,900	CY	$750.00	$8,925,000.00
14	Roller Compacted Concrete (RCC)	55,900	CY	$90.00	$5,031,000.00
15	Bridge (over Spillway)	3,800	SF	$50.00	$190,000.00
16	Bridge (to Outlet Works)	5,700	SF	$90.00	$513,000.00
17	Gates, Including Anchoring System	4,800	SF	$700.00	$3,360,000.00
18	Gate Hoist and Operating System	4	EA	$215,000.00	$860,000.00
19	Stop Gate and Lift Beam	8	EA	$67,000.00	$536,000.00
20	Low-Flow Outlet	1	LS	$4,223,000.00	$4,223,000.00
21	Barrier and Warning System	1	LS	$127,000.00	$127,000.00
22	Embankment Instrumentation	1	LS	$2,961,000.00	$2,961,000.00
23	Miscellaneous Internal Drainage	1	LS	$593,000.00	$593,000.00
				EMBANKMENT & SPILLWAY SUBTOTAL	**$273,706,000**
				ENGINEERING SERVICE & CONTIGENCY - 35%	**$95,797,000**
				EMBANKMENT & SPILLWAY TOTAL	**$369,503,000**

Notes:

Sulphur Basin Comparitive Analysis
Talco Reservoir
Normal Pool - 350 ft-msl

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OPINION OF PROBABLE CONSTRUCTION COSTS

January 14, 2014

ESTIMATOR	CHECKED BY	ACCOUNT NO
JPM	JLR	UFH12387

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Dam and Spillway					
1	Mobilization	1	LS	$5,531,000.00	$5,531,000.00
2	Clearing and Grubbing	180	AC	$7,500.00	$1,350,000.00
3	Care of Water During Construction	1	LS	$1,082,000.00	$1,082,000.00
4	Excavation	1,318,700	CY	$3.00	$3,957,000.00
5	Fill (Core Compacted)	808,300	CY	$7.50	$6,063,000.00
6	Fill (Random Compacted)	3,717,300	CY	$6.50	$24,163,000.00
7	Soil Bentonite Slurry Trench	955,100	SF	$12.00	$11,462,000.00
8	Soil Cement	229,300	CY	$75.00	$17,198,000.00
9	Flex Road Base	20,700	CY	$60.00	$1,242,000.00
10	Sand Filter Drain	285,100	CY	$35.00	$9,979,000.00
11	Grassing	70	AC	$3,630.00	$255,000.00
12	Reinforced Concrete (Mass)	29,600	CY	$450.00	$13,320,000.00
13	Reinforced Concrete (Piers & Walls)	9,000	CY	$750.00	$6,750,000.00
14	Roller Compacted Concrete (RCC)	31,100	CY	$90.00	$2,799,000.00
15	Bridge (over Spillway)	4,800	SF	$50.00	$240,000.00
16	Bridge (to Outlet Works)	4,200	SF	$90.00	$378,000.00
17	Gates, Including Anchoring System	6,000	SF	$700.00	$4,200,000.00
18	Gate Hoist and Operating System	5	EA	$215,000.00	$1,075,000.00
19	Stop Gate and Lift Beam	8	EA	$67,000.00	$536,000.00
20	Low-Flow Outlet	1	LS	$3,245,000.00	$3,245,000.00
21	Barrier and Warning System	1	LS	$160,000.00	$160,000.00
22	Embankment Instrumentation	1	LS	$957,000.00	$957,000.00
23	Miscellaneous Internal Drainage	1	LS	$192,000.00	$192,000.00
				EMBANKMENT & SPILLWAY SUBTOTAL	**$116,134,000**
				ENGINEERING SERVICE & CONTIGENCY - 35%	**$40,647,000**
				EMBANKMENT & SPILLWAY TOTAL	**$156,781,000**

Notes:

APPENDIX B
CONFLICTS/RELOCATIONS COST ESTIMATES

4055 International Plaza, Suite 200 • Fort Worth, Texas 76109 • 817-735-7300 • fax 817-735-7491 www.freese.com

TO: Becky Griffith

CC: File

FROM: Patrick Miles, P.E.

SUBJECT: Sulphur Basin Comparative Analysis
Reservoir Conflicts Cost Estimate

DATE: April 30, 2014

PROJECT: UFH12387

Estimates of the conflicts costs for each alternative were developed by MTG Engineers and Surveyors (MTG) from a “desktop review” of aerial imagery and LiDAR topography data, and Texas Railroad Commission (TRC) and Texas Commission on Environmental Quality (TCEQ) databases, in conjunction with updates of previous studies. MTG’s assumptions are documented in the attached memo. (Attachment B-1)

The desktop review was augmented with field surveys to spot check elevations on the Union Pacific railroad, as well as a number of road crossings/bridge elevations, within the Wright Patman Reservoir footprint. Locations of the spot elevations are shown in Figure 3-1, included in the Main Report. Based on the survey data, a number of bridges, originally assumed to require raising in place, were determined to be adequate for different reallocation scenarios without additional modification. This effort allowed a significant refinement to the initial Wright Patman conflicts costs estimates.

LIDAR sources included 2006 imagery collected in 2006 by M7 Visual Intelligence for the U.S. Army Corps of Engineers and Tarrant Regional Water District. Aerial photographs were obtained from 2012 ArcGIS data files. Information relative to oil and gas wells within each alternative footprint, as well as a number of other features, was obtained from Texas Railroad Commission maps of current and historical producing oil and gas wells and other permitted well locations. This data is current through July 2013. Information relative to local water supply systems potentially affected was derived from the TCEQ Groundwater/Purchased Water and/or Surface Water Operating Reports.

Based on the spillway design, it was determined the conflicts assessment should include an additional five feet above the top of the normal conservation pool to address the potential impacts to facilities and infrastructure associated with a larger-than-normal pool after a flood event. Because the reservoirs other than Wright Patman would not have dedicated flood storage, this type of inundation would be occasional and temporary, and an operational plan to reduce the pool to normal elevations as quickly as possible is envisioned. Wright Patman Lake already has a flood easement in place for facilities and structures within the footprint of the contemplated reallocations, so consideration was given only to the conflicts resolution needed to address the permanent inundation of infrastructure and facilities associated with a given reallocation scenario. In consequence, conflict estimates for the Parkhouse reservoirs, Marvin Nichols scenarios and the Talco options are based on 5’ above the normal pool elevation while the conflicts estimates for Patman scenarios are based on the actual normal pool elevation.

Minor adjustments to MTG's initial estimates were made by FNI to improve consistency with the overall cost estimates. These adjustments fall into three categories:

- *Transfer of "structures" costs to the real estate line item*
  MTG's initial estimates included a line item estimate to purchase structures that were identified by aerial photographs to be located within the reservoir footprint. The "structures" value estimated by MTG has been subtracted from the "Conflicts" spreadsheets and added to the "Land" category.

- *Use of Engineering News Record (ENR) cost escalation factors in lieu of the Consumer Price Index*
  MTG escalated costs from several previous studies to 2013 values using the Consumer Price Index. To improve consistency with other dimensions of the cost estimates, these escalations were re-calculated to July 2013 price levels by FNI using the ENR construction cost index

- *Removal or modification of certain proposed bridge improvements where current elevations were determined to be adequate*
  Modifications were made for the Wright Patman conflict cost estimates only. All other estimates were deemed appropriate. Based on the field surveys discussed above, FNI removed costs for raising a number of bridges from the Wright Patman conflicts estimates. Specifically, U.S. Highway 67 and the Union Pacific railroad were removed from all three reallocation alternatives. These bridges were confirmed to be located above the existing Wright Patman flood pool elevation of 259.5 feet-msl. Interstate 30 and U.S. Highway 259 were confirmed to be above the flood pool, but these roads were not considered impacted by the original MTG estimates anyway. Additionally, State Highway 8 was removed from the two lower re-allocation alternatives (232.5 and 242.5).

  While these road and bridge impacts were removed, further evaluation of the Wright Patman conflicts led FNI to modify the normal pool plus 5 feet rule applied to the other alternatives in favor of an additional 10 feet. The additional vertical clearance considers that the reservoir elevations at Wright Patman are expected to have a much greater range of fluctuation because it is a flood control reservoir. The other proposed reservoirs are not designed for flood control and would, therefore, have very little rise in reservoir elevation during a large flood event. For those roadways and bridges that would still be impacted, FNI increased the proposed raised in place elevation to reflect this change in methodology.

  It should also be noted that the elevations assumed for all roadway conflicts, whether normal pool plus 5 feet or 10 feet, represents the embankment elevation specifically. It is understood that the bridge openings may require additional clearance for boat traffic or other considerations. However, such additional clearance is not reflected in the current cost estimates.

These adjustments are reflected in the following tables. Table B-1 reflects a rollup/summary of the adjusted conflicts costs, consistent with the protocol previously described. Tables B-2 through B-11 present the detailed conflicts cost estimate for each alternative.

Table B-1 Reservoir Conflicts Summary

Reservoir Name	Conservation Pool (ft-msl)	Conflict Cost	Engineering & Contingencies (35%)	Total Conflict Cost
Wright Patman	252.5	$114,070,736	$39,924,758	$153,995,494
	242.5	$47,530,714	$16,635,750	$64,166,464
	232.5	$23,256,655	$8,139,829	$31,396,484
Marvin Nichols 1A	328	$105,815,266	$37,035,343	$142,850,609
	313.5	$45,190,393	$15,816,638	$61,007,031
	296.5	$18,171,679	$6,360,088	$24,531,767
Talco Reservoir	370	$185,140,766	$64,799,268	$249,940,034
	350	$68,759,407	$24,065,792	$92,825,199
George Parkhouse I	401	$32,308,969	$11,308,139	$43,617,108
George Parkhouse II	410	$33,273,140	$11,645,599	$44,918,739

Maps of the roadway conflicts for each reservoir alternative, including which roadways are assumed to be raised in place, are provided in Figures B-1 through B-10. For each of these figures, roads highlighted green were included in the cost estimate as being raised in place to the conservation pool plus 5 feet elevation. Roads highlighted orange were not included in the cost estimate and are assumed to be abandoned or are acceptable to sustain brief periods of flooding because of their low service level (i.e. rural county roads or unnamed streets located above the conservation pool but below the additional 5 foot buffer). In Figures B-8 through B-10, there are roadways highlighted yellow, which represent those roads and bridges that have been confirmed to be above the flood pool of Wright Patman Lake by spot elevation field verification. Those spot elevations are presented again in Figure B-11, which is duplicated from Figure 3-1 in the main report.

Table B-2
Reservoir Conflicts Estimate
Wright Patman (Normal Pool 232.5)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	-	LF	-	$ -	
State Highway	-	LF	-	$ -	
Farm-to-Market Road	3,882	LF	$631	$ 2,451,411	FM 991
County Road	-	LF	-	$ -	
Bridges (Raised in Place)					
None	-	SF	-	$ -	
Roads (Abandoned/No Cost)					
County/Local Road	19,862	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	-	EA	-	$ -	There are no Public Water Wells
Public Surface Intake	1	EA	$3,329,531	$ 3,329,531	City of Texarkana
	1	EA	$1,304,022	$ 1,304,022	International Paper Texarkana Mill
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	40,042	LF	$52	$ 2,082,184	
Oil Pipeline					
Size Unknown	-	LF	-	$ -	
Electric Power Lines					
Transmission	23,408	LF	$520	$ 12,172,160	
Cemeteries (per grave site)					
None	-	EA	-	$ -	There are no Cemeteries
Oil & Gas Wells					
Active Wells	6	EA	$71,500	$ 429,000	
Total Wells to Plug	31	EA	$35,800	$ 1,109,800	
Permitted Location	3	EA	$17,400	$ 52,200	
Well Lines (distribution, field)	14,189	LF	$23	$ 326,347	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	-	EA	-	$ -	There are no State Historic Sites
Museums	-	EA	-	$ -	There are no Museums
Reservoir Conflicts Subtotal				**$ 23,256,655**	
Engineering & Contingencies (35%)				**$ 8,139,829**	
Reservoir Conflicts Total				**$ 31,396,484**	

Table B-3
Reservoir Conflicts Estimate
Wright Patman (Normal Pool 242.5)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	-	LF	-	$ -	
State Highway	-	LF	-	$ -	
Farm-to-Market Road	4,789	LF	$970	$ 4,643,410	FM 991
County Road	4,268	LF	$848	$ 3,619,896	CR 4126
County Road	851	LF	$807	$ 686,473	CR 4125
Bridges (Raised in Place)					
Farm-to-Market Road	79,824	SF	$50	$ 3,991,200	FM 991
Roads (Abandoned/No Cost)					
County/Local Road	74,519	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	-	EA	-	$ -	There are no Public Water Wells
Public Surface Intake	1	EA	$4,388,239	$ 4,388,239	City of Texarkana
	1	EA	$1,418,748	$ 1,418,748	International Paper Texarkana Mill
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	56,462	LF	$52	$ 2,936,024	
Oil Pipeline					
Size Unknown	-	LF	-	$ -	
Electric Power Lines					
Transmission	44,315	LF	$520	$ 23,043,800	
Cemeteries (per grave site)					
None	-	EA	-	$ -	There are no Cemeteries
Oil & Gas Wells					
Active Wells	8	EA	$71,500	$ 572,000	
Total Wells to Plug	50	EA	$35,800	$ 1,790,000	
Permitted Location	3	EA	$17,400	$ 52,200	
Well Lines (distribution, field)	16,901	LF	$23	$ 388,723	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	-	EA	-	$ -	There are no State Historic Sites
Museums	-	EA	-	$ -	There are no Museums
Reservoir Conflicts Subtotal				**$ 47,530,714**	
Engineering & Contingencies (35%)				**$ 16,635,750**	
Reservoir Conflicts Total				**$ 64,166,464**	

Table B-4
Reservoir Conflicts Estimate
Wright Patman (Normal Pool 252.5)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	-	LF	-	$ -	
State Highway	15,453	LF	$883	$ 13,637,598	State Hwy 8
Farm-to-Market Road	1,835	LF	$768	$ 1,409,552	FM 1766
Farm-to-Market Road	5,210	LF	$1,044	$ 5,437,696	FM 991
Farm-to-Market Road	1,687	LF	$789	$ 1,331,480	FM 2149
County Road	5,180	LF	$1,221	$ 6,327,274	CR 4126
County Road	1,650	LF	$1,044	$ 1,722,111	CR 4125
County Road	2,463	LF	848	$ 2,088,989	CR 1113
Bridges (Raised in Place)					
State Highway	131,920	SF	$50	$ 6,596,000	HWY 8
Farm-to-Market Road	132,000	SF	$50	$ 6,600,000	FM 991
Roads (Abandoned/No Cost)					
County/Local Road	135,116	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	1	EA	$128,864	$ 128,864	Big Creek Landing
	1	EA	$130,266	$ 130,266	Kelly Creek Landing
	1	EA	$162,530	$ 162,530	Kelly Creek Landing
Public Surface Intake	1	EA	$5,761,324	$ 5,761,324	City of Texarkana
	1	EA	$1,533,473	$ 1,533,473	International Paper Texarkana Mill
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	86,031	LF	$52	$ 4,473,612	
Oil Pipeline					
Size Unknown	232	LF	$52	$ 12,064	
Electric Power Lines					
Transmission	100,559	LF	$520	$ 52,290,680	
Cemeteries (per grave site)					
Unknown Cemetery	10	EA	6,900	$ 69,000	There are no Cemeteries
Oil & Gas Wells					
Active Wells	13	EA	$71,500	$ 929,500	
Total Wells to Plug	82	EA	$35,800	$ 2,935,600	
Permitted Location	6	EA	$17,400	$ 104,400	
Well Lines (distribution, field)	16,901	LF	$23	$ 388,723	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	-	EA	-	$ -	There are no State Historic Sites
Museums	-	EA	-	$ -	There are no Museums
Reservoir Conflicts Subtotal				**$ 114,070,736**	
Engineering & Contingencies (35%)				**$ 39,924,758**	
Reservoir Conflicts Total				**$ 153,995,494**	

Table B-5
Reservoir Conflicts Estimate
Marvin Nichols 1A (Normal Pool 296.5)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	-	LF	-	$ -	
State Highway	-	LF	-	$ -	
Farm-to-Market Road	2,197	LF	$630	$ 1,384,110	FM 1487
Farm-to-Market Road	8,229	LF	$670	$ 5,513,430	FM 412
County Road	-	LF	-	$ -	
Bridges (Raised in Place)					
Farm-to-Market Road	4,896	SF	$50	$ 244,800	FM 1487
Farm-to-Market Road	15,330	SF	$50	$ 766,500	FM 412
Roads (Abandoned/No Cost)					
County/Local Road	19,268	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	-	EA	-	$ -	There are no Public Water Wells
Public Surface Intake	-	EA	-	$ -	There are no Public Surface Intakes
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	6,324	LF	$52	$ 328,848	
Oil Pipeline					
Size Unknown	4,730	LF	$52	$ 245,960	
Electric Power Lines					
Transmission	-	LF	-	$ -	There are no Transmission Lines
Cemeteries (per grave site)					
Unknown Cemetery	10	EA	$6,900	$ 69,000	
Oil & Gas Wells					
Active Wells	74	EA	$71,500	$ 5,291,000	
Total Wells to Plug	115	EA	$35,800	$ 4,117,000	
Permitted Location	12	EA	$17,400	$ 208,800	
Well Lines (distribution, field)	97	LF	$23	$ 2,231	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	-	EA	-	$ -	There are no State Historic Sites
Museums	-	EA	-	$ -	There are no Museums
Reservoir Conflicts Subtotal				**$ 18,171,679**	
Engineering & Contingencies (35%)				**$ 6,360,088**	
Reservoir Conflicts Total				**$ 24,531,767**	

Table B-6
Reservoir Conflicts Estimate
Marvin Nichols 1A (Normal Pool 313.5)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	5,048	LF	1,193	$ 6,022,264	US HWY 271
State Highway	-	LF	-	$ -	
Farm-to-Market Road	572	LF	$599	$ 342,628	FM 1487
Farm-to-Market Road	4,974	LF	$669	$ 3,327,606	FM 412
County Road	-	LF	-	$ -	
Bridges (Raised in Place)					
US Highway	75,735	SF	$50	$ 3,786,750	US HWY 271
Farm-to-Market Road	222,288	SF	$50	$ 11,114,400	FM 1487
Farm-to-Market Road	129,540	SF	$50	$ 6,477,000	FM 412
Roads (Abandoned/No Cost)					
County/Local Road	81,178	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	-	EA	-	$ -	There are no Public Water Wells
Public Surface Intake	-	EA	-	$ -	There are no Public Surface Intakes
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	20,074	LF	$52	$ 1,043,848	
Oil Pipeline					
Size Unknown	10,851	LF	$52	$ 564,252	
Electric Power Lines					
Transmission	-	LF	-	$ -	There are no Transmission Lines
Cemeteries (per grave site)					
Unknown Cemetery	10	EA	$6,900	$ 69,000	
Evergreen	57	EA	$6,900	$ 393,300	
Oil & Gas Wells					
Active Wells	86	EA	$71,500	$ 6,149,000	
Total Wells to Plug	155	EA	$35,800	$ 5,549,000	
Permitted Location	17	EA	$17,400	$ 295,800	
Well Lines (distribution, field)	2,415	LF	$23	$ 55,545	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	-	EA	-	$ -	There are no State Historic Sites
Museums	-	EA	-	$ -	There are no Museums
Reservoir Conflicts Subtotal				**$ 45,190,393**	
Engineering & Contingencies (35%)				**$ 15,816,638**	
Reservoir Conflicts Total				**$ 61,007,031**	

Table B-7
Reservoir Conflicts Estimate
Marvin Nichols 1A (Normal Pool 328)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	11,528	LF	1,521	$ 17,534,088	US Hwy 271
State Highway	-	LF	-	$ -	
Farm-to-Market Road	1,939	LF	$609	$ 1,180,851	FM 44
Farm-to-Market Road	22,479	LF	$780	$ 17,533,620	FM 412
Farm-to-Market Road	323	LF	$787	$ 254,201	FM 909
Farm-to-Market Road	6,609	LF	$793	$ 5,240,937	FM 910
County Road	-	LF	-	$ -	
Bridges (Raised in Place)					
US Highway	440,045	SF	$50	$ 22,002,250	US Hwy 271
Farm-to-Market Road	3,960	SF	$50	$ 198,000	FM 910
Farm-to-Market Road	231,696	SF	$50	$ 11,584,800	FM 1487
Farm-to-Market Road	205,800	SF	$50	$ 10,290,000	FM 412
Roads (Abandoned/No Cost)					
County/Local Road	167,090	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	1	EA	$367,518	$ 367,518	City of Talco
	1	EA	$413,292	$ 413,292	City of Talco
	1	EA	$404,236	$ 404,236	City of Talco
Public Surface Intake	-	EA	-	$ -	There are no Public Surface Intakes
Municipal Wastewater Systems					
WWTPs	1	EA	$22,000	$ 22,000	City of Talco
Gas Pipeline					
Size Unknown	66,116	LF	$52	$ 3,438,032	
Oil Pipeline					
Size Unknown	13,323	LF	$52	$ 692,796	
Electric Power Lines					
Transmission	-	LF	-	$ -	There are no Transmission Lines
Cemeteries (per grave site)					
Unknown Cemetery	10	EA	$6,900	$ 69,000	
Evergreen	57	EA	$6,900	$ 393,300	
Oil & Gas Wells					
Active Wells	99	EA	$71,500	$ 7,078,500	
Total Wells to Plug	186	EA	$35,800	$ 6,658,800	
Permitted Location	22	EA	$17,400	$ 382,800	
Well Lines (distribution, field)	3,315	LF	$23	$ 76,245	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	-	EA	-	$ -	There are no State Historic Sites
Museums	-	EA	-	$ -	There are no Museums
Reservoir Conflicts Subtotal				**$ 105,815,266**	
Engineering & Contingencies (35%)				**$ 37,035,343**	
Reservoir Conflicts Total				**$ 142,850,609**	

Table B-8
Reservoir Conflicts Estimate
Talco Reservoir (Normal Pool 350)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	-	LF	-	$ -	
State Highway	-	LF	-	$ -	
Farm-to-Market Road	10,355	LF	$550	$ 5,695,250	FM 1896
County Road	-	LF	-	$ -	
Bridges (Raised in Place)					
State Highway	506,528	SF	50	$ 25,326,400	State Hwy 37
Roads (Abandoned/No Cost)					
County/Local Road	84,649	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	-	EA	-	$ -	There are no Public Water Wells
Public Surface Intake	-	EA	-	$ -	There are no Public Surface Intakes
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	101,078	LF	$52	$ 5,256,056	
Oil Pipeline					
Size Unknown	41,742	LF	$52	$ 2,170,584	
Electric Power Lines					
Transmission	35,537	LF	$520	$ 18,479,240	
Cemeteries (per grave site)					
Murphy, Murphree	25	EA	$6,900	$ 172,500	
Smith	3	EA	$6,900	$ 20,700	
Midway	296	EA	$6,900	$ 2,042,400	
Prairie Academy	50	EA	$6,900	$ 345,000	
Oil & Gas Wells					
Active Wells	66	EA	$71,500	$ 4,719,000	
Total Wells to Plug	92	EA	$35,800	$ 3,293,600	
Permitted Location	47	EA	$17,400	$ 817,800	
Well Lines (distribution, field)	18,299	LF	$23	$ 420,877	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	-	EA	-	$ -	There are no State Historic Sites
Museums	-	EA	-	$ -	There are no Museums
			Reservoir Conflicts Subtotal	**$ 68,759,407**	
			Engineering & Contingencies (35%)	**$ 24,065,792**	
			Reservoir Conflicts Total	**$ 92,825,199**	

Table B-9
Reservoir Conflicts Estimate
Talco Reservoir (Normal Pool 370)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	-	LF	-	$ -	
State Highway	14,759	LF	$758	$ 11,187,322	State Hwy 37
Farm-to-Market Road	10,355	LF	$550	$ 5,695,250	FM 1896
Farm-to-Market Road	13,636	LF	$945	$ 12,886,020	FM 900
County Road	-	LF	-	$ -	
Bridges (Raised in Place)					
State Highway	506,528	SF	$50	$ 25,326,400	State Hwy 37
Roads (Abandoned/No Cost)					
County/Local Road	263,532	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	-	EA	-	$ -	There are no Public Water Wells
Public Surface Intake	-	EA	-	$ -	There are no Public Surface Intakes
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	253,339	LF	$52	$ 13,173,628	
Oil Pipeline					
Size Unknown	113,483	LF	$52	$ 5,901,116	
Electric Power Lines					
Transmission	133,576	LF	$520	$ 69,459,520	
Cemeteries (per grave site)					
Murphy, Murphree	25	EA	$6,900	$ 172,500	
Smith	3	EA	$6,900	$ 20,700	
Midway	296	EA	$6,900	$ 2,042,400	
Prairie Academy	50	EA	$6,900	$ 345,000	
Colliers Chapel	203	EA	$6,900	$ 1,400,700	
Oil & Gas Wells					
Active Wells	283	EA	$71,500	$ 20,234,500	
Total Wells to Plug	378	EA	$35,800	$ 13,532,400	
Permitted Location	77	EA	$17,400	$ 1,339,800	
Well Lines (distribution, field)	105,370	LF	$23	$ 2,423,510	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	-	EA	-	$ -	There are no State Historic Sites
Museums	-	EA	-	$ -	There are no Museums
Reservoir Conflicts Subtotal				**$ 185,140,766**	
Engineering & Contingencies (35%)				**$ 64,799,268**	
Reservoir Conflicts Total				**$ 249,940,034**	

Table B-10
Reservoir Conflicts Estimate
George Parkhouse I (Normal Pool 401)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	-	LF	-	$ -	
State Highway	1,445	LF	$603	$ 871,335	State Hwy 154
State Highway	16,112	LF	$742	$ 11,955,104	State Hwy 19
Farm-to-Market Road	5,752	LF	$900	$ 5,176,800	FM 1536
Farm-to-Market Road	9,135	LF	$787	$ 7,189,245	FM 895
County Road	-	LF	-	$ -	
Bridges (Raised in Place)					
State Highway	72,920	SF	$50	$ 3,646,000	State HWY 19
Roads (Abandoned/No Cost)					
County/Local Road	92,254	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	-	EA	-	$ -	There are no Public Water Wells
Public Surface Intake	-	EA	-	$ -	There are no Public Surface Intakes
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	34,713	LF	$52	$ 1,805,076	
Oil Pipeline					
Size Unknown	22,352	LF	$52	$ 1,162,304	
Electric Power Lines					
Transmission	-	LF	-	$ -	There are no Transmission Lines
Cemeteries (per grave site)					
Unknown Cemetery	10	EA	$6,900	$ 69,000	
Kensing	26	EA	$6,900	$ 179,400	
Oil & Gas Wells					
Active Wells	-	EA	-	$ -	
Total Wells to Plug	5	EA	$35,800	$ 179,000	
Permitted Location	1	EA	$17,400	$ 17,400	
Well Lines (distribution, field)	2,535	LF	$23	$ 58,305	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	1	EA	$0	$ -	Despain Bridge (marker only)
Museums	-	EA	-	$ -	There are no Museums
			Reservoir Conflicts Subtotal	**$ 32,308,969**	
			Engineering & Contingencies (35%)	**$ 11,308,139**	
			Reservoir Conflicts Total	**$ 43,617,108**	

Table B-11
Reservoir Conflicts Estimate
George Parkhouse II (Normal Pool 410)

Conflict Description	Quantity	Units	Unit Cost	Conflict Cost	Notes
Roads (Raised in Place)					
Federal Highway	-	LF	-	$ -	
US Highway	-	LF	-	$ -	
State Highway	4,876	LF	$763	$ 3,720,388	State Hwy 19
Farm-to-Market Road	7,934	LF	$688	$ 5,458,592	FM 1498
County Road	-	LF	-	$ -	
Bridges (Raised in Place)					
State Highway	42,480	SF	$50	$ 2,124,000	State Hwy 19
Farm-to-Market Road	105,360	SF	$50	$ 5,268,000	FM 1498
Roads (Abandoned/No Cost)					
County/Local Road	263,532	LF	$0	$ -	
Railroads					
None	-	EA	-	$ -	There are no Railroads
Airports					
None	-	EA	-	$ -	There are no Airports
Municipal Water Systems					
Public Water Wells	-	EA	-	$ -	There are no Public Water Wells
Public Surface Intake	-	EA	-	$ -	There are no Public Surface Intakes
Municipal Wastewater Systems					
WWTPs	-	EA	-	$ -	There are no WWTP Systems
Gas Pipeline					
Size Unknown	69,150	LF	$52	$ 3,595,800	
Oil Pipeline					
Size Unknown	13,700	LF	$52	$ 712,400	
Electric Power Lines					
Transmission	23,633	LF	$520	$ 12,289,160	
Cemeteries (per grave site)					
Unknown/Union Church	10	EA	$6,900	$ 69,000	
Oil & Gas Wells					
Active Wells	-	EA	-	$ -	
Total Wells to Plug	1	EA	$35,800	$ 35,800	
Permitted Location	-	EA	-	$ -	
Well Lines (distribution, field)	-	LF	-	$ -	
National Registered Properties					
Historic Landmarks	-	EA	-	$ -	There are no Historic Landmarks
State Historic Sites	1	EA	$0	$ -	Leroy Nelson DeWitt (marker only)
Museums	-	EA	-	$ -	There are no Museums
			Reservoir Conflicts Subtotal	**$ 33,273,140**	
			Engineering & Contingencies (35%)	**$ 11,645,599**	
			Reservoir Conflicts Total	**$ 44,918,739**	

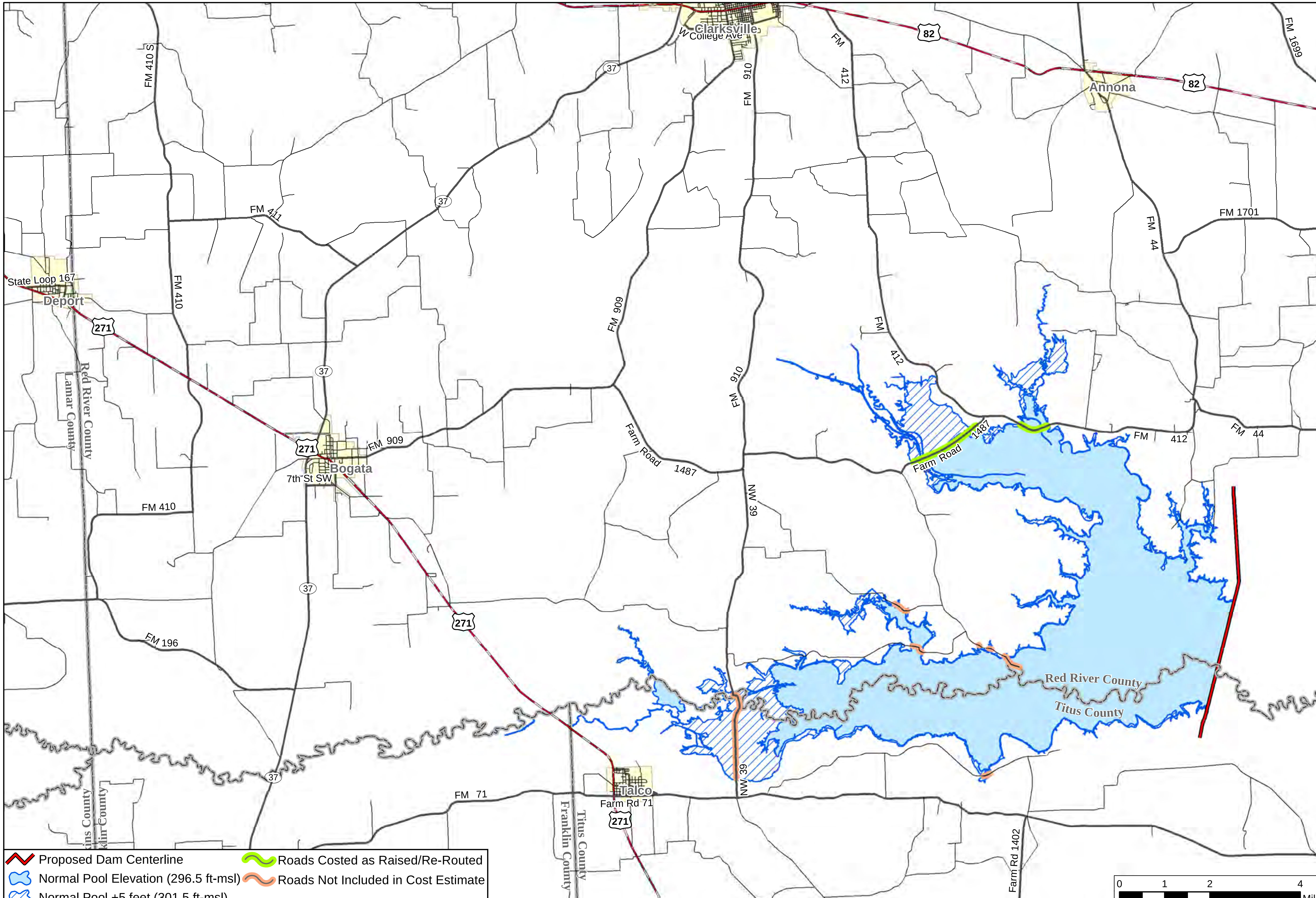


FIGURE B-1

N
W E
S

MARVIN NICHOLS 1A (NORMAL POOL 296.5)

ROADWAY CONFLICTS

FREESE AND NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE ReservoirConflicts_MN1A-296_5
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY JPM

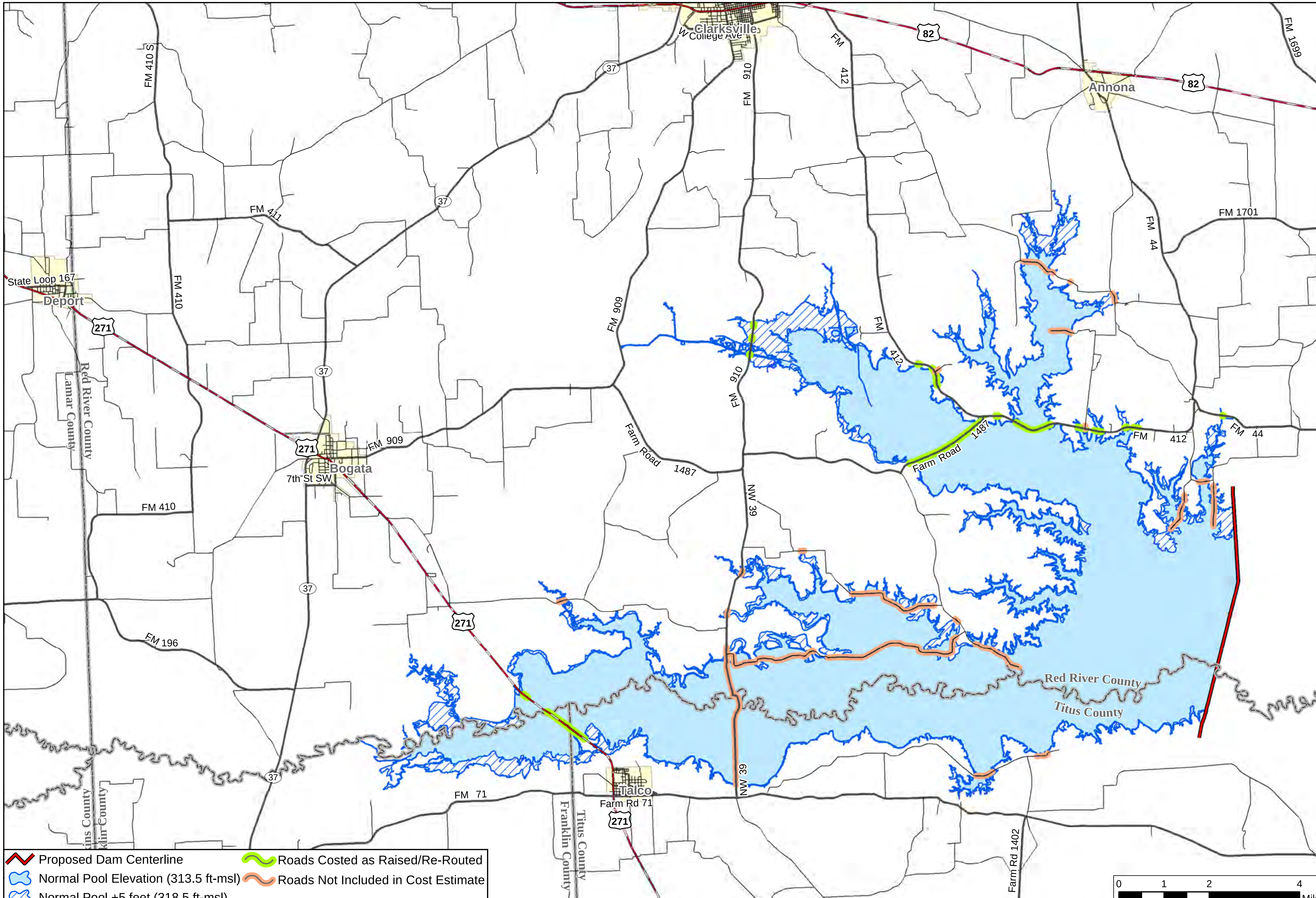


FIGURE B-2

N S E W

MARVIN NICHOLS 1A (NORMAL POOL 313.5)

ROADWAY CONFLICTS

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE ReservoirConflicts_MN1A-313_5
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY JPM

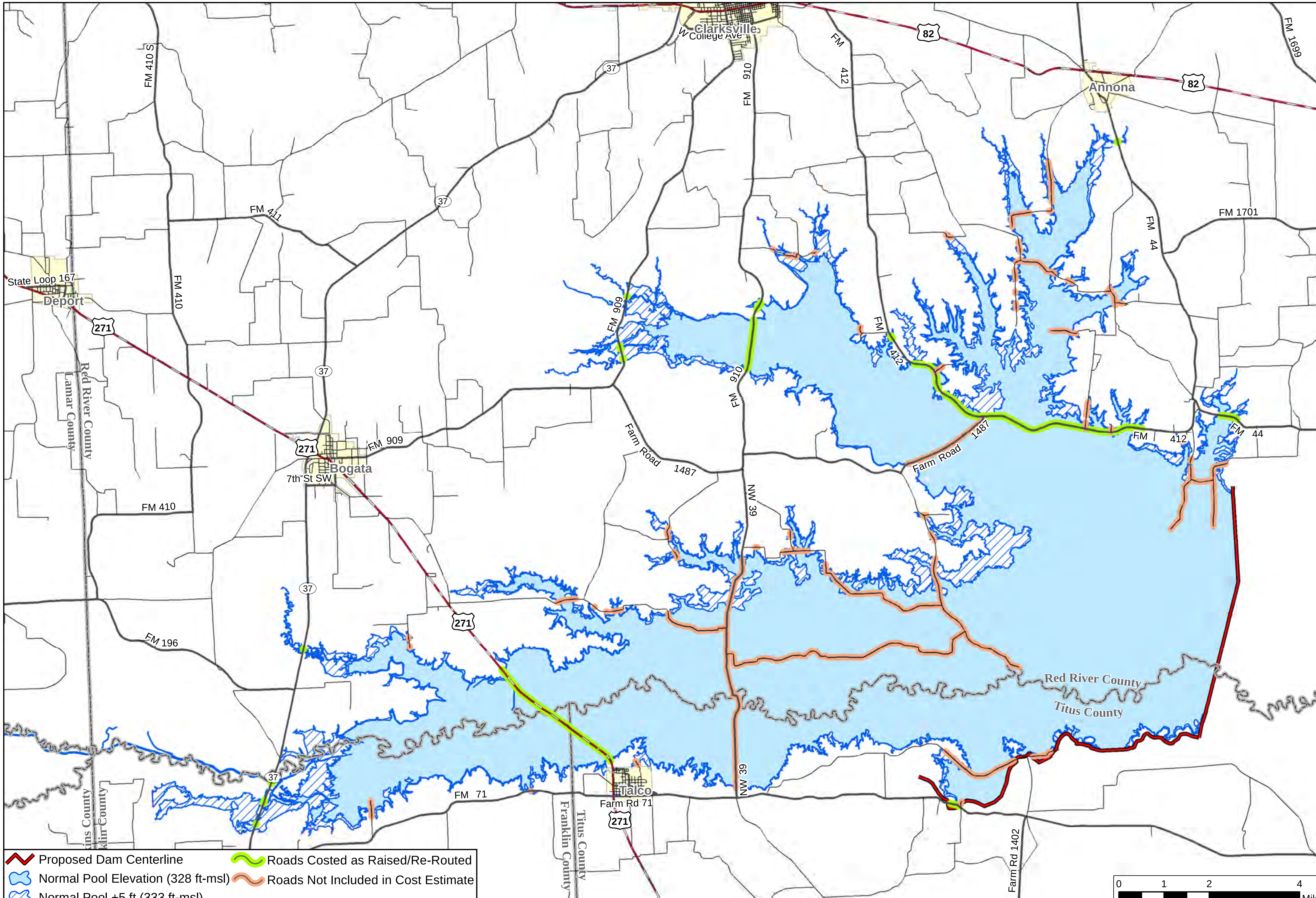


FIGURE B-3

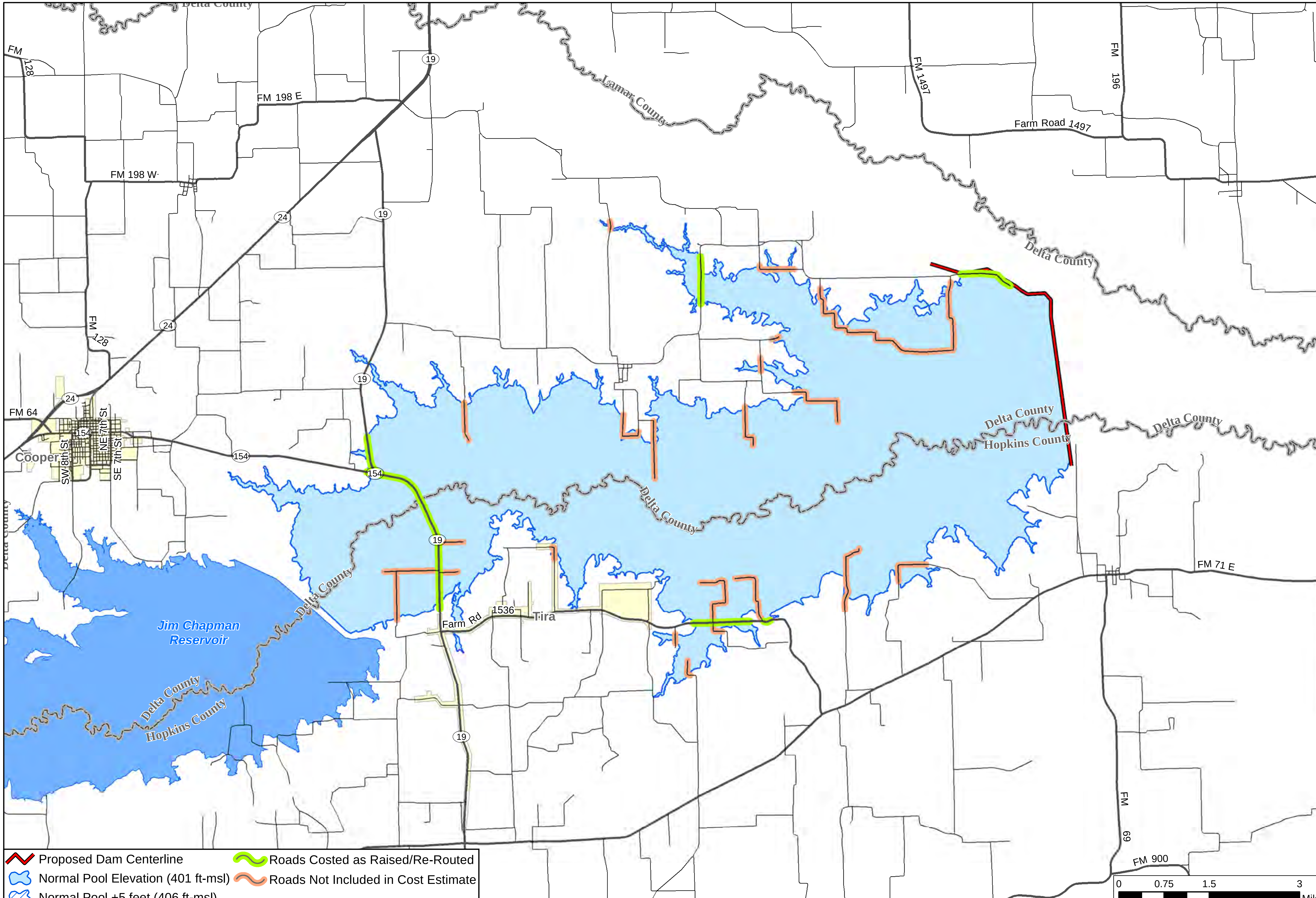
N W E S

MARVIN NICHOLS 1A (NORMAL POOL 328)

ROADWAY CONFLICTS

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT: UFH12387
FILE: ReservoirConflicts_MN1A-328
DATUM & COORDINATE SYSTEM: NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE: April, 2014
PREPARED BY: JPM



GEORGE PARKHOUSE I (NORMAL POOL 401)

ROADWAY CONFLICTS

FIGURE B-4

N E S W

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT: UFH12387
FILE: ReservoirConflicts_PH1-401
DATUM & COORDINATE SYSTEM: NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE: April, 2014
PREPARED BY: JPM

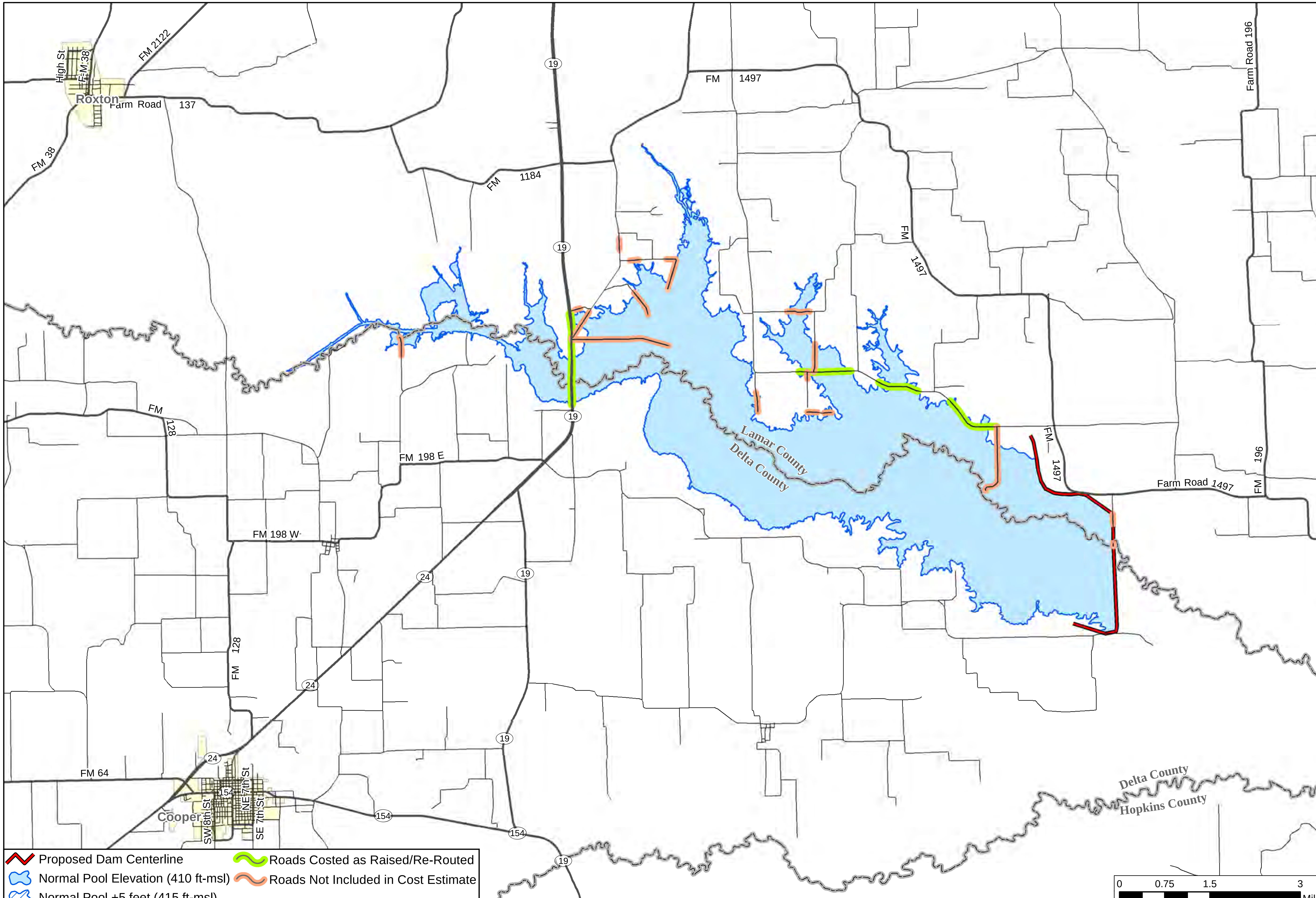


FIGURE B-5

N W E S

GEORGE PARKHOUSE II (NORMAL POOL 410)

ROADWAY CONFLICTS

FREESE NICHOLS

4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE ReservoirConflicts_PH2-410
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY JPM

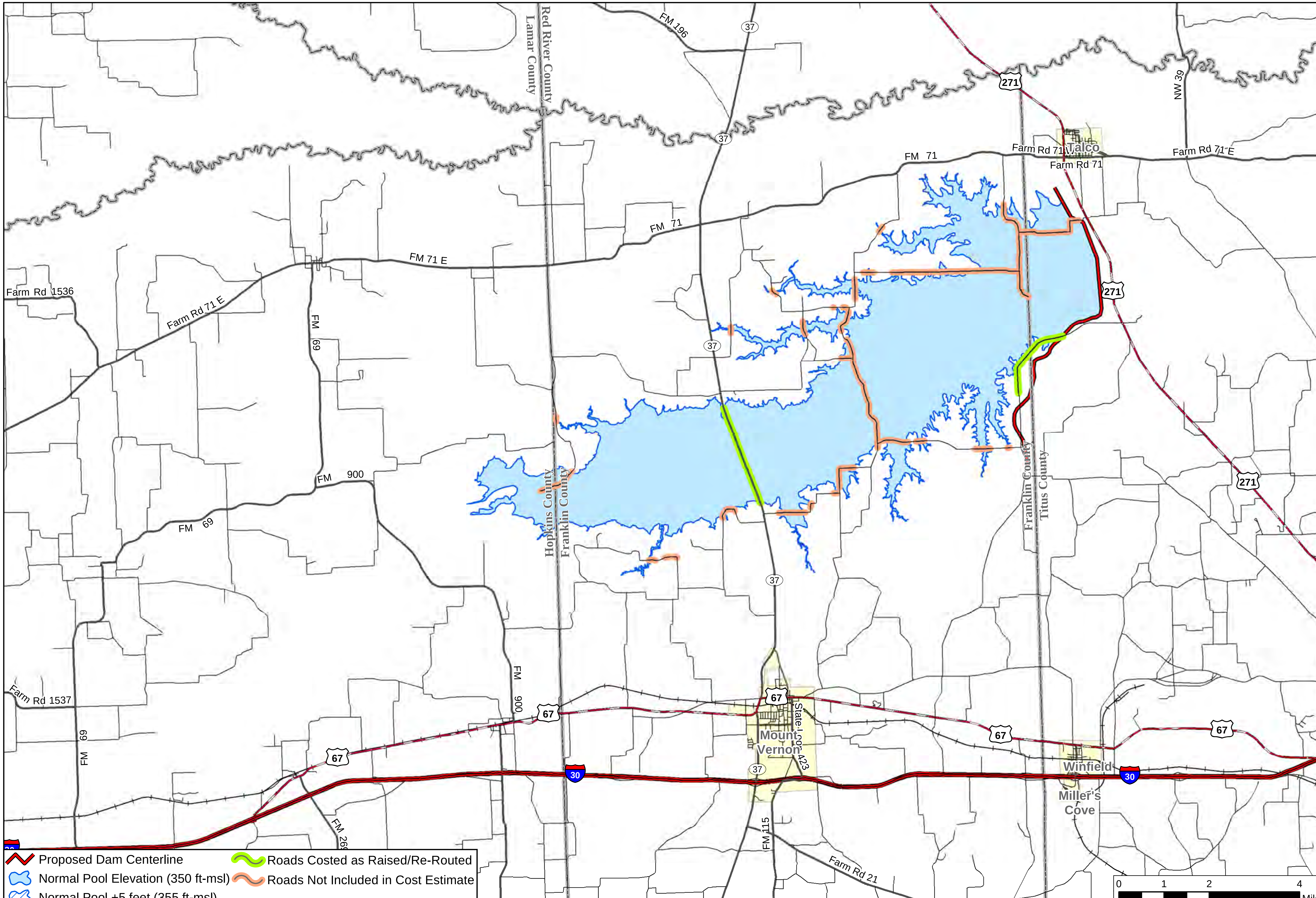


FIGURE B-6

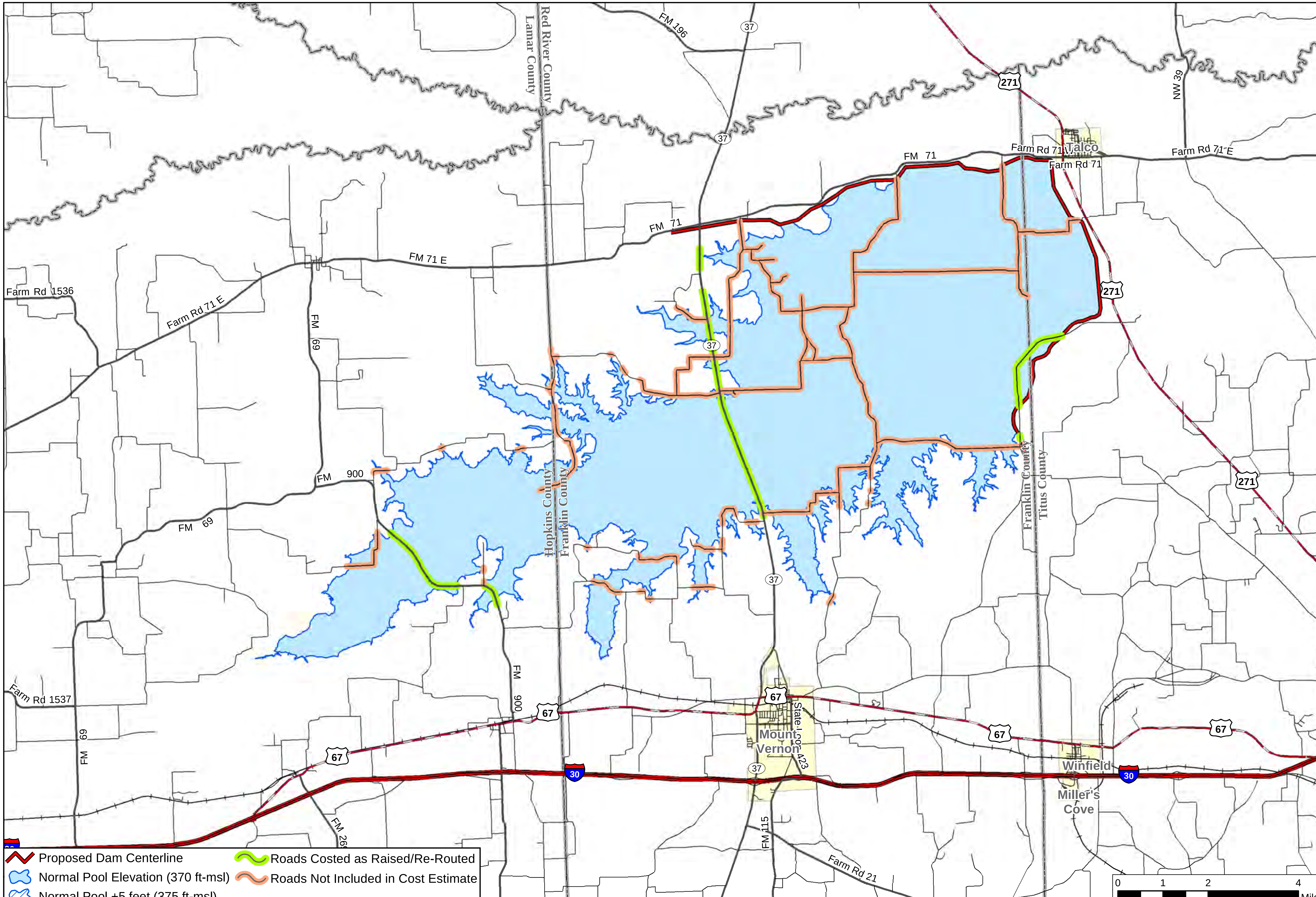
N W E S

TALCO RESERVOIR (NORMAL POOL 350)

ROADWAY CONFLICTS

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE ReservoirConflicts_Talco-350
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY JPM



TALCO RESERVOIR (NORMAL POOL 370)

ROADWAY CONFLICTS

FIGURE B-7

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT	UFH12387
FILE	ReservoirConflicts_Talco-370
DATUM & COORDINATE SYSTEM	NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE	April, 2014
PREPARED BY	JPM

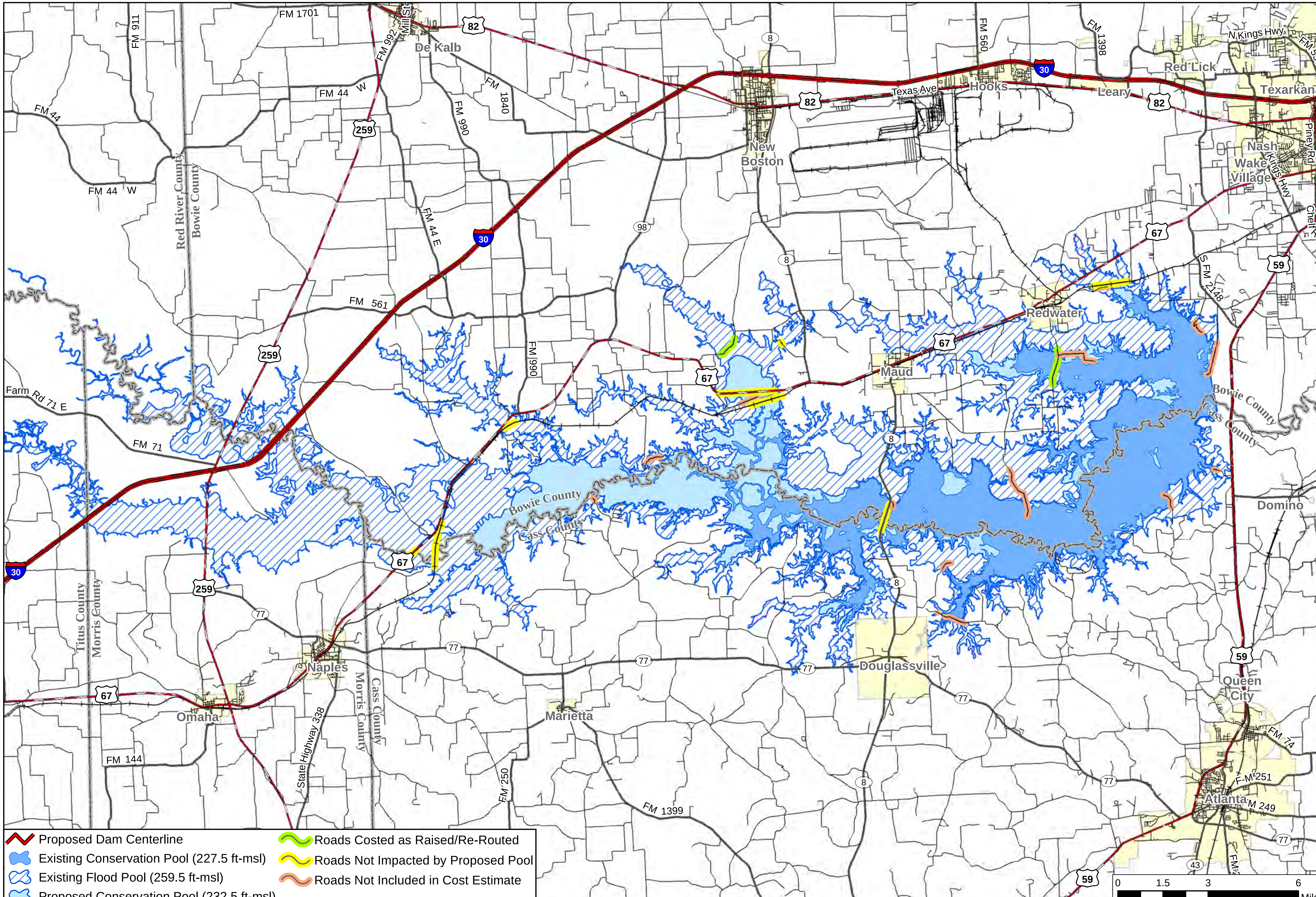


FIGURE
B-8

WRIGHT PATMAN RE-ALLOCATION (NP 232.5)

ROADWAY CONFLICTS

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT	UFH12387
FILE	ReservoirConflicts_WP-232_5
DATUM & COORDINATE SYSTEM	NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE	April, 2014
PREPARED BY	JPM

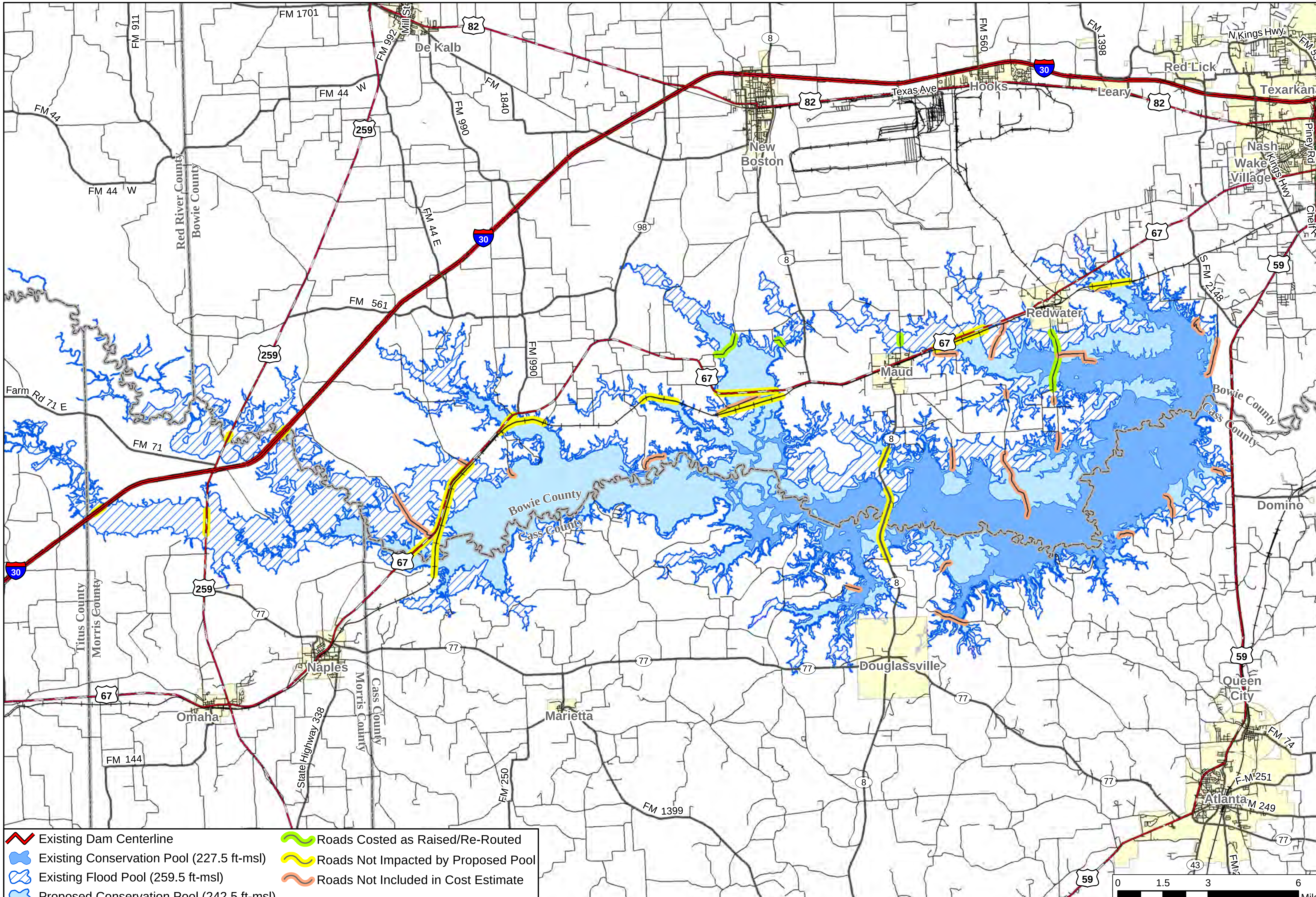


FIGURE B-9

WRIGHT PATMAN RE-ALLOCATION (NP 242.5)

ROADWAY CONFLICTS

FREESE NICHOLS

4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT	UFH12387
FILE	ReservoirConflicts_WP-242_5
DATUM & COORDINATE SYSTEM	NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE	April, 2014
PREPARED BY	JPM

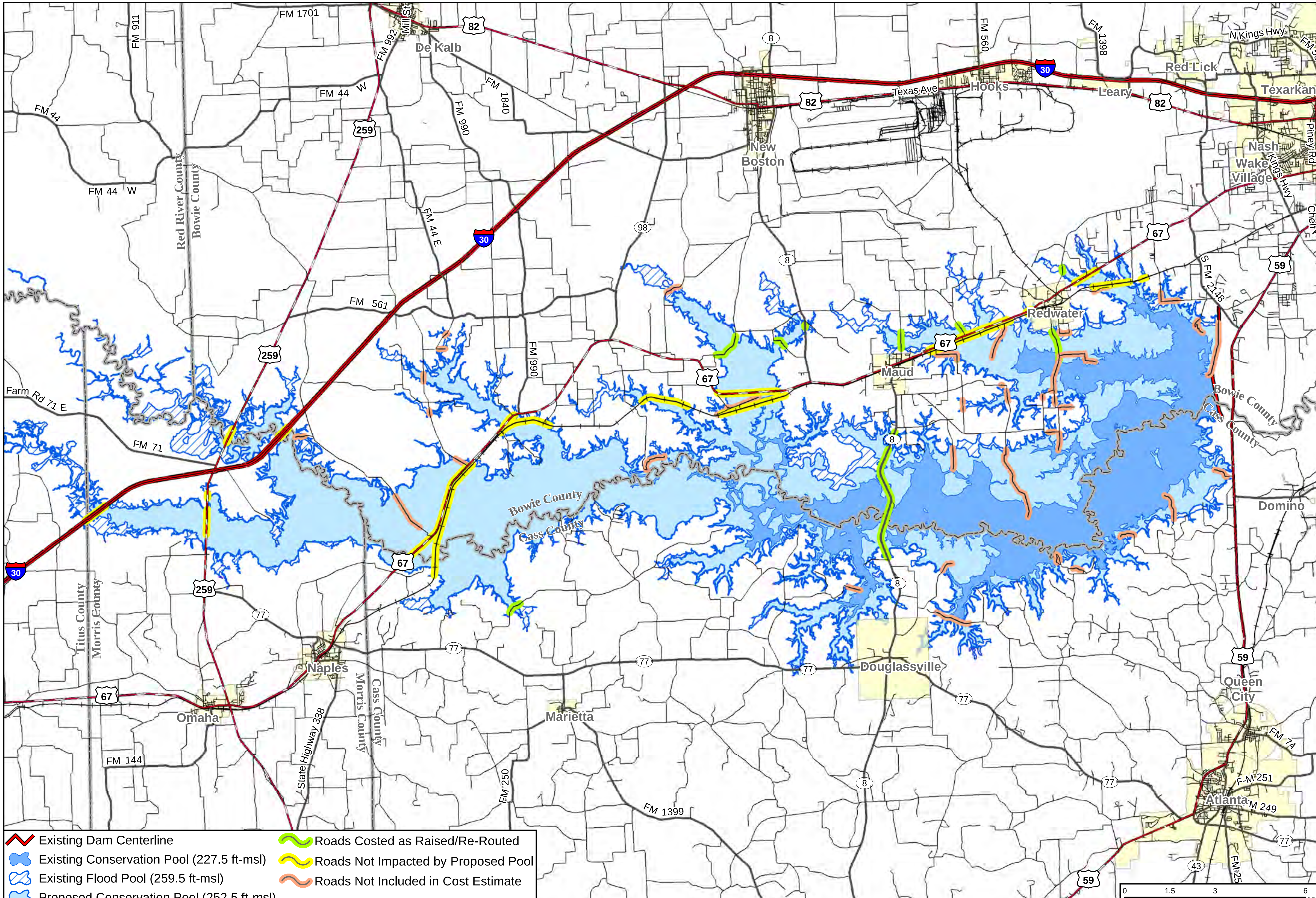


FIGURE B-10

WRIGHT PATMAN RE-ALLOCATION (NP 252.5)

ROADWAY CONFLICTS

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT: UFH12387
FILE: ReservoirConflicts_WP-252_5
DATUM & COORDINATE SYSTEM: NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE: April, 2014
PREPARED BY: JPM

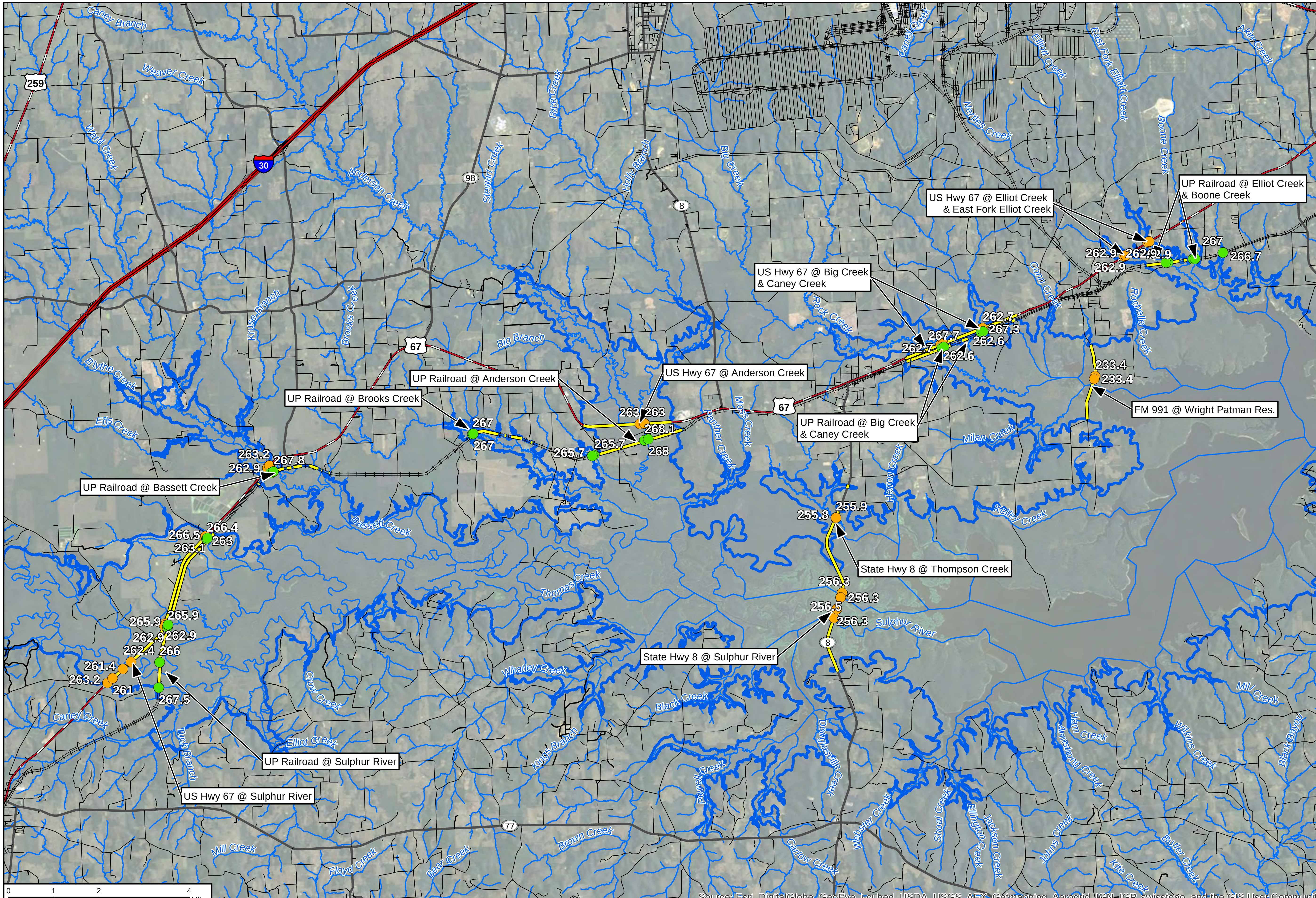


FIGURE B-11

N W E S

SULPHUR BASIN COMPARITIVE ANALYSIS

BRIDGE SPOT ELEVATIONS

FREESE NICHOLS

4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT	XXX11111
FILE	BridgeSpotElevations_WP
DATUM & COORDINATE SYSTEM	NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE	April, 2014
PREPARED BY	JPM

TECHNICAL REPORT

DATE: February 24, 2014

SUBJECT: SRBA/SBG - Contract 4
Conflict Cost

BY: Robert H. Murray, P.E. and Christina N. Trowler, P.E.

---

1. Overall Assumptions
    a. When the "2008 Texas Water Development Board Report" is referred to it is the following report:
        i. HDR Engineering, Inc., R.J. Brandes Company, Freese and Nichols, Inc., Texas Water Development Board, July 2008, Reservoir Site Protection Study: Texas Water Development Board, Report 370.
    b. When the "2003 Study for the Sulphur Basin Group" is referred to it is the following report:
        i. Freese and Nichols, Inc., January 2003, Marvin C. Nichols Reservoir Site Selection Study: Sulphur Basin Group, SBG01397.
    c. In our estimate, when the term "inflated cost from 2003 Study for the Sulphur Basin Group" was used, a 23.4% inflation was applied. The United States Department of Labor Consumer Price Index (CPI) inflation calculator was used to determine the inflation rate. The CPI calculator uses the average Consumer Price Index for a given calendar year. This data represents changes in prices of all goods and services purchased for consumption by urban households. This index value has been calculated every year since 1913.
    d. In our estimate, when the term "inflated cost from 2008 Texas Water Development Board Report" was used, a 8.5% inflation was applied. The United States Department of Labor Consumer Price Index (CPI) inflation calculator was used to determine the inflation rate.
    e. When elevations are referenced, available LiDAR or DEM files that have been provided to FN were used.
    f. Engineering and Contingencies of 35% were included in the cost of each reservoir similar to what was assumed in the 2008 Texas Water Development Board Report.

2. Roads Assumptions
    a. Federal Highway, US Highways, and State Highways are assumed:
        i. To be raised 5' above Normal Pool for the entire length of roadway impacted.
        ii. To determine embankment cost, a profile of each roadway was cut to determine the length of roadway below NP +5' elevation. At each location the roadway profile was below NP+5', an average height of roadway was determined and the difference between the average height and NP+5' elevation along with 4:1 side slopes was used to determine the amount of embankment needed to raise the roadway. Embankment pricing and cost of similar pavement sections from TxDOT and FHWA were used and figured on a $/LF basis for each reservoir depending on the height of embankment needed with 4:1 side slopes and can be found in the attached cost spreadsheet for each reservoir alternative.
            1. Embankment cost $10/CY
            2. 4 Lane Rural Cost - $975/LF
            3. 2 Lane Rural Cost - $550/LF
        iii. After cutting existing roadway profiles, the NP+5' elevation was lowered 20' and anything below this elevation was considered to be a bridge.
        iv. Bridge construction cost used from TxDOT.
            1. Bridge Cost - $50/SF
        v. The cost and conflict length for Federal Highway, US Highways, and State Highways were kept the same for the NP and NP+5'.
    b. Farm-to-Market (FM) roads are being looked at on an individual basis, but generally:

i. The roads analyzed appear to be the only arteries connecting one side of the reservoir to the other without extensive drives.

ii. Extraordinary Instances include:

1. Talco (350, 355, 370 & 375) – FM 1896 was assumed to be re-routed on top of the dam due to the close proximity. An approximate re-routed length was used for pavement cost only. It was assumed the embankment cost will be included in the dam cost.

iii. The FM roads not listed above, but have a cost associated with them were analyzed on the same assumptions for bridges, embankment, and roads cost as outlined above for the Federal Highway, US Highways, and State Highways.

iv. The cost and conflict length for FM roads were kept the same for the NP and NP+5'.

c. County Roads, Driveways, and Unnamed Streets have no cost associated with flooding.

i. Wright Patman was the only exception to this as there were several main County Roads that were analyzed and cost applied.

3. Railroad Assumption
   a. Railroads are assumed to be raised 5' above Normal Pool for the entire length of railroad impacted.
   b. Embankment pricing and cost of similar railroad sections at $1 Million/mile or $190/LF per Union Pacific Railroad.

4. Public Water Systems
   a. Public Water Wells
      i. These costs were performed by FN using the well depth and well capacity from TCEQ and a cost table from the Region C Water Planning cost assumptions. This information is included in each of the reservoir elevation spreadsheets that contain public water wells.
      ii. Wright Patman (257.5, 252.5, & 247.5) – 1 at Big Creek Landing and 2 at Kelly Creek Landing
      iii. Marvin Nichols (328 & 333) – 3 for the City of Talco
   b. Public Surface Intake
      i. These costs were performed by FN using pump capacity from TCEQ and intake depth from Wright Patman bathymetric survey. The head and pump power were calculated and the pump efficiency was assumed. This information is included in each of the reservoir elevation spreadsheets that contain public surface intakes.
      ii. Wright Patman (All)– 1 for the City of Texarkana and 1 for International Paper Texarkana Mill

5. Public Wastewater Treatment Plants
   a. Marvin Nichols (328 & 333) – 1 for the City of Talco @ Elevation 324.82', berm at ~330'. It appears that there is a berm around the site at an approximate elevation of 330, but it is hard to confirm. It was assumed that the berm would need to be raised approximately 5' around the perimeter of the site. Embankment costs of $10/CY were used.

6. Pipelines
   a. Gas
      i. These values are linear feet values of gas lines taken from the Railroad Commission; however, they do not have a break down on the size of line. They classify by type and company.
      ii. The average inflated cost from 2008 TWDB of $105 cost/30", $45 cost/16", $25 cost/8" with the $22 cost/6" gets an average cost of $49/LF.
   b. Oil
      i. These values are linear feet values of oil lines taken from the Railroad Commission; however, they do not have a break down on the size of line. They classify by type and company.
      ii. Otherwise it is suggested to take the inflated cost from 2008 TWDB of $49/LF as stated above for gas.

7. Power Lines

a. Transmission Lines
    i. The transmission lines locations were performed from 2013 aerials, no other data was available. The cost was inflated from the 2008 TWDB Report cost to $488/LF.

8. Cemeteries
    a. This data was provided by the Texas Historic Commission (THC).
    b. From the THC data the name of the cemetery was researched to determine the number of graves, the sources of the grave count can be found in the attached cost spreadsheets.
    c. If the cemetery name was unknown in the database it was assumed that this was a family cemetery and an assumption of 10 graves was used to be conservative.
    d. An inflated cost from 2008 of $6,495/grave was used with the assumption that the graves would need to be relocated. However, land cost was not included.

9. Oil & Gas Wells
    a. This data was provided by the Railroad Commission.
    b. The cost for active wells and wells needing to be plugged are inflated cost from 2003.
        i. Active - $61,800 Each
        ii. Wells to Plug - $30,900 Each
        iii. Permitted Locations - $15,000 Each
    c. The oil field lines are assumed to be 6" or smaller and the cost of $22 cost/LF was used from the 6" oil and gas lines.

10. Structures
    a. The structure count was performed from 2013 aerials.
    b. The cost was performed from the 2012 improvement value listed on the parcels inside the NP+5 reservoir shape for each reservoirs alternative.
    c. This value was then divided by the number of structures to get a $/Structure for each reservoir. We did not have digital parcel information for Cass, Morris, or Hopkins Counties. In these counties, I obtained the average $/Structure from the other counties in the reservoirs and applied the $/Structure to the amount of structures in Cass/Hopkins counties. These costs do not account for demolition and removal of the houses. Therefore, a 1.5 multiplier was used to account for demolition (plugging septic and water wells), removal, relocation, and/or prime real estate rates.

11. State Historic Sites
    a. Costs associated with these Historical Markers conflicts were performed on a site by site and elevation basis.
    b. Two Sites include:
        i. Parkhouse 1 – Despain Bridge (401 NP and 406 NP+5)
            1. Located near the intersection of SH 19 and SH 154 near Cooper, Texas. There is only a marker at this location due to the original location being flooded by the completion of Cooper Lake. The approximate elevation at the location of the marker is 399.0' and the marker is near the edge of the reservoir (within 300'). It is assumed this marker can be relocated easily during the raising of the road; therefore no cost was given (contingencies should cover these cost).
        ii. Parkhouse 2 – Leroy Nelson DeWitt (418 MWSE)
            1. Located near FM 1742 about 8 mi. north of Cooper, Delta County. From what I can tell there is only a marker at this location. The approximate elevation at the location of the marker is 410.0'. It is assumed this marker can be relocated in this area along SH 19; therefore no cost was given (contingencies should cover these cost).

12. Land Cost
    a. Land costs were performed on the NP and NP+5' elevation, accept for Wright Patman and it was only performed on the NP+5' elevation. If a parcel of land was partially in the reservoir shapefile the entire track of land was included in the cost. Digital parcel information is not available for Hopkins, Morris, or Cass Counties. Similar to the interpolation performed for structure cost for these counties; I used average land cost

per acre and acres per parcel of the available county data within the reservoir and applied those values to the area in Hopkins, Morris, or Cass Counties. This information and calculations can be found in the Land Cost NP+5' spreadsheet.

13. Our normal QA/QC protocol is arranged more for "construction projects" than for "studies" but we used similar protocol for this analysis as follows:

    a. Determination & Verification of Data
        i. Data generated by MTG
            1. This data applied only to determination of building structures and power transmission lines;
            2. QA/QC protocol for this data was accomplished by three staff members as follows:
                a. Original data was observed from 2013 aerials by Project Engineer;
                b. CAD Technician did follow up verification of data generated by engineer; and
                c. Project Manager did random checks of data.
        ii. Data provided by others
            1. No QA/QC was undertaken as all provided data was assumed correct.

    b. QA/QC for Analysis of Data – In every instance the following protocol for all analysis was followed:P
        i. roject Engineer did initial analysis;
        ii. CAD Technician did further processing, compilation, and confirmation;
        iii. Project Engineer reviewed results of CAD Technician efforts and quantified/qualified any conflicts; and
        iv. Project Manager Reviewed and performed random visual (unnoted) verification.

APPENDIX C
TRANSMISSION FACILITY HYDRAULICS AND COST ANALYSIS MEMORANDUM

4055 International Plaza, Suite 200 • Fort Worth, Texas 76109 • 817-735-7300 • fax 817-735-7491 www.freese.com

Innovative approaches
Practical results
Outstanding service

TO: Joint Committee for Program Development (JCPD)

CC: Becky Griffith

FROM: Rusty Gibson, P.E., Ryan Ramsey, E.I.T.

SUBJECT: Transmission Facility Hydraulics and Cost Analysis

DATE: November 25, 2014

PROJECT: UFH12387 – Sulphur Basin Comparative Analysis

DRAFT

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF RUSSELL GIBSON, P.E., TEXAS NO. 61883 ON November 25, 2014. IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.
FREESE AND NICHOLS, INC.
TEXAS REGISTERED ENGINEERING FIRM
F- 2144

OVERVIEW

The transmission facilities required to convey the Sulphur Basin alternative yields to the desired delivery locations significantly influence the overall costs for each option. As part of the development to compare the capital and annual costs of the transmission components of the Sulphur Basin alternatives, a transmission "costing model" was created containing the overall transmission costs and associated hydraulic calculations. The costing model has been developed specifically to analyze the Sulphur Basin alternatives but is based on the assumptions and methods from the Integrated Water Supply Plan (IWSP) model that was previously created for TRWD. The costing model performs hydraulic calculations and associated transmission facility cost analysis for each Sulphur Basin Reservoir alternative.

It is important to emphasize that the goal of the analysis is to differentiate the cost for each of the various sources and combinations. The comparative costs are based on the assumptions described in this report. These assumptions may differ slightly from final design criteria but are reasonable and consistent in each cost model to allow comparison of alternatives. Also, the analysis did not intend to fine-tune the configurations of the transmission system for each alternative. This planning level study of the transmission system provides good estimates of the relative costs of the alternatives.

Unless otherwise noted, the costing methodology used is consistent with the Texas Water Development Board's (TWDB) regional planning guidelines for Region C.

Sulphur Basin Reservoir Alternatives

Five potential reservoirs at various top of conservation pool (TCP) levels within the Sulphur River Basin were analyzed as standalone alternatives and as combination alternatives to transmit water from the basin to various delivery locations throughout North Texas. The TCP is the elevation of the reservoir's normal maximum operating level. The Sulphur River Basin reservoirs along with their TCP levels considered are shown in **Table C-1**.

The analysis included all the reservoirs listed in **Table C-1** as standalone options as well as all potential combinations of two reservoirs in tandem. This resulted in 60 possible Sulphur Basin alternatives. A standard alternative identification (ID) naming convention was created to easily distinguish the options and is included in the "Alternative Combinations" worksheet of the costing model. This ID value is a required data input value and is displayed throughout each model run.

Table C-1. Top of Conservation Pool Levels for Sulphur Basin Reservoirs

Name	TCP
Marvin Nichols	296.5
	313.5
	328.0
Wright Patman (Reallocation)	232.5
	242.5
	252.5
Talco	350.0
	370.0
	350 (*P)
	370 (*P)
George Parkhouse I	401.0
George Parkhouse II	410.0

(*P) Talco Configuration 2 pumping water from the Sulphur River southward to supply the reservoir. This alternative would divert Marvin Nichols supply water and therefore cannot be in combination with Marvin Nichols.

HYDRAULIC CALCULATIONS

Hydraulic Assumptions

For each Sulphur Basin alternative, hydraulic calculations were performed to determine the required pipeline and pump station configurations, to size and cost the transmission facilities and to determine annual energy costs.

Pipeline routes for each alternative and their corresponding ground profiles were developed at a planning level using GIS. The ground profiles were imported into the costing model and used to develop the hydraulic grade lines.

To size the pump stations and associated facilities the following assumptions were applied:

- Pump station “wire to water” efficiency = 75%
- Goal average flow pump station discharge pressure = 200 psi
- Goal peak flow maximum pump station discharge pressure = 250 psi
    - Never to exceed 275 psi
- Storage at each booster pump station (BPS) in an earthen reservoir or open ground storage tank with a capacity of 0.25 times the maximum daily flow (6 hour storage)
- BPS ground storage water surface elevation (WSEL) to pump to = Ground Surface Elevation + 40 feet
    - Assumed 40 foot WSEL in tank or reservoir
- Pumping Rate based on assumed 8,760 hours/year pumping
    - Assumed an annual delivery of the full annual yield total
- Transmission peaking factors for each Owner are based on Owner input and are given in **Table C-2**

Table C-2. Design Transmission Peaking Factors for Each Owner

	TRWD	DWU	NTMWD	UTRWD	Irving	SRBA
Peaking Factor	1.25	1.50	1.40	1.25	1.25	1.25

The following assumptions were applied to size the pipelines:

- Target headloss at average flow = 0.8 feet per thousand feet (FPT)
  - Within a range from 0.6 to 1.0 FPT
- Target headloss at maximum flow = 1.5 FPT
  - Within a range from 1.2 to 1.8 FPT
- Hazen Williams C factor of 120
- Maximum pipe diameter = 120 inches
- Pipe diameters based on 6 inch increments
- Equal diameter of parallel pipelines

Other assumptions relating to transmission facilities include:

- Pump stations located downstream of dams to maximize operations at lowest lake elevations
- Pump stations sized based on total dynamic head values to operate at lowest lake and storage reservoir levels
- Pump station pumping elevations based on ground surface elevation at pump station location
- Owner delivery locations are based on Owner input and are listed in **Table C-3**

Table C-3. Delivery Locations for Each Owner

	TRWD	DWU	NTMWD	UTRWD	Irving	SRBA
Delivery Location	Lake Bridgeport	Trinity River & Lake Ray Roberts	NWTP & Wylie WTP	Trinity River & Lake Ray Roberts	*Trinity River & Lake Ray Roberts	Unspecified

***Irving prefers to use the existing Chapman Lake pipeline to transmit a portion their water from the Sulphur Basin to Lewisville Lake if feasible.**

Pipeline Sizing

Pipelines were sized based on the required flow to transmit, and therefore several pipeline segments exist due to changes at each source flow connection and delivery point branch from the base route. For standalone source alternatives, five flow changes and pipeline segments exist from the source reservoir to Lake Bridgeport. Flow changes on the base route occur after distribution to Chapman Lake (Irving), the North WTP, the Wylie WTP and Lake Ray Roberts/Trinity River.

Pipeline diameters were based on six inch intervals with the maximum assumed diameter equal to 120-inches. It was assumed that if capacities could be met with a 120-inch diameter or smaller then only one pipeline was required. If a 120-inch pipeline could not meet the required capacity then two or more parallel pipelines were considered. After capacity of a single 120-inch diameter pipeline was exceeded, parallel pipelines were applied with equal diameters starting at 96-inches increasing in 6-inch increments up to two 120-inch diameter pipelines.

It was discovered that two 120-inch diameter pipelines would not meet design requirements for the largest yield alternatives. For certain cases, it was calculated that three parallel pipelines would be required for a portion of the base route pipeline. The transition between two 120-inch parallel pipelines and three parallel pipelines corresponds to a Metroplex JCPD Owner total yield value of approximately 725,000 acre-feet per year. Note this 725,000 acre-feet per year value is based on the Metroplex JCPD Owner yields transmitted through the Sulphur Basin pipeline system and does not include consideration for local users or environmental flows. Assuming equal flow through each pipe and 6-inch diameter increments, after two 120-inch parallel pipelines were exceeded the next design alternatives were found to be three 108-inch pipelines followed by three 114-inch and finally three 120-inch parallel pipelines. The maximum yield cases including ID21- Patman252.5 and MN328 did require three 114-inch parallel pipelines for a portion of the base route.

Some pipeline segments required manually upsizing diameters in the model based on gravity flow requirements to reach a specific HGL elevation and also cases where larger diameters were required to decrease pump discharge pressures. For these cases the upsized pipes resulted in headloss values lower than the target values. For nearly every Sulphur Basin alternative, the branch line from the main route to the Wylie WTP required upsizing the diameter of the segment by at least 6 inches to reach the HGL elevation at the storage tank.

Two alternatives with Marvin Nichols as one of the sources (ID 6 and 47) required upsizing the pipeline diameters out of the LPS by 6 inches to lower the pump discharge pressures below the 275 psi limit. Although several alternatives had pump discharge pressures slightly greater than 250 psi at BPS #2, the segment diameters were not upsized since the pressures were below 275 psi.

COSTING METHODOLOGY

Cost Assumptions

The costing methodology for transmission facilities is consistent with the TWDB regional planning guidelines for Region C. The unit costs for transmission facilities were taken from the TWDB's Costing Tool, developed in 2012, unless otherwise noted. Multiple Sulphur Basin alternatives require transmission facilities that are larger than those listed in the TWDB's Costing Tool. Where required, unit cost values were extrapolated to account for larger facilities. All unit costs have been indexed to November 2013 dollars. Details of the cost indices are listed in the "Price Index" sheet in the costing model. A new date and index can be entered in the yellow cells on the "Price Index" sheet to use unit costs corresponding to a different date.

The following assumptions were made to determine pipeline and pump station costs:

- Pipeline lengths were assumed to be straight-line distances increased by 10 percent to account for slope distances and routing around obstacles
- It was assumed that storage equivalent to 25 percent of the maximum flow was required at the booster pump stations, equivalent to 6 hours of storage

The total capital costs included costs for pipeline right-of-way (ROW), engineering and contingencies, and permitting. Assumptions were made as follows:

- Pipeline ROW costs are shown in **Table C-4**.
- All pipeline ROW were assumed as either "rural county" or "urban county"

Table C-4. Pipeline Right-of-Way Costs

	Rural County (Cost/LF)	Urban County (Cost/LF)
60-foot Permanent Easement (Single Pipe)	$15.81	$93.76
100-foot Permanent Easement (2 Parallel Pipes)	$25.98	$155.89
150-foot Permanent Easement (3 Parallel Pipes)	$38.41	$233.84
180-foot Permanent Easement (4 Parallel Pipes)	$46.32	$280.15

- Pump Station Engineering and Contingencies = 35% of pump station construction costs
- Pipeline Engineering and Contingencies = 30% of pipeline construction costs
- Permitting and mitigation for transmission facilities were assumed to be 1 percent of the total construction cost. However, a 20% allowance for construction contingencies was included for permitting.
    - Permitting and Mitigation = Initial Construction Cost * 1.2 * 1%

Annual Costs

Annual costs assumptions include:

- Debt service is annualized over 40 years
- Annual interest rate for debt service = 5.5%
- Electricity costs = $0.07 per kilowatt hour
- Operation and Maintenance (O&M) costs were calculated based on the construction cost of the capital improvement. Engineering, permitting, etc. were not included as a basis for this calculation. However, a 20% allowance for construction contingencies was included for all O&M calculations. Annual O&M costs were calculated as follows:
    - 1 percent of the construction costs for pipelines
    - 2.5 percent of the construction costs for pump stations and storage tanks

Phasing Options

FNI asked the JCPD participants to provide the water delivery dates required for the Sulphur Basin yields to determine feasibility of project phasing. Based on the results and further discussions with the Owners, each of their yield percentage requirements by year are summarized in **Table C-5.**

Table C-5. Delivery Dates for Each Owner (as a percentage of their total yield)

	TRWD	DWU	NTMWD	UTRWD	Irving	SRBA
2020	0	0%	0%	0%	0%	0%
2030	0	0%	0%	0%	100%	100%
2040	100%	0%	50%	50%	100%	100%
2050	100%	30%	100%	100%	100%	100%
2060	100%	100%	100%	100%	100%	100%

As seen in **Table C-5**, the schedule will require approximately half of the yield to be delivered by 2040 and the full yield by 2060. This allows some flexibility for pipeline phasing, and the pipelines have been designed to transmit the total yield evenly between two parallel pipelines where two are required. The second of the two pipelines could be constructed at a later time (by 2050) to reduce costs before the full yield is required.

As will be discussed in further detail, NTMWD and the City of Irving's (Irving) existing Chapman Lake transmission system can be utilized to convey a portion of Irving's Sulphur River Basin yields. Irving will require their entire allocated yield by 2030. To meet this requirement, the first of the parallel pipelines (if two are required) must be constructed from the Sulphur Basin source(s) to the Chapman Lake outfall by 2030. To transmit Irving's yield the remainder of the way from Chapman Lake to Lewisville Lake the existing Chapman Lake system will require existing pump station upgrades.

Owners' Portions of Pipeline and Pump Station Components

INITIAL OWNERSHIP ALLOCATION

Each JCPD Owner has designated percentages of ownership to the individual transmission component costs including pipeline segments, pump stations, storage reservoirs and discharge structures. The initial percent allocations for the Owners are shown in **Table C-6**. However, due to varying distribution locations, initial yields and assumptions, the cost allocations will also vary between Owners for each transmission component. Because transmission components are sized based on capacity, cost responsibility for each transmission component in the model has been allocated based on the percentage of peak flow each Owner conveys through the individual component.

Table C-6. Initial Percent Ownership of Sulphur Basin Reservoir Alternatives

Ownership Component	Percent Ownership						
	TRWD	NTMWD	DWU	UTRWD	Irving	SRBA	Total
All Raw Water	23.918%	23.918%	23.358%	4.807%	4.000%	20.000%	100.000%
Metroplex JCPD Sections	29.897%	29.897%	29.197%	6.009%	5.000%	0.000%	100.000%

The "Owners' Share PL & PS & Struct" sheet in the costing model is a summary of each transmission component and the corresponding ownership percentage for the JCPD participants. Transmission components in the list reference the HGL spreadsheets and look at each Owners' peak capacity through the component to calculate the individual cost percentages. These values may change for each alternative run and are dependent on initial assumptions such as the percentage of yield to transmit through the existing Chapman Lake system and Owner peaking factors. These transmission ownership percentages were multiplied by capital costs in the Cost Summary to determine individual owner costs of each component.

TALCO DIVERSION RIVER PUMP STATION

Talco Reservoir as a Sulphur Basin source has two TCP levels (350 and 370 feet) and two possible configurations for each TCP level. Talco in Configuration 1 is supplied by the drainage basin south of the ridge between Marvin Nichols and Talco. Therefore, the two reservoirs do not share supply water and can be in combination in the Configuration 1 scenario.

The Talco Configuration 2 (TalcoConfig2) alternative consists of a diversion pump station located approximately four miles northeast of the Talco Reservoir dam on the Sulphur River. For this alternative, water will be diverted from the main stem of the Sulphur River to fill the Talco Reservoir at flow rates dependent on the TCP level of the reservoir. The location of the diversion pump station and pumping rates were developed at a conceptual design level and used to estimate the available Talco Reservoir yields. It is assumed that Talco at a TCP level of 350 feet will be supplied by diverting up to 1,000 CFS from the Sulphur River and Talco at a TCP of 370 feet will divert up to 2,000 CFS to the reservoir. The Talco diversion pump station, also known as the Talco scalping pump station in the models, is a required component to make the Talco Reservoir yields available to the Owners in TalcoConfig2 scenario.

ROUTE SELECTION

Pipeline Route Selection

Various factors were considered when selecting pipeline routes from the Sulphur Basin reservoirs to the Owner specified distribution locations. For the route selections, it was assumed that up to two of the Sulphur Basin reservoirs can be constructed at one time to operate together. This results in sixty possible alternative combinations to model. Considering a route location that would be compatible with the multiple source alternatives was a major influence in the route selection. The proposed pipeline routes and locations of pump stations and delivery points are shown in **Figures C-1** through **C-3**.

Lake pump stations (LPS) were located at the downstream side at the base of the dams near the channel bottom and reservoir minimum elevations. This allows for pumping approximately the full capacity of the reservoir as requested by the JCPD members. The pipeline route best suited for this LPS configuration runs north of Wright Patman (Patman) between Marvin Nichols and Talco and south of the George Parkhouse (Parkhouse) reservoirs. A pipeline route alongside the north of Patman originating from the pump station at the base of the dam is significantly shorter than a route running along the south side of the reservoir starting at the same location. This is especially evident for Marvin Nichols and Patman combination alternatives because Marvin Nichols is located slightly north of Patman.

This pipeline route running near and between the dams was selected as the base route to analyze.
The base route is common to all of the alternatives except those with Parkhouse I in operation due to the base route severing the reservoir footprint. The base pipeline route was designed to stay north of Chapman Lake and continue west on a straight line path before it bends slightly southwest near Ray Roberts Lake to ultimately deliver to Lake Bridgeport. Reasons for selection of this northern base route (in respect to the existing Chapman Lake System south route) include:

- Based on the location of intake LPS at the reservoir dams, the preferred pipeline route runs between the source reservoirs and north of Chapman Lake
- The northern base route is located nearer to potential Sulphur Basin local users (such as Texarkana and Clarksville) who will be allocated 20% of the Sulphur Basin yields
- The route was estimated to be the least expensive route
- The existing Chapman Lake pipeline ROW does not appear wide enough for additional Sulphur Basin parallel pipelines (up to three new parallel pipelines may be required)
- It is anticipated that the Denton, Frisco, and McKinney area will experience significant development northward by 2040 and the base route mostly avoids these growing areas
- The base route is located on primarily rural land

- The base route runs next to one of NTMWD's delivery locations (North Water Treatment Plant at Leonard)
- The base route avoids running through the middle of Denton to deliver water to Lake Bridgeport
- The base route runs just south of Lake Ray Roberts allowing convenient delivery of DWU, UTRWD and Irving water
- The base route runs across the Elm Fork Trinity River allowing for another distribution point for DWU, Irving and UTRWD
- The base route is independent of the existing transmission systems allowing for greater flexibility, pumping operations, and operation and maintenance (O&M) procedures

Booster Pump Station Locations

The base route profile was developed in GIS and exported to the cost model. From the HGL calculations after applying the target headloss values, it was determined that a minimum of four booster pump stations (BPS) are required to deliver water over the longest route alternative (Patman to Lake Bridgeport). The BPS locations are common to every Sulphur Basin alternative with the exception that BPS #1 is only required for Patman options. The other Sulphur Basin reservoirs can pump directly from their associated LPS to BPS #2 bypassing BPS #1. All route combinations excluding Patman will require three BPS to deliver water to Lake Bridgeport.

The BPS were located to keep the average flow maximum pump discharge pressures below or near a 200 psi limit and the peak flow maximum pump discharge pressures below or near a 250 psi limit. For alternatives producing pump station maximum discharge pressures greater than 250 psi an ultimate limit of 275 psi was applied. Pipe diameters had to be manually increased in the hydraulic calculations to two alternatives (ID 6 and 47) to get below 275 psi discharge pressure at the LPS.

Other factors were considered when locating BPS besides pumping discharge pressures. Where possible, the BPS were located on high surface elevations at peaks along the pipeline profile to conserve head at low flows and to make operations easier. The locations were observed in GIS aerials to ensure that they did not conflict with existing structures. Also, branch delivery lines from the base route were coordinated with BPS locations to allow for bypass piping within the pump station sites.

A standard naming convention was applied for pump stations that is consistent throughout each model alternative. BPS were labeled as BPS #1, BPS #2, etc… from east to west. Alternatives that do not require BPS #1 start with their first BPS labeled as BPS #2 to have consistent names based on location throughout all models. LPS were also labeled from east to west with each name designating the reservoir of origin. The existing Chapman system pump station names are also consistent throughout each model containing "Future Chapman BPS", "Existing Chapman LPS", and "Existing Irving BPS".

Alternate Routes

As previously mentioned, the Parkhouse I alternative is the only deviation from the base route. This case requires an alternate route that diverges from the base route east of Parkhouse I, runs south of the reservoir and connects back to the base route at BPS #2 as shown in **Figure C-2**. It was determined to route along the south side of Parkhouse I instead of discharging into the east side of the reservoir which would require an additional LPS on the west portion of the reservoir. A LPS on the west side of the reservoir would significantly limit the ability to utilize the full capacity and discharging into the reservoir would increase evaporation yield losses. The extra pipe length and pumping requirements associated with this alternate route were considered in the cost estimate calculations.

For the single case of Parkhouse I and II reservoirs in combination an alternate Parkhouse II extension pipeline was routed from the Parkhouse II LPS directly to the Parkhouse I LPS.

Delivery Locations

As requested by each JCPD Owner, the Sulphur Basin water delivery locations are listed in **Table C-3**. TRWD has the longest distribution distance of any Owner from any of the five sources to Lake Bridgeport. This extra pipeline distance causes TRWD to have a higher unit cost value than the other JCPD Owners.

Irving has the option of utilizing the existing Chapman system to deliver a portion of their Sulphur Basin yields to Lewisville Lake as described further in the next section. The remaining portion of Irving's Sulphur Basin yield, along with DWU and UTRWD yields, will be distributed to the Elm Fork Trinity River just below Lake Ray Roberts as well as through a branch line leading to Lake Ray Roberts.

NTMWD has requested that half of their Sulphur Basin yield be delivered to their North WTP in Leonard and the other half to the existing Wylie WTP. The proposed northern base route runs approximately 1.7 miles south of the assumed future terminal storage reservoir (TSR) at the North WTP. A water surface elevation (WSEL) of around 740 feet was assumed for hydraulic calculations when pumping to the TSR from BPS #2.

A tank WSEL of 572.5 feet was assumed at the Wylie WTP. After reviewing data regarding NTMWD's existing Lake Texoma pipeline to Wylie WTP it was determined that the existing system will not be able to support additional NTMWD yield from the Sulphur Basin. The magnitude of NTMWD Sulphur Basin yields to Wylie will require an additional parallel pipeline to the WTP. At the maximum yield alternative (ID21), NTMWD will deliver approximately 126 MGD average Sulphur Basin flow to the Wylie WTP which will require a new 96-inch diameter pipe. The segment required upsizing the optimal headloss diameter in order to maintain gravity flow.

Existing Chapman Lake Transmission System

After discussions with Irving and UTRWD, the hydraulic calculations and costing model was designed to distribute a portion of Irving's Sulphur Basin yield allocation to Chapman Lake where it can then be conveyed through the existing Chapman Lake water transmission system, which is jointly owned with NTMWD. It was decided that up to 20 MGD of Irving's average Sulphur Basin flow will be distributed into Chapman Lake.

The existing Chapman transmission system was completed in 1995 and is NTMWD and Irving's only method of transferring their water right out of Chapman Lake. From the Chapman Lake pump station water is pumped through the 84-inch diameter Phase I pipeline approximately 40 miles west to a creek discharge (NTMWD outfall) that runs to Lake Lavon. The Phase II 72-inch diameter pipeline extends further west to deliver Irving's and UTRWD's water to Lewisville Lake.

The pipeline from Chapman Lake to the NTMWD outfall has an ultimate capacity of 220 MGD and the section from the outfall to Lewisville Lake has an ultimate capacity of 110 MGD. However, these pipeline ultimate capacities are currently not being met due to the existing Chapman LPS only being capable of pumping at a maximum rate of about 110 MGD. If upgrades are applied to the existing Chapman LPS and Irving BPS along with construction of a new BPS, the Chapman system ultimate capacities could be utilized. This would allow for a portion and potentially all of Irving's Sulphur Basin yields to be conveyed through the existing system.

Peaking factors were applied to average flows to determine how much could be transmitted through the existing Chapman system without exceeding the ultimate capacities of the Chapman Phase I and II pipelines. For the existing Chapman Phase I pipeline from the LPS up to the NTMWD outfall, it was assumed that the capacity will be divided with NTMWD owning 50 percent and the remainder split between UTRWD and Irving. The Phase II pipeline from the NTMWD outfall to Lewisville Lake is owned by Irving. Based on these assumptions the Phase I pipeline ultimate capacity of 220 MGD was found to be the limiting factor of allowable flows through the existing Chapman system. A total average flow of 167 MGD can be transmitted through the existing Chapman system with 79 MGD to NTMWD and 84 MGD split between UTRWD and Irving to reach the ultimate capacity of 220 MGD after applying each Owner's peaking factor.

The hydraulic and cost models have been set up capable of specifying how much of Irving and UTRWD's Sulphur Basin yields to transmit through the existing Chapman Lake system. These yield values are specified in the HGL calculations for Chapman LPS to the Lewisville Lake outlet. The yields not sent through the Chapman System can be transferred with the other Owners' share through the northern base pipeline route. UTRWD and Irving's water would then be delivered to the Elm Fork Trinity River and Lake Ray Roberts by the same route as DWU.

The hydraulic and cost calculations also account for upgrading the existing Chapman transmission facilities and the addition of a new BPS. Increasing the flows to reach the ultimate capacities of the existing Chapman pipelines will require upgrades to the existing Chapman LPS and the addition of a new BPS approximately 20 miles west of the LPS. NTMWD owns 50 percent of the capacity of the Phase I Chapman pipeline and existing LPS. Therefore, the overall ownership allocations for the upgrades to the LPS and construction of a new BPS are 50 percent for NTMWD and the remaining 50 percent split between UTRWD and Irving. Of UTRWD and Irving's portion of the Chapman System it was assumed that Irving will utilize 77 percent and UTRWD 23 percent. For the Phase II portion of the Chapman System, this results in 85 peak MGD to Irving and 25 peak MGD to UTRWD.

Because Irving is the only JCPD Owner that will utilize the existing Chapman system to convey Sulphur Basin water (up to 20 MGD) based on the current model assumptions, only their cost portion of the Chapman system upgrades was included in the Sulphur Basin cost models. Therefore, although NTMWD and UTRWD will have partial ownership in upgrading the Chapman system, their associated costs to upgrade the system have not been included. Irving's cost is based on their percentage of flow through the system. A total unit cost value of $10,000,000 was applied to upgrade the existing Chapman LPS and $5,000,000 for upgrading the Irving BPS based on cost data from previous projects. The unit cost of the new Chapman BPS is based on the standard unit cost methodology. To estimate the new annual power costs associated with upgrading the existing pump stations, only Irving's Sulphur Basin water was considered.

COST MODEL STRUCTURE

Data Input Requirements and Base Route HGL Calculations

The first worksheet in the costing model includes an index which contains links to other sheets in the file. Also included on a worksheet are maps of the various Sulphur Basin reservoir alternatives, pump station locations, delivery points and pipeline routes.

Data input is required for each alternative to model at certain locations within the spreadsheet (data input parameters are indicated as light blue text). This data input is centralized around two model worksheets, the "Cost Summary" and the "DATA INPUT Source-Yield-MainHGL". The following input cost parameters are required at the top of the "Cost Summary" worksheet:

- Energy costs
- Raw water costs
- Debt repayment periods
- Debt service

The hydraulic calculations in the model are mostly automated but require defining parameters that are unique for each alternative option. The "DATA INPUT Source-Yield-MainHGL" worksheet in the model is the location of the base route HGL calculations and the central location for defining hydraulic and Sulphur Basin reservoir source(s) data parameters including:

- Source(s) Name
- Alternative identification value
- Top of conservation pool (TCP) levels
- Pumping static elevations
- Supply yields
- Project participants for each transmission system component
- Distribution locations
- Yield distribution percentages
- Peaking factors
- Target headloss values
- Hazen Williams C factor
- Pump efficiency
- Pumping rate
- Storage tank elevations
- Whether the existing Chapman system is utilized
- HGL specific control points
- Designation of pipeline segments

The number of sources and the alternative identification value must be defined first followed by specific source information for either a standalone option or up to two sources in combination. The total yield and pump station sizing calculations are directly dependent on the defined source(s) information.

The middle portion of the "DATA INPUT Source-Yield-MainHGL" worksheet requires defining the percentage of distribution and peaking factors for each owner. Once input, pipeline segment capacity changes (flow reaches) are calculated which are in turn used to calculate each pipeline segment diameter. The name and location (station) of HGL control points must be defined in the “Sources & Delivery Points” section of the spreadsheet. It is important to accurately define the flow reach segment for each control point. The flow reach segment is an integer value that corresponds to the yield calculations portion of the spreadsheet.

A lookup table has been added to the model based on Hazen Williams hydraulic calculations, that looks at the pipeline segment capacities and the target average flow headloss which is defined in the “Pipeline and Pump Station Variables” section. The optimal diameter is determined from the lookup table and then used to calculate the average and peak flow headloss values in FPT. For certain alternatives the optimal headloss diameter may not be desired (i.e. cases where a lower headloss value is required to reach a specific HGL elevation or where a larger diameter is required to decrease pump discharge pressures). Here, the user must manually input the desired diameter in the calculations spreadsheet.

Once the pipeline diameters are defined and the headloss values are calculated, the bottom portion of the “Data Input Source-Yield-MainHGL” spreadsheet performs the HGL and pump sizing calculations. As noted in the spreadsheet, the HGL calculations are dependent on control points that must be defined in the “Sources & Delivery Points” area with specific key terms. Storage tank water surface elevation control points at booster pump stations must be defined with the key term “Storage”. Likewise, high point ground surface elevation control points must include the key term “Surface Elevation”. The HGL calculations are designed to look for these key terms to calculate HGL elevations. If pipeline alignments change, the data on the profile sheets in the costing model will need to be updated using GIS or similar methods including specific HGL control points such as high elevations.

From the HGL calculations the average and maximum pumping discharge pressures and horsepower are determined. For the average flow discharge pressures the energy costs are also calculated based on the user defined pumping rate. A planning level pumping rate value was used in the model that assumes an annual delivery of the full annual yield amount.

Additional Route HGL Calculations

As previously described, the “DATA INPUT Source-Yield-MainHGL” worksheet performs the HGL calculations for the base pipeline route from the furthest east source (Source #1 in the data input) to Lake Bridgeport. The flow reaches must be defined at each HGL control point to allow for automatic pipeline sizing calculations of segments as the flow changes along the base route.

After the base route HGL calculations are performed, the following HGL calculation worksheets size branch pipeline diameters and additional pump stations that either tie-in to or diverge from the base route. All potential pump stations and pipeline segments are modeled on the subsequent HGL calculation worksheets. This includes calculations for sizing the pump station and pipeline for potential second Sulphur Basin sources to the base route. Each sub worksheet looks at the data parameters that are defined in the data input/base route HGL worksheet. Because base route HGL values are already calculated, the sub HGL calculation worksheets link to the base route values for points connecting to and diverging from the base route.

All the HGL calculation worksheets in the model may not be required for every alternative option. For single source alternatives the “Calcs LPS #2 to Main Route” worksheet is not required. Likewise, only alternatives assuming Talco Configuration 2 will require sizing the diversion pump station which is performed on the worksheet “Calcs Talco Scalping PS”.

As previously discussed, the existing Chapman transmission system is modeled on a separate HGL calculation worksheet to determine requirements for upgrading the existing pump stations and sizing a new BPS. This worksheet is where the user defines how much of UTRWD and Irving's Sulphur Basin yields to distribute into Chapman Lake and how much yield to transmit through the existing Chapman system. The data input/base route HGL worksheet reads the amount of Sulphur Basin yield to deliver to Chapman Lake from this worksheet and uses this information to size pump stations and pipelines on the base route west of Chapman Lake.

HGL Charts

To the right of each HGL calculation worksheet is its associated HGL chart. These charts display various types of information including:

- Source and delivery information
- Alternative ID
- Total yield
- HGL values
- Pipe profile
- Pressure classes
- Pump station locations
- HGL control points
- Unique flow reach segments
- Average flow rate in each segment
- Number of pipelines per segment
- Size of pipeline(s) per segment

The charts are mostly dynamic and will update the required number of pipelines and diameters as they change in the HGL calculation worksheets. Two source alternatives contain an additional flow reach section in the HGL charts compared to one source alternatives. A model run (ID21) base pipeline route HGL chart is shown in **Figure C-4**. **Figures C-5** through **C-10** show the associated HGL charts for all the branch lines and system components of alternative ID 21.

Transmission Facility Summary Information

After completion of sizing the pipelines and pump stations in the calculations on the individual HGL worksheets, the "Pipeline Summary" and "Pump Station Summary" worksheets near the end of the model link to the separate calculations and summarize the facility information. The pipeline summary separates each pipeline segment where a flow change, change in size or change in ownership occurs. Extra placeholders are held for alternatives that may have more pipeline segments than others.

Information for each pipeline segment found in the summary includes:

- Pipeline segment ID
- Starting and ending location
- Number of pipelines
- Size of pipelines
- Length of pipeline segment
- Percentage of rural versus urban length
- Discharge structure name ID and location
- Discharge structure size and unit cost

The pipeline summary also contains information about the required discharge structures. These structures are found at each distribution location including the Talco Reservoir when the Talco river diversion pump station is applied. The discharge structure summary table includes the location, size and unit cost of the structure on this worksheet. Discharge structure costs are based on the standard unit cost methodology except for cases discharging into water treatment plants (North WTP and Wylie WTP). For the WTP discharge structures the base unit costs were doubled to account for the flow control valves that will be required into the existing facilities.

The pump station summary also links to the locations in the individual HGL worksheets where the pump station sizing calculations are performed. The summary includes all LPS, BPS and pump station storage tanks/reservoirs including those for the existing Chapman system. The sizes of storage tanks/reservoirs are calculated on the summary worksheet based on the storage time that is defined at the top of the summary table. A six hour storage time at peak flow was assumed in this study.

The pump station summary includes the following information:

- Pump station name
- Location
- Average discharge pressure
- Maximum discharge pressure
- Maximum horsepower
- Average horsepower
- Average flow kilowatt-hours
- Cost per kilowatt-hour

The pipeline and pump station summary worksheets were set up to link to specific locations in the separate HGL worksheets where the component calculations were performed. During most alternative model runs, the summary worksheets should automatically update the component information accurately. However, there may be alternatives in which a linked component does not exist or the calculation location has slightly changed. Therefore, both the pipeline and pump station summaries should be verified for every model run to ensure that the links to the components are as intended.

Cost Summary

All transmission facility components are compiled and summarized on the "Cost Summary" worksheet. The cost summary performs multiple processes to reach the final costs of each alternative. Required cost data input parameters are located at the top of the worksheet and include (study values):

- Debt Service Rate (5.5%)
- Debt Payment Period (40 years)
- Electric Cost ($0.07 per kWh)
- Pipeline Engineering and Contingencies (30%)
- Pump Station Engineering and Contingencies (35%)

The cost summary references the pipeline and pump station summaries as well as the unit costs and Owners' Share worksheets to perform the following cost procedures:

- Separates each transmission component by changes in ownership and capacity
- Assigns unit costs to each component based on type and size
- Calculates initial construction costs
- Adds engineering and contingencies
- Adds permitting and mitigation
- Lists the Owner's percentage of costs below each component
- Calculates each Owner's separate component costs
- Summarizes capital pipeline costs and separates by Owner
- Summarizes capital pump station costs and separates by Owner
- Summarizes capital pipeline and pump station construction costs (first costs) and separates by Owner
- Calculates JCPD Owners' interest during construction
- Calculates annual debt service costs
- Calculates annual electricity costs
- Calculates annual operation and maintenance costs
- Calculates total annual costs during and after debt service and separates by Owner
- Calculates total unit costs during and after debt service and separates by Owner

Each Sulphur Basin alternative has its own cost summary output file that includes both total costs and costs separated between JCPD Owners. An example of the entire output for a single alternative in which each transmission component cost is separated is located in **Attachment C-1**. This output first separates transmission component costs and then summarizes total and unit capital and annual costs on the last five pages. The cost model output results can be provided for each of the Sulphur Basin alternatives, as requested. The total estimated transmission costs for each of the sixty alternatives are summarized in **Table C-7**.

RESULTS

Cost results are based on the total capital and annual costs and assume constructing each Sulphur Basin alternative in one phase. As seen in the "Phasing Options" section only about half of the total yield is required by

2040 with the remaining half not required until 2060. These delivery dates may allow construction phasing of the transmission system which would also reduce initial capital costs of a potential project phase I. It should be noted that Irving has requested their entire allocated yield to be delivered by 2030. Therefore, construction of a potential project phase I designed to deliver half of the Sulphur Basin yields up to at least Chapman Lake (if all of Irving water is distributed into Chapman Lake) may be required by 2030 rather than 2040.

Project phasing is also dependent on various other factors for each alternative such as whether a single pipeline is required or if multiple (up to three) parallel pipelines are required to transport the total yields. Several source options require a single pipeline from the first source up to the second source, two parallel pipelines after adding the second source yields, followed by single pipelines as water is delivered along the route. Construction phasing and cost allotment will require further consideration for each Sulphur Basin alternative, and is not part of this analysis.

The majority of the Sulphur Basin alternatives result in total yields that are too large to be conveyed through one 120-inch diameter pipeline and therefore two parallel pipelines are required for a portion of the route. Nine of the alternatives had flows that resulted in three parallel pipelines required for a portion of the base pipeline route. The large flow values associated with the TalcoConfig2 diversion pump station result in the need for two 120-inch diameter pipelines to fill the reservoir when diverting 1,000 CFS and four 120-inch diameter pipelines if diverting 2,000 CFS. Large discharge structures are also required for the water diverted from the Sulphur River to the Talco Reservoir depending on the number of pipelines (either two or four). As previously stated, it is assumed that only the Metroplex JCPD Owners will be responsible for the costs associated with the TalcoConfig2 diversion pump station and its components.

When including interest during construction, transmission total costs range from approximately $864M (ID12 – Parkhouse II standalone) up to $6.75B (ID21 – Patman at TCP 252.5 and Marvin Nichols at TCP 328). Total costs are a reflection of multiple factors including pipe lengths, the number of pump stations and parallel pipelines required, and sizes of components such as pipe diameters. All Patman options have high total costs because they require pumping large yields at longer distances than other sources. The proposed base pipeline route from Patman to Lake Bridgeport is approximately 218 miles long. On the other hand, the standalone route from Parkhouse II to Lake Bridgeport is only approximately 145 miles resulting in the lowest total transmission capital costs of any of the alternatives.

Total transmission costs are only one factor when deciding which Sulphur Basin alternative to implement. A desired minimum yield amount may be applied that results in many alternatives being discarded due to small yield totals. Nineteen alternatives have total yields greater than 700K AFY.

Unit cost values give a better representation of the costs effectiveness of each alternative by showing how much the option costs compared to how much water is made available. Transmission unit cost values during debt service range from approximately $1.72 to $2.65 per 1000 gallons delivered. Overall, two source alternatives with Marvin Nichols as one of the sources were shown to have the lowest unit costs during debt service. The higher yield Marvin Nichols and Talco Configuration 1 alternatives, and multi-source alternatives with these sources have some of the more cost efficient transmission options.

The alternative with the lowest transmission unit costs during debt service and the seventh lowest after debt service was found to be Marvin Nichols at TCP of 328 feet combined with Talco Configuration 1 at TCP of 370 feet (ID 45). The combined total yield of the option is 846,510 AFY with 677,208 AFY available to the Metroplex JCPD

Owners. Marvin Nichols standalone at 328 feet TCP (ID 6) had the lowest unit costs of any of the single source alternatives and provides approximately 472,000 AFY to the Metroplex JCPD Owners.

The two smallest yield alternatives in the top ten lowest unit costs were Talco Configuration 1 at TCP of 370 in combination with Parkhouse I and Parkhouse II (ID 54 and 58). These options resulted in Metroplex JCPD Owner yield totals of 309,344 and 307,912 AFY, respectively. The three alternatives with Marvin Nichols at TCP of 328 feet in combination with Patman at various TCP values (ID 19, 20, 21) had similar unit costs and had the lowest unit costs of any option with Patman as a source.

Costs associated with transmission components are shown to play a significant influence in the overall costs of each option but other factors must be considered when determining the optimal or preferred Sulphur Basin alternative. These transmission cost values will be incorporated to both environmental impact data and reservoir costs to assist in the selection of the Sulphur Basin reservoir source or sources to implement in the future.

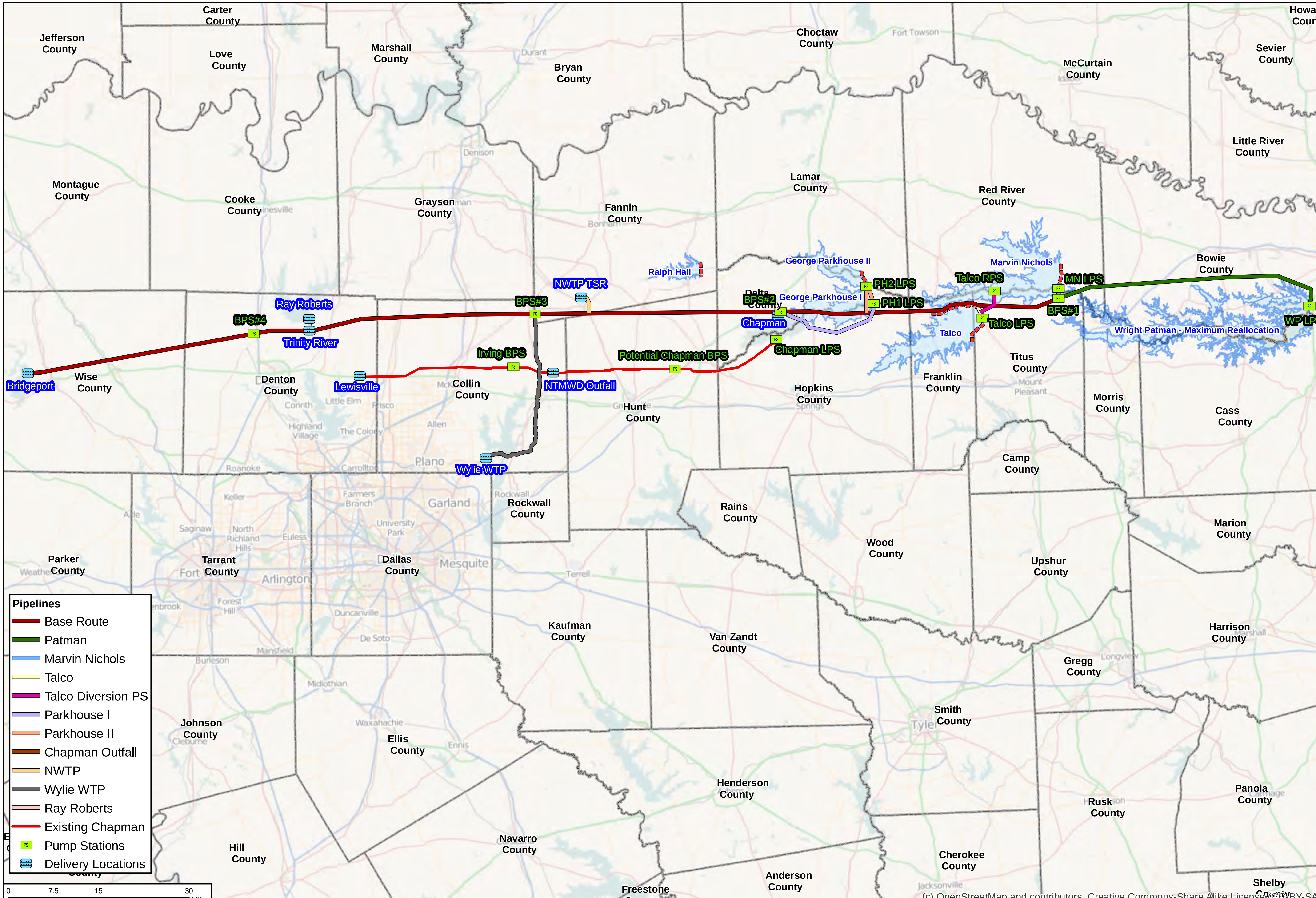


FIGURE C-1

SULPHUR BASIN COMPARITIVE ANALYSIS
PROPOSED OVERALL TRANSMISSION SYSTEM

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE H:\PIPES_PUMPS\FINAL_EXHIBITS
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY 02150

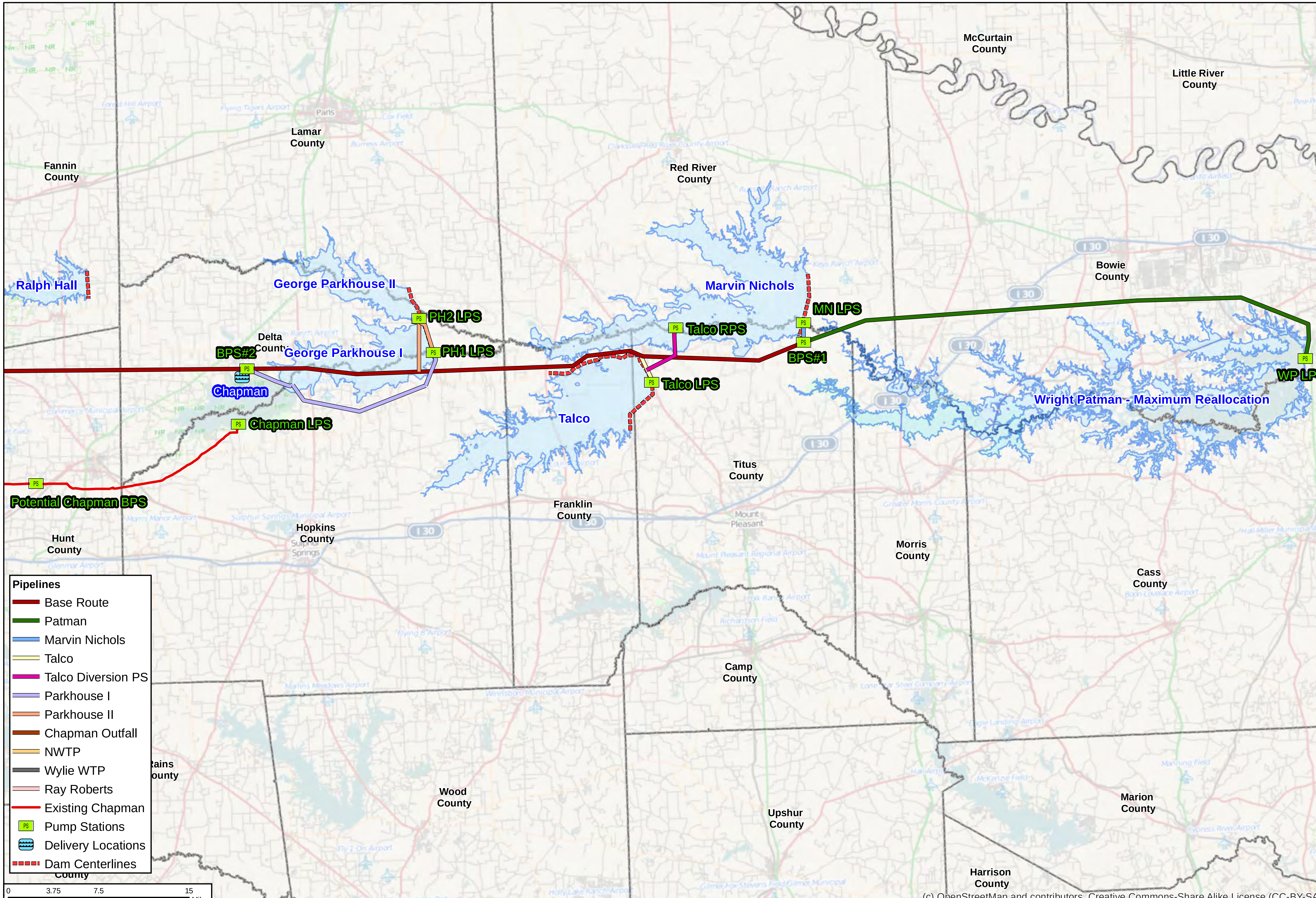


FIGURE C-2

SULPHUR BASIN COMPARITIVE ANALYSIS

PROPOSED TRANSMISSION SYSTEM - EAST SECTION

FREESE AND NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE H:\PIPES_PUMPS\FINAL_EXHIBITS
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY 02150

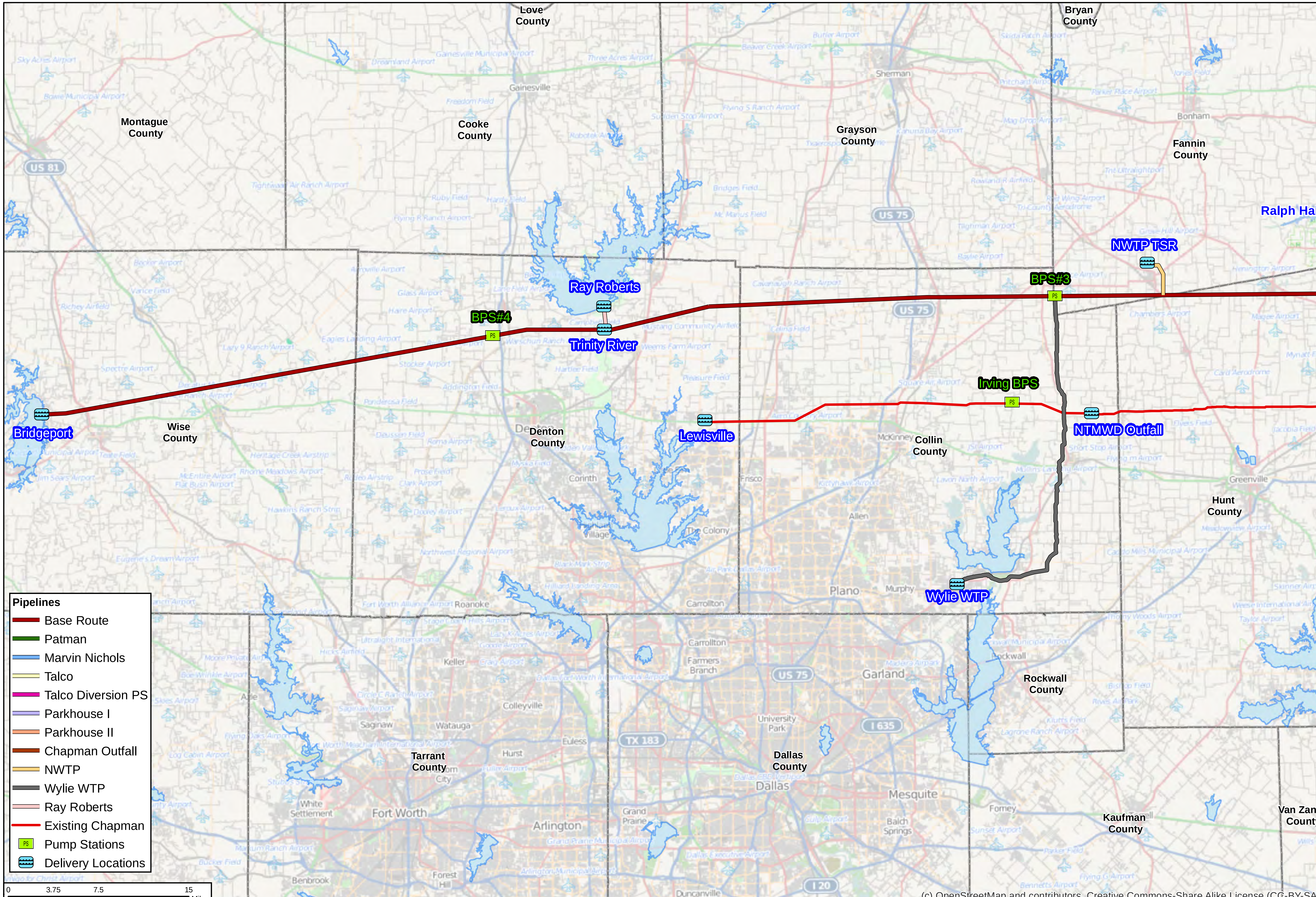


FIGURE C-3

N W E S

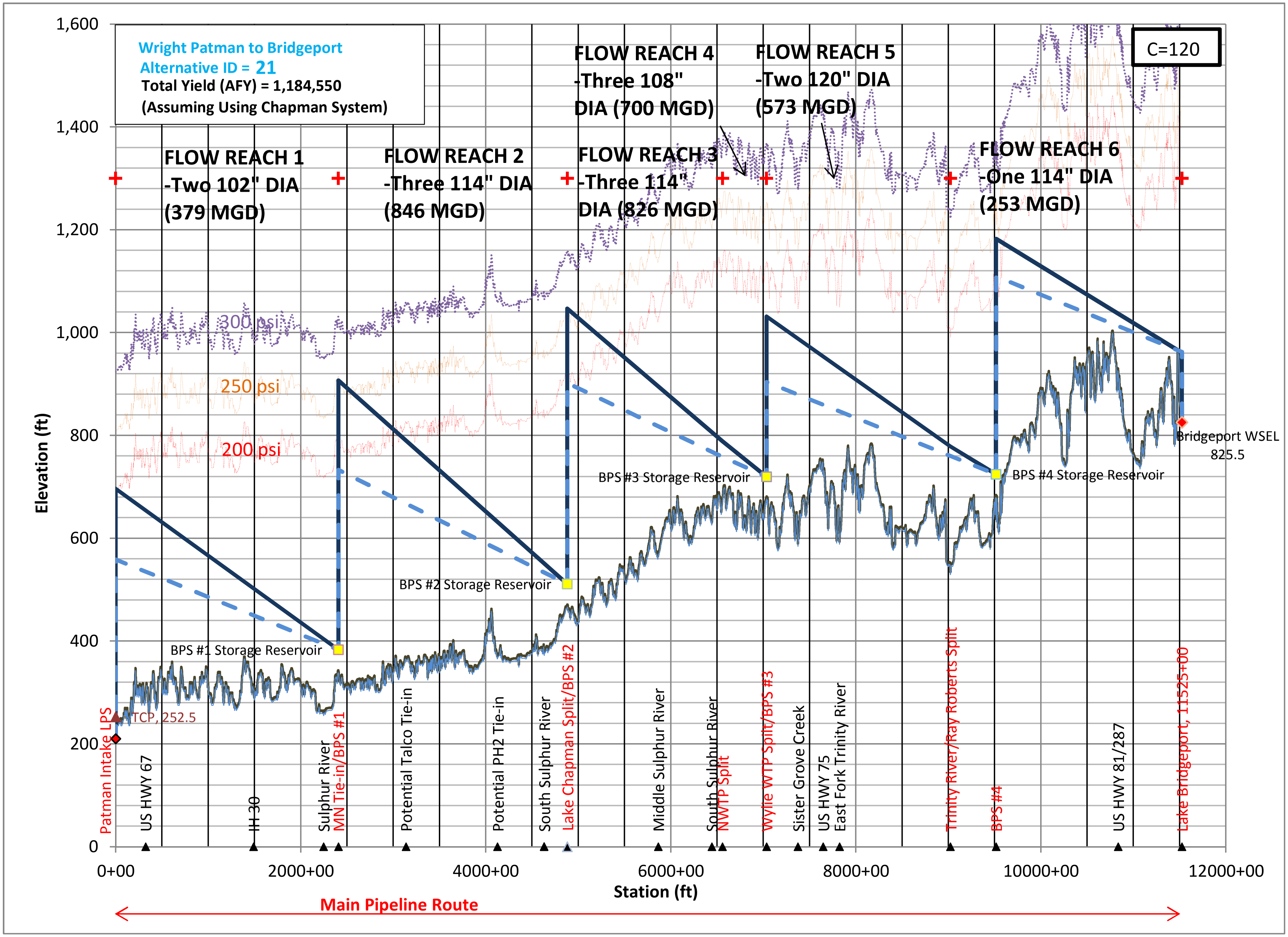
SULPHUR BASIN COMPARITIVE ANALYSIS

PROPOSED TRANSMISSION SYSTEM - WEST SECTION

FREESE NICHOLS
4055 International Plaza
Suite 200
Fort Worth, TX 76109

FNI PROJECT UFH12387
FILE H:\PIPES_PUMPS\FINAL_EXHIBITS
DATUM & COORDINATE SYSTEM NAD 1983 StatePlane Texas North Central FIPS 4202 Feet
DATE April, 2014
PREPARED BY 02150

Figure C-4



Wright Patman to Bridgeport
Alternative ID = 21
Total Yield (AFY) = 1,184,550
(Assuming Using Chapman System)
C=120
FLOW REACH 1
-Two 102" DIA
(379 MGD)
FLOW REACH 2
-Three 114" DIA
(846 MGD)
FLOW REACH 3
-Three 114"
DIA (826 MGD)
FLOW REACH 4
-Three 108"
DIA (700 MGD)
FLOW REACH 5
-Two 120" DIA
(573 MGD)
FLOW REACH 6
-One 114" DIA
(253 MGD)
300 psi
250 psi
200 psi
BPS #1 Storage Reservoir
BPS #2 Storage Reservoir
BPS #3 Storage Reservoir
BPS #4 Storage Reservoir
TCP, 252.5
Bridgeport WSEL
825.5
Patman Intake LPS
US HWY 67
IH 30
Sulphur River
MN Tie-in/BPS #1
Potential Talco Tie-in
Potential PH2 Tie-in
South Sulphur River
Lake Chapman Split/BPS #2
Middle Sulphur River
South Sulphur River
NWTP Split
Wylie WTP Split/BPS #3
Sister Grove Creek
US HWY 75
East Fork Trinity River
Trinity River/Ray Roberts Split
BPS #4
US HWY 81/287
Lake Bridgeport, 11525+00
Elevation (ft)
1,600
1,400
1,200
1,000
800
600
400
200
0
Station (ft)
0+00
2000+00
4000+00
6000+00
8000+00
10000+00
12000+00
Main Pipeline Route

Figure C-5

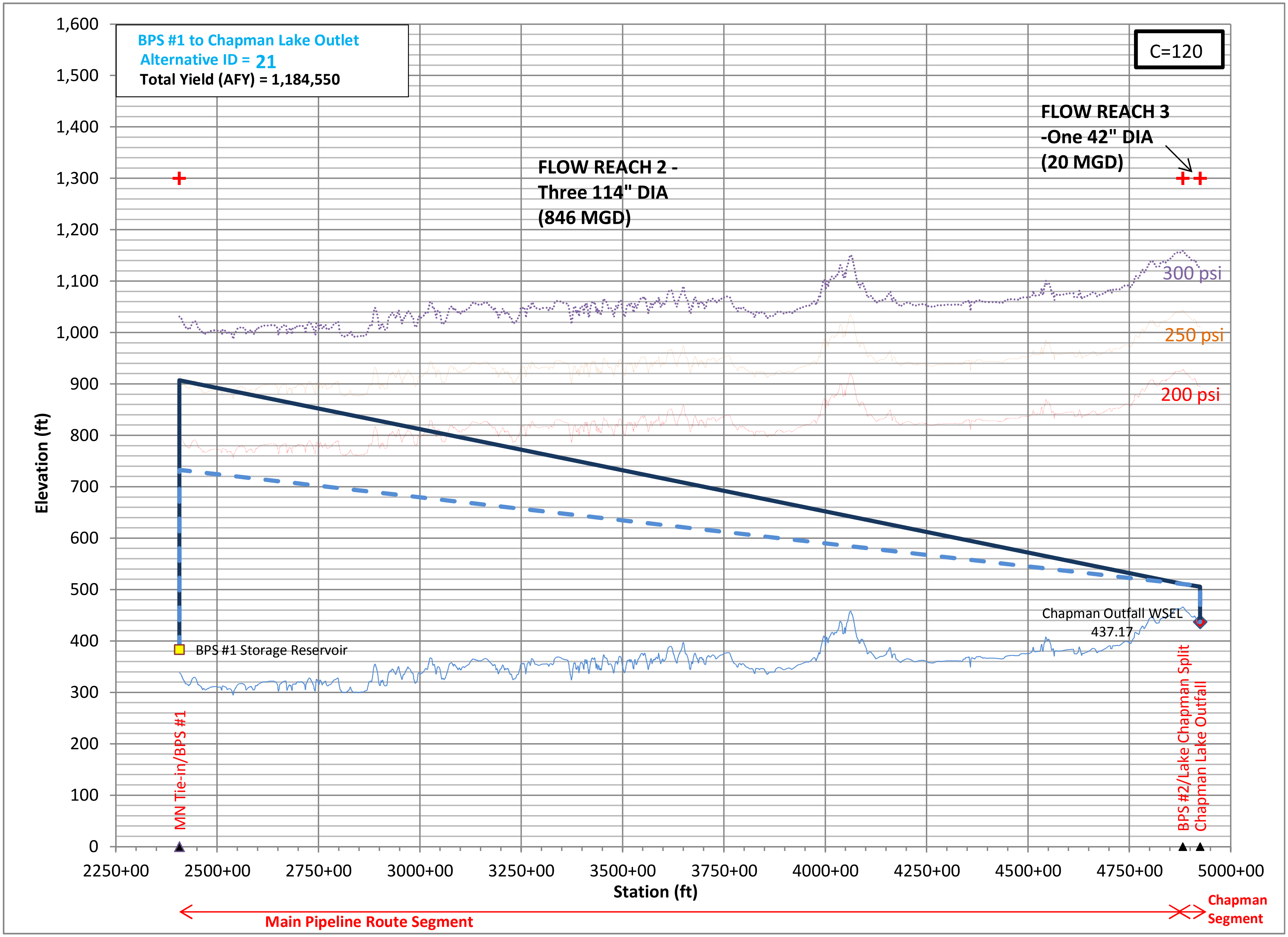
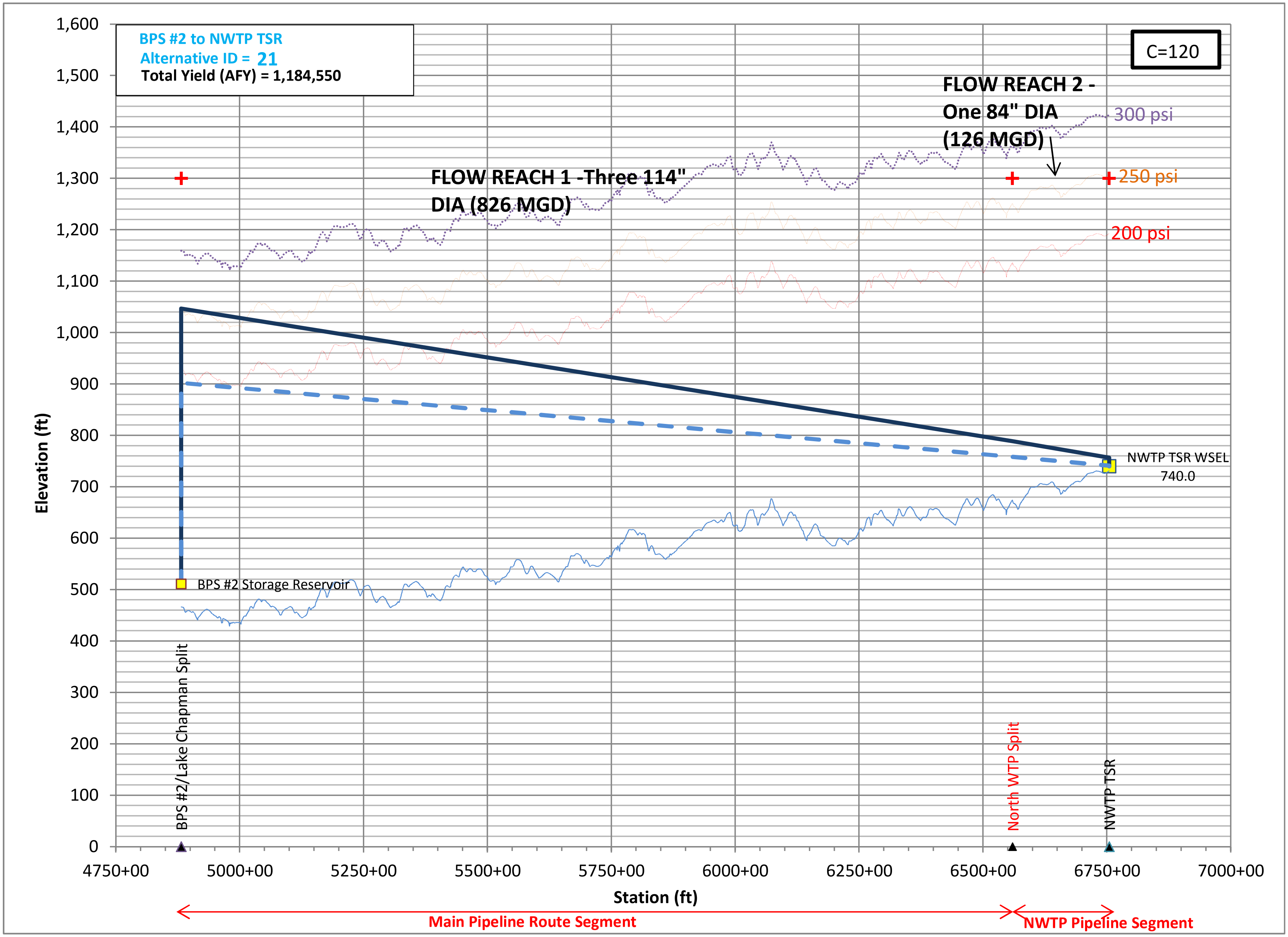

BPS #1 to Chapman Lake Outlet
Alternative ID = 21
Total Yield (AFY) = 1,184,550
C=120
FLOW REACH 2 -
Three 114" DIA
(846 MGD)
FLOW REACH 3
-One 42" DIA
(20 MGD)
300 psi
250 psi
200 psi
Chapman Outfall WSEL
437.17
BPS #1 Storage Reservoir
MN Tie-in/BPS #1
BPS #2/Lake Chapman Split
Chapman Lake Outfall
Elevation (ft)
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
2250+00
2500+00
2750+00
3000+00
3250+00
3500+00
3750+00
4000+00
4250+00
4500+00
4750+00
5000+00
Station (ft)
Main Pipeline Route Segment
Chapman Segment

Figure C-6



BPS #2 to NWTP TSR
Alternative ID = 21
Total Yield (AFY) = 1,184,550
C=120
FLOW REACH 1 -Three 114" DIA (826 MGD)
FLOW REACH 2 - One 84" DIA (126 MGD)
300 psi
250 psi
200 psi
NWTP TSR WSEL
740.0
BPS #2 Storage Reservoir
BPS #2/Lake Chapman Split
North WTP Split
NWTP TSR
Elevation (ft)
Station (ft)
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
4750+00
5000+00
5250+00
5500+00
5750+00
6000+00
6250+00
6500+00
6750+00
7000+00
Main Pipeline Route Segment
NWTP Pipeline Segment

Figure C-7

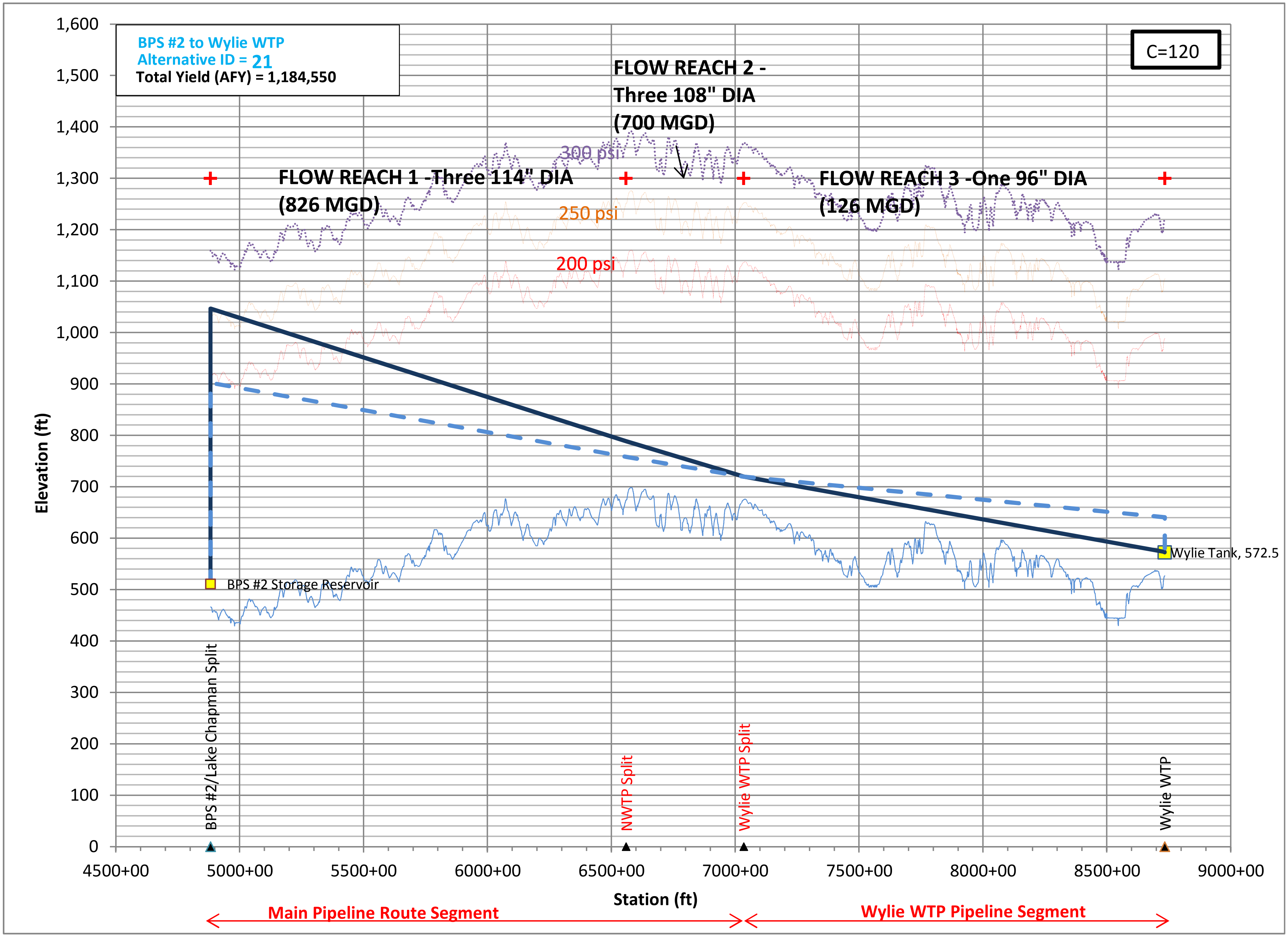
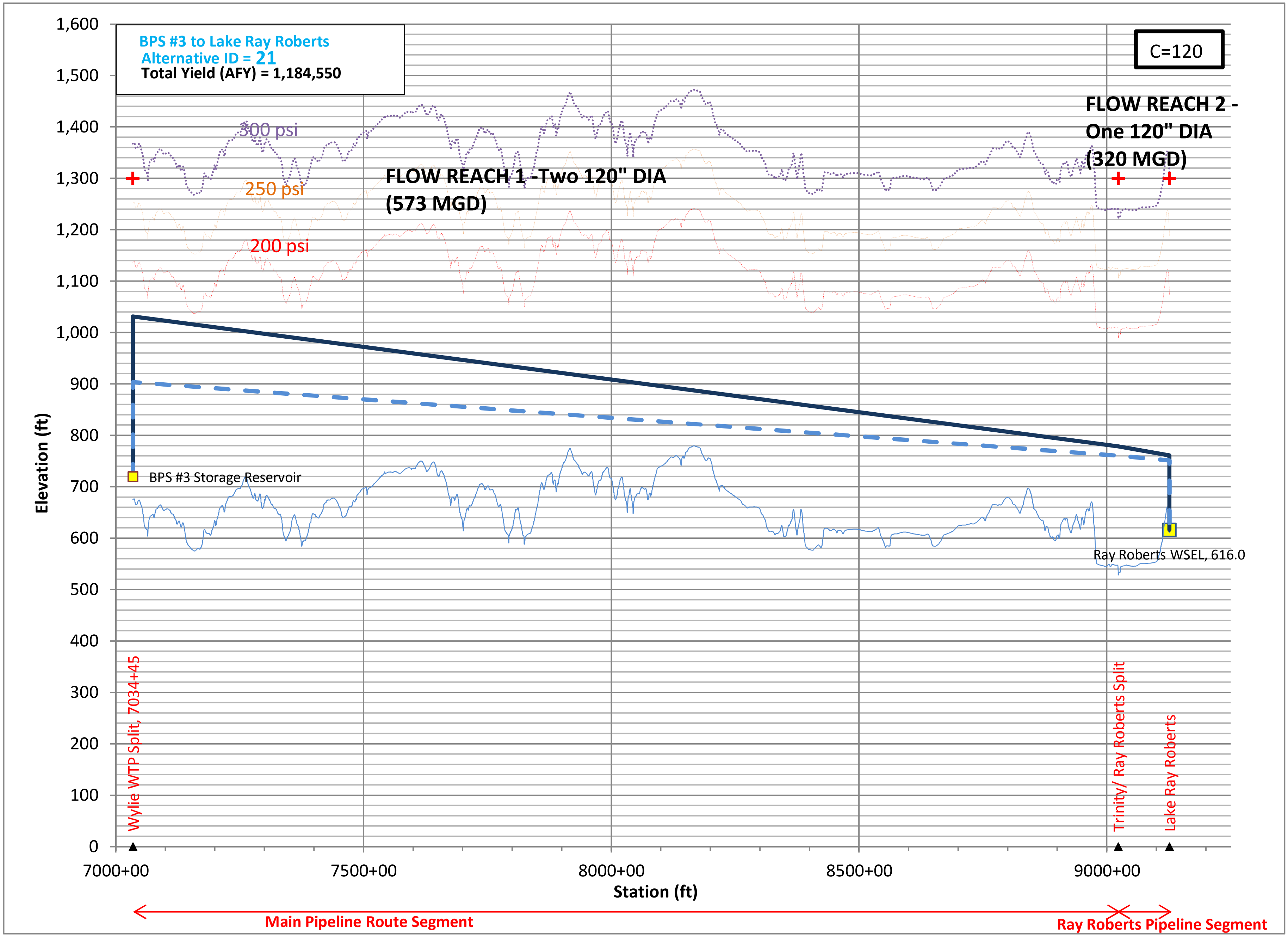
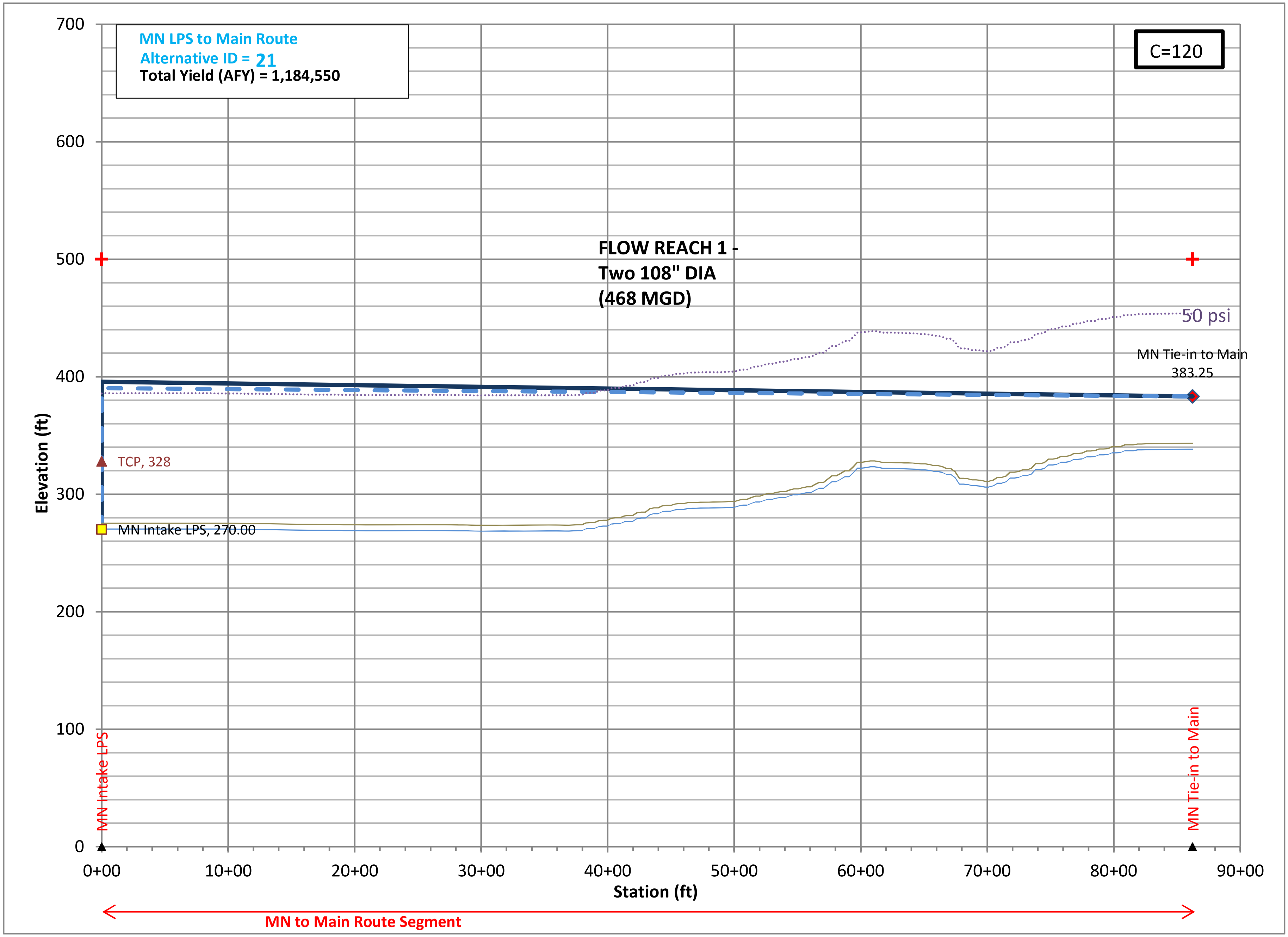

BPS #2 to Wylie WTP
Alternative ID = 21
Total Yield (AFY) = 1,184,550
C=120
FLOW REACH 1 - Three 114" DIA (826 MGD)
FLOW REACH 2 - Three 108" DIA (700 MGD)
FLOW REACH 3 - One 96" DIA (126 MGD)
300 psi
250 psi
200 psi
BPS #2 Storage Reservoir
Wylie Tank, 572.5
BPS #2/Lake Chapman Split
NWTP Split
Wylie WTP Split
Wylie WTP
Elevation (ft)
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
4500+00
5000+00
5500+00
6000+00
6500+00
7000+00
7500+00
8000+00
8500+00
9000+00
Station (ft)
Main Pipeline Route Segment
Wylie WTP Pipeline Segment

Figure C-8



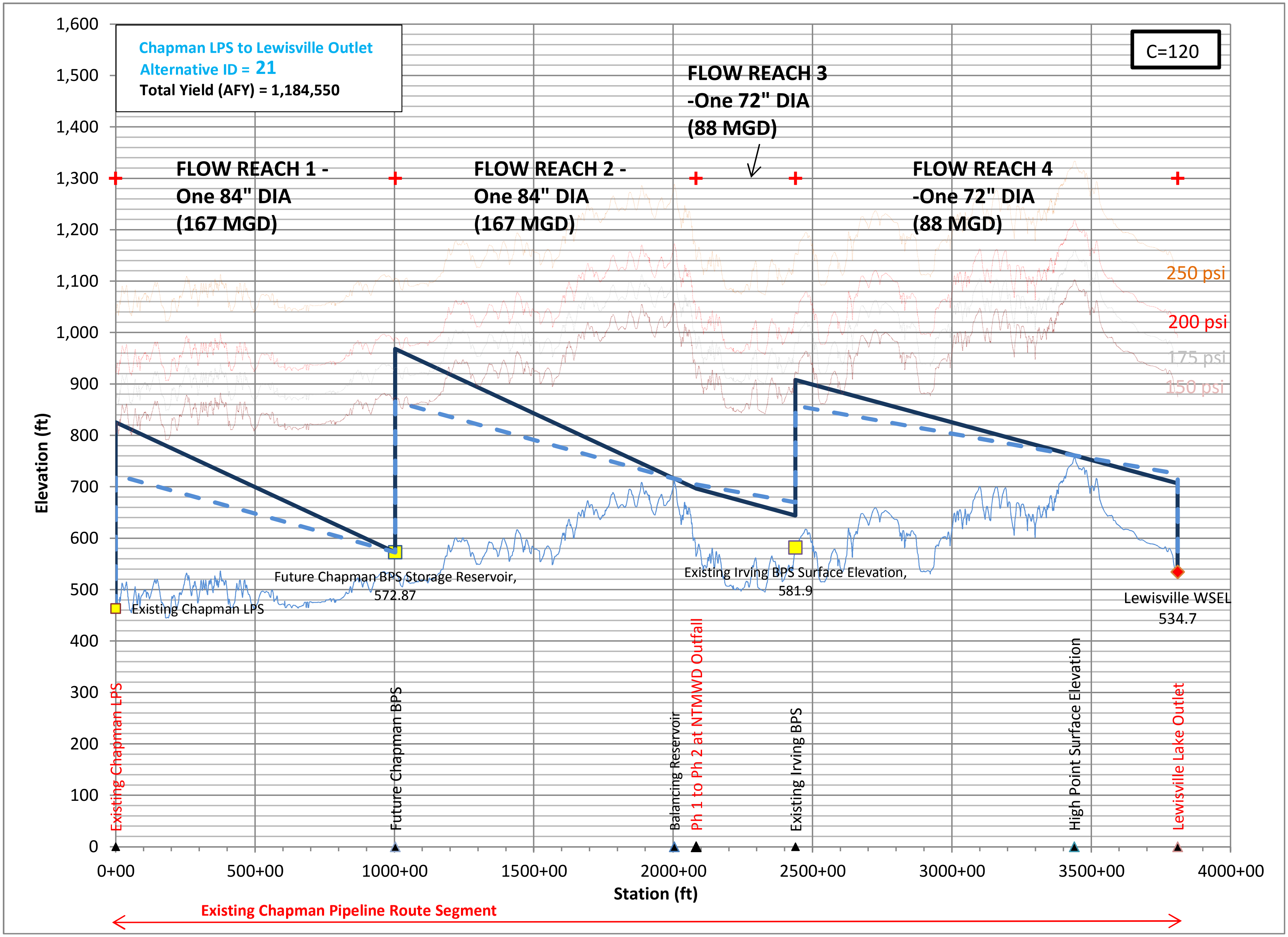
BPS #3 to Lake Ray Roberts
Alternative ID = 21
Total Yield (AFY) = 1,184,550
C=120
FLOW REACH 1 -Two 120" DIA (573 MGD)
FLOW REACH 2 - One 120" DIA (320 MGD)
300 psi
250 psi
200 psi
BPS #3 Storage Reservoir
Ray Roberts WSEL, 616.0
Wylie WTP Split, 7034+45
Trinity/ Ray Roberts Split
Lake Ray Roberts
Elevation (ft)
Station (ft)
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
7000+00
7500+00
8000+00
8500+00
9000+00
Main Pipeline Route Segment
Ray Roberts Pipeline Segment

Figure C-9



MN LPS to Main Route
Alternative ID = 21
Total Yield (AFY) = 1,184,550
C=120
FLOW REACH 1 -
Two 108" DIA
(468 MGD)
50 psi
MN Tie-in to Main
383.25
TCP, 328
MN Intake LPS, 270.00
Elevation (ft)
700
600
500
400
300
200
100
0
MN Intake LPS
MN Tie-in to Main
0+00
10+00
20+00
30+00
40+00
50+00
60+00
70+00
80+00
90+00
Station (ft)
MN to Main Route Segment

Figure C-10



Chapman LPS to Lewisville Outlet
Alternative ID = 21
Total Yield (AFY) = 1,184,550
C=120
FLOW REACH 1 - One 84" DIA (167 MGD)
FLOW REACH 2 - One 84" DIA (167 MGD)
FLOW REACH 3 -One 72" DIA (88 MGD)
FLOW REACH 4 -One 72" DIA (88 MGD)
250 psi
200 psi
175 psi
150 psi
Existing Chapman LPS
Future Chapman BPS Storage Reservoir, 572.87
Existing Irving BPS Surface Elevation, 581.9
Lewisville WSEL 534.7
Existing Chapman LPS
Future Chapman BPS
Balancing Reservoir
Ph 1 to Ph 2 at NTMWD Outfall
Existing Irving BPS
High Point Surface Elevation
Lewisville Lake Outlet
Elevation (ft)
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
0+00
500+00
1000+00
1500+00
2000+00
2500+00
3000+00
3500+00
4000+00
Station (ft)
Existing Chapman Pipeline Route Segment

Table C-7. Overall Transmission Cost Summary Results

SOURCE INFORMATION		YIELD SUMMARY	TRANSMISSION FIRST COSTS				TRANSMISSION ANNUAL COSTS				TRANSMISSION UNIT COSTS				Cost Rankings	
											Per Acre-ft		Per 1,000 Gallons		1 = Least Expensive	
Alternative ID	Alternative Description	Total Yield (AFY)	Pipelines (Before Interest)	Pump Station (Before Interest)	Total (Before Interest)	Total (After Interest)	Debt Service	O&M	Electricity	Total	During Debt Service	After Debt Service	During Debt Service	After Debt Service	During Debt Service	After Debt Service
1	Patman 232.5	281,000	$1,444,112,000	$385,793,000	$1,829,905,000	$2,272,138,000	$141,600,000	$21,468,000	$30,795,000	$193,863,000	$862	$232	$2.65	$0.71	60	60
2	Patman 242.5	592,700	$2,683,930,000	$630,200,000	$3,314,130,000	$4,115,056,000	$256,452,000	$38,112,000	$69,000,000	$363,564,000	$767	$226	$2.35	$0.69	58	59
3	Patman 252.5	854,400	$3,689,963,000	$791,961,000	$4,481,924,000	$5,565,071,000	$346,816,000	$50,854,000	$95,704,000	$493,374,000	$722	$214	$2.22	$0.66	51	56
4	MN296.5	200,000	$884,629,000	$260,241,000	$1,144,870,000	$1,421,551,000	$88,592,000	$13,622,000	$17,318,000	$119,532,000	$747	$193	$2.29	$0.59	57	30
5	MN313.5	400,000	$1,406,061,000	$377,798,000	$1,783,859,000	$2,214,964,000	$138,037,000	$20,983,000	$35,168,000	$194,188,000	$607	$175	$1.86	$0.54	14	20
6	MN328	590,000	$2,111,305,000	$473,979,000	$2,585,284,000	$3,210,070,000	$200,053,000	$29,497,000	$51,980,000	$281,530,000	$596	$173	$1.83	$0.53	12	15
7	Talco 350/config1	169,600	$701,704,000	$236,935,000	$938,639,000	$1,165,480,000	$72,633,000	$11,451,000	$14,046,000	$98,130,000	$723	$188	$2.22	$0.58	52	24
8	Talco 350/config2	217,100	$953,931,000	$323,263,000	$1,277,194,000	$1,585,855,000	$98,831,000	$15,651,000	$22,424,000	$136,906,000	$788	$219	$2.42	$0.67	59	58
9	Talco 370/config1	265,100	$950,422,000	$291,637,000	$1,242,059,000	$1,542,227,000	$96,113,000	$14,931,000	$22,208,000	$133,252,000	$628	$175	$1.93	$0.54	20	17
10	Talco 370/config2	382,800	$1,441,065,000	$443,196,000	$1,884,261,000	$2,339,632,000	$145,808,000	$22,745,000	$41,550,000	$210,103,000	$686	$210	$2.11	$0.64	36	54
11	PH1	124,300	$516,137,000	$183,493,000	$699,630,000	$868,710,000	$54,138,000	$8,592,000	$8,967,000	$71,697,000	$721	$177	$2.21	$0.54	50	22
12	PH2	124,200	$514,206,000	$182,052,000	$696,258,000	$864,523,000	$53,876,000	$8,543,000	$8,857,000	$71,276,000	$717	$175	$2.20	$0.54	47	18
13	Patman 232.5/MN296.5	446,200	$1,708,483,000	$507,792,000	$2,216,275,000	$2,751,882,000	$171,498,000	$26,571,000	$45,014,000	$243,083,000	$681	$201	$2.09	$0.62	32	38
14	Patman 242.5/MN296.5	625,200	$2,540,049,000	$632,113,000	$3,172,162,000	$3,938,778,000	$245,466,000	$36,863,000	$64,739,000	$347,068,000	$694	$203	$2.13	$0.62	39	44
15	Patman 252.5/MN296.5	872,000	$3,520,313,000	$809,612,000	$4,329,925,000	$5,376,338,000	$335,056,000	$49,689,000	$93,282,000	$478,027,000	$685	$205	$2.10	$0.63	35	46
16	Patman 232.5/MN313.5	627,950	$2,451,827,000	$602,635,000	$3,054,462,000	$3,792,634,000	$236,359,000	$35,404,000	$59,090,000	$330,853,000	$659	$188	$2.02	$0.58	27	25
17	Patman 242.5/MN313.5	804,950	$3,090,144,000	$736,476,000	$3,826,620,000	$4,751,399,000	$296,109,000	$44,169,000	$80,554,000	$420,832,000	$654	$194	$2.01	$0.59	25	31
18	Patman 252.5/MN313.5	999,650	$4,040,159,000	$873,719,000	$4,913,878,000	$6,101,415,000	$380,242,000	$55,796,000	$102,341,000	$538,379,000	$673	$198	$2.07	$0.61	30	36
19	Patman 232.5/MN328	806,600	$2,951,005,000	$709,910,000	$3,660,915,000	$4,545,648,000	$283,286,000	$42,311,000	$76,637,000	$402,234,000	$623	$184	$1.91	$0.57	18	23
20	Patman 242.5/MN328	990,500	$3,683,014,000	$855,931,000	$4,538,945,000	$5,635,872,000	$351,229,000	$52,164,000	$99,888,000	$503,281,000	$635	$192	$1.95	$0.59	22	27
21	Patman 252.5/MN328	1,184,550	$4,451,346,000	$986,600,000	$5,437,946,000	$6,752,134,000	$420,795,000	$62,037,000	$120,369,000	$603,201,000	$637	$192	$1.95	$0.59	23	28
22	Patman 232.5/PH1	395,140	$1,659,839,000	$473,374,000	$2,133,213,000	$2,648,747,000	$165,072,000	$25,367,000	$38,706,000	$229,145,000	$725	$203	$2.22	$0.62	53	42
23	Patman 242.5/PH1	687,540	$3,015,712,000	$681,479,000	$3,697,191,000	$4,590,691,000	$286,094,000	$42,247,000	$72,292,000	$400,633,000	$728	$208	$2.24	$0.64	54	53
24	Patman 252.5/PH1	943,630	$4,068,623,000	$834,463,000	$4,903,086,000	$6,088,015,000	$379,408,000	$55,214,000	$98,019,000	$532,641,000	$706	$203	$2.17	$0.62	44	43
25	Patman 232.5/PH2	400,300	$1,664,073,000	$468,842,000	$2,132,915,000	$2,648,377,000	$165,048,000	$25,306,000	$38,680,000	$229,034,000	$715	$200	$2.19	$0.61	45	37
26	Patman 242.5/PH2	658,750	$2,861,955,000	$641,217,000	$3,503,172,000	$4,349,784,000	$271,081,000	$39,978,000	$66,447,000	$377,506,000	$716	$202	$2.20	$0.62	46	41
27	Patman 252.5/PH2	903,400	$3,664,098,000	$832,286,000	$4,496,384,000	$5,583,025,000	$347,936,000	$51,500,000	$96,705,000	$496,141,000	$686	$205	$2.11	$0.63	37	47
28	Patman 232.5/Talco350-config1	447,010	$1,785,522,000	$509,193,000	$2,294,715,000	$2,849,279,000	$177,569,000	$27,305,000	$44,889,000	$249,763,000	$698	$202	$2.14	$0.62	40	39
29	Patman 242.5/Talco350-config1	713,240	$3,088,501,000	$691,234,000	$3,779,735,000	$4,693,184,000	$292,481,000	$43,129,000	$74,309,000	$409,919,000	$718	$206	$2.20	$0.63	48	48
30	Patman 252.5/Talco350-config1	943,670	$3,998,537,000	$848,690,000	$4,847,227,000	$6,018,656,000	$375,085,000	$54,876,000	$99,678,000	$529,639,000	$702	$205	$2.15	$0.63	43	45
31	Patman 232.5/Talco350-config2	497,550	$2,111,056,000	$596,229,000	$2,707,285,000	$3,361,555,000	$209,493,000	$32,156,000	$54,340,000	$295,989,000	$744	$217	$2.28	$0.67	56	57
32	Patman 242.5/Talco350-config2	721,750	$3,164,577,000	$741,259,000	$3,905,836,000	$4,849,758,000	$302,238,000	$44,923,000	$77,813,000	$424,974,000	$736	$213	$2.26	$0.65	55	55
33	Patman 252.5/Talco350-config2	941,650	$4,115,661,000	$875,469,000	$4,991,130,000	$6,197,335,000	$386,219,000	$56,531,000	$99,565,000	$542,315,000	$720	$207	$2.21	$0.64	49	50
34	Patman 232.5/Talco370-config1	536,900	$2,164,669,000	$549,945,000	$2,714,614,000	$3,370,655,000	$210,061,000	$31,633,000	$51,728,000	$293,422,000	$683	$194	$2.10	$0.60	33	32
35	Patman 242.5/Talco370-config1	803,130	$3,318,570,000	$728,972,000	$4,047,542,000	$5,025,711,000	$313,203,000	$46,067,000	$80,718,000	$439,988,000	$685	$197	$2.10	$0.61	34	35
36	Patman 252.5/Talco370-config1	1,033,560	$4,148,245,000	$909,154,000	$5,057,399,000	$6,279,621,000	$391,348,000	$57,577,000	$109,365,000	$558,290,000	$675	$202	$2.07	$0.62	31	40
37	Patman 232.5/Talco370-config2	653,830	$2,638,112,000	$684,664,000	$3,322,776,000	$4,125,790,000	$257,120,000	$38,913,000	$69,873,000	$365,906,000	$700	$208	$2.15	$0.64	41	51
38	Patman 242.5/Talco370-config2	869,430	$3,598,108,000	$834,566,000	$4,432,674,000	$5,503,918,000	$343,006,000	$50,936,000	$93,824,000	$487,766,000	$701	$208	$2.15	$0.64	42	52
39	Patman 252.5/Talco370-config2	1,079,130	$4,443,529,000	$973,481,000	$5,417,010,000	$6,726,138,000	$419,175,000	$61,684,000	$116,291,000	$597,150,000	$692	$206	$2.12	$0.63	38	49
40	MN296.5/Talco350-config1	365,460	$1,286,216,000	$389,661,000	$1,675,877,000	$2,080,886,000	$129,682,000	$20,148,000	$31,220,000	$181,050,000	$619	$176	$1.90	$0.54	17	21
41	MN313.5/Talco350-config1	566,820	$1,970,990,000	$495,524,000	$2,466,514,000	$3,062,596,000	$190,863,000	$28,701,000	$49,362,000	$268,926,000	$593	$172	$1.82	$0.53	10	14
42	MN328/Talco350-config1	751,620	$2,557,863,000	$597,798,000	$3,155,661,000	$3,918,290,000	$244,190,000	$36,286,000	$66,572,000	$347,048,000	$577	$171	$1.77	$0.52	6	12
43	MN296.5/Talco370-config1	460,350	$1,580,021,000	$435,965,000	$2,015,986,000	$2,503,189,000	$155,999,000	$23,836,000	$39,107,000	$218,942,000	$594	$171	$1.82	$0.52	11	11
44	MN313.5/Talco370-config1	661,710	$2,164,882,000	$543,042,000	$2,707,924,000	$3,362,348,000	$209,542,000	$31,519,000	$57,442,000	$298,503,000	$564	$168	$1.73	$0.52	3	6
45	MN328/Talco370-config1	846,510	$2,790,490,000	$641,844,000	$3,432,334,000	$4,261,826,000	$265,599,000	$39,384,000	$74,490,000	$379,473,000	$560	$168	$1.72	$0.52	1	7
46	MN296.5/PH1	314,500	$1,127,937,000	$352,792,000	$1,480,729,000	$1,838,577,000	$114,581,000	$17,884,000	$26,039,000	$158,504,000	$630	$175	$1.93	$0.54	21	16
47	MN313.5/PH1	502,890	$1,719,890,000	$456,290,000	$2,176,180,000	$2,702,097,000	$168,396,000	$25,551,000	$43,376,000	$237,323,000	$590	$171	$1.81	$0.53	9	13
48	MN328/PH1	681,410	$2,379,011,000	$550,936,000	$2,929,947,000	$3,638,027,000	$226,723,000	$33,613,000	$59,501,000	$319,837,000	$587	$171	$1.80	$0.52	8	10
49	MN296.5/PH2	310,650	$1,096,087,000	$350,974,000	$1,447,061,000	$1,796,772,000	$111,976,000	$17,552,000	$25,975,000	$155,503,000	$626	$175	$1.92	$0.54	19	19
50	MN313.5/PH2	465,930	$1,525,307,000	$436,028,000	$1,961,335,000	$2,435,331,000	$151,770,000	$23,345,000	$39,962,000	$215,077,000	$577	$170	$1.77	$0.52	5	9
51	MN328/PH2	644,960	$2,234,463,000	$515,120,000	$2,749,583,000	$3,414,075,000	$212,767,000	$31,524,000	$53,922,000	$298,213,000	$578	$166	$1.77	$0.51	7	4
52	Talco350-config1/PH1	292,750	$998,183,000	$336,283,000	$1,334,466,000	$1,656,966,000	$103,263,000	$16,347,000	$23,390,000	$143,000,000	$611	$170	$1.87	$0.52	16	8
53	Talco350-config2/PH1	337,170	$1,228,895,000	$417,315,000	$1,646,210,000	$2,044,050,000	$127,386,000	$20,236,000	$31,297,000	$178,919,000	$663	$191	$2.04	$0.59	28	26
54	Talco370-config1/PH1	386,680	$1,210,513,000	$386,575,000	$1,597,088,000	$1,983,057,000	$123,586,000	$19,398,000	$31,695,000	$174,679,000	$565	$165	$1.73	$0.51	4	3
55	Talco370-config2/PH1	486,980	$1,790,734,000	$516,897,000	$2,307,631,000	$2,865,316,000	$178,568,000	$27,535,000	$48,989,000	$255,092,000	$655	$196	$2.01	$0.60	26	34
56	Talco350-config1/PH2	292,660	$991,149,000	$331,349,000	$1,322,498,000	$1,642,106,000	$102,337,000	$16,174,000	$23,013,000	$141,524,000	$604	$167	$1.86	$0.51	13	5
57	Talco350-config2/PH2	322,330	$1,163,603,000	$408,744,000	$1,572,347,000	$1,952,336,000	$121,670,000	$19,450,000	$30,352,000	$171,472,000	$665	$193	$2.04	$0.59	29	29
58	Talco370-config1/PH2	384,890	$1,201,047,000	$381,193,000	$1,582,240,000	$1,964,620,000	$122,436,000	$19,192,000	$31,022,000	$172,650,000	$561	$163	$1.72	$0.50	2	2
59	Talco370-config2/PH2	462,180	$1,644,327,000	$501,140,000	$2,145,467,000	$2,663,963,000	$166,020,000	$25,868,000	$46,422,000	$238,310,000	$645	$196	$1.98	$0.60	24	33
60	PH1/PH2	236,410	$805,586,000	$286,302,000	$1,091,888,000	$1,355,765,000	$84,492,000	$13,500,000	$17,259,000	$115,251,000	$609	$163	$1.87	$0.50	15	1

Red Highlight = Cases that require 3 parallel pipelines for a portion of the main route

- **Talco Config2 pumps water from the Sulphur River to supply the reservoir. This alternative would divert MN supply and therefore cannot be in combination with MN.**
- **Cases where Metroplex JCPD Owners Yield > 1000 CFS require three pipelines for a portion of the main route. All Talco370 Config2 cases require 4 pipelines from the diversion pump station at the Sulphur River to Talco Reservoir**
- **Before and after interest specified in the transmission first costs refers to the interest accrued during the project construction period**

Attachment C-1

Example Cost Model Output Summary
(ID 21 – Patman 252.5/MN 328)

Sulphur River Basin Reservoir and Transmission System Alternatives
North Texas MWD, Tarrant Regional WD, Dallas Water Utilities, Irving, Upper Trinity RWD, Local Users

Source Information	
Source(s) =	Patman, Marvin Nichols
Alternative ID =	21

Total Yield (AFY) =	**1,184,550**
Total Yield (MGD) =	**1,058**

	TRWD	DWU	NTMWD	UTRWD	Irving	Local Users
Distribution Location	Bridgeport	Trinity/Ray Roberts	NWTP & Wylie WTP	Trinity/Ray Roberts	Trinity/Ray Roberts	Unknown
Peaking Factor	1.25	1.5	1.4	1.25	1.25	1.25
% of Total Yield	23.9%	23.4%	23.9%	4.8%	4.0%	20.0%
Yield (ac-ft/yr)	283,316	276,682	283,316	56,944	47,382	236,910

Cost Variables

Debt Service (%) =	5.5
Debt Payment Period (Years) =	40
Electric Cost (per kWh) =	$0.07
Pipeline Engineering and Contingencies (%) =	30
Pump Station Engineering and Contingencies (%) =	35

****All Values in This Blue Color Must be Input/Defined****

CONSTRUCTION COSTS

TRANSMISSION FACILITIES*

Pipeline Segment 1 Patman Intake LPS to BPS #1/MN Tie-in

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - Patman Intake LPS to BPS #1/MN Tie-in	2	102 in	523,888	LF	$946	$495,598,000
Pipeline Urban - Patman Intake LPS to BPS #1/MN Tie-in	2	102 in	5,595	LF	$1,325	$7,413,000
Right of Way Easements Rural (ROW)			261,944	LF	$26	$6,806,000
Right of Way Easements Urban (ROW)			2,797	LF	$156	$436,000
Engineering and Contingencies (30%)						$150,903,000
Permitting & Mitigation						$6,036,000
Subtotal of Pipeline (Patman Intake LPS to BPS #1/MN Tie-in)						**$667,192,000**

Owners' Portions of Pipeline Segment 1

TRWD	27.32%	$182,286,199
NTMWD	30.60%	$204,160,543
DWU	32.02%	$213,621,841
UTRWD	5.49%	$36,637,715
Irving	4.57%	$30,485,701
Total Check	100.00%	$667,192,000

Pipeline Segment 2 BPS #1/MN Tie-in to Lake Chapman Split/BPS #2

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - BPS #1/MN Tie-in to Lake Chapman	3	114 in	797,709	LF	$1,145	$913,377,000
Pipeline Urban - BPS #1/MN Tie-in to Lake Chapman	3	114 in	19,120	LF	$1,603	$30,640,000
Right of Way Easements Rural (ROW)			265,903	LF	$38	$10,213,000
Right of Way Easements Urban (ROW)			6,373	LF	$234	$1,490,000
Engineering and Contingencies (30%)						$283,205,000
Permitting & Mitigation						$11,328,000
Subtotal of Pipeline (BPS #1/MN Tie-in to Lake Chapman Split/BPS #2)						**$1,250,253,000**

Owners' Portions of Pipeline Segment 2

TRWD	27.32%	$341,586,631
NTMWD	30.60%	$382,577,027
DWU	32.02%	$400,306,581
UTRWD	5.49%	$68,655,519
Irving	4.57%	$57,127,242
Total Check	100.00%	$1,250,253,000

Pipeline Segment 3 BPS #2/Lake Chapman Split to North WTP Split

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - BPS #2/Lake Chapman Split to North WTP	3	114 in	538,867	LF	$1,145	$617,003,000
Pipeline Urban - BPS #2/Lake Chapman Split to North WTP	3	114 in	14,705	LF	$1,603	$23,564,000
Right of Way Easements Rural (ROW)			179,622	LF	$38	$6,899,000
Right of Way Easements Urban (ROW)			4,902	LF	$234	$1,146,000
Engineering and Contingencies (30%)						$192,170,000
Permitting & Mitigation						$7,687,000
Subtotal of Pipeline (BPS #2/Lake Chapman Split to North WTP Split)						**$848,469,000**

Owners' Portions of Pipeline Segment 3

TRWD	27.92%	$236,931,647
NTMWD	31.28%	$265,363,445
DWU	32.72%	$277,661,035
UTRWD	5.61%	$47,620,907
Irving	2.46%	$20,891,965
Total Check	100.00%	$848,469,000

Pipeline Segment 4 North WTP Split to Wylie WTP Spilt/BPS #3

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - North WTP Split to Wylie WTP Spilt/BPS #3	3	108 in	156,742	LF	$1,041	$163,169,000
Pipeline Urban - North WTP Split to Wylie WTP Spilt/BPS	3	108 in	0	LF	$1,458	$0
Right of Way Easements Rural (ROW)			52,247	LF	$38	$2,007,000
Right of Way Easements Urban (ROW)			0	LF	$234	$0
Engineering and Contingencies (30%)						$48,951,000
Permitting & Mitigation						$1,958,000
Subtotal of Pipeline (North WTP Split to Wylie WTP Spilt/BPS #3)						**$216,085,000**

Owners' Portions of Pipeline Segment 4

TRWD	33.10%	$71,525,964
NTMWD	18.54%	$40,054,540
DWU	38.79%	$83,821,530
UTRWD	6.65%	$14,376,008
Irving	2.92%	$6,306,958
Total Check	100.00%	$216,085,000

Pipeline Segment 5 BPS #3/Wylie WTP Split to Trinity River/Ray Roberts Split

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - BPS #3/Wylie WTP Split to Trinity	2	120 in	424,348	LF	$1,260	$534,678,000
Pipeline Urban - BPS #3/Wylie WTP Split to Trinity	2	120 in	13,200	LF	$1,764	$23,278,000
Right of Way Easements Rural (ROW)			212,174	LF	$26	$5,513,000
Right of Way Easements Urban (ROW)			6,600	LF	$156	$1,029,000
Engineering and Contingencies (30%)						$167,387,000
Permitting & Mitigation						$6,695,000
Subtotal of Pipeline (BPS #3/Wylie WTP Split to Trinity River/Ray Roberts Split)						**$738,580,000**

Owners' Portions of Pipeline Segment 5

TRWD	40.63%	$300,105,143
NTMWD	0.00%	$0
DWU	47.62%	$351,694,279
UTRWD	8.17%	$60,318,153
Irving	3.58%	$26,462,425
Total Check	100.00%	$738,580,000

Pipeline Segment 6 Trinity River/Ray Roberts Split to BPS #4

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - Trinity River/Ray Roberts Split to BPS #4	1	114 in	50,277	LF	$1,145	$57,567,000
Pipeline Urban - Trinity River/Ray Roberts Split to BPS #4	1	114 in	3,850	LF	$1,603	$6,170,000
Right of Way Easements Rural (ROW)			50,277	LF	$16	$795,000
Right of Way Easements Urban (ROW)			3,850	LF	$94	$361,000
Engineering and Contingencies (30%)						$19,121,000
Permitting & Mitigation						$765,000
Subtotal of Pipeline (Trinity River/Ray Roberts Split to BPS #4)						**$84,779,000**

Owners' Portions of Pipeline Segment 6

TRWD	100.00%	$84,779,000
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	100.00%	$84,779,000

Pipeline Segment 7 BPS #4 to Lake Bridgeport

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - BPS #4 to Lake Bridgeport	1	114 in	218,860	LF	$1,145	$250,595,000
Pipeline Urban - BPS #4 to Lake Bridgeport	1	114 in	2,200	LF	$1,603	$3,526,000
Right of Way Easements Rural (ROW)			218,860	LF	$16	$3,461,000
Right of Way Easements Urban (ROW)			2,200	LF	$94	$206,000
Engineering and Contingencies (30%)						$76,236,000
Permitting & Mitigation						$3,049,000
Subtotal of Pipeline (BPS #4 to Lake Bridgeport)						**$337,073,000**

Owners' Portions of Pipeline Segment 7

TRWD	100.00%	$337,073,000
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	100.00%	$337,073,000

Pipeline Segment 8 North WTP Split to NWTP TSR

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - North WTP Split to NWTP TSR	1	84 in	21,494	LF	$628	$13,498,000
Pipeline Urban - North WTP Split to NWTP TSR	1	84 in	0	LF	$879	$0
Right of Way Easements Rural (ROW)			21,494	LF	$16	$340,000
Right of Way Easements Urban (ROW)			0	LF	$94	$0
Engineering and Contingencies (30%)						$4,049,000
Permitting & Mitigation						$162,000
Subtotal of Pipeline (North WTP Split to NWTP TSR)						**$18,049,000**

Owners' Portions of Pipeline Segment 8		
TRWD	0.00%	$0
NTMWD	100.00%	$18,049,000
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	100.00%	$18,049,000

Pipeline Segment 9 Wylie WTP Spilt/BPS #3 to Wylie WTP

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - Wylie WTP Spilt/BPS #3 to Wylie WTP	1	96 in	181,454	LF	$845	$153,328,000
Pipeline Urban - Wylie WTP Spilt/BPS #3 to Wylie WTP	1	96 in	5,500	LF	$1,183	$6,507,000
Right of Way Easements Rural (ROW)			181,454	LF	$16	$2,870,000
Right of Way Easements Urban (ROW)			5,500	LF	$94	$516,000
Engineering and Contingencies (30%)						$47,951,000
Permitting & Mitigation						$1,918,000
Subtotal of Pipeline (Wylie WTP Spilt/BPS #3 to Wylie WTP)						**$213,090,000**

Owners' Portions of Pipeline Segment 9		
TRWD	0.00%	$0
NTMWD	100.00%	$213,090,000
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	100.00%	$213,090,000

Pipeline Segment 10 Trinity River/Ray Roberts Split to Lake Ray Roberts

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - Trinity River/Ray Roberts Split to Lake Ray	1	120 in	11,323	LF	$1,260	$14,267,000
Pipeline Urban - Trinity River/Ray Roberts Split to Lake Ray	1	120 in	0	LF	$1,764	$0
Right of Way Easements Rural (ROW)			11,323	LF	$16	$179,000
Right of Way Easements Urban (ROW)			0	LF	$94	$0
Engineering and Contingencies (30%)						$4,280,000
Permitting & Mitigation						$171,000
Subtotal of Pipeline (Trinity River/Ray Roberts Split to Lake Ray Roberts)						**$18,897,000**

Owners' Portions of Pipeline Segment 10

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	80.21%	$15,157,008
UTRWD	13.76%	$2,599,538
Irving	6.04%	$1,140,454
Total Check	100.00%	$18,897,000

Pipeline Segment 11 BPS #2/Lake Chapman Split to Chapman Lake Outfall

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - BPS #2/Lake Chapman Split to Chapman	1	42 in	4,701	LF	$224	$1,051,000
Pipeline Urban - BPS #2/Lake Chapman Split to Chapman	1	42 in	0	LF	$313	$0
Right of Way Easements Rural (ROW)			4,701	LF	$16	$74,000
Right of Way Easements Urban (ROW)			0	LF	$94	$0
Engineering and Contingencies (30%)						$315,000
Permitting & Mitigation						$13,000
Subtotal of Pipeline (BPS #2/Lake Chapman Split to Chapman Lake Outfall)						**$1,453,000**

Owners' Portions of Pipeline Segment 11		
TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	100.00%	$1,453,000
Total Check	100.00%	$1,453,000

Pipeline Segment 12 MN Intake LPS to MN Tie-in to Main

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - MN Intake LPS to MN Tie-in to Main	2	108 in	18,971	LF	$1,041	$19,748,000
Pipeline Urban - MN Intake LPS to MN Tie-in to Main	2	108 in	0	LF	$1,458	$0
Right of Way Easements Rural (ROW)			9,485	LF	$26	$246,000
Right of Way Easements Urban (ROW)			0	LF	$156	$0
Engineering and Contingencies (30%)						$5,924,000
Permitting & Mitigation						$237,000
Subtotal of Pipeline (MN Intake LPS to MN Tie-in to Main)						**$26,155,000**

Owners' Portions of Pipeline Segment 12		
TRWD	27.32%	$7,145,912
NTMWD	30.60%	$8,003,422
DWU	32.02%	$8,374,320
UTRWD	5.49%	$1,436,257
Irving	4.57%	$1,195,089
Total Check	100.00%	$26,155,000

Potential Segment 13 NA to NA

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - NA to NA	-	-	0	LF	#N/A	$0
Pipeline Urban - NA to NA	-	-	0	LF	#N/A	$0
Right of Way Easements Rural (ROW)			0	LF	$0	$0
Right of Way Easements Urban (ROW)			0	LF	$0	$0
Engineering and Contingencies (30%)						$0
Permitting & Mitigation						$0
Subtotal of Pipeline (NA to NA)						**$0**

Owners' Portions of Potential Segment 13

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	0.00%	$0

Potential Segment 14 NA to NA

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - NA to NA	-	-	0	LF	#N/A	$0
Pipeline Urban - NA to NA	-	-	0	LF	#N/A	$0
Right of Way Easements Rural (ROW)			0	LF	$0	$0
Right of Way Easements Urban (ROW)			0	LF	$0	$0
Engineering and Contingencies (30%)						$0
Permitting & Mitigation						$0
Subtotal of Pipeline (NA to NA)						**$0**

Owners' Portions of Potential Segment 14

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	0.00%	$0

Potential Segment 15 NA to NA

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - NA to NA	-	-	0	LF	#N/A	$0
Pipeline Urban - NA to NA	-	-	0	LF	#N/A	$0
Right of Way Easements Rural (ROW)			0	LF	$0	$0
Right of Way Easements Urban (ROW)			0	LF	$0	$0
Engineering and Contingencies (30%)						$0
Permitting & Mitigation						$0
Subtotal of Pipeline (NA to NA)						**$0**

Owners' Portions of Potential Segment 15

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	0.00%	$0

Potential Segment 16 NA to NA

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - NA to NA	-	-	0	LF	#N/A	$0
Pipeline Urban - NA to NA	-	-	0	LF	#N/A	$0
Right of Way Easements Rural (ROW)			0	LF	$0	$0
Right of Way Easements Urban (ROW)			0	LF	$0	$0
Engineering and Contingencies (30%)						$0
Permitting & Mitigation						$0
Subtotal of Pipeline (NA to NA)						**$0**

Owners' Portions of Potential Segment 16

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	0.00%	$0

Potential Segment 17 NA to NA

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - NA to NA	-	-	0	LF	#N/A	$0
Pipeline Urban - NA to NA	-	-	0	LF	#N/A	$0
Right of Way Easements Rural (ROW)			0	LF	$0	$0
Right of Way Easements Urban (ROW)			0	LF	$0	$0
Engineering and Contingencies (30%)						$0
Permitting & Mitigation						$0
Subtotal of Pipeline (NA to NA)						**$0**

Owners' Portions of Potential Segment 17

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	0.00%	$0

Potential Segment 18 NA to NA

	# of Pipelines	Size	Quantity	Unit	Unit Price	Cost
Pipeline Rural - NA to NA	-	-	0	LF	#N/A	$0
Pipeline Urban - NA to NA	-	-	0	LF	#N/A	$0
Right of Way Easements Rural (ROW)			0	LF	$0	$0
Right of Way Easements Urban (ROW)			0	LF	$0	$0
Engineering and Contingencies (30%)						$0
Permitting & Mitigation						$0
Subtotal of Pipeline (NA to NA)						**$0**

Owners' Portions of Potential Segment 18

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	0.00%	$0

Discharge Structure 1 Chapman Lake Outfall

		Size (MGD)	Quantity	Unit	Unit Price	Cost
Discharge Structure - Chapman Lake Outfall		25	1	LS	$118,000	$118,000
Engineering and Contingencies (30%)						$35,000
Permitting & Mitigation						$1,000
Subtotal of Discharge Structure (Chapman Lake Outfall)						**$154,000**
Owners' Portions of Discharge Structure 1						
TRWD	0.00%					$0
NTMWD	0.00%					$0
DWU	0.00%					$0
UTRWD	0.00%					$0
Irving	100.00%					$154,000
Total Check	100.00%					$154,000

Discharge Structure 2 NWTP TSR

		Size (MGD)	Quantity	Unit	Unit Price	Cost
Discharge Structure - NWTP TSR		176	1	LS	$2,885,000	$2,885,000
Engineering and Contingencies (30%)						$866,000
Permitting & Mitigation						$35,000
Subtotal of Discharge Structure (NWTP TSR)						**$3,786,000**
Owners' Portions of Discharge Structure 2						
TRWD	0.00%					$0
NTMWD	100.00%					$3,786,000
DWU	0.00%					$0
UTRWD	0.00%					$0
Irving	0.00%					$0
Total Check	100.00%					$3,786,000

Discharge Structure 3 Wylie WTP

	Size (MGD)	Quantity	Unit	Unit Price	Cost
Discharge Structure - Wylie WTP	176	1	LS	$2,885,000	$2,885,000
Engineering and Contingencies (30%)					$866,000
Permitting & Mitigation					$35,000
Subtotal of Discharge Structure (Wylie WTP)					**$3,786,000**

Owners' Portions of Discharge Structure 3

TRWD	0.00%	$0
NTMWD	100.00%	$3,786,000
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	100.00%	$3,786,000

Discharge Structure 4,5 Trinity River/Ray Roberts

	Size (MGD)	Quantity	Unit	Unit Price	Cost
Discharge Structure - Trinity River/Ray Roberts	462	2	LS	$6,795,000	$13,590,000
Engineering and Contingencies (30%)					$4,077,000
Permitting & Mitigation					$163,000
Subtotal of Discharge Structure (Trinity River/Ray Roberts)					**$17,830,000**

Owners' Portions of Discharge Structure 4,5

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	80.21%	$14,301,183
UTRWD	13.76%	$2,452,758
Irving	6.04%	$1,076,060
Total Check	100.00%	$17,830,000

Discharge Structure 6 Lake Bridgeport

	Size (MGD)	Quantity	Unit	Unit Price	Cost
Discharge Structure - Lake Bridgeport	316	1	LS	$4,356,000	$4,356,000
Engineering and Contingencies (30%)					$1,307,000
Permitting & Mitigation					$52,000
Subtotal of Discharge Structure (Lake Bridgeport)					**$5,715,000**

Owners' Portions of Discharge Structure 6

TRWD	100.00%	$5,715,000
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	0.00%	$0
Total Check	100.00%	$5,715,000

Total Pipeline Cost	**$4,451,346,000**
TRWD Portion of Pipeline	*$1,567,148,000*
NTMWD Portion of Pipeline	*$1,138,870,000*
Dallas Portion of Pipeline	*$1,364,938,000*
Upper Trinity RWD Portion of Pipeline	*$234,097,000*
Irving Portion of Pipeline	*$146,293,000*
Total Check	*$4,451,346,000*

Pump Station(s)		Size (per PS)	Quantity	Unit	Unit Price	Cost
Patman Intake LPS		58929 HP	1	LS	$83,710,000	$83,710,000
Engineering and Contingencies (35%)						$29,299,000
Permitting & Mitigation						$1,005,000
Subtotal (Patman Intake LPS)						**$114,014,000**
Owners' Portions of Patman Intake LPS						
TRWD	27.32%					$31,150,222
NTMWD	30.60%					$34,888,248
DWU	32.02%					$36,505,055
UTRWD	5.49%					$6,260,885
Irving	4.57%					$5,209,590
Total Check	100.00%					$114,014,000
		Size (per PS)	**Quantity**	**Unit**	**Unit Price**	**Cost**
MN Intake LPS		18833 HP	1	LS	$44,335,000	$44,335,000
Engineering and Contingencies (35%)						$15,517,000
Permitting & Mitigation						$532,000
Subtotal (MN Intake LPS)						**$60,384,000**
Owners' Portions of MN Intake LPS						
TRWD	27.32%					$16,497,755
NTMWD	30.60%					$18,477,485
DWU	32.02%					$19,333,777
UTRWD	5.49%					$3,315,885
Irving	4.57%					$2,759,099
Total Check	100.00%					$60,384,000

		Size (per PS)	Quantity	Unit	Unit Price	Cost
Potential Talco Scalping PS		-	1	LS	#VALUE!	$0
Engineering and Contingencies (35%)						$0
Permitting & Mitigation						$0
Subtotal (Potential Talco Scalping PS)						**$0**
Owners' Portions of Potential Talco Scalping PS						
TRWD	0.00%					$0
NTMWD	0.00%					$0
DWU	0.00%					$0
UTRWD	0.00%					$0
Irving	0.00%					$0
Total Check	0.00%					$0

		Size (per PS)	Quantity	Unit	Unit Price	Cost
BPS #1/MN Tie-in		152696 HP	1	LS	$159,510,000	$159,510,000
Engineering and Contingencies (35%)						$55,829,000
Permitting & Mitigation						$1,914,000
Subtotal (BPS #1/MN Tie-in)						**$217,253,000**
Owners' Portions of BPS #1/MN Tie-in						
TRWD	27.32%					$59,356,563
NTMWD	30.60%					$66,479,350
DWU	32.02%					$69,560,165
UTRWD	5.49%					$11,930,079
Irving	4.57%					$9,926,843
Total Check	100.00%					$217,253,000

		Size (per PS)	Quantity	Unit	Unit Price	Cost
BPS #2/Lake Chapman Split		152461 HP	1	LS	$159,289,000	$159,289,000
Engineering and Contingencies (35%)						$55,751,000
Permitting & Mitigation						$1,911,000
Subtotal (BPS #2/Lake Chapman Split)						**$216,951,000**
Owners' Portions of BPS #2/Lake Chapman Split						
TRWD	27.92%					$60,582,718
NTMWD	31.28%					$67,852,644
DWU	32.72%					$70,997,101
UTRWD	5.61%					$12,176,524
Irving	2.46%					$5,342,013
Total Check	100.00%					$216,951,000

		Size (per PS)	Quantity	Unit	Unit Price	Cost
BPS #3/Wylie WTP Split		64017 HP	1	LS	$76,268,000	$76,268,000
Engineering and Contingencies (35%)						$26,694,000
Permitting & Mitigation						$915,000
Subtotal (BPS #3/Wylie WTP Split)						**$103,877,000**
Owners' Portions of BPS #3/Wylie WTP Split						
TRWD	40.63%					$42,208,051
NTMWD	0.00%					$0
DWU	47.62%					$49,463,764
UTRWD	8.17%					$8,483,399
Irving	3.58%					$3,721,787
Total Check	100.00%					$103,877,000

		Size (per PS)	Quantity	Unit	Unit Price	Cost
BPS #4		36832 HP	1	LS	$51,192,000	$51,192,000
Engineering and Contingencies (35%)						$17,917,000
Permitting & Mitigation						$614,000
Subtotal (BPS #4)						**$69,723,000**
Owners' Portions of BPS #4						
TRWD	100.00%					$69,723,000
NTMWD	0.00%					$0
DWU	0.00%					$0
UTRWD	0.00%					$0
Irving	0.00%					$0
Total Check	100.00%					$69,723,000

		Size (per PS)	Quantity	Unit	Unit Price	Cost
Future Chapman BPS		22515 HP	1	LS	$41,172,000	$41,172,000
Engineering and Contingencies (35%)						$14,410,000
Permitting & Mitigation						$494,000
Subtotal (Future Chapman BPS)						**$56,076,000**
Owners' Portions of Future Chapman BPS						
TRWD	0.00%					$0
NTMWD	0.00%					$0
DWU	0.00%					$0
UTRWD	0.00%					$0
Irving	38.50%					$21,589,260
Total Check	38.50%					$21,589,260

		Size (per PS)	Quantity	Unit	Unit Price	Cost
Existing Chapman LPS (Upgrades)		18722 HP	1	LS	$10,000,000	$10,000,000
Engineering and Contingencies (35%)						$3,500,000
Permitting & Mitigation						$120,000
Subtotal (Existing Chapman LPS (Upgrades))						**$13,620,000**
Owners' Portions of Existing Chapman LPS (Upgrades)						
TRWD	0.00%					$0
NTMWD	0.00%					$0
DWU	0.00%					$0
UTRWD	0.00%					$0
Irving	38.50%					$5,243,700
Total Check	38.50%					$5,243,700

		Size (per PS)	Quantity	Unit	Unit Price	Cost
Existing Irving BPS (Upgrades)		8385 HP	1	LS	$5,000,000	$5,000,000
Engineering and Contingencies (35%)						$1,750,000
Permitting & Mitigation						$60,000
Subtotal (Existing Irving BPS (Upgrades))						**$6,810,000**
Owners' Portions of Existing Irving BPS (Upgrades)						
TRWD	0.00%					$0
NTMWD	0.00%					$0
DWU	0.00%					$0
UTRWD	0.00%					$0
Irving	77.00%					$5,243,700
Total Check	77.00%					$5,243,700

		Size (per PS)	Quantity	Unit	Unit Price	Cost
BPS #1 Storage Reservoir		289 MG	1	EA	$39,633,000	$39,633,000
Engineering and Contingencies (35%)						$13,872,000
Permitting & Mitigation						$476,000
Subtotal (BPS #1 Storage Reservoir)						**$53,981,000**

Owners' Portions of BPS #1 Storage Reservoir

TRWD	27.32%	$14,748,365
NTMWD	30.60%	$16,518,169
DWU	32.02%	$17,283,661
UTRWD	5.49%	$2,964,275
Irving	4.57%	$2,466,529
Total Check	100.00%	$53,981,000

		Size (per PS)	Quantity	Unit	Unit Price	Cost
BPS #2 Storage Reservoir		283 MG	1	EA	$38,912,000	$38,912,000
Engineering and Contingencies (35%)						$13,619,000
Permitting & Mitigation						$467,000
Subtotal (BPS #2 Storage Reservoir)						**$52,998,000**

Owners' Portions of BPS #2 Storage Reservoir

TRWD	27.92%	$14,799,484
NTMWD	31.28%	$16,575,422
DWU	32.72%	$17,343,568
UTRWD	5.61%	$2,974,549
Irving	2.46%	$1,304,977
Total Check	100.00%	$52,998,000

		Size (per PS)	Quantity	Unit	Unit Price	Cost
BPS #3 Storage Reservoir		195 MG	1	EA	$28,705,000	$28,705,000
Engineering and Contingencies (35%)						$10,047,000
Permitting & Mitigation						$344,000
Subtotal (BPS #3 Storage Reservoir)						**$39,096,000**
Owners' Portions of BPS #3 Storage Reservoir						
TRWD	40.63%					$15,885,768
NTMWD	0.00%					$0
DWU	47.62%					$18,616,588
UTRWD	8.17%					$3,192,882
Irving	3.58%					$1,400,762
Total Check	100.00%					$39,096,000

		Size (per PS)	Quantity	Unit	Unit Price	Cost
BPS #4 Storage Reservoir		79 MG	1	EA	$14,940,000	$14,940,000
Engineering and Contingencies (35%)						$5,229,000
Permitting & Mitigation						$179,000
Subtotal (BPS #4 Storage Reservoir)						**$20,348,000**
Owners' Portions of BPS #4 Storage Reservoir						
TRWD	100.00%					$20,348,000
NTMWD	0.00%					$0
DWU	0.00%					$0
UTRWD	0.00%					$0
Irving	0.00%					$0
Total Check	100.00%					$20,348,000

	Size (per PS)	Quantity	Unit	Unit Price	Cost
Future Chapman BPS Storage Reservoir	55 MG	1	EA	$11,248,000	$11,248,000
Engineering and Contingencies (35%)					$3,937,000
Permitting & Mitigation					$135,000
Subtotal (Future Chapman BPS Storage Reservoir)					**$15,320,000**

Owners' Portions of Future Chapman BPS Storage Reservoir

TRWD	0.00%	$0
NTMWD	0.00%	$0
DWU	0.00%	$0
UTRWD	0.00%	$0
Irving	38.50%	$5,898,200
Total Check	38.50%	$5,898,200

****Total Pump Station Costs (Including Storage)**	**$986,600,000**
TRWD Portion of Pump Stations	*$345,300,000*
NTMWD Portion of Pump Stations	*$220,791,000*
Dallas Portion of Pump Stations	*$299,104,000*
Upper Trinity RWD Portion of Pump Stations	*$51,298,000*
Irving Portion of Pump Stations	*$70,106,000*
Total Check	*$986,599,000*

SUMMARY OF RESULTS

PIPELINE & PUMP STATION CONSTRUCTION TOTAL (FIRST COSTS)		**$5,437,946,000**
TRWD		$1,912,448,000
NTMWD		$1,359,661,000
Dallas		$1,664,042,000
Upper Trinity RWD		$285,395,000
Irving		$216,399,000
Total Check		$5,437,945,000
Interest During Construction	**(72 months - pipeline)**	**$1,314,188,000**
TOTAL COST (Interest Included)		**$6,752,134,000**
TRWD		*$2,374,629,000*
NTMWD		*$1,688,250,000*
Dallas		*$2,066,191,000*
Upper Trinity RWD		*$354,366,000*
Irving		*$268,696,000*
Total Check		*$6,752,132,000*

APPENDIX D
CARBON FOOTPRINT ANALYSIS

MEMORANDUM

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TO: Becky Griffith

CC: File

FROM: Keeley Kirksey, P.E.

SUBJECT: Carbon Footprint Analysis for Sulphur Basin Alternatives

DATE: November 25, 2014

PROJECT: UFH12387 – Sulphur Basin Comparative Analysis

DRAFT

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KEELEY KIRKSEY, P.E., TEXAS NO. 111518 ON NOVEMBER 25, 2014. IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.
FREESE AND NICHOLS, INC.
TEXAS REGISTERED ENGINEERING FIRM F- 2144

1.0 INTRODUCTION

A carbon footprint analysis was performed to compare the carbon emissions from each of the 60 alternatives assessed as part of the Sulphur Basin Comparative Analysis. The analysis provides information on the carbon emissions associated with moving different amounts of water various distances. A carbon footprint is an inventory of the greenhouse gas (GHG) emissions caused by an organization, event, or product over a given period of time and is often expressed in terms of carbon dioxide equivalents (CO_2e). The greenhouse gases included in this carbon analysis are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Where applicable, Global Warming Potentials (GWP) were used to convert methane and nitrous oxide emissions to carbon dioxide equivalents. The Global Warming Potential for a gas is a measure of the total energy a gas absorbs over a particular time period (usually 100 years), compared to carbon dioxide. The larger the GWP, the more warming a gas causes. The GWPs for carbon dioxide, methane and nitrous oxide for a 100 year time horizon are 1, 21, and 310 (U.S. EPA, 2014), respectively.

This carbon analysis includes the embodied emissions of the key materials used for the pipelines, pump stations, and dams, as well as, the emissions due to the reservoir inundation, and the emissions associated with pumping the water over the life of each project.

2.0 METHODOLOGY

2.1 GENERAL ASSUMPTIONS

The carbon emissions for each alternative were assessed over 100 years. One hundred years was chosen to represent the typical life of a large-scale water supply project. This timeframe is common for project evaluations. The 100 year period is assumed to start after construction is complete and water is being moved from point A to point B. Because this analysis is for comparative purposes only and is not intended to calculate exact amounts of carbon emissions, several simplifying assumptions were made.

- The emissions from transporting the construction materials from the factory gate to the project site, as well as the emissions due to construction, were not included. It was assumed these emissions would be similar for each alternative and would be minimal when compared to the embodied, inundation, and operational emissions.
- Emissions associated with operation and maintenance activities (including the replacement of parts, driving, etc.) over the 100 year life of each alternative were not considered. At this point in the planning process it would be difficult to accurately quantify these emissions and they will likely be negligible relative to the other emissions considered in this analysis.
- Only the net increase in emissions from upgrades to existing pump stations was included.
- Phasing of the construction of the infrastructure is an option and would change the total amount of operation emissions over the 100 year life of each alternative, but this is outside of the scope of the Sulphur Basin Project and was not considered in the carbon footprint analysis. Phasing would not affect the embodied and inundation emissions because, regardless of the phasing, all of the infrastructure would be built within the 100 year life of each alternative.

2.2 EMISSIONS CONSIDERED IN ANALYSIS

This carbon analysis includes the embodied emissions of the key materials used for the pipelines, pump stations, and dams, the emissions due to the reservoir inundation, and the emissions associated with pumping the water over the 100 year life of each project.

2.3 EMBODIED EMISSIONS

"The embodied energy (carbon) of a building material can be taken as the total primary energy consumed (carbon released) over its life cycle. This would normally include (at least) extraction, manufacturing, and transportation

(Hammond and Jones, 2008)." The embodied emission coefficients for the major materials in the pipelines, pump stations, and dams were obtained from the University of Bath's Inventory of Carbon and Energy (ICE), Version 2.0. ICE is a database of embodied energy and carbon coefficients for building materials. Nearly all of the material coefficients used in this analysis had boundaries of "cradle-to-gate" meaning all energy (in primary form) is included until the product leaves the factory gate. The one exception was the coefficient used for the soil cement of the dams. The boundary condition for this material was "Cradle-to-site," which includes all of the energy emitted until the product has reached its point of use.

The embodied emission coefficients do not take into consideration the fuel mix used to produce the material. Thus, to calculate the embodied carbon of the materials, the fuel mix was estimated using the U.S. Environmental Protection Agencies (EPA) Emission and Generation Resource Integrated Database (eGRID). The eGRID is a collection of data on environmental characteristics of almost all electric power generation in the United States. Emission rates of carbon dioxide equivalents for the ERCOT subregion, which includes most of Texas, were obtained using the most recent data available (eGRID ninth edition with year 2010 data).

2.3.1 Pipelines

It was assumed steel pipe, rather than concrete, would be used. The embodied carbon of the steel, mortar lining, and polyurethane coating were estimated. The quantities of the steel, mortar, and polyurethane were estimated based on pipe diameter and length as determined in the transmission cost estimates. (See **Chapter 4.**) The steel thickness varied based on the pipe diameter. The mortar coating was assumed to be 0.75 inches thick and the polyurethane coating was assumed to be 0.035 inches thick, regardless of the pipe diameter. Table D-1 shows the material thickness and calculated quantity of material for various pipe diameters.

Table D-1. Material Thickness and Quantity for Steel Pipes

Pipe Diameter (in)	Material Thickness (in)			Quantity of Material (ft^3/LF)		
	Steel	Mortar	Polyurethane Coating	Steel	Mortar	Polyurethane Coating
36	0.1875	0.75	0.035	0.1542	0.6013	0.0289
42	0.1875	0.75	0.035	0.1787	0.6995	0.0335
48	0.208696	0.75	0.035	0.2263	0.7977	0.0381
54	0.234783	0.75	0.035	0.2855	0.8958	0.0428
60	0.26087	0.75	0.035	0.3515	0.9940	0.0474
66	0.286957	0.75	0.035	0.4244	1.0922	0.0520
72	0.313043	0.75	0.035	0.5041	1.1904	0.0566
78	0.33913	0.75	0.035	0.5907	1.2885	0.0612
84	0.365217	0.75	0.035	0.684	1.387	0.066
90	0.391304	0.75	0.035	0.784	1.485	0.070
96	0.417391	0.75	0.035	0.892	1.583	0.075
102	0.443478	0.75	0.035	1.006	1.681	0.080
108	0.469565	0.75	0.035	1.127	1.779	0.084
114	0.495652	0.75	0.035	1.254	1.878	0.089
120	0.521739	0.75	0.035	1.389	1.976	0.094

The embodied energy coefficient and density for each material were obtained from the ICE Database. The carbon dioxide equivalents were then calculated using Equation 1. Table D-2 presents an example of the table used for each of the 60 alternatives to estimate the embodied emissions of the pipelines.

$$CO_2e \text{ (metric tons)} = \text{Weight of material (tons)} * \text{Embodied Energy Coefficient (MJ/Kg)} \div 3.6 \text{ (MJ/Kwh)} * 1000 \text{ (kg/ton)} * \text{eGRID } CO_2e \text{ emission rate (tons/Kwh)} \quad (1)$$

Table D-2. Embodied Carbon Dioxide Equivalent Emissions for Steel Pipe – Wright Patman 232.5 Standalone

Pipeline Segment	Material	Length of Pipeline Segment (feet)	Pipe Diameter (in)	Quantity of Material (ft^3)	Embodied Energy (MJ/Kg)	Density of Material (lb/ft^3)	Weight of Material (metric tons)	Metric Tons of CO_2e
1	Steel	264,741	102	266,243	24.90	486.0	58,816	226,126
	Mortar Lining			445,095	1.33	118.0	23,873	4,903
	Polyurethane Coating			21,109	101.50	1.9	18	286
2	Steel	272,276	102	273,821	24.90	486.0	60,490	232,562
	Mortar Lining			457,763	1.33	118.0	24,553	5,042
	Polyurethane Coating			21,710	101.50	1.9	19	294
3	Steel	184,524	102	185,571	24.90	486.0	40,994	157,609
	Mortar Lining			310,230	1.33	118.0	16,640	3,417
	Polyurethane Coating			14,713	101.50	1.9	13	199
4	Steel	52,247	96	46,586	24.90	486.0	10,291	39,566
	Mortar Lining			82,711	1.33	118.0	4,436	911
	Polyurethane Coating			3,924	101.50	1.9	3	53
5	Steel	218,774	90	171,622	24.90	486.0	37,913	145,762
	Mortar Lining			324,856	1.33	118.0	17,424	3,578
	Polyurethane Coating			15,422	101.50	1.9	13	209
6	Steel	54,127	66	22,970	24.90	486.0	5,074	19,509
	Mortar Lining			59,117	1.33	118.0	3,171	651
	Polyurethane Coating			2,815	101.50	1.9	2	38
7	Steel	221,060	66	93,812	24.90	486.0	20,724	79,677
	Mortar Lining			241,441	1.33	118.0	12,950	2,659
	Polyurethane Coating			11,497	101.50	1.9	10	156
8	Steel	21,494	48	4,865	24.90	486.0	1,075	4,132
	Mortar Lining			17,145	1.33	118.0	920	189
	Polyurethane Coating			820	101.50	1.9	1	11
9	Steel	186,954	60	65,714	24.90	486.0	14,517	55,812
	Mortar Lining			185,836	1.33	118.0	9,968	2,047
	Polyurethane Coating			8,859	101.50	1.9	8	120
10	Steel	11,323	72	5,708	24.90	486.0	1,261	4,848
	Mortar Lining			13,479	1.33	118.0	723	148
	Polyurethane Coating			641	101.50	1.9	1	9
11	Steel	4,701	36	725	24.90	486.0	160	616
	Mortar Lining			2,827	1.33	118.0	152	31
	Polyurethane Coating			136	101.50	1.9	0	2
Total Steel				**1,137,637**	**24.9**	**486.0**	**251,314**	**966,218**
Total Mortar Lining				**2,140,499**	**1.3**	**118.0**	**114,809**	**23,577**
Total Polyurethane Coating				**101,646**	**101.5**	**1.9**	**88**	**1,376**
Total				**3,379,781**			**366,211**	**991,171**

2.3.2 Pump Stations

The embodied emissions for the pump stations were calculated by taking the maximum horsepower for each pump station, as calculated for the transmission cost estimates, and determining the number of pumps required assuming the largest single pump would not be greater than 5,000 horsepower. The motor weights for various horsepower amounts were obtained from pump manufacture catalogues. These weights were then used to calculate the weights of the various materials in the pump, motor, and valves. It was assumed the motor, pump, and valves each weigh what the motor weights (i.e. total pump weight is equal to three times the motor weight). This assumption was made because pump and valve weights were not easily attainable at this point in the planning process, but needed to be accounted for in the embodied emission calculations. The assumptions regarding the pump, motor, and valve materials, as well as the material densities are shown in Table D-3. The assumptions are based on input from design engineers with experience in the design of large pump stations.

Table D-3. Pump, Motor, and Valve Materials and Densities

Material	Percent of Weight	Density of Material (kg/m^3)	Embodied Energy (MJ/kg)
Pump			
Cast Iron	5%	7,870	25
Stainless Steel	15%	7,850	57
Carbon Steel	80%	7,800	25
Motor			
Cast Iron	50%	7,870	25
Copper	50%	8,600	42
Valve			
Cast Iron	100%	7,870	25

The material weights, densities, embodied energy coefficients, and eGRID CO2e emission rate were then used, as seen in Equation 1, to calculate the embodied emissions for the pump stations for each of the 5 alternatives with the highest embodied emissions, 5 alternatives with the lowest emissions, and 5 alternatives with the median range of emissions.

The calculations include embodied emissions from new pump stations as well as emissions from modifications to existing pump stations. Five percent was added to the total embodied emissions of the pumps, valves, and motors to account for the embodied emissions of the materials used for the pump station building. These emissions were accounted for as a percent of the pump, valve, and motor emissions because, at this point in the planning process, there is not enough information available (building/pump configurations, size of building, building materials, etc.) to accurately quantify the building emissions separately.

2.3.3 Dams

The Sulphur Basin Project considers ten different reservoir footprints. The embodied emissions from the key components of the dam were considered for each of the ten footprints. The key components considered and the corresponding embodied energy coefficients are included in Table D-4. The key materials were obtained from cost estimates developed as part of the Sulphur Basin Study. The carbon dioxide equivalent emissions for the dams were calculated using Equation 1. The Wright Patman alternatives have no emissions associated with the embodied energy of the dam because no modifications are needed to the dam to raise the pool. Spillway modification (widening) may be needed, but that information is not available at this time. The embodied emissions from these potential modifications will be minor relative to the embodied emissions from the construction of the new dams for the other alternatives.

Table D-4. Key Dam Components Considered in Embodied Emissions Calculations

Description	Material in ICE v 2.0	Embodied Energy (MJ/kg)
Fill (Core Compacted)	general rammed soil	0.45
Fill (Random Compacted)	general rammed soil	0.45
Soil Cement	Cement with fly ash	0.85
Flex Road Base	aggregate	0.083
Sand Filter Drain	general sand	0.081
Reinforced Concrete (Mass)	RC 25/30 with 15% fly ash	1.2
Reinforced Concrete (Piers & Walls)	RC 25/30 with 15% fly ash	1.9
Roller Compacted Concrete (RCC)	GEN 1	0.7
Bridge (over Spillway)		
Prestressed Concrete	RC 40/50 w/ 15% fly ash	1.1
Reinforced Concrete	RC 32/40 w/ 15% fly ash	0.97
Rebar	bar and rod - World avg.	21.6
Bridge (to Outlet Works)		
Prestressed Concrete	RC 40/50 w/ 15% fly ash	1.1
Reinforced Concrete	RC 32/40 w/ 15% fly ash	0.97
Rebar	bar and rod - World avg.	21.6
Gates, Including Anchoring System	engineering steel	13.1
Gate Hoist and Operating System	engineering steel	13.1
Stop Gate and Lift Beam	engineering steel	13.1

2.3.4 Summary of Embodied Emissions

Figure D-1 shows the total embodied emissions for the pipelines, pump stations, and dams for the 60 alternatives and Figure D-2 shows the unit embodied emissions. The majority of the embodied emissions are due to the pipelines and dams. On average, the embodied emissions from the pipelines account for 56 percent of the total embodied emissions, the dams account for 44 percent, and the emissions from the pump stations account for less than one percent. The total embodied emissions are more a function of the amount of supply than the length of the pipeline or size of the dam. Figure D-2 shows there is very little variation in the unit embodied emissions from one alternative to another with the dam emissions contributing to the variation more than the pipeline or pump station emissions.

2.4 RESERVOIR INUNDATION EMISSIONS

The lake inundation analysis considers the amount of greenhouse gases that are currently being removed by existing vegetation within each reservoir site in addition to the greenhouse gases emitted by the reservoir surface over a 100 year lifetime. The analysis is based on the following equation adapted from St. Louis et al (2000)[1].

Net change in GHGs due to reservoir creation = previous CO2, CH4, and N2O uptake by pre-project land cover + CO2, CH4 and N2O flux from the reservoir surface (2)

Net change in GHGs is estimated in two steps:

1) Estimate previous CO_2, CH_4, and N_2O uptake by pre-project land cover.
    - Multiply the removal rate for a specific land cover (lbs/ha/year) by the land cover area (ha)
2) Estimate CO_2, CH_4 and N_2O flux from the reservoir surface.
    - For the first 10 years, estimate the CO_2 equivalents in the biomass that will decompose after flooding as a result of conversion to permanently flooded land
    - After 10 years, assume any additional flux from the reservoir is from organic material that would have decomposed with or without the project.

[1] The equation presented in St. Louis et al (2000) was modified to consider N_2O. The term "previous CO_2, CH_4, and N_2O uptake by pre-project land cover" considers both "previous CO_2 and CH_4 uptake from terrestrial regions" and "previous CO_2 and CH_4 emissions from aquatic regions in watershed."

Figure D-1. Total Embodied Emissions for Pipelines, Pump Stations, and Dams

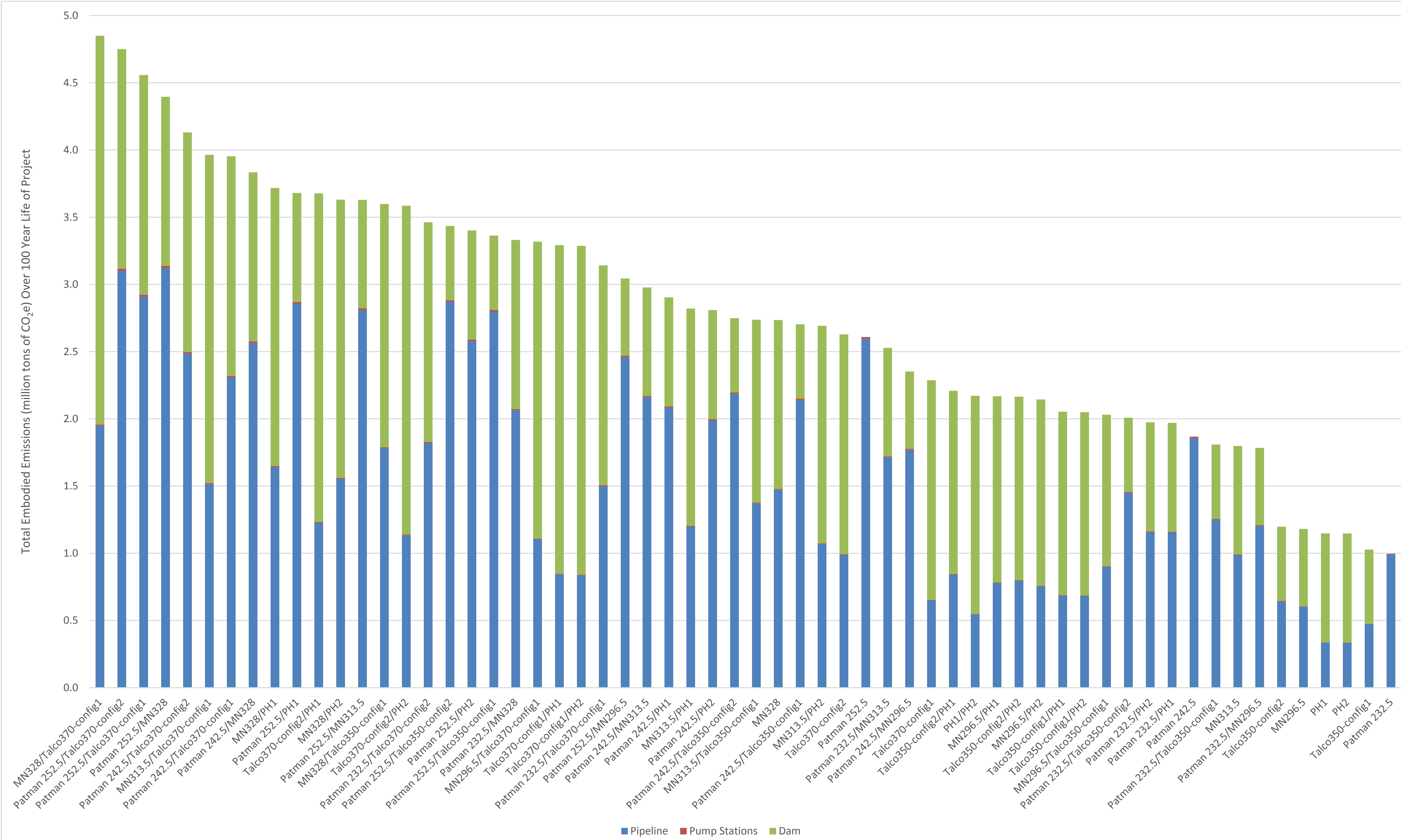
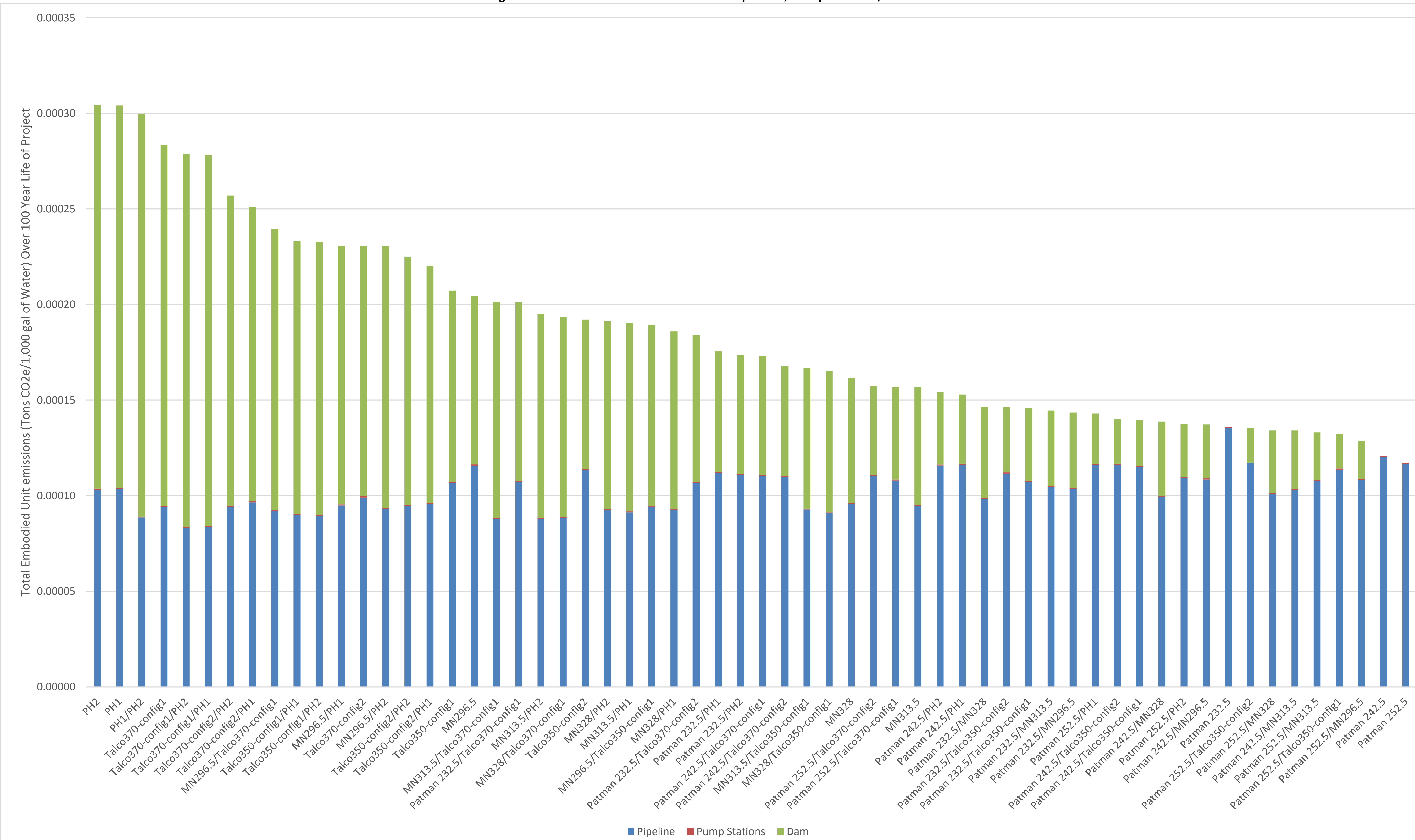


Figure D-2. Unit Embodied Emissions for Pipelines, Pump Stations, and Dams



The amount of GHGs removed by pre-existing vegetation is assumed to be the amount of CO_2, CH_4, and N_2O that would be removed from the atmosphere given the reservoir is not constructed and the existing vegetation is allowed to remain. For this reason, it is added to the GHGs being emitted from the reservoir surface throughout the lifetime of the reservoir. For this study, the entire project footprint, including the footprint of the dam, is used to determine pre-project uptake.

When the area is inundated, the vegetation will begin to decompose. Greenhouse gas fluxes from decomposition of pre-existing vegetation are expected to be higher for young reservoirs because of the newly flooded reactive carbon (Kelly et al. 1997). Only the area inundated is considered for biomass decomposition.

The land cover of the reservoir site is required information for both steps of the methodology. The original land cover classification scheme, which has 12 classes, was reclassified into 5 general categories: wetland, grassland, forest, croplands and water for each of the 10 reservoir sites. The Texas Ecological Systems Classification Project (Texas Parks and Wildlife Department) as well as the Forested Wetlands National Wetland Inventory (U.S. Fish and Wildlife Service) were used to determine the land classifications.

2.4.1 Pre-project Removal of CO_2, CH_4, and N_2O

Previous CO_2, CH_4, and N_2O uptake by pre-project land cover is estimated using Equation 3.

$$Annual\ CO_2eq\ Removal = \sum_i A_i\left(R_{CO_2\_i} + R_{CH_4\_i} * EF_{CH_4} + R_{N_2O\_i} * EF_{N_2O}\right) \quad (3)$$

A_i is the area of the original land use type *i*. There are four major land use types in the permanently flooded area of each reservoir site: wetlands, grasslands, forest and cropland. R_{CO2_i} is the rate of CO_2 removal by land use type *i* (lbs/ha/yr). Likewise, R_{CH4_i} and R_{N2O_i} are the rates of CH_4 and N_2O removal for land use type *i*, respectively. EF_{CH4} and EF_{N2O} are the CO_2 equivalents of CH_4 and N_2O, respectively. The summation is repeated for the four land use types.

The analysis requires three removal rates for each of the four types of vegetation for a total of 12 rates. The values used in this study are based on a review of the literature. Medians of the values reported in the literature are used instead of averages to reduce the sensitivity to extreme values. Zero net carbon emissions were assumed for croplands because they can function as a source or a sink depending on management practices (Morgan et al, 2010; Follet, 2001). The share of agriculture in consumption of fossil fuel is relatively low (Sauerbeck, 2001).

2.4.2 Flux of CO2, CH4, and N2O from Reservoir Surface

As mentioned previously, the flux of GHGs from the reservoir surface is calculated in two steps: 1) the first 10 years considers degradation of pre-existing biomass and 2) a stasis is assumed to be reached after the first 10 years.

During the first 10 years following flooding, CO_2 emissions are due to decay of organic matter present on the land prior to flooding (IPCC, 2006; St. Louis et al., 2000). After 10 years, CO_2 emissions are sustained by the input of organic material transferred into the reservoir from the watershed (IPCC, 2006; St. Louis et al., 2000; Bergstom et al., 2004). Whether to include CO_2 emissions from the reservoir surface after the initial 10 year period in calculations of net CO_2 emissions depends on the relative change in decomposition rates (Svensson, 2005; Houel et al., 2006). No studies have been conducted to determine if organic material retained in a freshwater environment decomposes at a different rate than in a marine environment (St. Louis et al., 2000). The consensus is that since the carbon originates outside the reservoir, it should not be included in calculations of net CO_2 emissions (IPCC, 2006). This study calculates the net CO_2 emission without consideration of long-term reservoir flux.

Methane is generated by anaerobic processes. When a flowing river is converted to a still lake, water near the bottom can become oxygen-depleted, allowing methane to form. Methane must be considered in net GHG calculations if the decomposition of organic material results in the generation of more methane than would have been emitted in the absence of the reservoir (Fearnside, 2002). If the lake is deep enough (approximately 100 feet), methanotrophic bacteria are likely to consume the methane before it reaches the water surface (Svensson, 2005). All of the reservoirs considered in this analysis are less than 100 feet deep on average, so CH_4 emissions are considered in the analysis.

The total amount of GHG emitted from the reservoir during the first 10 years is assumed to be equal to the carbon stored in the pre-project biomass after being converted to CO_2. The approach is based on Equation 7.10 from IPCC Vol 4 Ch7 (2006), which estimates the CO_2 emissions on land converted to flooded land. While some biomass losses can lead to emissions of carbon other than as CO_2, this study assumes all biomass is converted to CO_2. The modified version of Equation 7.10 used in this study is reproduced below (Equation 4).

$$CO_{2\_flooded} = \frac{44}{12} * \left(\sum_i A_i * B_{Before_i} * CF_i\right) \qquad (4)$$

$CO_{2\_flooded}$ are the CO_2 emissions on land converted to permanently flooded land (lbs). A_i is the area of land converted to flooded land from original land use type *i*. $B_{Beforei}$ is the biomass in land use type *i* immediately before conversion to flooded land (lbs of dry matter). CF_i is carbon fraction of dry matter associated with land use type *i* (lbs C/lbs of dry matter). The fraction 44/12 divides the molecular weight of CO_2 by the molecular weight of C in order to convert from carbon equivalents to CO_2 equivalents. Unique values for A, B, and CF are obtained for each of the land use types (IPCC, 2006). These values and Equation 4 are used to calculate the CO_2 emissions from biomass degradation for land use types for each of the 10 reservoir footprints. After the initial 10 years, the annual greenhouse gas emissions from the reservoir surface are estimated using Equation 5.

$$Annual\ CO_2eq\ Emissions = \left(R_{CO_2\_res} + R_{CH_4\_res} * EF_{CH_4} + R_{N_2O\_res} * EF_{N_2O}\right) * A \quad (5)$$

R_{CO2_res}, R_{CH4_res}, R_{N2O_res} are the emissions rates of CO_2, CH_4, and N_2O from the surface of the reservoir, respectively (Table D-5). Again, medians of the values reported in the literature are used instead of averages to reduce the sensitivity to extreme values. EF_{CH4} and EF_{N2O} are the CO_2 equivalents of CH_4 and N_2O, respectively. A is the surface area of the reservoir, which is distinct from the total area of land use types (which includes the area of the dam).

Table D-5. Fluxes of Greenhouse Gases from the Reservoir Surfaces

Greenhouse Gas	Areal Flux (lb/ha/yr)	Source
CO_2	5,564	Therrien et al (2005), Soumis et al (2004)
CH_4	56	St. Louis et al (2000), Soumis et al (2004)
N_2O	0.56	Hendzel et al (2005), Huttunen et al (2002), Duchemin et al (2002)

2.4.3 Results of Lake Inundation Calculations

Over the 100 year life of the reservoir, the total inundation CO_2e emissions for each of the 60 alternatives range from 600 thousand tons CO_2e to 17.7 million tons CO_2e. On a unit emissions basis (tons of CO_2e per 1,000 gallons of water), the emissions range from 0.00015 to 0.00057. The CO_2e emissions from the reservoirs throughout the 100 year lifetime are included in Table D-6. For the Wright Patman alternatives, only the new area to be inundated is included in this analysis. Figure D-3 shows the total inundation emissions, Figure D-4 shows the unit inundation emissions per 1,000 gallons of project yield and Figure D-5 shows the inundation emissions per 1,000 of project yield per acre inundated. The inundation emissions are more a function of the area inundated than the amount of supply, but both criteria are closely correlated to the inundation emissions. There is greater variability for the inundation emissions based on the area inundated as opposed to the inundation emissions per unit of supply. The results are also a function of the land type. Reservoirs inundating large areas of forest and wetlands will have higher emissions because those land types have higher biomass emission rates. The Wright Patman 252.5 alternative has the largest area of wetland and forested area being inundated which would explain why in Figure D-3, any alternative involving Wright Patman 252.5 has the largest inundation emissions associated with it. Parkhouse II has the smallest area of wetland and forested area being inundated, hence many of the alternatives including Parkhouse II have lower total inundation emissions.

Table D-6. Total Lake Inundation Emissions Over 100 Year Life of Project

Alternative	Name	Total Yield (ac-ft/yr)	Lake Inundation Emissions*	Unit Emissions (Tons CO_2e/1000 Gallons of Water)
1	Patman 232.5	281,000	2,200,868	0.0002404
2	Patman 242.5	592,700	5,872,308	0.0003041
3	Patman 252.5	854,400	10,899,648	0.0003915
4	MN296.5	200,000	1,506,410	0.0002312
5	MN313.5	400,000	3,719,535	0.0002854
6	MN328	590,000	6,753,683	0.0003513
7	Talco350-config1	169,600	2,730,125	0.0004940
8	Talco350-config2	217,100	2,730,125	0.0003859
9	Talco370-config1	265,100	4,965,882	0.0005749
10	Talco370-config2	382,800	4,965,882	0.0003981
11	PH1	124,300	1,586,792	0.0003918
12	PH2	124,200	601,078	0.0001485

* Amounts do not include long-term reservoir flux

Figure D-3. Total Inundation Emissions Over 100 Year Life of Project

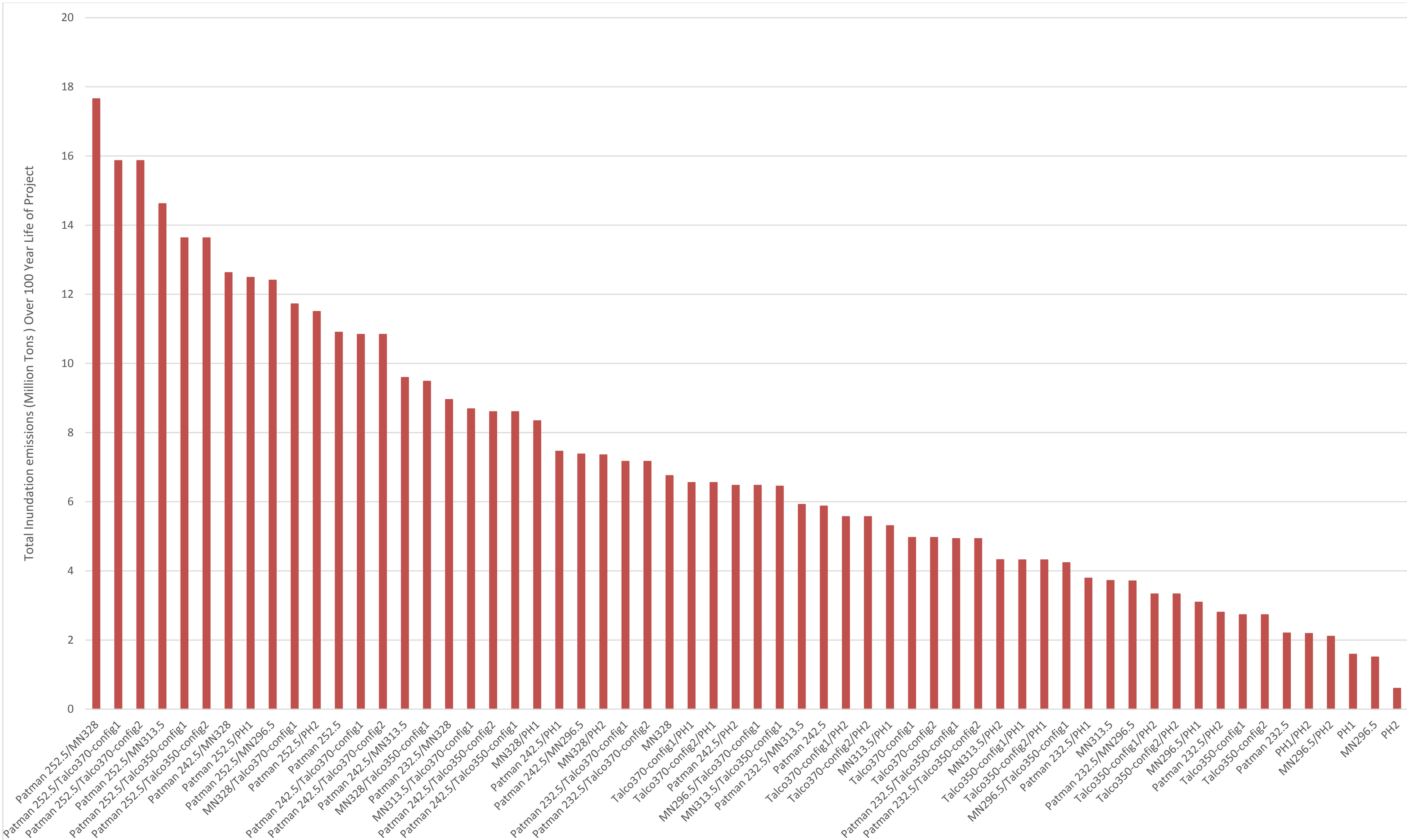


Figure D-4. Inundation Unit Emissions Per 1,000 Gallons of Water Over 100 Year Life of Project

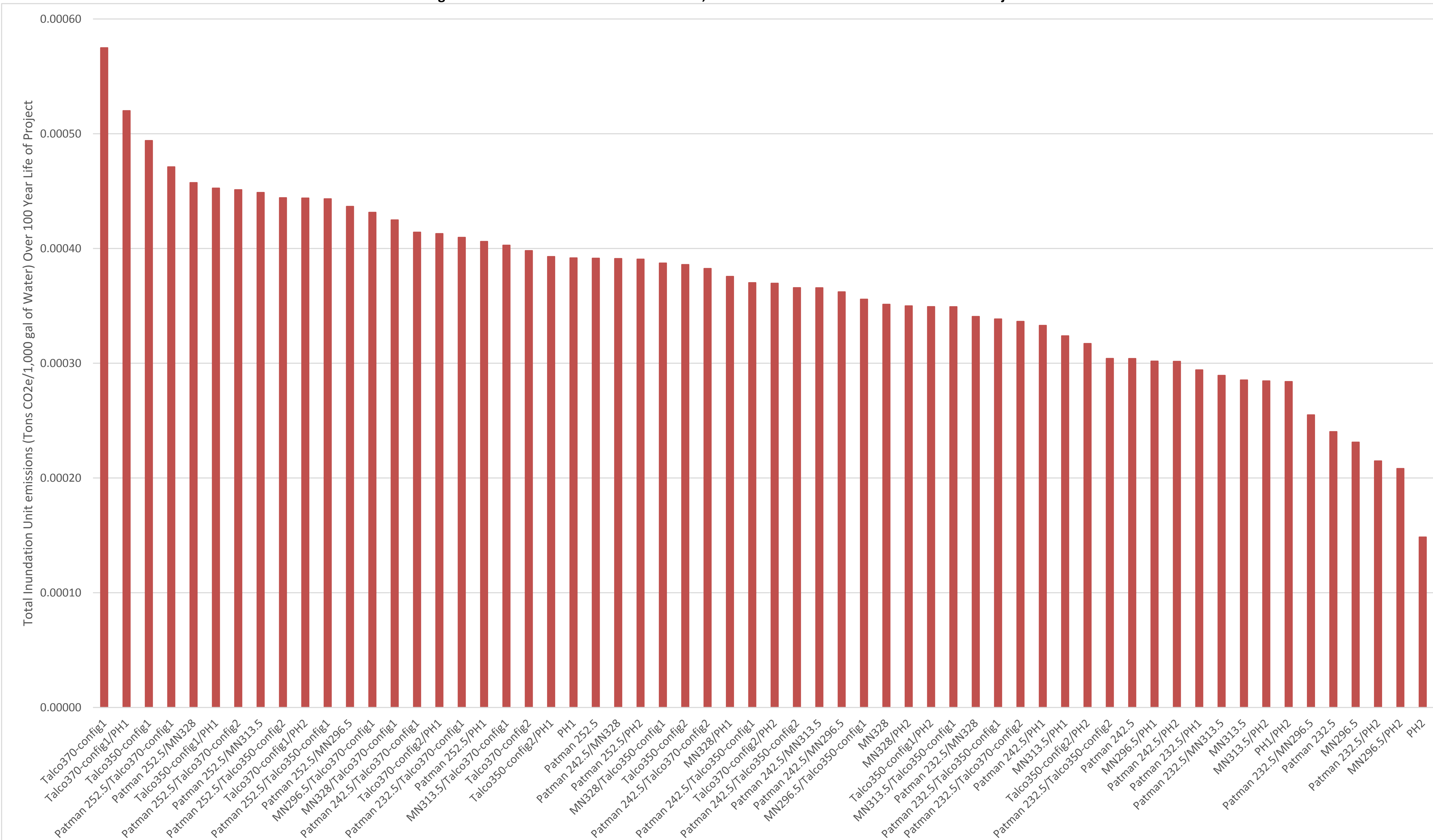
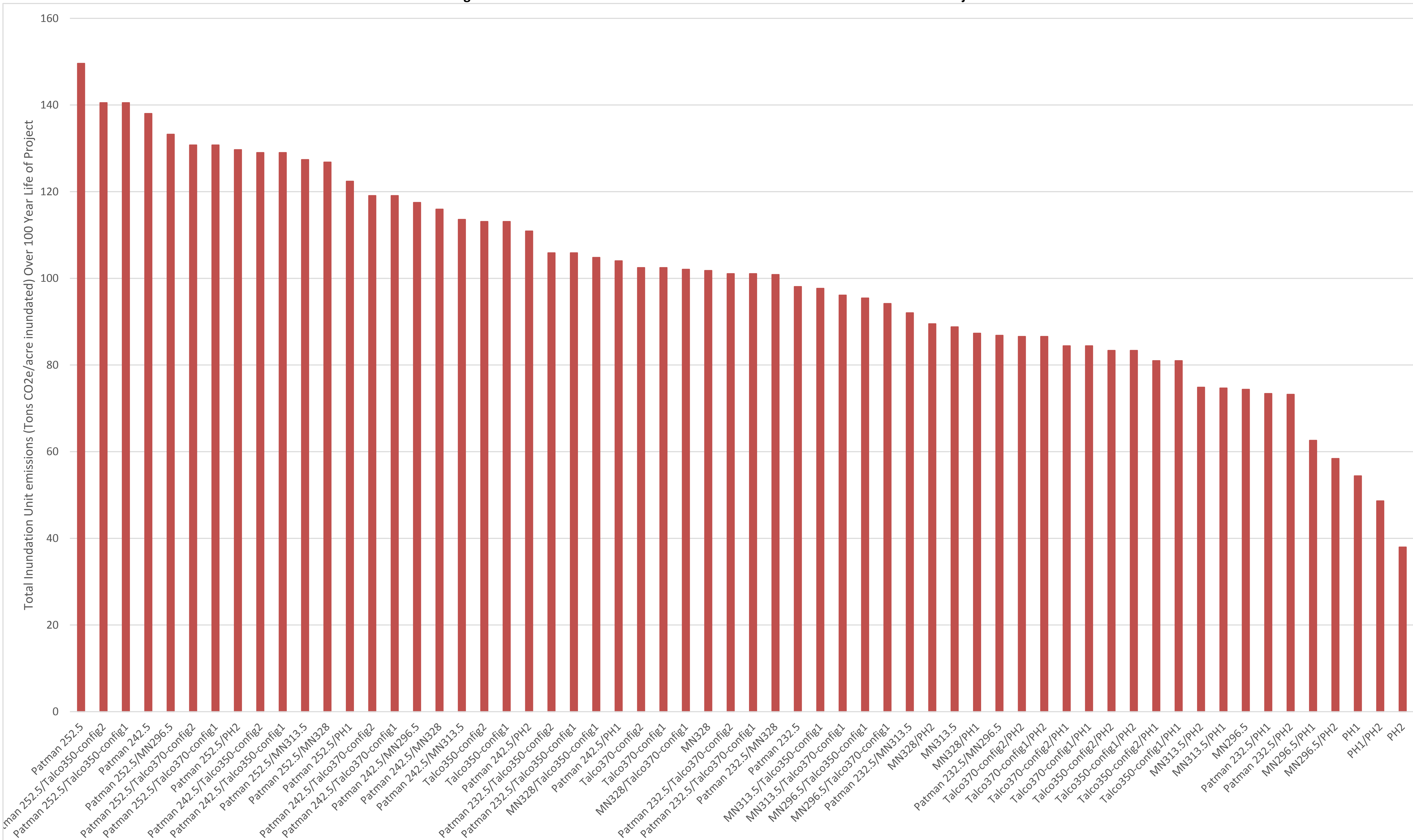


Figure D-5. Inundation Unit Emissions Per Acre Inundated Over 100 Year Life of Project



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2.5 POWER GENERATION EMISSIONS

The emissions associated with pumping the water from point A to point B, or power generation emissions, were calculated using the kilowatt hours at average flow for all of the pump stations along the pipeline route as calculated for the transmission cost estimates. For the upgraded pump stations, only the emissions from the increase in kilowatt hours used were included. The annual carbon dioxide equivalent emissions for each of the 60 alternatives were then calculated by multiplying the electricity use at average flow by the eGRID CO_2e emission rate for the ERCOT subregion, which includes nearly all of Texas. There is a direct correlation between the supply for an alternative and the amount of power generation emissions. Figure D-6 shows the total power generation emissions, Figure D-7 shows the unit emissions (emissions per 1,000 gallons of supply), and Figure D-8 shows the unit emissions per mile of pipeline. Figure D-7 shows that per thousand gallons of water, the power generation emissions are function of the length of the pipeline, with the closest alternatives requiring the least amount of energy per thousand gallons and the farthest alternatives requiring the most. Figure D-8 indicates that when volume of supply and length of the pipeline are controlled for, there is very little variability in the power generation emissions, with the exception of the Wright Patman standalone and the Talco Configuration 2 alternatives which both require an extra booster pump station.

Figure D-6. Total Power Generation Emissions for Sulphur Basin Study Alternatives

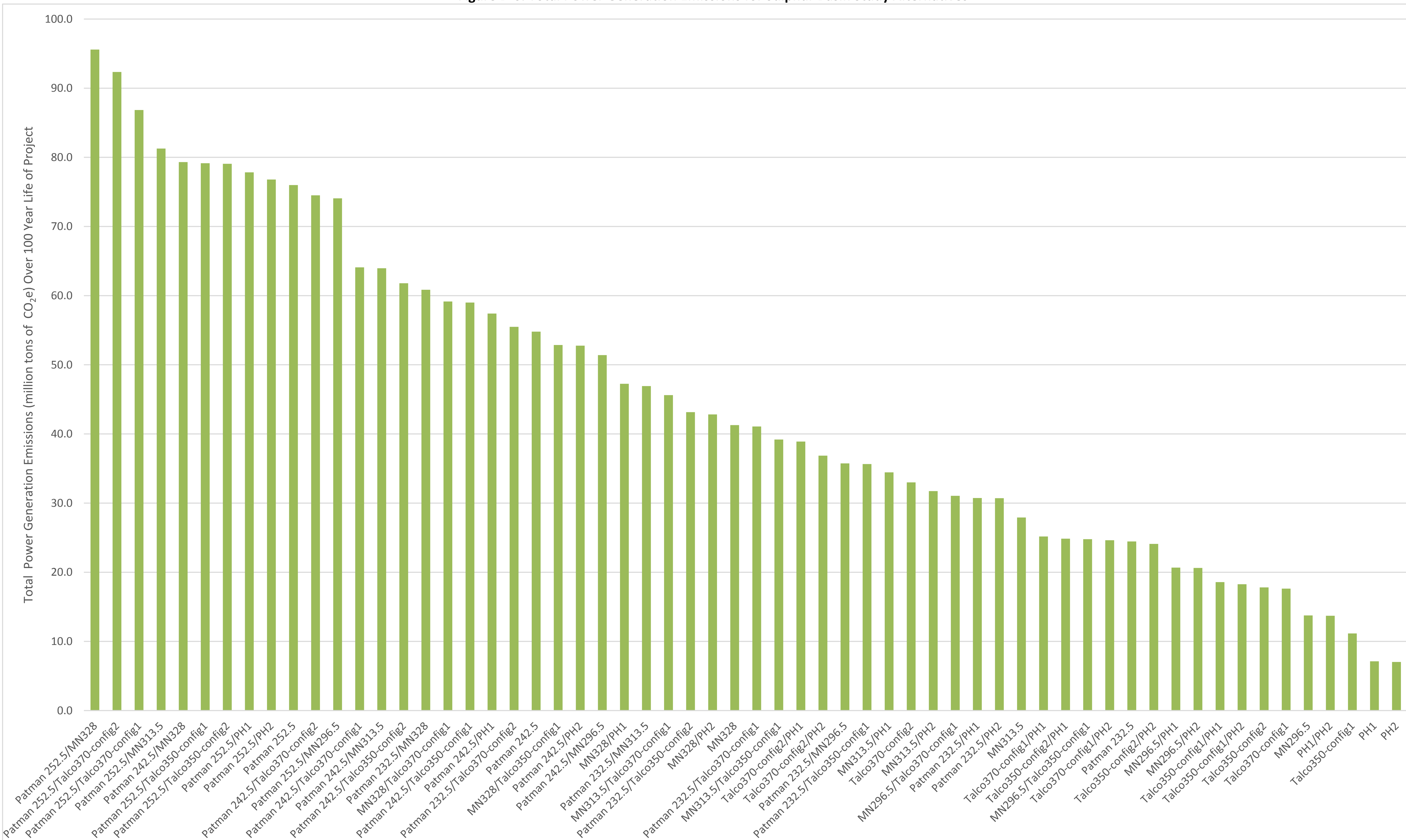


Figure D-7. Unit Power Generation Emissions Over 100 Year Life of Project

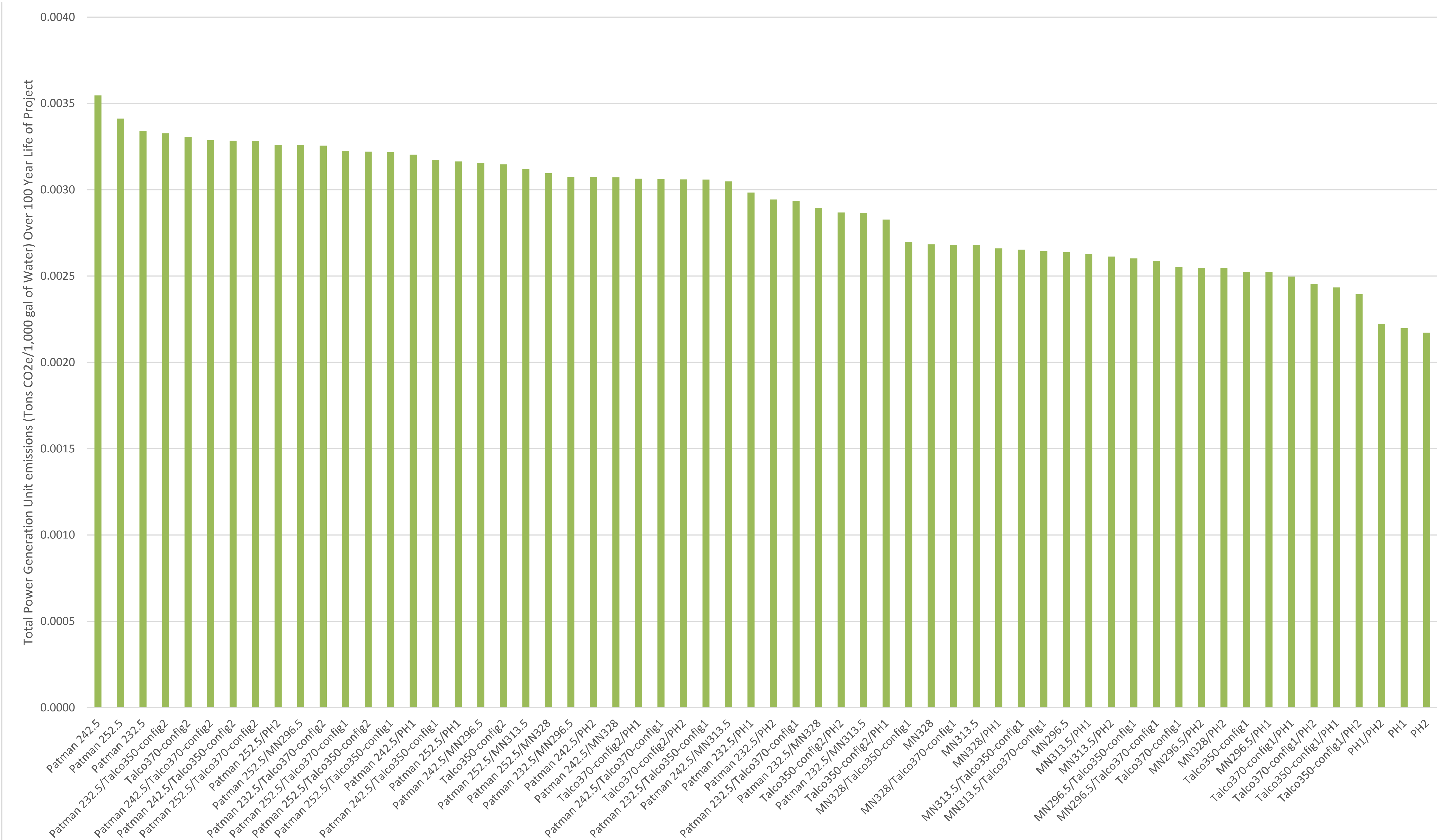
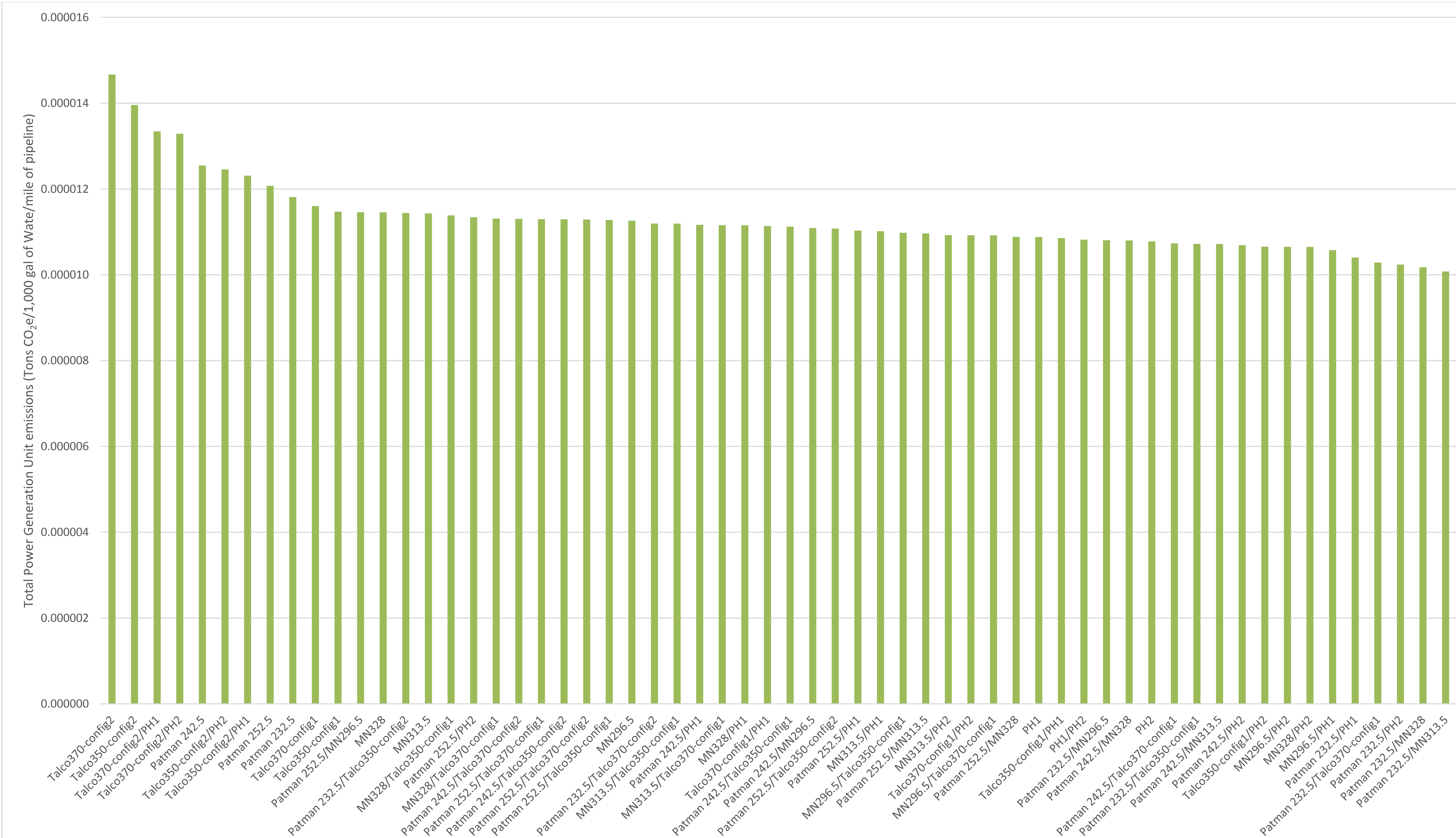


Figure D-8. Unit Power Generation Emissions Per Mile of Pipeline



2.6 RESULTS AND CONCLUSIONS

The power generation emissions have the greatest impact on this carbon footprint analysis and account for up to 88 percent of the total emissions, depending on the alternative and on average account for 81 percent of the total emissions for each of the 60 alternatives. As shown in Figure D-9, the alternative with the lowest total emissions is the Parkhouse II (PH2) Alternative. The PH2 alternative has the smallest project yield and has the lowest emissions for the reservoir inundation and power generation categories, which are the categories that have more of a direct influence on the total emissions than the embodied emissions. The Patman 252.5/Marvin Nichols 328 alternative has the highest total emissions. It is logical that the Patman 252.5/Marvin Nichols 328 alternative would have the highest total emissions because it is the largest alternative in terms of supply.

As mentioned above the carbon dioxide equivalent emissions were also considered on a unit of water basis (amount of CO_2e/1,000 gallons of water) to eliminate the variability introduced by the different supply amounts. It is suggested that these results are used to make recommendations because they take into account the amount of supply provided by a specific alternative. The unit emissions for each of the 60 alternatives are presented in Figure D-10. The average unit emissions for the 60 alternatives is 0.00345 CO_2e/1,000 gallons of water. The total emissions are most closely correlated to the power generation emissions and least closely correlated to the embodied emissions. Figure D-10 shows there is little variability between alternatives and thus, the carbon footprint of an alternative should not necessarily be a critical factor in recommending one alternative over another.

Figure D-9. Total Carbon Dioxide Equivalent Emissions Over 100 Year Project Life

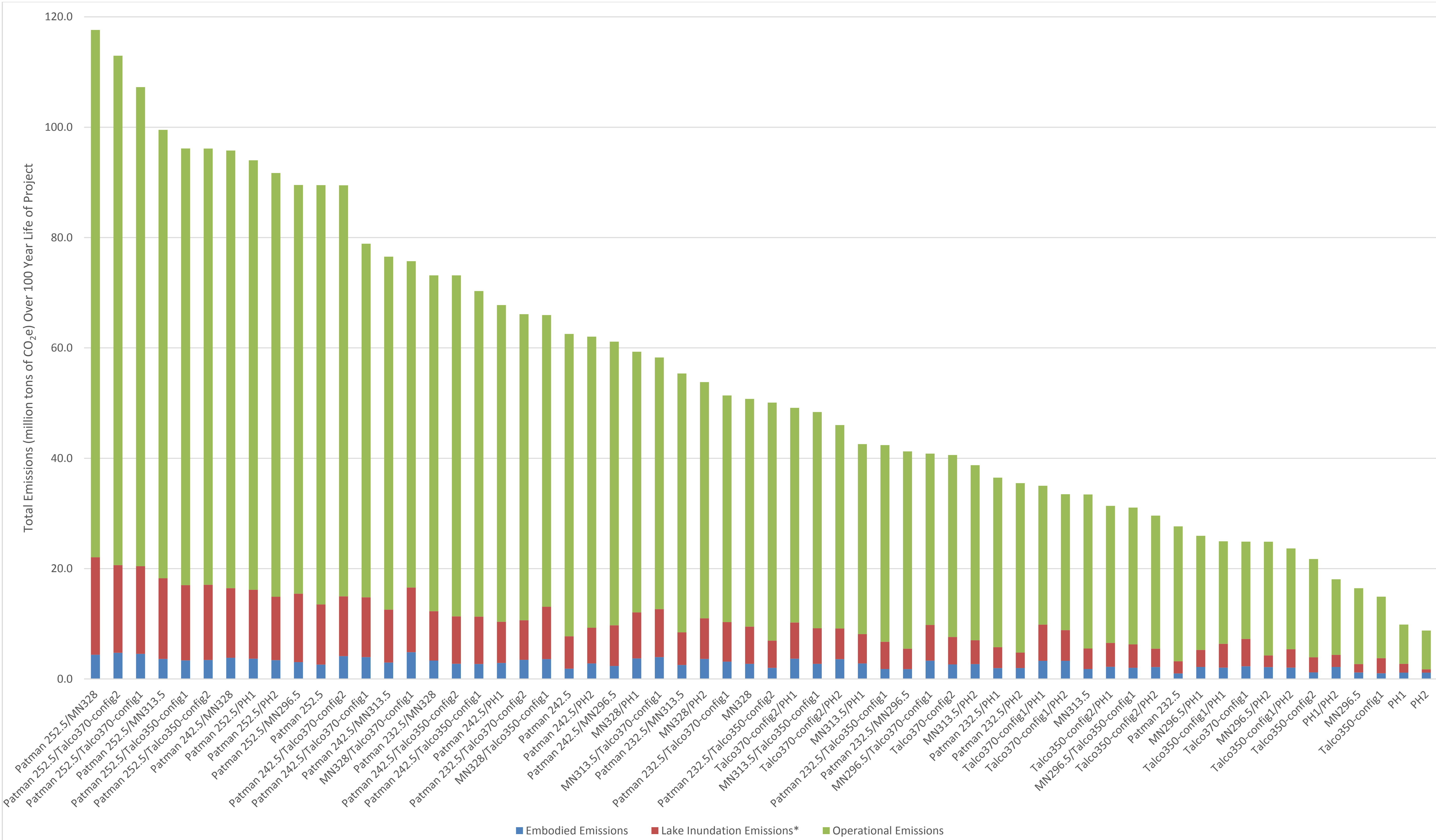
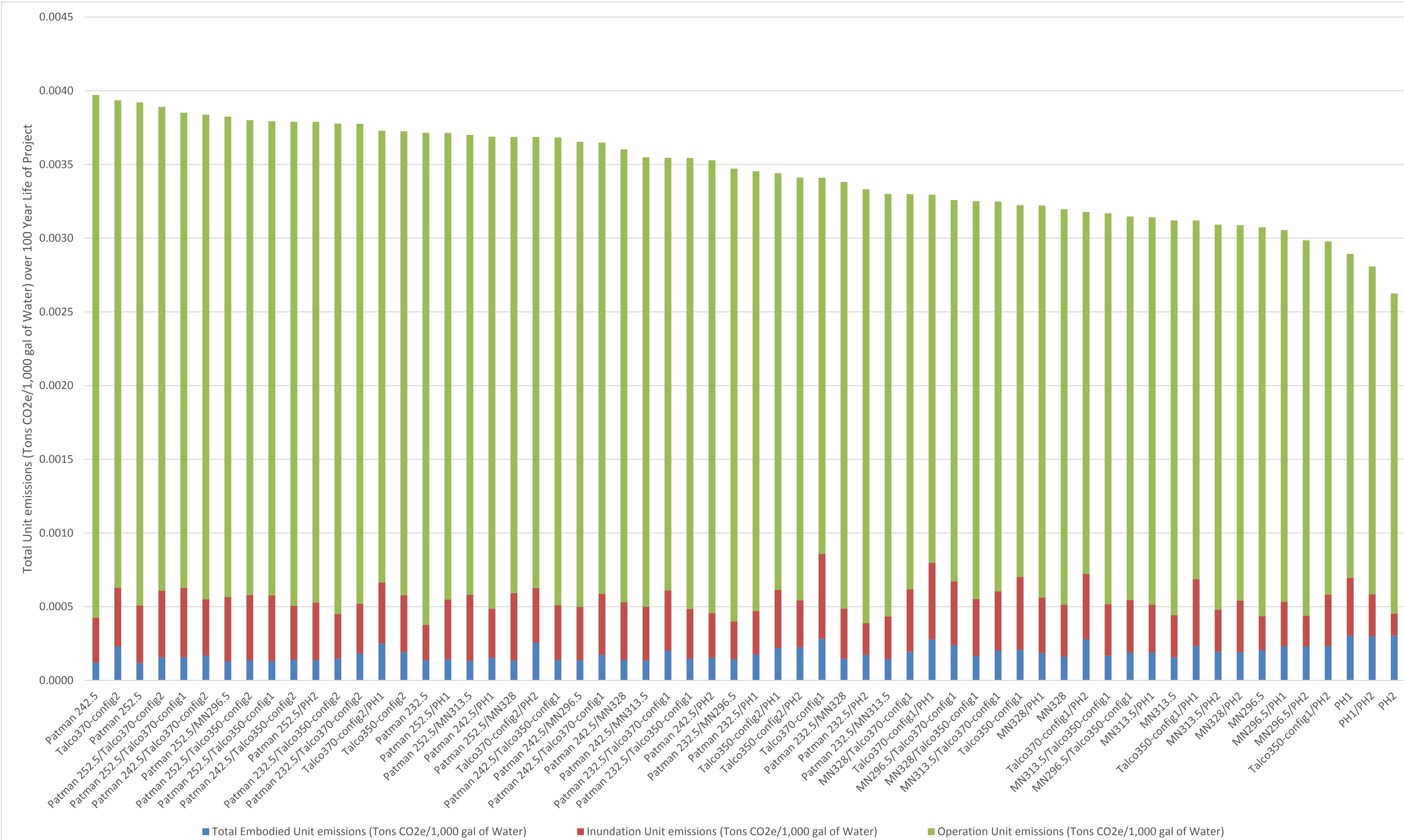


Figure D-10. Total Unit Emissions Over 100 Year Life Of Project



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APPENDIX E
RECREATION COST ESTIMATES

Wright Patman Lake Pool Rise Facility
Relocation Estimate Summary Sheet

The below estimates are based on 2014 construction / relocations cost and does not account for Timber, Boundary Lane Assets or Cultural Resource Concerns.

	Cost Estimate		
Facility Name	Lake Elevation 232.5	Lake Elevation 242.5	Lake Elevation 252.5
Rocky Point Park	$1,401,500.00	$4,245,000.00	$19,021,000.00
Piney Point Park	$1,646,500.00	$2,738,575.00	$7,176,775.00
Spillway Park	$0.00	$0.00	$150,000.00
Elliott's Bluff Park	$3,049,750.00	$4,703,750.00	$8,007,750.00
Sportsman Cove	$1,278,125.00	$3,661,125.00	$4,388,125.00
North Shore Park	$1,845,500.00	$5,983,650.00	$7,049,150.00
Clear Springs Park	$2,413,400.00	$6,676,900.00	$10,691,650.00
Malden Campground	$565,600.00	$762,950.00	$7,461,750.00
Malden Day-Use	$46,000.00	$2,936,500.00	$2,936,500.00
Jackson Creek Park	$326,200.00	$457,200.00	$578,200.00
Overcup Park	$236,700.00	$381,200.00	$556,950.00
Herron Creek Park	$1,777,475.00	$1,777,475.00	$1,777,475.00
Thomas Lake Park	$420,000.00	$3,434,800.00	$3,434,800.00
Hunting Access Roads	$19,436,760.00	$29,396,320.00	$31,711,600.00
TOTAL	$34,443,510.00	$67,155,445.00	$104,941,725.00

Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Clear Springs Park

Number of Campsites Potentially Impacted at each Pool Level in Clear Springs Park

232.5 ft: 6
242.5 ft: 35
252.5 ft: 71

Legend

Proposed Pool Rise

Extrapolated Elevation Contour

- 232.5 ft MSL
- 242.5 ft MSL
- 252.5 ft MSL
- Road Centerline
- Hiking Trail
- Fee Boundary
- Parking Area
- Volleyball Court
- Dump Station
- Septic Tank
- Lift Station
- Playground
- Swim Beach
- Pavilion
- Building
- Boat Ramp

0 200 400 800 1,200 1,600 Feet

US Army Corps of Engineers
Fort Worth District

Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Elliott Bluff Park

Number of Campsites Potentially Impacted at each Pool Level in Elliott Bluff Park

232.5 ft: 0
242.5 ft: 0
252.5 ft: 0

Legend

Proposed Pool Rise

Extrapolated Elevation Contour

- 232.5 ft MSL
- 242.5 ft MSL
- 252.5 ft MSL

- Fee Boundary
- Volleyball Court
- Parking Area
- Fishing Area
- Hiking Trail
- Road Centerline

- Building
- Playground
- Ampitheater
- Boat Ramp

- Dump Station
- Septic Tank
- Lift Station
- Swim Beach
- Pavilion

0 62.5 125 250 375 500 Feet

US Army Corps of Engineers
Fort Worth District

Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Herron Creek Park

Number of Campsites Potentially Impacted at each Pool Level in Herron Creek Park

232.5 ft: 1
242.5 ft: 1
252.5 ft: 1

Legend

Proposed Pool Rise

Extrapolated Elevation Contour

- 232.5 ft MSL
- 242.5 ft MSL
- 252.5 ft MSL
- Fee Boundary
- Volleyball Court
- Parking Area
- Hiking Trail
- Road Centerline
- Building
- Playground
- Ampitheater
- Boat Ramp
- Dump Station
- Septic Tank
- Lift Station
- Swim Beach
- Pavilion

0 75 150 300 450 600 Feet

N S E W

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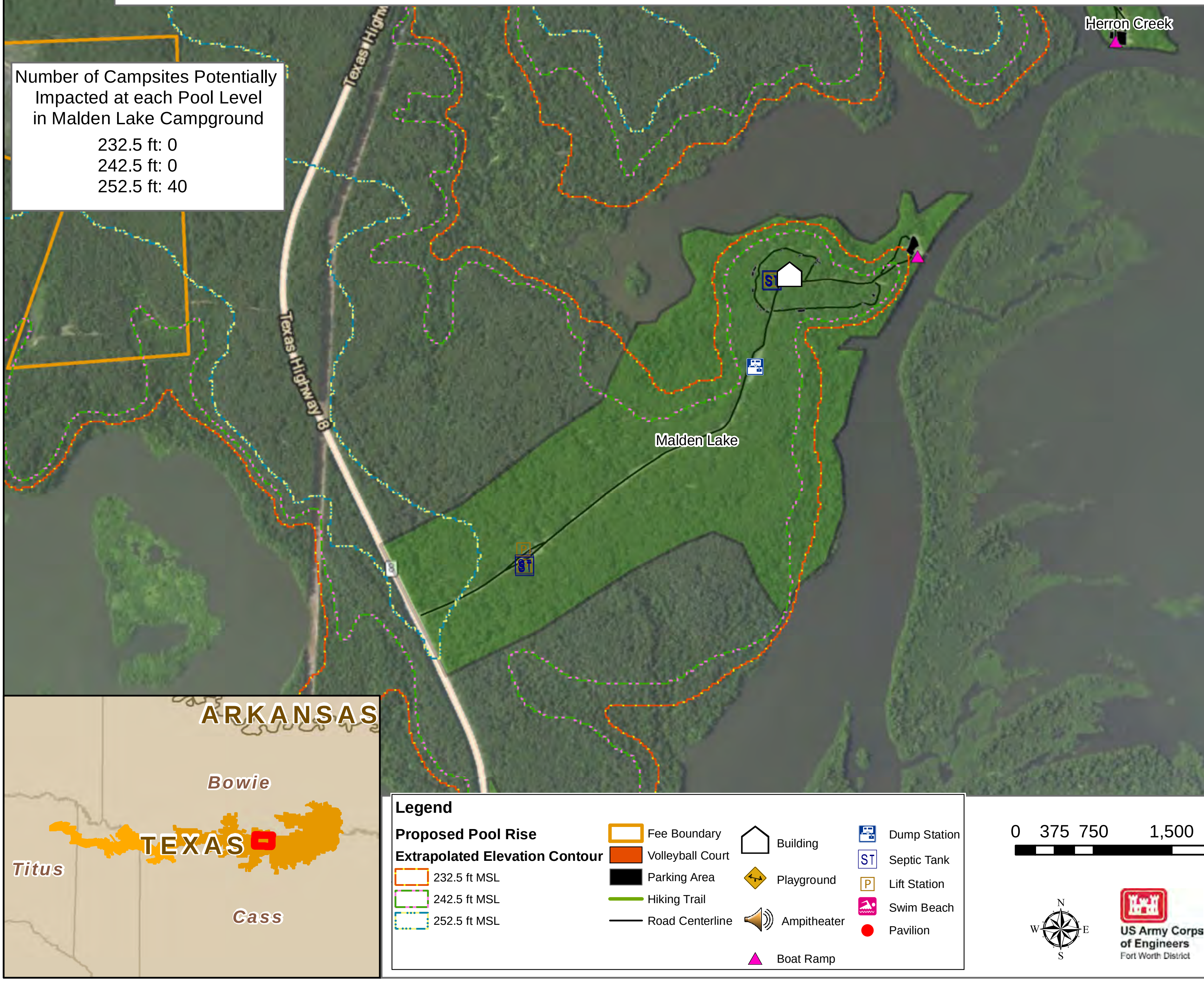
Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Malden Lake Campground



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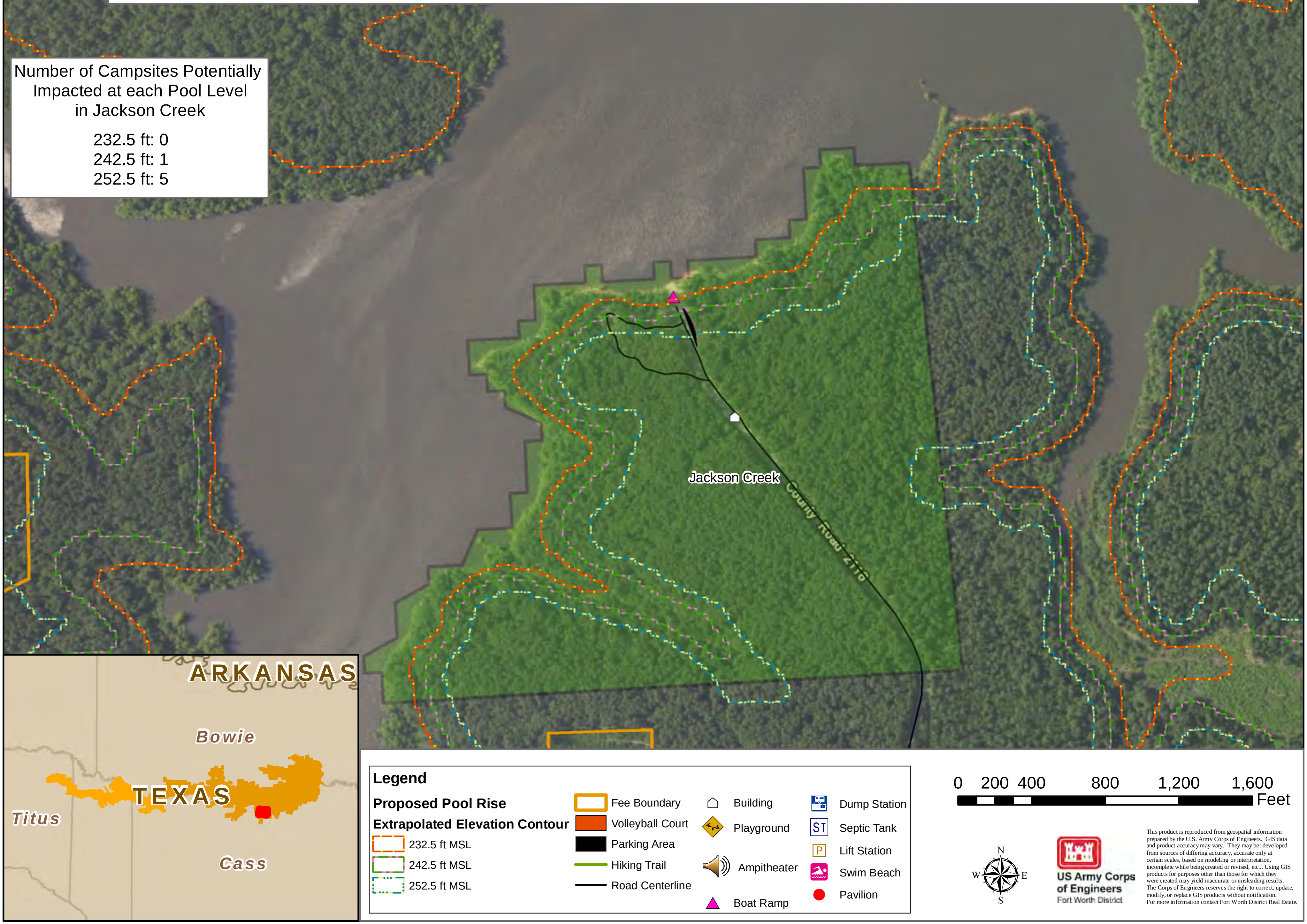
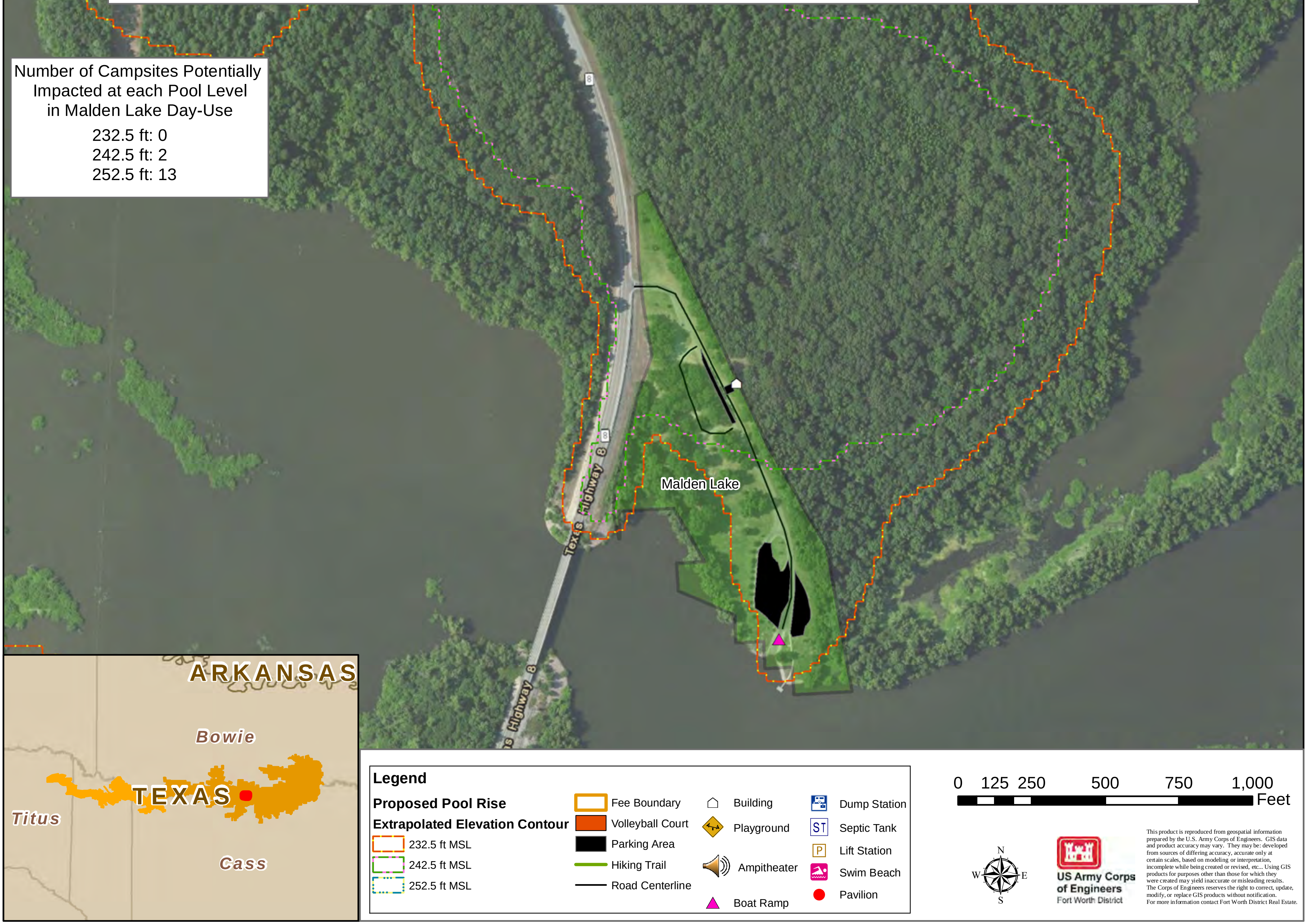
Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Jackson Creek



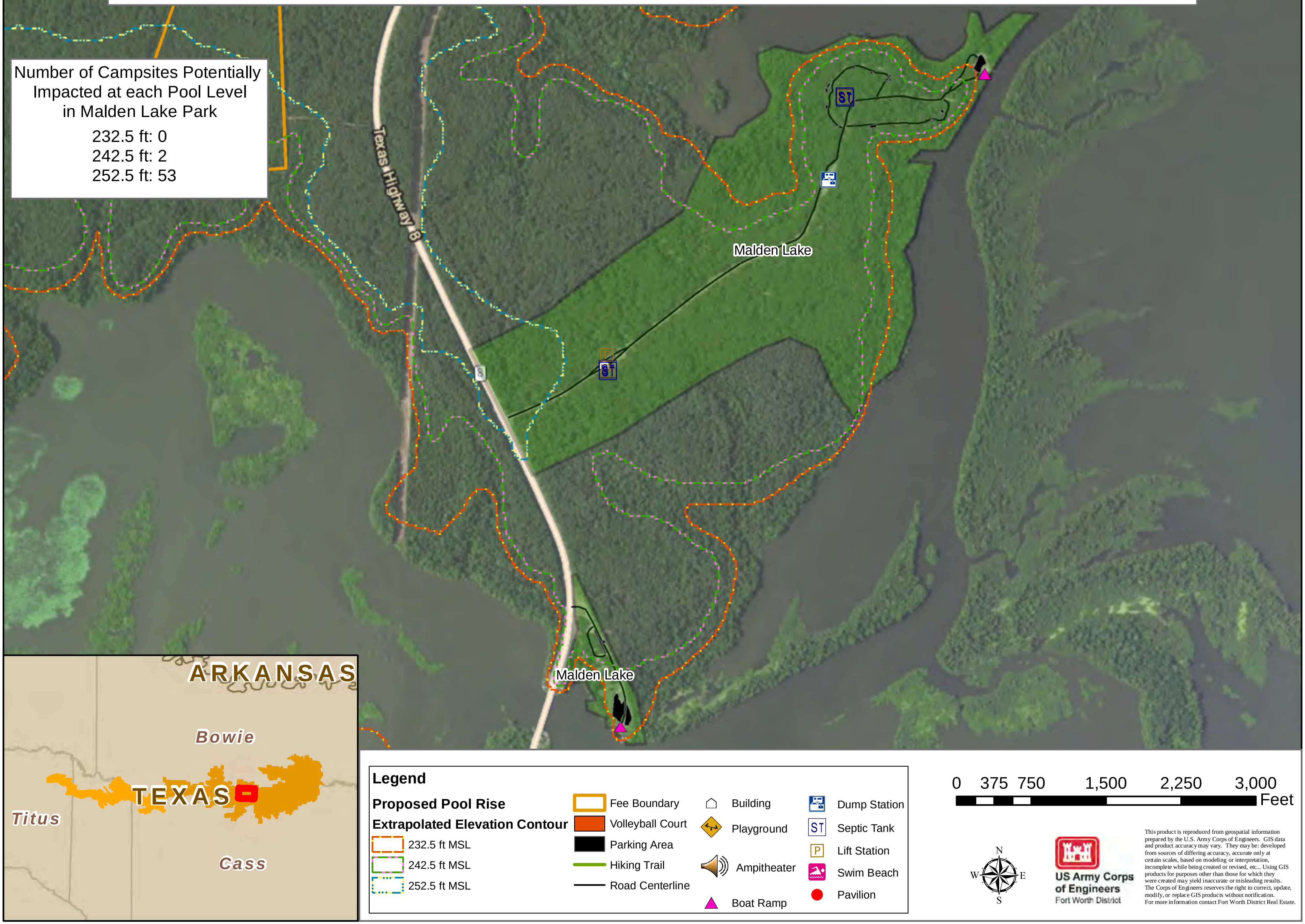
Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Malden Lake Day-Use



Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Malden Lake Park

Number of Campsites Potentially Impacted at each Pool Level in Malden Lake Park

232.5 ft: 0
242.5 ft: 2
252.5 ft: 53



Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
North Shore Park

Legend

Proposed Pool Rise
Extrapolated Elevation Contour
- 232.5 ft MSL
- 242.5 ft MSL
- 252.5 ft MSL

- Fee Boundary
- Volleyball Court
- Parking Area
- Hiking Trail
- Road Centerline
- Building
- Playground
- Ampitheater
- Boat Ramp
- Dump Station
- Septic Tank
- Lift Station
- Swim Beach
- Pavilion

0 200 400 800 1,200 1,600 Feet

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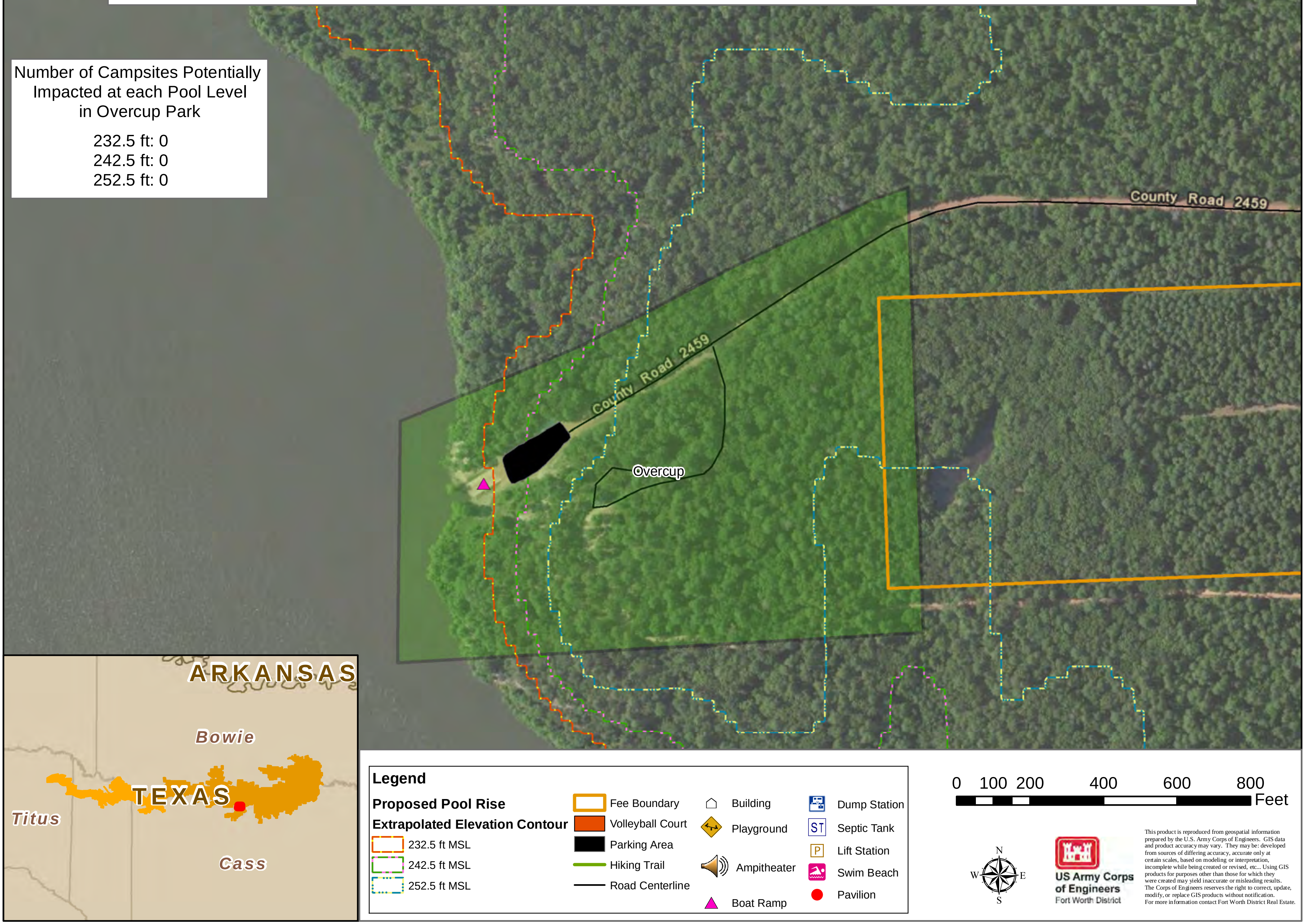
Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Overcup Park



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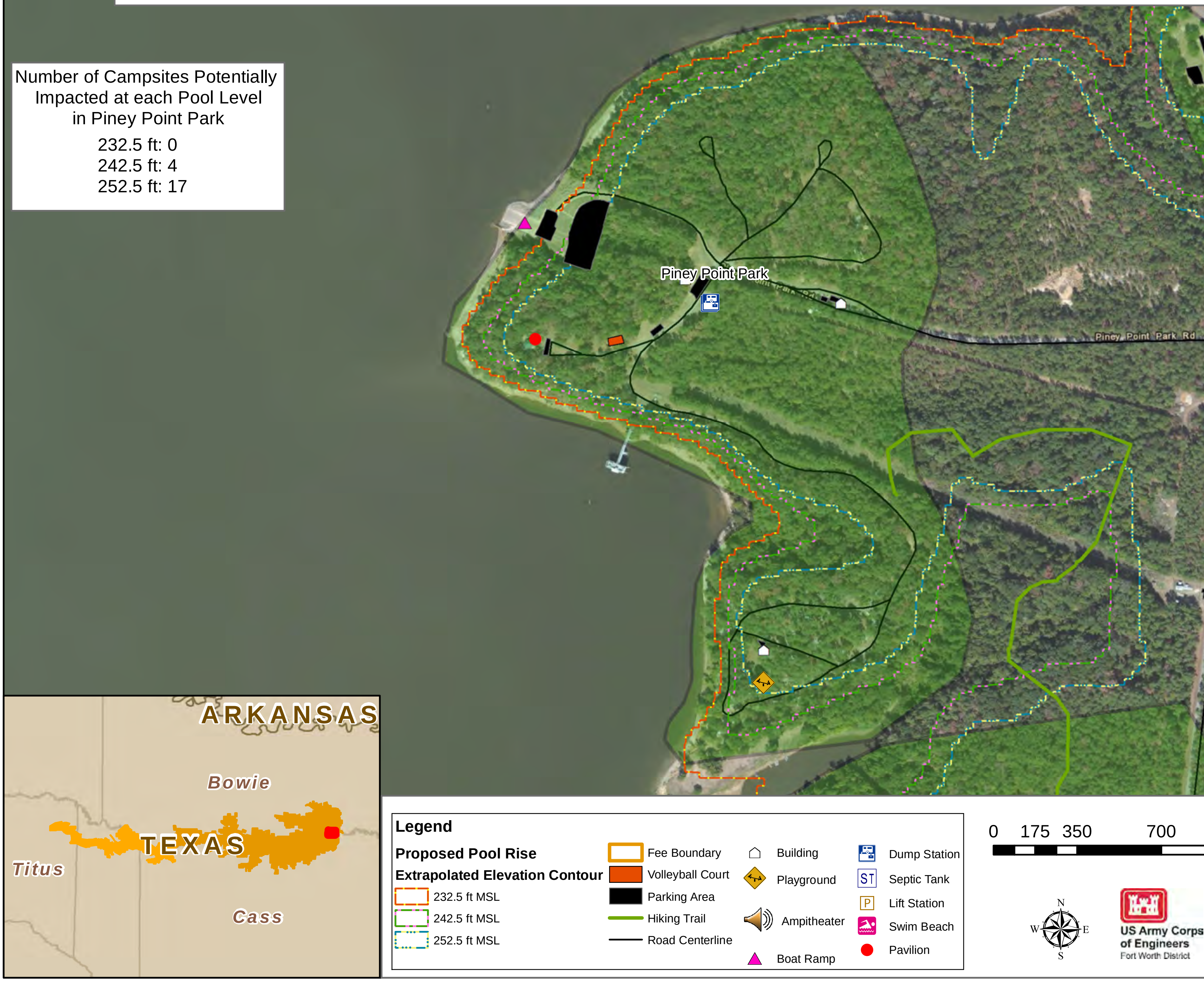
Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Piney Point Park



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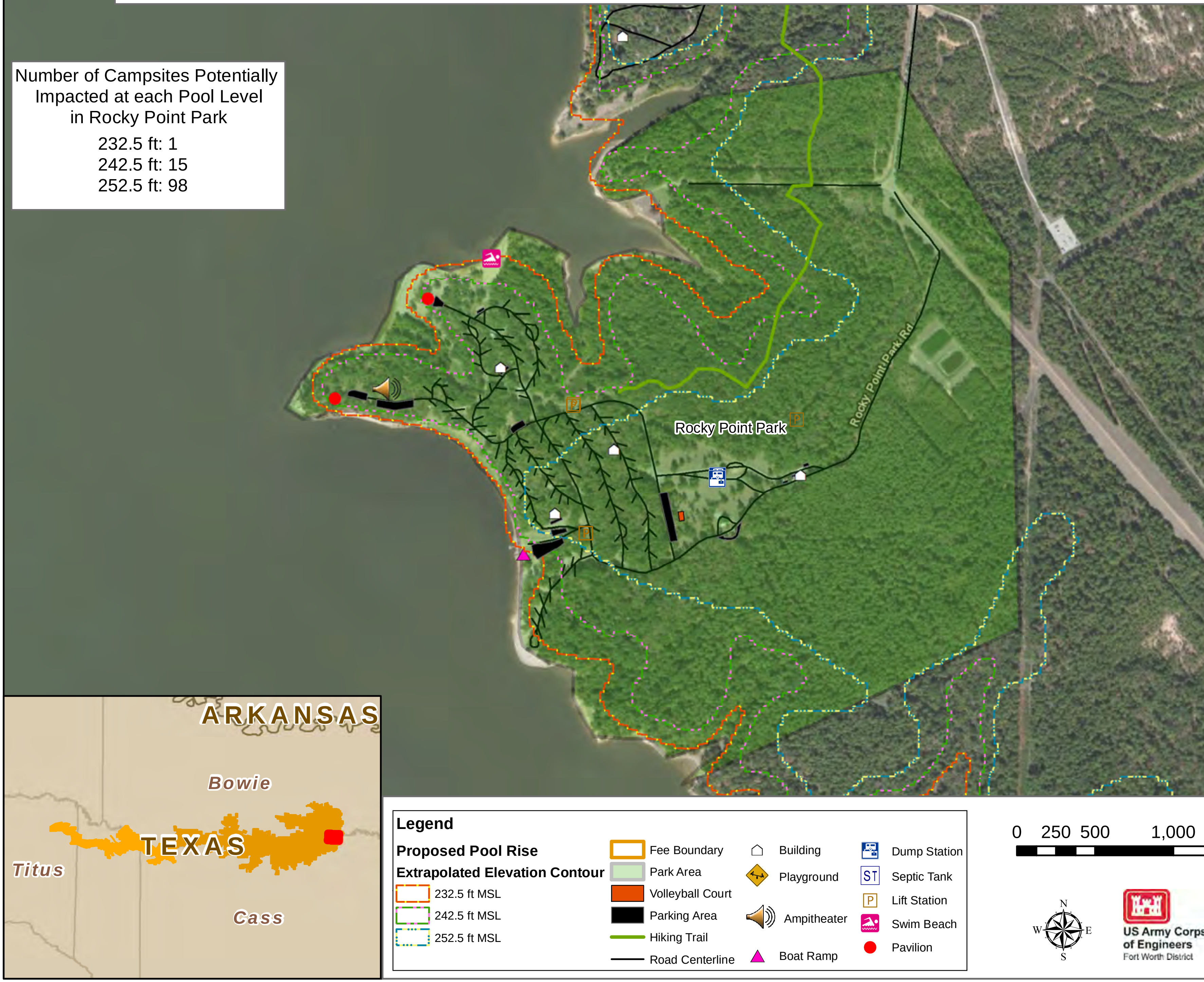
Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Rocky Point Park



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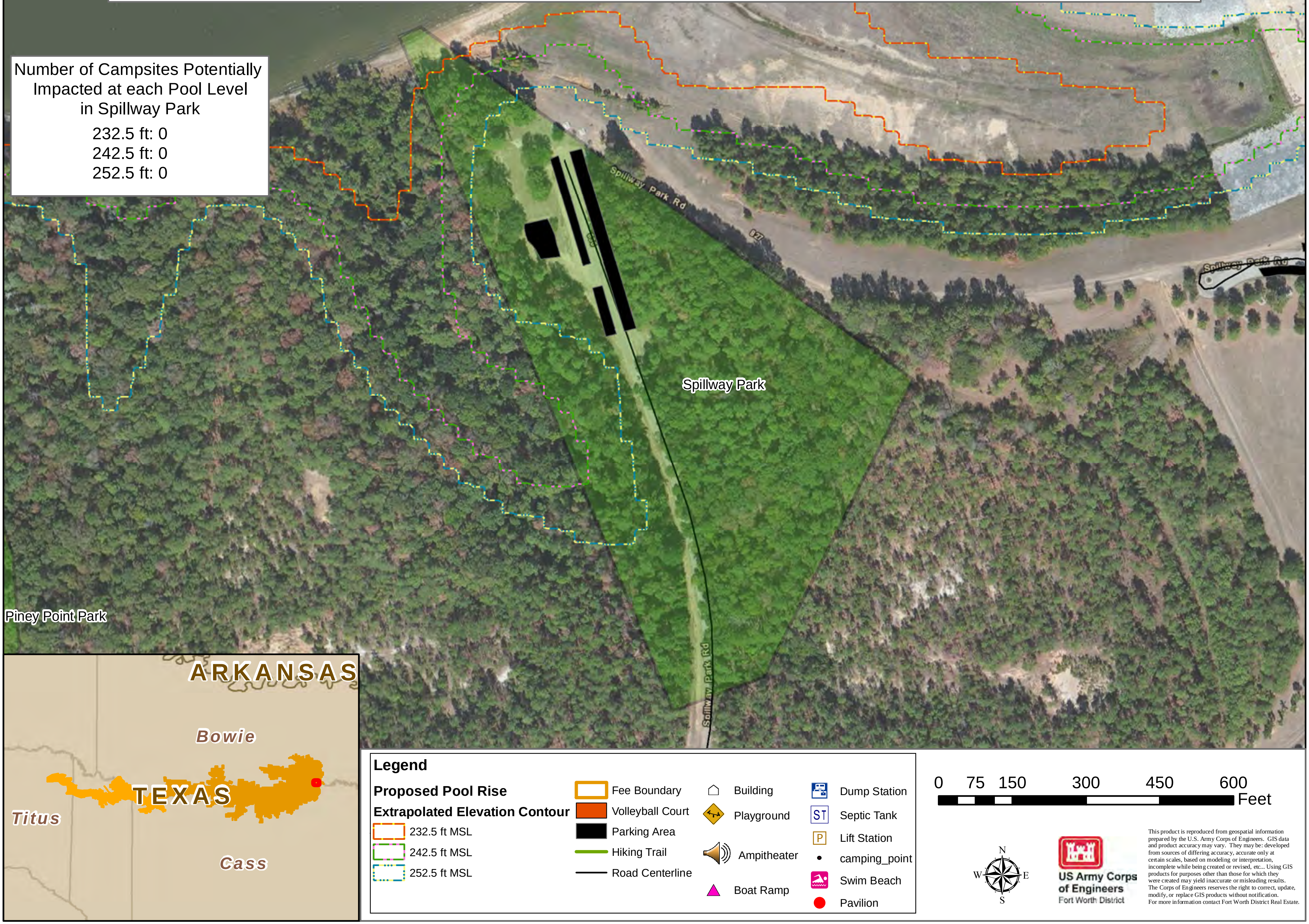
Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Spillway Park

Number of Campsites Potentially Impacted at each Pool Level in Spillway Park

232.5 ft: 0
242.5 ft: 0
252.5 ft: 0



Legend

Proposed Pool Rise Extrapolated Elevation Contour
- 232.5 ft MSL
- 242.5 ft MSL
- 252.5 ft MSL

- Fee Boundary
- Volleyball Court
- Parking Area
- Hiking Trail
- Road Centerline
- Building
- Playground
- Ampitheater
- Boat Ramp
- Dump Station
- Septic Tank
- Lift Station
- camping_point
- Swim Beach
- Pavilion

0 75 150 300 450 600 Feet

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Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Thomas Lake Park

Number of Campsites Potentially Impacted at each Pool Level in Thomas Lake Park

232.5 ft: 0
242.5 ft: 3
252.5 ft: 3

Legend

Proposed Pool Rise

Extrapolated Elevation Contour

- 232.5 ft MSL
- 242.5 ft MSL
- 252.5 ft MSL
- Fee Boundary
- Volleyball Court
- Parking Area
- Hiking Trail
- Road Centerline
- Building
- Playground
- Ampitheater
- Boat Ramp
- Dump Station
- Septic Tank
- Lift Station
- Swim Beach
- Pavilion

0 125 250 500 750 1,000 Feet

N W E S

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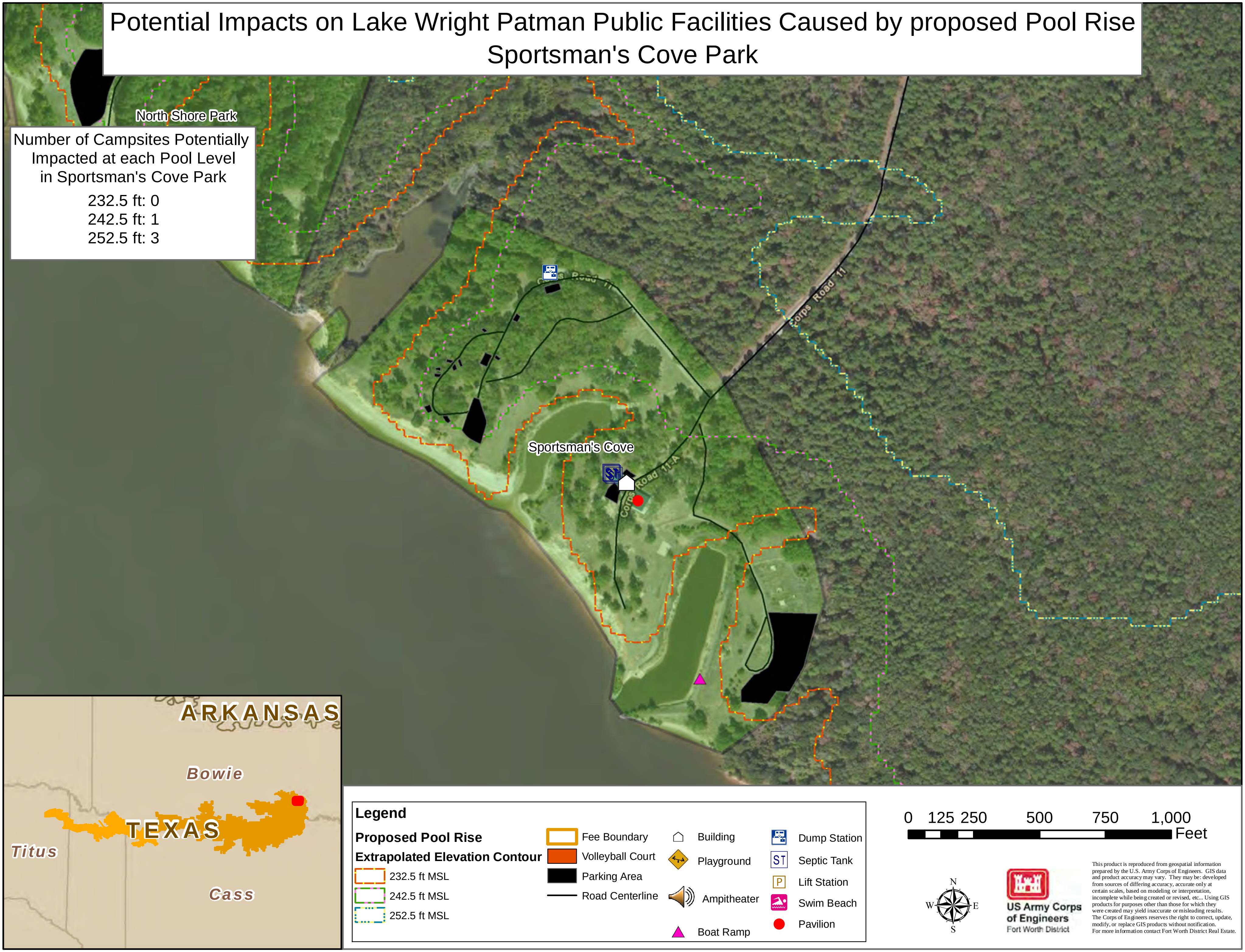
Potential Impacts on Lake Wright Patman Public Facilities Caused by proposed Pool Rise
Sportsman's Cove Park



Number of Campsites Potentially Impacted at each Pool Level in Sportsman's Cove Park

232.5 ft: 0
242.5 ft: 1
252.5 ft: 3

Legend

Proposed Pool Rise

Extrapolated Elevation Contour

- 232.5 ft MSL
- 242.5 ft MSL
- 252.5 ft MSL
- Fee Boundary
- Volleyball Court
- Parking Area
- Road Centerline
- Building
- Playground
- Ampitheater
- Boat Ramp
- Dump Station
- Septic Tank
- Lift Station
- Swim Beach
- Pavilion

0 125 250 500 750 1,000 Feet

N W E S

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