trwd Tarrant Regional Water District

Save Water. Nothing can replace it.

TARRANT REGIONAL WATER DISTRICT INTEGRATED WATER SUPPLY PLAN

2013

Buhman Associates, LLC

IN COOPERATION WITH: CDM Smith Freese and Nichols

Tarrant Regional Water District

Integrated Water Supply Plan

June 2014

trwd Tarrant Regional Water District

STATE OF TEXAS
DANIEL L. BUHMAN
96237
LICENSED
PROFESSIONAL ENGINEER

6/8/14

Daniel L. Buhman, P.E.
Buhman Associates, LLC
Texas Registered Firm F-11197

STATE OF TEXAS
RACHEL A. ICKERT
97379
LICENSED
PROFESSIONAL ENGINEER

6/8/14

Rachel A. Ickert, P.E.
Freese and Nichols, Inc.
Texas Registered Firm F-2144

Buhman Associates, LLC

CDM Smith

FREESE AND NICHOLS

STATE OF TEXAS
ROBERT WILLIAM BRASHEAR
80771
LICENSED
PROFESSIONAL ENGINEER

6/8/2014

Robert W. Brashear, P.E.
CDM Smith, Inc.
Texas Registered Firm F-3043

Table of Contents

Table of Tables

Table of Figures

Appendices

Integrated Water Supply Plan Executive Summary

Tarrant Regional Water District (TRWD) operations span an 11-county area reaching from Jack County to Freestone County. The District has two primary missions: water supply and flood control. TRWD provides raw water to more than 1.7 million people in the North Central Texas area, serving more than 30 wholesale customers including the cities of Fort Worth, Arlington, Mansfield, and the Trinity River Authority. The current sources of supply for TRWD include four supply reservoirs (Lake Bridgeport, Eagle Mountain Lake and the Cedar Creek and Richland-Chambers Reservoirs), three terminal storage reservoirs (Lake Arlington, Lake Benbrook, and Lake Worth), and permitted reuse projects associated with Cedar Creek and Richland-Chambers Reservoirs. The District has constructed more than 150 miles of water pipelines, 27 miles of floodway levees, more than 40 miles of Trinity River Trails and a 260-acre wetland water reuse project designed to increase future water supplies. TRWD's service area, in relationship to the service areas of neighboring regional water suppliers City of Dallas Water Utilities (Dallas, or DWU) and North Texas Municipal Water District (NTMWD), is shown in Figure ES.1.

This report summarizes the results of the *Tarrant Regional Water District Integrated Water Supply Plan* (IWSP). The IWSP is an integration of the discrete planning that has been done over many years by TRWD and its customers and identifies the new water supplies with the greatest potential benefit for water supply reliability. The IWSP is not an endpoint (i.e., a final comprehensive plan), but is rather a *platform* that will be constantly built upon by integrating new opportunities, technologies, and strategies with the plan presented here.

Developing plans to meet the water supply needs of nearly 2 million people in North Central Texas has been a function of TRWD for decades. Because those plans have been implemented by building reservoirs, transmission pipelines, and reuse projects, and by encouraging conservation, the District can reliably supply water to its customers for another 15 years or more using current supplies, even assuming rapid population and water demand growth.

The purposes of this IWSP are:

1. Integrate what have historically been independent planning efforts for new supply strategies.
2. Develop an implementation plan for the next 50 years that is adaptive and maximizes reliability.
3. Develop a 50-year implementation plan that minimizes the effect on customer rates.
4. Communicate the implementation plans to stakeholders.
5. Support integration of District planning with other regional water providers

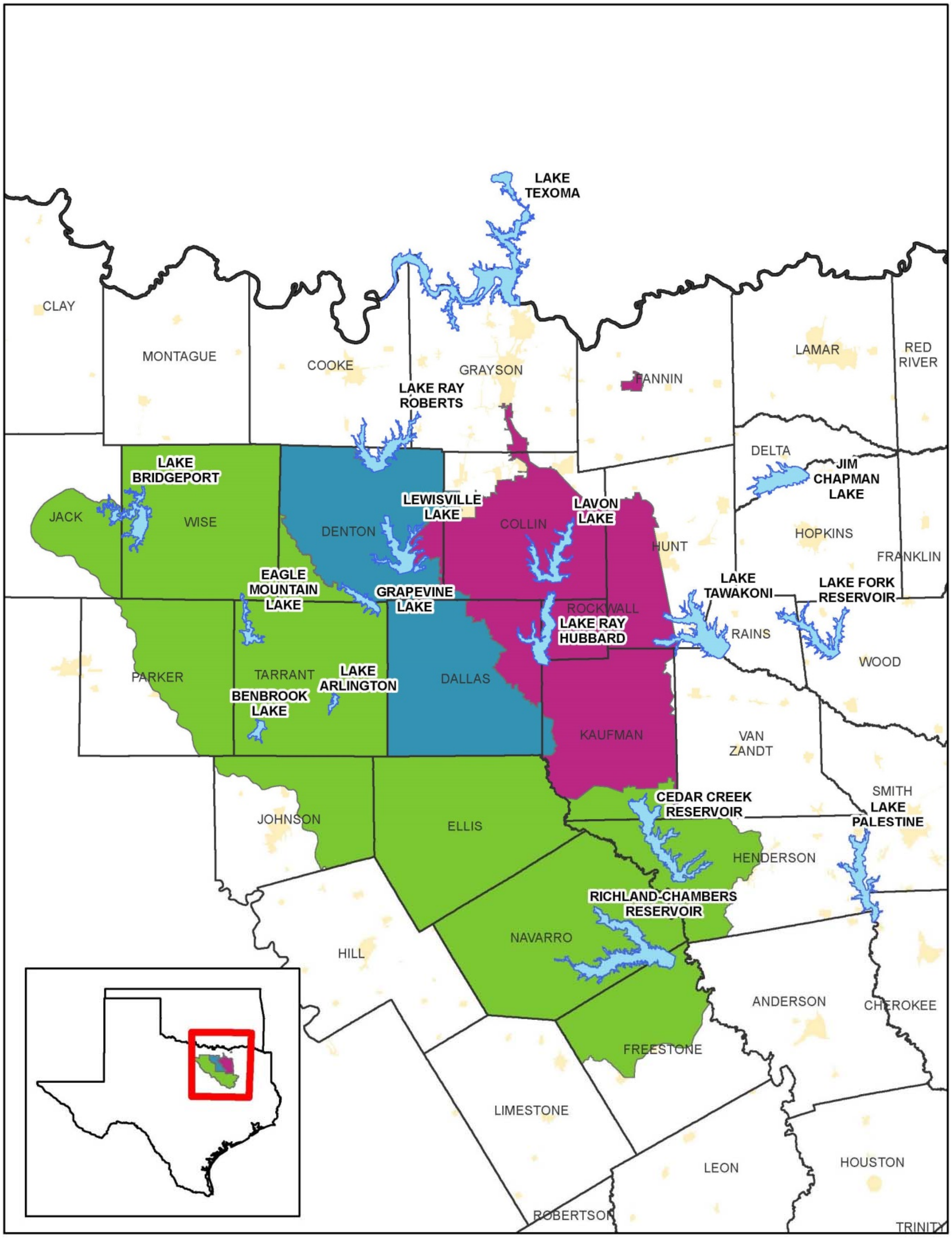


Figure ES.1 - Service Area Maps (TRWD in green, Dallas in blue, NTMWD in purple)

Overall, the IWSP aims at achieving these goals in a planning environment that acknowledges risk. In other words, there are many uncertainties about future water availability, population and demand trends, and economic conditions. The IWSP is structured around these uncertainties, addressing each in a systematic way that will allow TRWD to adapt the recommended plan to conditions as they evolve and materialize.

The following new (or expanded) water management strategies were analyzed in this plan and considered for inclusion in the final implementation plan. They are illustrated and described in Figures ES.2, ES.3, and Table ES.1 below.

- Conservation
- Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs (often shortened to “Unpermitted CC/RC Firm Yield” or “CC/RC Firm”)
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (often shortened to “CC/RC Wetlands Full Yield” or “CC/RC Wetlands”)
- Lake Columbia
- Excess Flow Optimization for Eagle Mountain Lake and Lake Benbrook (EXFLO)
- Kiamichi River
- Marvin Nichols Reservoir
- Lake Ringgold
- Lake Tehuacana
- Temple Reservoir
- Lake Texoma
- Toledo Bend Reservoir
- Lake Wright Patman

In response to the inherent uncertainty and imprecision in demand estimates, this study relies on scenario planning: two sets of demand projections are used to create multiple water supply plans that bracket the high and low predictions for the variables that significantly affect water demand. The first set of projections is based on the 2011 Region C Water Plan and represents a conservatively high estimate of future water demand. The second set of projections, developed by TRWD, is based on an extrapolation of the recent trends in actual water demand; it represents a low estimate of future demands assuming that recent trends continue. The two demand projections are compared in Figure ES.4.

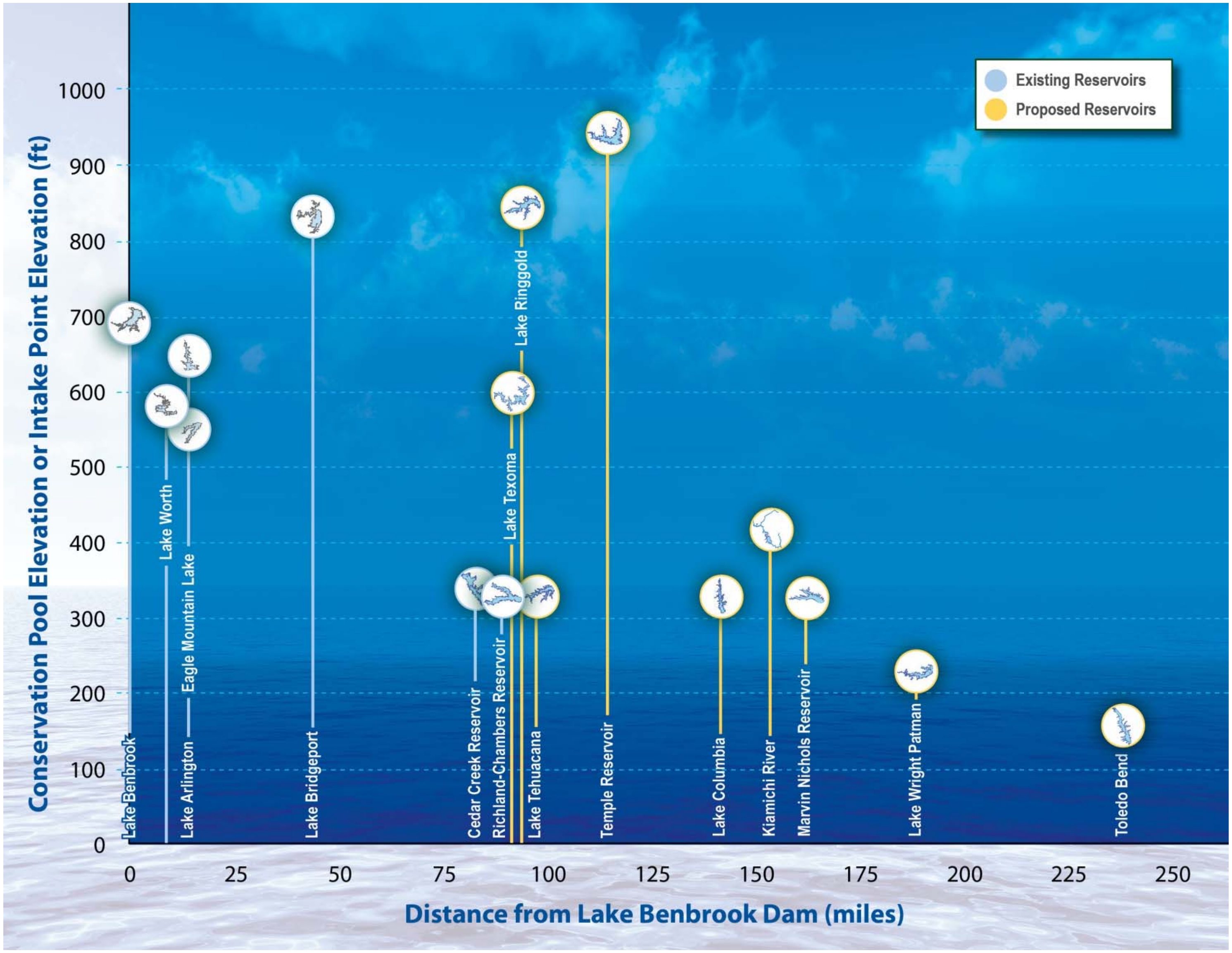


Figure ES.2 – Water Management Strategies Included in IWSP

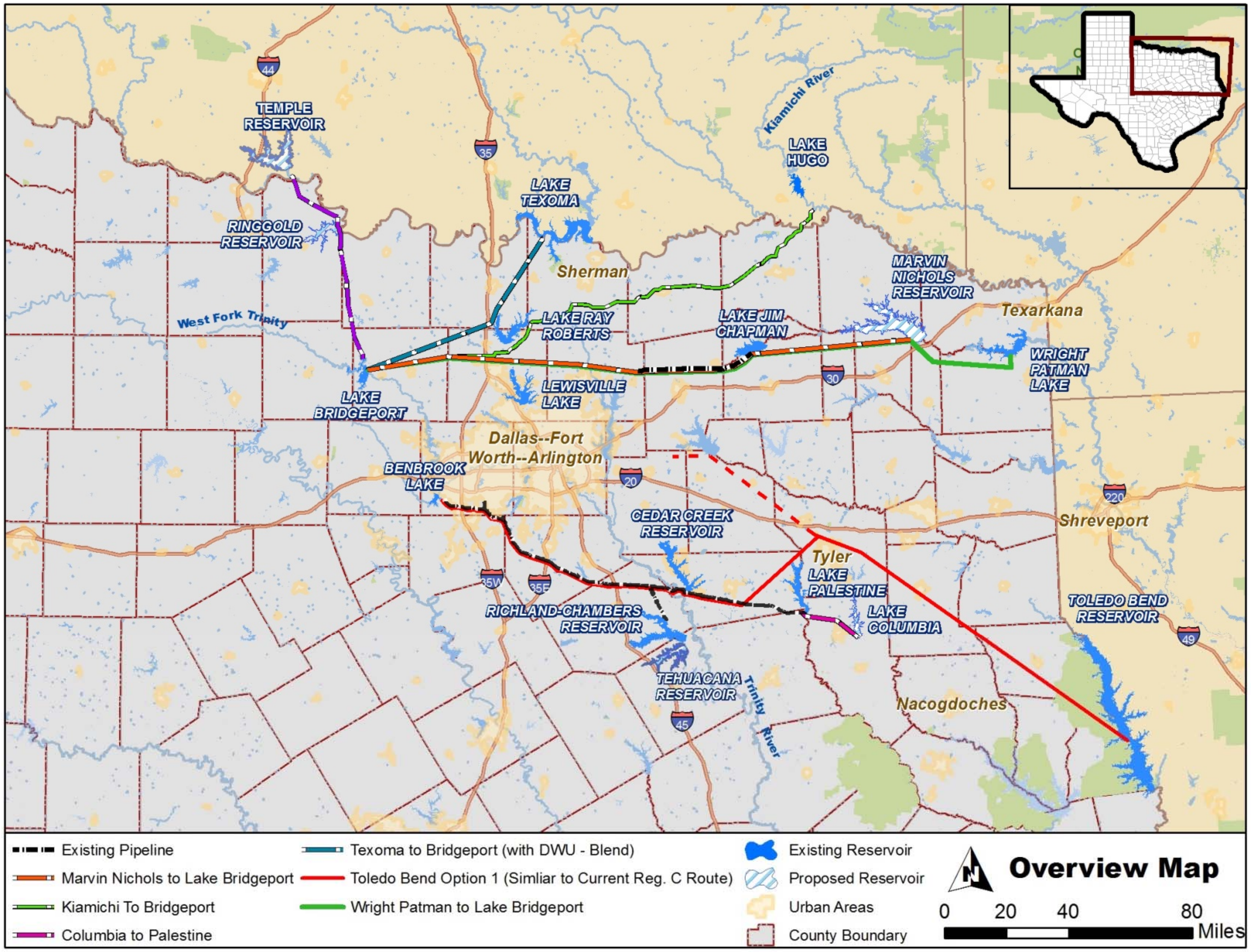


Figure ES.3 – Water Management Strategies' Transmission Routes

Table ES.1 – Summary of Water Management Strategies

Supply Option	Existing or New Reservoir / System	Total Yield / TRWD Yield (acre-feet/year)*	Probable Number of Years Required to Make Operational	Probable Capital Cost (2012 Dollars)
Unpermitted CC Firm Yield	Existing	17,201 in 2020, decreasing to 7,223 in 2060	3	$0 (short term) New Pipeline for 'CC/RC Firm': $415 M New Pipeline for 'CC/RC Unpermitted Wetlands': $465M New Pipeline for 'CC/RC Firm' and 'CC/RC Unpermitted Wetlands': $725M New Pipeline for 'CC/RC Firm', and 'CC/RC Unpermitted Wetlands', and Tehuacana: $1.44B
Unpermitted RC Firm Yield	Existing	46,831 in 2020, decreasing to 38,444 in 2060		
Unpermitted CC Wetlands Yield	Existing	35,559	3	
Unpermitted RC Wetlands Yield	Existing	37,465		
Lake Columbia	New	40,188	10.5	$250,165,000**
EXFLO Benbrook	Existing	78,653 Interruptible (Firm Yield = 0)	<5	$0
EXFLO Eagle Mtn	Existing	63,899 Interruptible (Firm Yield = 0)		
Kiamichi River	New	310,000 / 155,000	18.5	$1,810,696,000
Marvin Nichols Reservoir	New	612,300 / 142,850	19	$1,695,867,000
Lake Ringgold	New	28,600	12.5	$397,735,000
Lake Tehuacana	New	41,900	11	$580,790,000 (short term***) New Pipeline for 'CC/RC Firm', and 'CC/RC Unpermitted Wetlands', and Tehuacana: $1.44B
Temple Reservoir	New	125,000	15	$972,530,000
Texoma	Existing	Average 21,050 Interruptible Yield in 2060 (at 10:1 Blending Ratio)	14	$313,065,000
Toledo Bend	Existing	700,000 / 200,000	17	$2,751,751,000
Wright Patman	Existing	180,000	15.5	$2,394,849,000

** Environmental flow requirements were considered in all strategies. The TWDB's guidelines for regional water planning require that yield analysis for water management strategies be in accordance with Senate Bill 3 environmental flow standards and associated TCEQ rules, In most cases, the 1997*

Consensus Criteria for Environmental Flow Needs is used. However, modeling of new environmental flow criteria is still underway and will likely impact the yield of several water supply strategies.

*** Assumed Columbia will flow through IPL and Toledo Bend pipeline. Cost attributed to Columbia is the amount needed to increase Toledo Bend transmission system capacity enough to carry Columbia flows plus costs specific to Columbia (reservoir, portion of the pipeline to TRWD). A pipeline to convey only Lake Columbia is assumed to be cost prohibitive and is not considered here.)*

****These costs do not include the new pipeline that will eventually be needed to convey flows from Lake Tehuacana. It is most probable that the new pipeline would be built to carry Tehuacana and another supply (such as Unpermitted Yields from Cedar Creek and Richland-Chambers).*

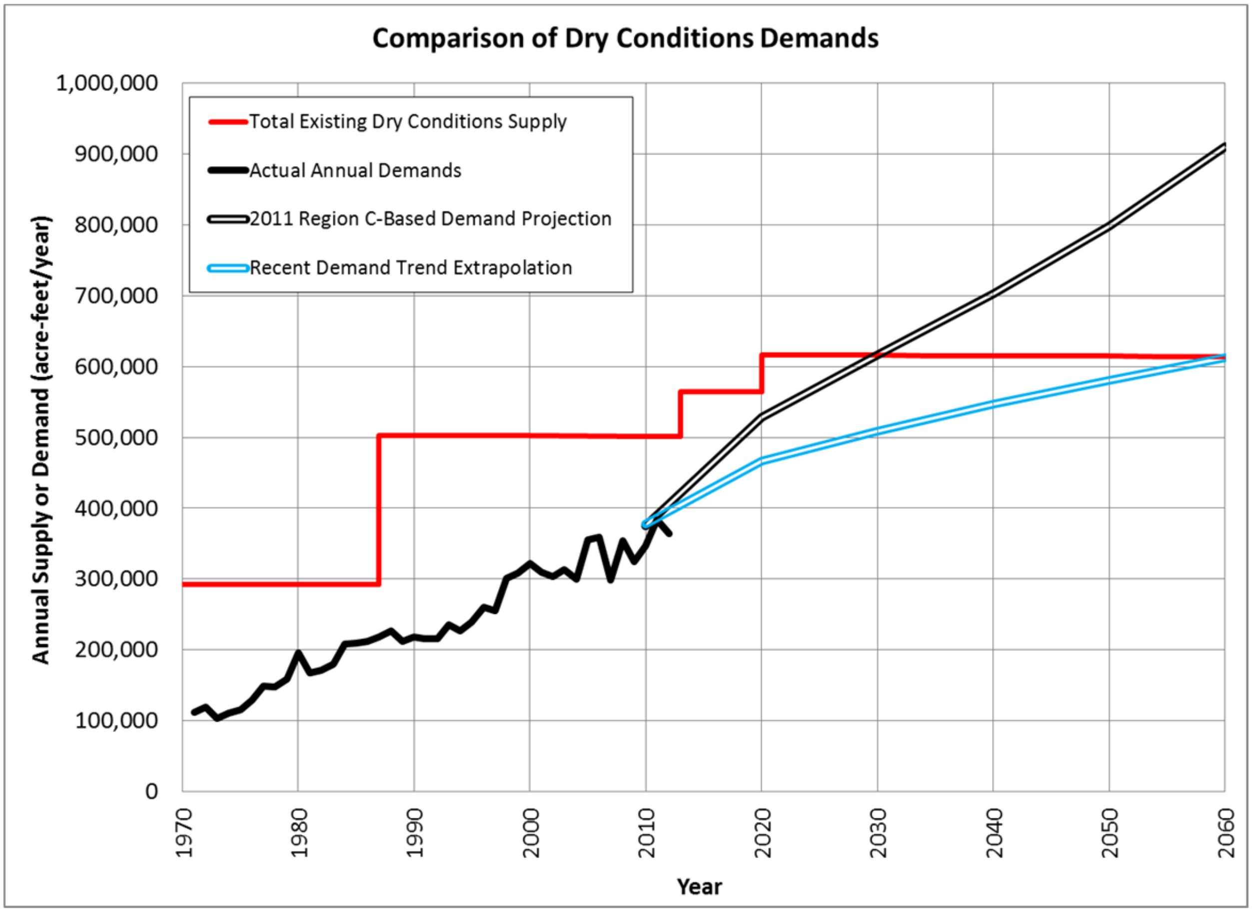


Figure ES.4 – Comparison of Demand Projections Used in IWSP

Characterization of Water Management Strategies (i.e. water supply strategies) was done by building on data from the 2011 Region C Water Plan and other previous studies. Strategies were characterized using the following information: 1) Annual yield estimates, 2) Capital and annual costs, 3) Transmission system hydraulic grade line, used to determine pipe size, pumping facility requirements, and to calculate pumping costs, 4) Risk Assessment, and 5) Implementation Schedule. Water supply strategies are configured by combining three primary variables – *Supply, Transmission,* and *Partnering/Other Options*. An example configuration would be an on-channel reservoir (the *Supply* variable) delivering through its own pipeline to TRWD's western reservoirs (the *Transmission* variable), shared with two other water suppliers (the *Partnering/Other* variable). Each strategy can be configured several different ways; the configuration that seemed to best meet TRWD's needs is used in this study.

ES.1 Definitions

The following definitions must be understood to make use of the recommended TRWD water supply plan.

- **Water Management Strategy (or simply "Strategy")**: a discrete water supply source, such as a new reservoir, groundwater, reuse water, or conservation (which is considered either as a strategy or a demand reduction, depending on the context).
- **Risk**: the chance that TRWD will be adversely impacted in its efforts to deliver water to customers reliably and economically.
- **System-wide Risks**: defined in this study as Population/Demand Growth Rate, Climate Variability, and Power Costs. These risks impact water supply reliability and cost for the entire TRWD system.
- **Strategy-specific Risks**: defined in this study as Institutional/Legal Risks, Regulatory/Environmental Risks, and Capital Cost Variability/Water Quality Risks. These risks impact project viability and schedule of individual projects.
- **Scenario**: alternative future conditions that address system risks; a combination of system risks that together define a possible future. An example scenario would be "stressed system" in which demands and power costs are on the high end of projections and climate variability reduces available supplies. It was necessary to limit the number of scenarios used in this study so that the results can be useful and digestible, so the following scenarios were selected for analysis:
    - Accepted Projections Scenario: a possible future in which demand grows as projected by the 2011 Region C based demand projections, historic climate and streamflow is an accurate prediction of the future, and power costs grow as predicted in Appendix H.
    - Stressed System Scenario: a possible future in which demand grows as projected by the 2011 Region C based demand projections, future flows are 15% lower and future evaporation is 15% higher than historic values, and power costs grow at a rate 25% greater than predicted.
    - Optimistic Projections Scenario: a possible future in which demand grows as projected based on extrapolation of recent trends, historic climate and streamflow is an accurate prediction of the future, and power costs grow at a rate 25% less than predicted.

- **Portfolios**: a combination of strategies based on a theme (e.g. low cost, low risk) and built to ensure system reliability under a specific scenario. Three themes were selected for the IWSP: Low Cost, Low Risk, Regional Partnerships/High Yield. Each portfolio was built by ranking water management strategies according to their metrics for that theme and then adding strategies to that portfolio in order of highest to lowest preference.

Table ES.2 – Portfolios

Low Risk	Low Cost	Regional Partnerships/High Yield
Conservation	Conservation	Conservation
EXFLO	EXFLO	EXFLO
CC/RC Wetland Permits	CC/RC Wetland Permits	CC/RC Wetland Permits
CC/RC Firm Yield Permits	CC/RC Firm Yield Permits	CC/RC Firm Yield Permits
Lake Ringgold	Temple Reservoir	Marvin Nichols Reservoir
Lake Tehuacana	Lake Tehuacana	Toledo Bend Reservoir
Toledo Bend Reservoir	Marvin Nichols Reservoir	Wright Patman Lake
	Lake Ringgold	Kiamichi River
	Kiamichi River	

- **Implementation Plans**: a plan for the order in which strategies should be developed and the schedule of when they should be connected to the TRWD system to maintain supply reliability.
- **Decision Tree**: an adaptive management plan based on major triggers that result in actions on selection and sequencing of strategies.
- **Performance Measure**: water supply reliability is the performance measure used to determine when new water supply strategies should be completed.

ES.2 Recommended Plan

A final adaptive management plan, a decision tree, has been built for use by TRWD decision makers to answer questions such as:

- What is the next preferred water management strategy?
- When does the next water management strategy need to be connected to the TRWD water supply system?
- When does TRWD need to begin developing the next water management strategy?
- If conditions change and a strategy is no longer viable, what is the next best alternative?
- When must the decision be made to substitute the existing plan for new strategies?

A detailed decision tree was built for the Accepted Projections Scenario and is available in Appendix G. A separate decision tree is not necessary for the Optimistic Projections Scenario because no additional water supply is needed in the 50-year planning timeframe if demand grows according to this scenario. Section 5.4.2 of this report describes modifications needed to the decision tree under the Stressed System Scenario.

This decision tree does not include every possible future scenario, decision point, or alternative branch because there are infinite possibilities. Instead, the most likely and the recommended paths are included. Two primary decision triggers were used:

1. Yes/No decision to prioritize the timing of a major regional water management strategy over the recommended TRWD implementation plan. As stated earlier, TRWD is committed to partnering with other water suppliers to develop large regional supplies. This decision point does not question whether or not TRWD will partner with other suppliers, instead it questions the *timing* of when those strategies need to be developed. Under almost every possible future scenario, at least one major regional water management strategy is recommended for TRWD; this decision trigger would only accelerate the timing of that strategy.

2. Project Viability – the decision tree recommends alternate strategies should any recommended implementation path become unfeasible.

It is recommended that TRWD implement water management strategies based on the Accepted Projections Scenario. The recommended TRWD water supply plan, based on the detailed decision tree in Appendix G, is shown in Figure ES.5 below. In narrative form, the recommendations from the decision tree are as follows:

- If demand, supply and power cost trends follow the Optimistic Projections Scenario, develop the No Regrets strategies, which include *Conservation, EXFLO, Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits* (i.e. "CC/RC Wetlands"), and *Unpermitted Firm Yield in Cedar Creek and Richland-Chambers Reservoirs* (i.e. "CC/RC Firm"). Though the additional supply is not needed until after 2060, it is recommended that the permits for these strategies be secured without delay because of their very low cost, low risk, and benefits to TRWD reliability and operational cost. However, if trends follow the Optimistic Projections Scenario, TRWD can delay building infrastructure to convey these sources until 2060.

- If demand, supply and power cost trends follow the Accepted Projections Scenario, develop the No Regrets strategies now, followed by the necessary transmission system by 2030. Conservation should be an on-going strategy. At the latest, develop EXFLO and CC/RC Wetlands permits by 2030 (including a new pipeline sized to carry CC/RC Wetlands permit water and CC/RC Firm permit water and Lake Tehuacana supply), followed by CC/RC Firm permits by 2040.

- **Decision Point 1**: Were the No Regrets strategies successfully developed?

- o If No Regrets strategies were successfully developed, it is recommended that TRWD continue to develop the Low Cost portfolio of strategies.

  - **Decision Point 2**: Should TRWD prioritize the timing of a major regional water management strategy over the recommended TRWD implementation plan?

    - If yes, develop Marvin Nichols Reservoir and its transmission system to Lake Bridgeport by 2045 and Lake Tehuacana, without a new pipeline since the additional pipeline added for CC/RC Wetlands and CC/RC Firm will be sized to also convey Lake Tehuacana supply, by 2055. **(Branch 1)**

    - If no, develop Temple Reservoir and its transmission system to Lake Bridgeport by 2045 and Lake Tehuacana, without a new pipeline since the additional pipeline added for CC/RC Wetlands and CC/RC Firm will be sized to also convey Lake Tehuacana supply, by 2055. If Temple Reservoir and/or Lake Tehuacana development is not possible, Marvin Nichols should be used as a substitute strategy for Temple Reservoir and Lake Ringgold as a substitute for Lake Tehuacana. **(Branch 2)**

- o If No Regrets permitting strategies are not successfully developed, it is recommended that TRWD develop the Low Risk portfolio of strategies because the timeframe for developing new supply will be more compressed and because the unsuccessful development of the lowest risk strategies signals that the risk of developing all other strategies has also grown and TRWD should place priority on their lowest risk options.

  - **Decision Point 2**: Should TRWD prioritize the timing of a major regional water management strategy over the recommended TRWD implementation plan?

    - Even if the answer to this decision point is yes, there is not sufficient time to develop a major regional water management strategy by 2030, when new supply is required to maintain system reliability. (The lowest risk major regional strategy is Toledo Bend Reservoir.)

    - If no, develop Lake Ringgold and its transmission system to Lake Bridgeport by 2030. Next develop Lake Tehuacana and a new pipeline to Lake Benbrook by 2035 *and* Toledo Bend Reservoir and its transmission system to Lake Benbrook . Development of the Lake Tehuacana and Toledo Bend projects will be concurrent so the transmission systems should be combined. **(Branch 3)**

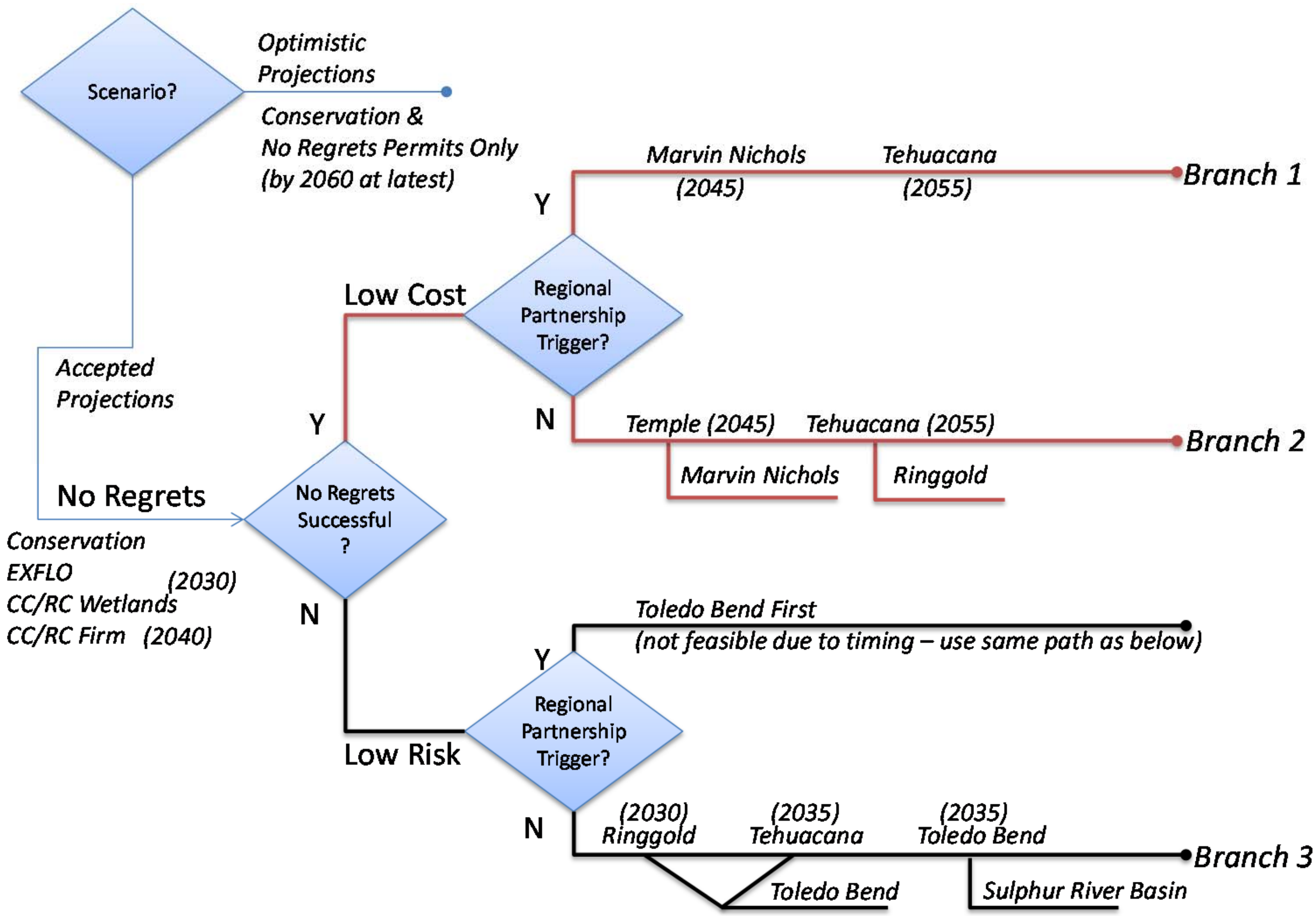


Figure ES.5 – Recommended TRWD Water Supply Plan

The detailed decision tree in Appendix G specifies several other possible paths TRWD could take to developing water management strategies. It also specifies the year by which decisions must be made to change paths should individual strategies become unviable.

A separate decision tree was not created for the Stressed System Scenario because it is nearly identical to the Accepted Projections Scenario decision tree. However, should TRWD demands grow, supplies diminish, and power costs grow as predicted in the Stressed System Scenario, some modifications are required.

- Branch 1 – accelerate the No Regret strategies by 5 years, which is feasible based on their implementation schedules. The timing of Marvin Nichols Reservoir and Lake Tehuacana are not significantly altered.
- Branch 2 – accelerate all strategies by by 5 years, which is feasible based on their implementation schedules. The system simulation modeing showed that some strategies need to be accelerated by five years while others may not need to be. To be conservative, a five year acceleration is recommended for all strategies..
- Branch 3 – replace development of Lake Ringgold in 2030 with development of Lake Tehuacana by 2025. Lake Ringgold and Toledo Bend would then be developed in 2035 under this scenario, instead of Lake Tehuacana and Toledo Bend by 2035, as recommended in the Accepted Projections scenario.

It is recommended that TRWD track key indicators as recommended in Section 7 to determine if these modifications, or additional modifications, are needed to the recommended TRWD water supply plan.

Section 6 provides the probable financial impact of each branch of the IWSP water supply plan shown in Figure ES.5 in terms of capital cost, annual costs, and impact on TRWD rates.

The recommended timing of the projects is contingent upon many things. Most importantly, the timing is based on projected water demands. If demand grows at rates slower or faster than those used in this analysis, project phasing can be adjusted accordingly, or alternative solutions may become more appropriate.

It is impossible to forecast with certainty what demand levels will be in fifty years. Likewise, it is impossible to forecast economic conditions or hydrologic trends. The decision tree is based on projections of possible future conditions, but it must be adapted as conditions change. In lieu of forecasting unpredictable future trends, the Integrated Water Supply Plan proposes tracking trends as part of the implementation of the plan. These trends should be reviewed periodically, and the decision tree or other portions of the plan adjusted as needed. It is recommended that this update occur at least every five years, and would involve updating the analyses in this study as needed and revising the decision tree according to the new results.

The following list offers guidance on the hydrologic, socio-economic, and institutional trends that should be tracked as part of the implementation of this plan:

- Annual Demand
- Seasonal Demand Peaking
- Storage Capacity
- Climate Trends
- Effectiveness of Conservation Measures
- Effectiveness of Drought Response Measures
- Regional Agreements and Decisions by Other Utilities
- Energy Prices
- Instream Flow Regulations
- Status of Project Implementation

Section 1 - Introduction and Background

Tarrant Regional Water District (TRWD) operations span an 11-county area reaching from Jack County to Freestone County. The District has two primary missions: water supply and flood control. TRWD provides raw water to more than 1.7 million people in the North Central Texas area, serving more than 30 wholesale customers including the cities of Fort Worth, Arlington, Mansfield, and the Trinity River Authority. TRWD supplies only raw water to wholesale customers and does not own or operate treatment or distribution facilities. Its water supplies include four major reservoirs (Lake Bridgeport, Eagle Mountain Lake and the Cedar Creek and Richland-Chambers Reservoirs) and three storage reservoirs (Lake Arlington, Lake Benbrook, and Lake Worth), and the District has constructed more than 150 miles of water pipelines, 27 miles of floodway levees, more than 40 miles of Trinity River Trails and a 2000+ acre wetland water reuse project designed to increase future water supplies. The raw water system is shown in Figure 1.2 and TRWD's service area, in relationship to the service areas of neighboring regional water suppliers City of Dallas Water Utilities (Dallas, or DWU) and North Texas Municipal Water District (NTMWD), is shown in Figure 1.1.

TRWD is located in the upper portion of the Trinity River Basin (see Figure 1.3 for major Texas river basins). Average annual precipitation in the region increases west to east from slightly more than 30 inches per year in western Jack County to more than 44 inches per year in the northeast corner of Fannin County. The rate of evaporation from a reservoir surface exceeds rainfall throughout the region on average (*2011 Region C Water Plan,* pg. 1.12). Surface water is the primary source of supply in the region and the only source currently utilized by TRWD, though some of its customers have relatively small amounts of local groundwater supply.

Developing plans to meet the water supply needs of nearly 2 million people in North Central Texas has been a function of TRWD for decades. Because those plans have been implemented by building reservoirs, transmission pipelines, and reuse projects, and by encouraging conservation, the District can reliably supply water to its customers for another 15 years or more using current supplies, even assuming rapid population and water demand growth.

Following completion of Eagle Mountain and Bridgeport Lakes on the West Fork Trinity River in the early 1930's, the District, then named Tarrant County Water Control & Improvement District Number One, began providing water supply to the City of Fort Worth in excess of the supply available to the City from Lake Worth.

The District's water supply operation was then financed by an ad valorem tax until 1959, when Fort Worth entered into a contract with the District to finance the construction of Cedar Creek Reservoir. Under this contract the City agreed to transfer pending water right applications with the State of Texas for both Cedar Creek and Richland-Chambers Reservoirs and initiated payment for water supply provided by the District.

1957 Plan - Report on Sources of Additional Supply (Freese & Nichols, Inc.)

As the drought of record in North Texas abated in the spring of 1957, a joint water supply study by the City of Fort Worth and the District was completed. Projections of population and water demand through the year 2000 were prepared. The report determined that projected 1960 water demands were 98 MGD while reliable supply was 81 MGD. Preliminary design and costs of the Cedar Creek and Richland-Tehuacana dams, reservoirs and transmission facilities were prepared. The report recommended construction of the Cedar Creek Reservoir and initial transmission facilities at an estimated cost of $50 million.

1979 Plan - Report on Sources of Additional Supply (Freese & Nichols, Inc.)

For this plan, projections of population and water demand through the year 2030 were prepared. Updated preliminary design and costs of the Richland-Tehuacana dam, reservoir and transmission facilities were prepared along with a staged development plan to accommodate project delivery correlated to water supply needs. The report projected that water demand would increase to equal the District's supply by 1990, and that a new source of supply should be added in time to be available on a regular operational basis by that date. The report recommended construction of the Richland-Chambers Reservoir and initial transmission facilities at an estimated cost of $300 million.

1982 Plan - Report on Sources of Additional Supply (Freese & Nichols, Inc.)

The previous recommendation to acquire and construct a significant volume of regulating storage in Tarrant County was reviewed and the recommendation was made to utilize Lake Benbrook instead of Lake Joe Pool for terminal storage of water delivered from Cedar Creek and Richland-Chambers Reservoirs. The report recommended construction of a pipeline and tunnel from the terminus of the District's East Texas pipelines in Southeast Fort Worth to Lake Benbrook by 1995 at an estimated cost of $42 million.

1990 Plan - Report on Sources of Additional Supply (Freese & Nichols, Inc.)

With completion of water supplies recommended in the 1959 Plan, the District, in association with the Texas Water Development Board, investigated additional water supply alternatives. The report found that water demand would increase to equal District supply by 2016, and that a new source of supply should be added in time to be available on a regular operational basis by that date. The report recommended construction of facilities to divert supplemental water from the Trinity River to augment the yield of Richland-Chambers Reservoir by 30% or 63,000 acre-feet by 2016. A similar capability should be constructed and in place at Cedar Creek Reservoir to augment the yield of the reservoir by 30% or 52,500 acre-feet by 2028.

1999 Plan – Water Management Plan (HDR, Inc. and Alan Plummer Associates, Inc.)

Projections of population and water demand through the year 2050 were prepared. The report projected that water demand would increase to equal the District's supply (including the additional supplies afforded by completion of Trinity River diversions into Richland-Chambers and Cedar Creek) by 2034, and that a new source of supply should be added in time to be available on a regular operational basis by 2034. The report recommended that the District proceed with engineering design studies for delivery of water for terminal storage at Eagle Mountain Lake. The study also recommended the following:

- Continue to review Safe Drinking Water Act issues, particularly the Source Water Protection Rules, for impacts to the District and treatment requirements placed on customers.
- Work closely with District customers to achieve the water conservation goals.
- Study Marvin Nichols Reservoir to compare permitting issues, construction costs, and delivery facility costs to Tehuacana Reservoir.

2002 Plan – System Reliability and Enhancement Study (Freese & Nichols, Inc.)

This report projected that water demand would increase to the District's supply (including the additional supplies afforded by completion of Trinity River diversions into Richland-Chambers and Cedar Creek) by 2037. To further accommodate terminal storage in Tarrant County and regulate transmission system operations, the report recommended construction of a pipeline from the terminus of the District's East Texas pipelines adjacent to Lake Benbrook to Eagle Mountain Lake at an estimated cost of $56 million.

TWDB Regional Water Planning

In 1997 the 75th Texas Legislature passed Senate Bill One (SB1), a landmark bill designed to ensure reliable water supply for Texans. TRWD became part of Region C, one of sixteen regional water planning groups established by SB1 and shown in Figure 1.4. The boundaries of Region C, and some of its major water resources, are shown in Figure 1.5. These regional water planning groups are responsible for developing a plan, updated every five years, to meet the next 50 years of water demands.

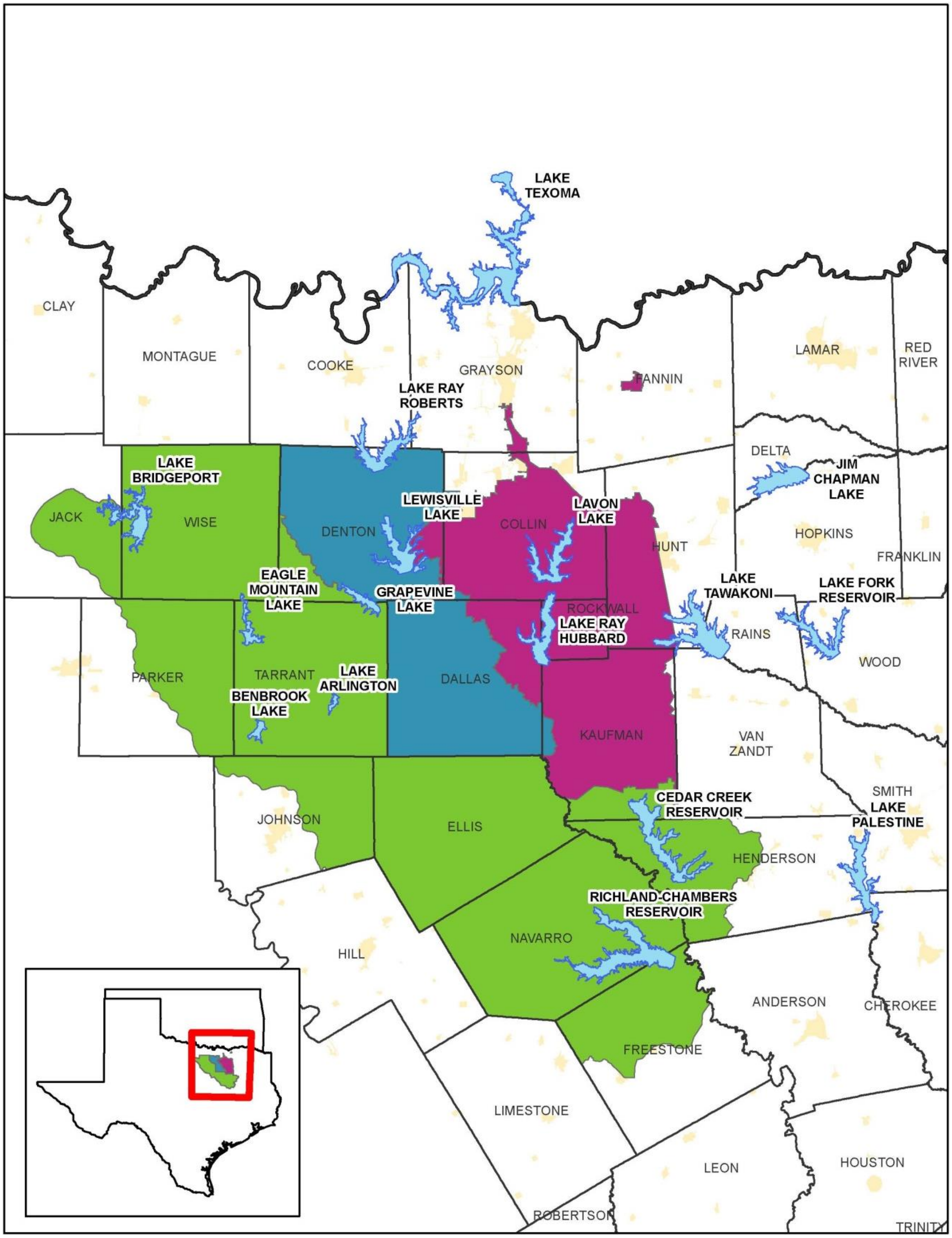


Figure 1.1 - Service Area Maps (TRWD in green, Dallas in blue, NTMWD in purple)

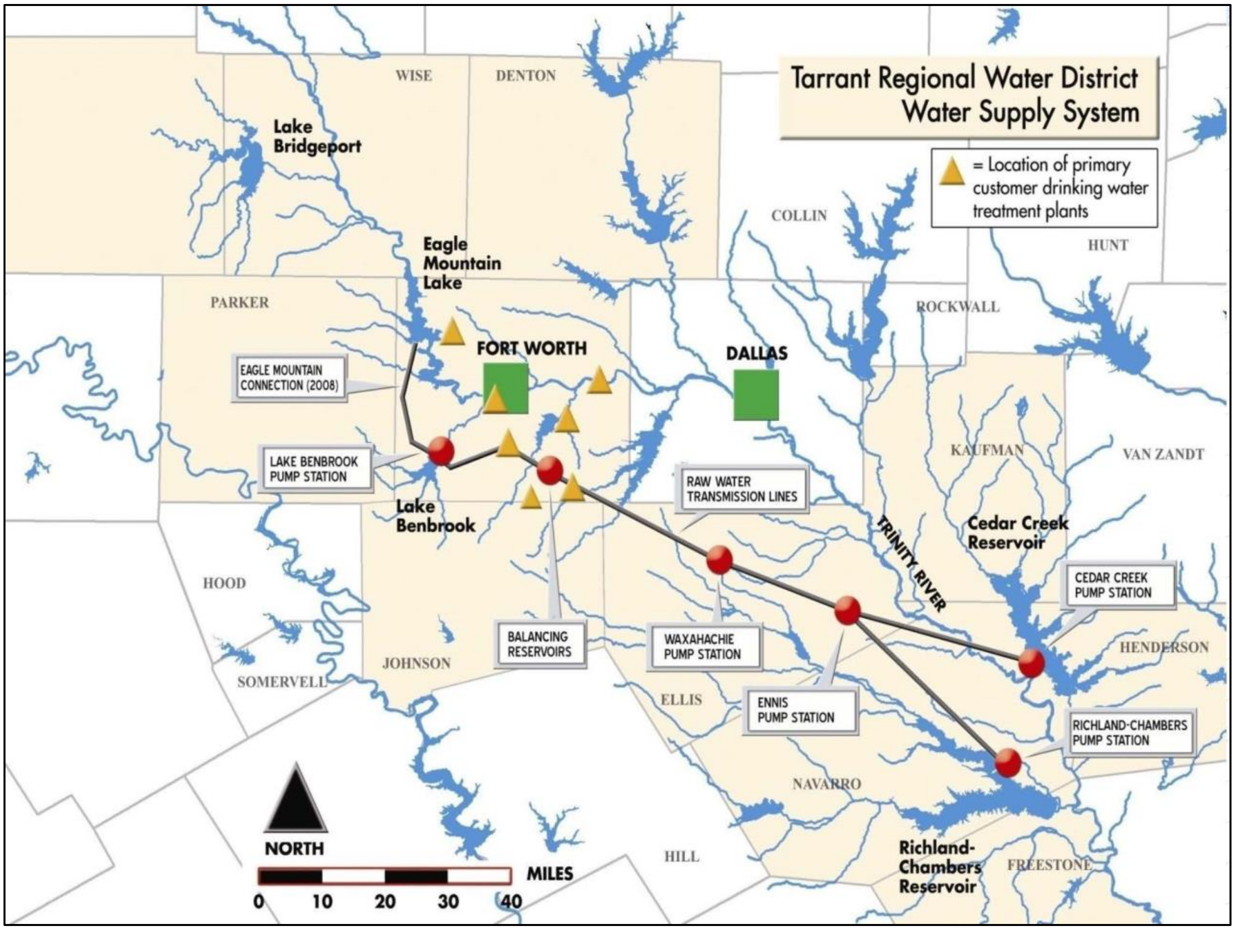


Figure 1.2 - TRWD System Map

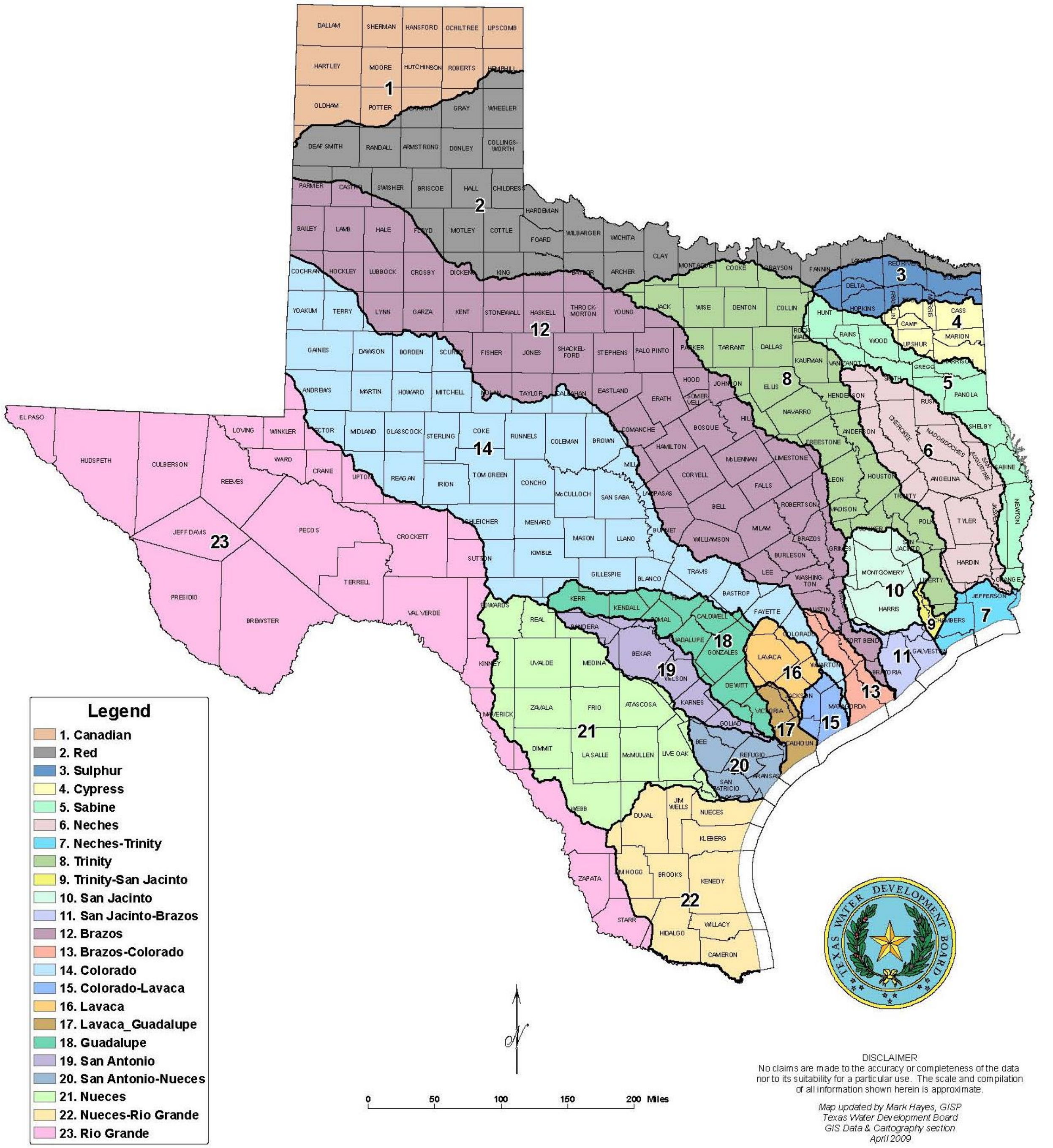
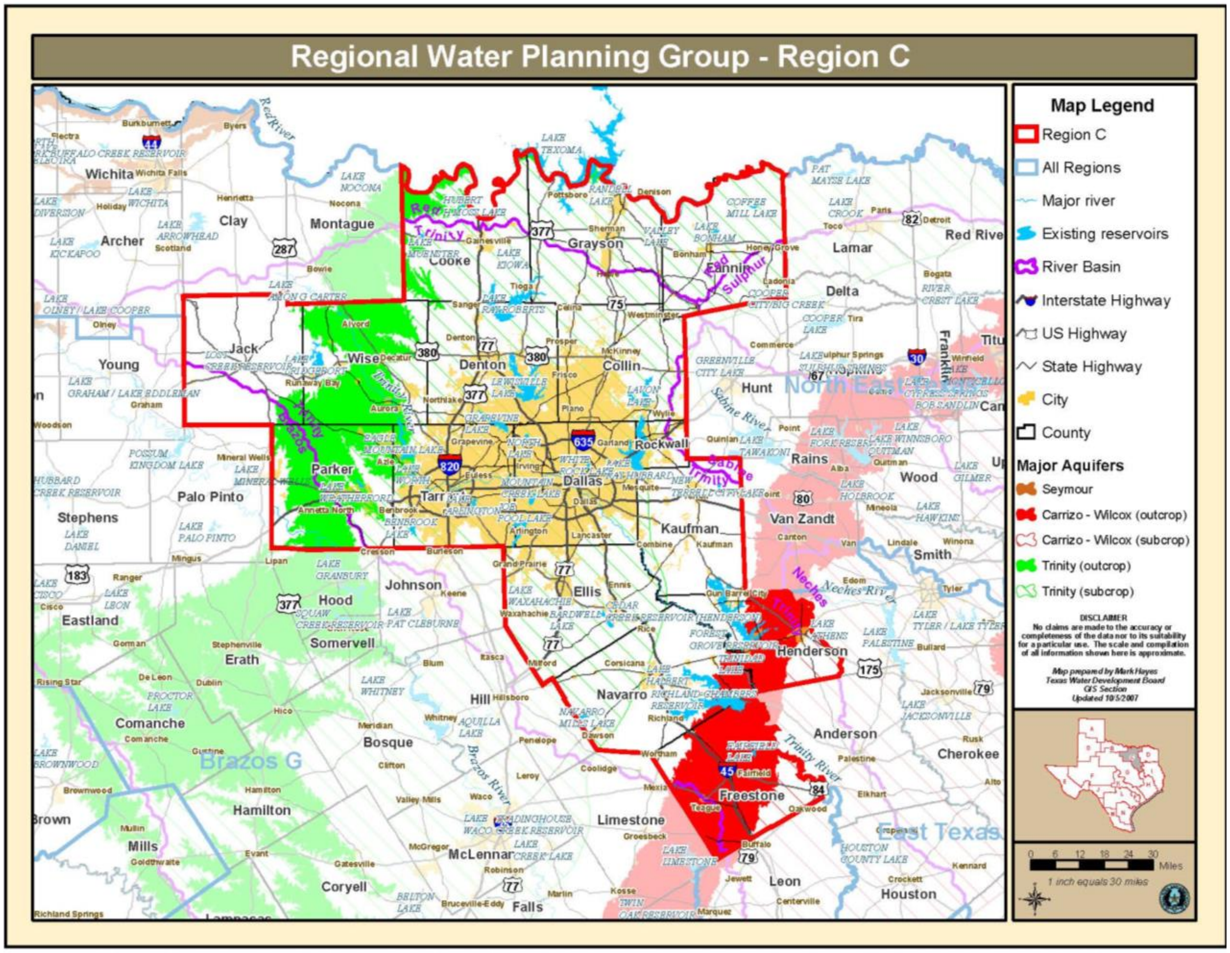


Figure 1.3 - Major River Basins in Texas (source: http://www.twdb.state.tx.us/mapping/maps.asp)

TRWD has participated in the regional planning process since its creation in 1997 and will continue to do so in the future. Many water suppliers in the region use the results of their own water supply planning efforts as input to the regional water plan; that is the case with TRWD. This Integrated Water Supply Plan will function as TRWD's roadmap to future water supply development and will be the basis for water supply strategies suggested for the regional planning process.

Figure 1.4 – Regional Water Planning Group Boundaries (source: http://www.twdb.state.tx.us/mapping/maps.asp)



Map updated by Mark Hayes, Texas Water Development Board, Planning Division, GIS Section (10/07) L:\projects\RIO\TS\carchuleta\Maps_ArcGIS\MXDs\Regional Water Planning Area Maps

Figure 1.5 - Region C Water Planning Group Boundaries (source: http://www.twdb.state.tx.us/mapping/maps.asp)

Demand Projections

Figure 1.6 compares historic demand projections with the demand projections being used in this study. All information shown in Figure 1.6 represents 'dry conditions' supply and demand, except for line showing actual TRWD deliveries since 1971. Supplies now available (or soon to be available) in dry conditions are also provided for reference against the dry conditions demands, though it should be noted that much more supply is available when the West Fork Trinity River supply reservoirs (Lakes Bridgeport and Eagle Mountain) are above low lake levels that trigger contract limits, which curtail their usage at low lake levels. The two demand projections used in this study ('2011 Region C Based Demand Projection" and 'Recent Demand Trend Extrapolation') are shown in Figure 1.6 and explained in Section 3. It is worth noting at this point, before the full explanation in Section 3, that the '2011 Region C Based Demand Projection' cannot be compared directly to the numbers found in the 2011 Region C Water Plan because they have been modified for use in this study.

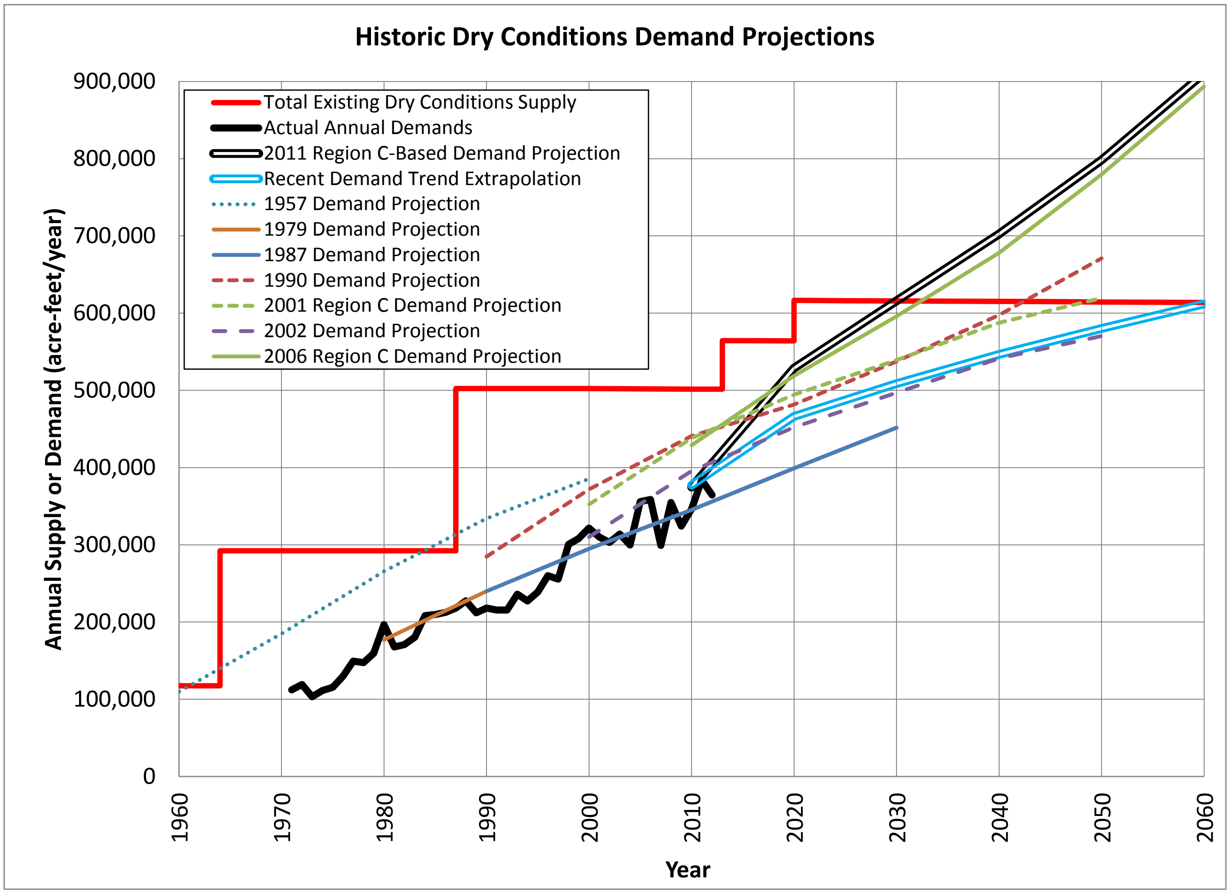


Figure 1.6 - Historic Water Demands, Supplies, and Demand Projections

1.1 The Need for an Integrated Plan

This report summarizes the results of the *Tarrant Regional Water District Integrated Water Supply Plan* (IWSP). The IWSP is an integration of the discrete planning that has been done over many years by TRWD and its customers and identifies the new water supplies with the greatest potential benefit for water supply reliability. The IWSP is not an endpoint (i.e., a final comprehensive plan), but is rather a *platform* that will be constantly built upon by integrating new opportunities (e.g. local sources, reuse of treated wastewater effluent), technologies (e.g. aquifer storage and recovery, advanced conservation), and strategies (e.g. groundwater) with the plan presented here. This enables TRWD to innovate and maximize value for its customers.

The purposes of this IWSP are:

1. Integrate what have historically been independent planning efforts for new supply strategies.

2. Develop an implementation plan for the next 50 years that is adaptive and maximizes reliability.
3. Develop a 50-year implementation plan that minimizes the effect on customer rates.
4. Communicate the implementation plans to stakeholders.
5. Support integration of District planning with other regional water providers

1.2 Scope of the Integrated Plan

As mentioned above, the IWSP is a platform for the integration of the discrete planning efforts that have been done over many years for TRWD's conservation efforts and new surface water supplies with the greatest potential impact on water supply reliability. Buhman Associates, LLC, in partnership with CDM Smith, Inc. and Freese and Nichols, Inc. have prepared this plan for TRWD based on the following scope of services:

- Characterization of Water Management Strategies (i.e. water supply strategies): building on data from the 2011 Region C Water Plan and many previous studies, water supply strategies were characterized using the following information, all of which was summarized in a fact sheet developed for each individual strategy:
    - Annual yield estimates (acre-feet/year)
    - Capital and annual costs. Opinions of probable capital and annual cost were developed using the methodology, level of detail, and parameters as used in the on-going 2016 Region C Water Plan project. These annual costs include debt service, electricity costs (pumping costs), and operations and maintenance costs. The electricity costs were developed based on the assumption that the full annual yield is delivered to TRWD each year. A second set of pumping costs was also developed using a time series of predicted monthly pumping; in other words, the monthly pumping costs were calculated based on simulations of probable monthly deliveries in future decades under various supply and demand scenarios. These simulated monthly deliveries are an output from the IWSP System Simulation Model (described below).
    - The transmission system hydraulic grade line, used to determine pipe size, pumping facility requirements, and to calculate pumping costs.
    - A risk assessment (described below).
    - An implementation schedule, which defines the probable amount of time required for each of the major tasks that need to be completed as part of planning, designing, and constructing each strategy.
    - TRWD raw water system supply reliability with and without each strategy. The IWSP System Simulation Model was used to calculate these reliability statistics.

The following water management strategies are included in this *Integrated Water Supply Plan;* fact sheets for each are included in Appendix A:

- Conservation
- Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs (often shortened to "Unpermitted CC/RC Firm Yield" or "CC/RC Firm")
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (often shortened to "CC/RC Wetlands Full Yield" or "CC/RC Wetlands")
- Lake Columbia
- Excess Flow Optimization for Eagle Mountain Lake and Lake Benbrook (EXFLO)
- Kiamichi River
- Marvin Nichols Reservoir
- Lake Ringgold
- Lake Tehuacana
- Temple Reservoir
- Lake Texoma
- Toledo Bend Reservoir
- Lake Wright Patman

- Characterization of Water Management Strategy Risks. "Risks" are issues or conditions that influence uncertainty in project performance or viability. In its most basic form, risk is comprised of likelihood and impact. In this project, two types of risk are defined: system-wide risks, such as population/demand growth and climate variability; and project specific risks, which impact project viability and schedule. Risks for each water management strategy were quantified (i.e. scored) using the professional judgment of the entire IWSP Team. The risk scores were then used to quantify the potential impact on each strategy's implementation schedule.

- IWSP System Simulation Model. As part of the TRWD-City of Dallas Integrated Pipeline (IPL) Project planning, completed in 2012, a model was built to simulate how the TRWD and Dallas raw water supply and transmission systems could meet future demands. The model was built using the STELLA software package. In this study, that model was substantially modified to include additional water supply sources and strategies. The model was then used to simulate water supply reliability under various conditions. The conditions were built by combining different levels of demand, hydrologic conditions, and available supplies.

- Implementation Plans and Decision Tree. Three portfolios (a combination of water management strategies based on some theme) were developed and tested against three possible scenarios (possible future conditions). Each scenario is a combination of one demand projection, one hydrologic condition, and one projection of power supply costs. An implementation plan was built for each portfolio/scenario combination and then summarized into a final IWSP Decision Tree. The implementation plan and decision tree include a sequencing plan and schedule for developing water supply strategies over the next 50 years.

1.3 Integrated Planning – General Methodology

Exhibit 1-1 describes the sequence employed to arrive at a recommended 50-year TRWD water supply planning decision tree, an adaptive management plan based on major triggers that result in selection and sequencing of strategies. The Integrated Water Supply Plan began when TRWD hired a consulting team to integrate planning for several independent water management strategies. TRWD selected a group of strategies for this Integrated Water Supply Plan, focusing primarily on surface water strategies that have already been part of District planning. The team then analyzed each strategy independently to assess their implementation risk, capital and annual cost, individual impact on supply reliability, project development (planning, design, construction) schedule, and yield. Demand projections were also selected and system-wide risks were defined.

Using those analyses as input, we next developed Portfolios and Scenarios. Portfolios are a combination of strategies based on a theme (e.g. low cost, low risk), built to ensure system reliability under a specific scenario. Scenarios are alternative futures that address system risks; in other words, a combination of system risks that together define a possible future. An example scenario would be “stressed system” in which demands and power costs are on the high end of projections and climate variability reduces available supplies.

Implementation Plans were then built for Portfolio/Scenario combinations. These plans define the order in which strategies should be developed and the schedule of when they should be connected to the TRWD system to maintain supply reliability. Supply reliability performance measures (frequency and magnitude of simulated shortages) determine when each new strategy should be connected, and these performance measures were calculated using the IWSP System Simulation Model. Each plan is essentially how to implement each portfolio under a possible future scenario.

The implementation plans provide the building block for an adaptive management plan, a decision tree that can be used by TRWD decision makers to answer questions such as:

- What is the next preferred water management strategy?
- When does the next water management strategy need to be connected to the TRWD water supply system?
- When do we need to begin developing the next water management strategy?
- If conditions change and a strategy is no longer viable, what is the next best alternative?
- When must the decision be made to substitute the existing plan for new strategies?

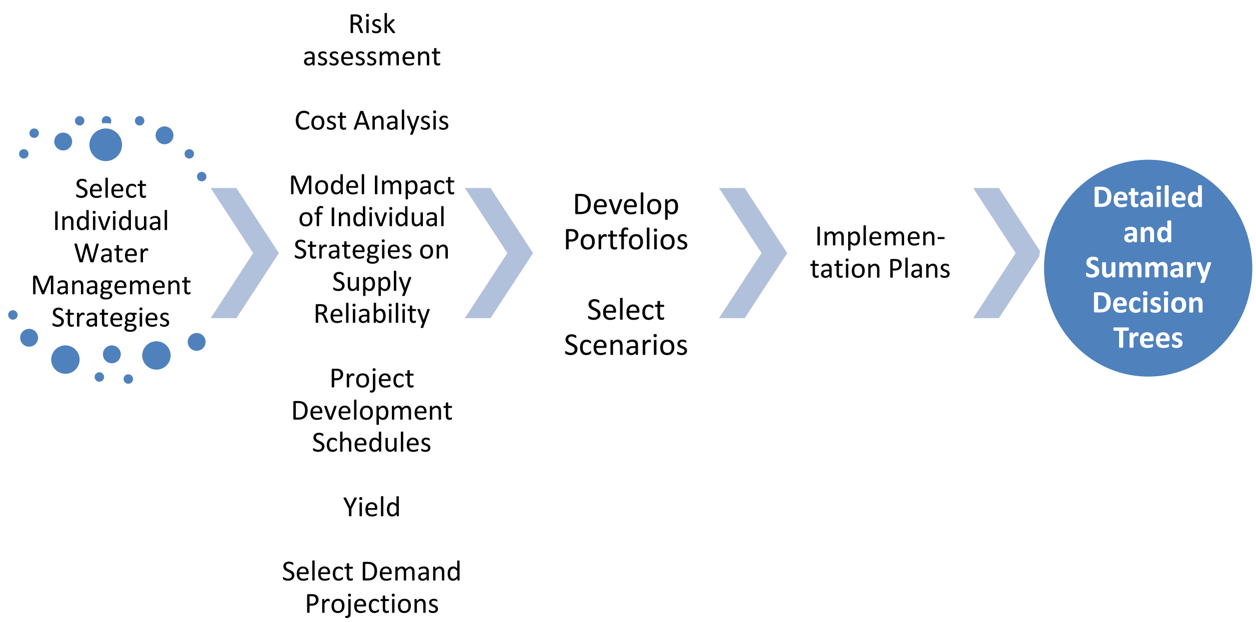


Exhibit 1-1 – Integrated Water Supply Planning Analysis Sequence

1.3.2 Risk-Based Planning

All demand projections have one thing in common – they are imperfect. Across the nation there has been a shift in demand trends towards lower demands, lower per capita per day demands and smaller seasonal peaks. This trend can be attributed to several factors without being fully credited to any single cause: rate increases, cultural shifts, demographics, economics, low-flow plumbing fixtures, water conserving appliances, irrigation efficiencies – in other words, both passive and active conservation efforts.

This IWSP uses the concepts of risk and scenario planning. Its intent is to analyze several possible future scenarios that bookend the future water supply possibilities. Using aggressive growth projections, we here develop an implementation plan to ensure the greatest possible reliability at the lowest possible cost. Using lower growth projections, we create an implementation plan that minimizes the effect on future rates. Thus every customer's two competing goals, low rates and high reliability, are addressed.

Risk can be seen as a negative term that is sometimes avoided by decision-makers. But it can also be used as a positive planning concept in which the purpose is to avoid and mitigate risk by making informed decisions. It is used in the TRWD Integrated Water Supply Plan to make many decisions. Risk is here defined as a forecasted possibility that projected demands cannot be met under a particular set of hydrologic, demand, supply, and institutional conditions. The conditions in question are:

- It is assumed that historical climate and hydrologic patterns are a reasonable predictor of future trends.

- It is assumed that projections of future demand are accurate, and that population and water demands grow as projected.
- TRWD's goal is to meet the full projected demand in every month, regardless of available supplies or institutional conditions.

The risk is therefore that projected demands will not be met under these conditions *unless* it is possible to change the conditions, such as by temporarily reducing demand (conservation or drought response measures) or temporarily increasing the amount of supply available to meet demands (overdrafting reservoirs beyond permit allowances). The ability to change these conditions is dependent on many factors that cannot be projected, such as political conditions, future climate, etc. Therefore, this study informs TRWD as to the level of system risk at any given point in the future, both with respect to the probability of supply shortfalls and their likely magnitude, and recommends ways to avoid those simulated future shortfalls by connecting new sources of supply and conserving existing resources.

Information as to the level of system risk is provided in quantitative terms through a system simulation model. STELLA was used in this study. This model simulates what could occur if demands increase as projected while some conditions (e.g. hydrology) remain the same and while new sources of water supply are added. Output is used to calculate the number of months (models are at a monthly time step) in which the full demand would not be satisfied when the historical hydrologic record is superimposed over any single year of increased demand in the future, and the amount that supply would fall short of demand in those months. The number of months represents the *frequency* of risk while the shortage in supply represents the *magnitude* of risk. Because the shortage frequency stems from simulating 67 years of historical hydrology over one future year of demand expectations, the frequency of shortage associated with such a simulation can be interpreted as the probability of a shortage in that future year, since the hydrology coincident with that year cannot be predicted.

Both frequency and magnitude are then described by what caused the simulated shortage; examples include a lack of capacity in the transmission system, insufficient water available in the supply system, or a lack of contracted/permitted water supply. The quantitative measurements together with the causes provide a clear picture as to what must be overcome to ensure reliable system operation.

Because the system simulation model simulates what could occur if demands increase as projected but other conditions remain the same, we will see that the number of months requiring "risk management strategies" (temporarily reduce demand, increase supply) increases in each decade. *Risk Tolerance* is the point at which the frequency or costs of risk management strategies is more than the District wants to accept, or the point at which the implementation costs (monetary or political or otherwise) are more than the benefits they provide.

TRWD has defined its risk tolerance. To calculate the year in which additional supply is needed, two criteria are used and subjectively balanced by the engineer to determine the final recommended year. Both criteria are calculated and evaluated concurrently to determine the final recommendation.

- First Criterion: Additional supply is needed when both the simulated water supply risk exceeds a 2% frequency probability and the magnitude of those risks is greater than roughly 5% of total system demand. The 2% frequency is based on simulations of supply and demand using a dataset of 804 months, but the same 2% criterion applies to any statistically significant number of timesteps.

- Second Criterion: Additional supply is needed when the risk profile (probability of simulated shortage plotted over time) exhibits a sudden change in the slope such that risks begin growing at a faster rate beyond that year.

When these criteria are met, it is recommended that a new water supply be connected to the TRWD system to maintain water supply reliability for District customers.

1.4 Terminology

- **Water Management Strategy (or simply "Strategy")**: a discrete water supply source, such as a new reservoir, groundwater, reuse water, or conservation (which is considered either as a strategy or a demand reduction, depending on the context).

- **Risk**: the chance that TRWD will be adversely impacted in its efforts to deliver water to customers reliably and economically.

- **System-wide Risks**: defined in this study as Population/Demand Growth Rate, Climate Variability, and Power Costs. These risks impact water supply reliability and cost for the entire TRWD system.

- **Strategy-specific Risks**: defined in this study as Institutional/Legal Risks, Regulatory/Environmental Risks, and Capital Cost Variability/Water Quality Risks. These risks impact project viability and schedule of individual projects.

- **Scenario**: alternative future conditions that address system risks; a combination of system risks that together define a possible future. An example scenario would be "stressed system" in which demands and power costs are on the high end of projections and climate variability reduces available supplies.

- **Portfolios**: a combination of strategies based on a theme (e.g. low cost, low risk) and built to ensure system reliability under a specific scenario.

- **Implementation Plans**: a plan for the order in which strategies should be developed and the schedule of when they should be connected to the TRWD system to maintain supply reliability.

- **Decision Tree**: an adaptive management plan based on major triggers that result in actions on selection and sequencing of strategies.

- **Performance Measure**: water supply reliability is the performance measure used to determine when new water supply strategies should be completed.

1.5 Report Outline

This is the summative report of the TRWD *Integrated Water Supply Plan* study. The remaining sections are organized as follows:

- Section 2 – details the supply current available to the District
- Section 3 – explains demand projections used in this study, and how they compare to actual historic TRWD usage and to other demand projections made in the past.
- Section 4 – provides a summary of the water management strategies used in this study, and explains how they were evaluated. Each strategy is defined briefly (full definitions are in Appendix A). Section 4 describes the risk assessment, modeling, implementation schedule development, and cost analyses that were used to develop a final recommended plan.
- Section 5 – describes the recommended TRWD water supply plan. Section 5 describes portfolios of water management strategies and how they were tested against future scenarios of demand, supply, and power cost. Implementation plans are also provided for different combinations of portfolios and scenarios, and a recommended decision tree is provided.
- Section 6 – lays out the financial impacts of each branch on the water supply plan decision tree in terms of capital cost, annual cost, and impact on TRWD customer rates.
- Section 7 – recommends which factors to track as part of the implementation of this plan, and includes tables as templates for updating this report on a periodic basis. Section 7 should be viewed as a "living record" of TRWD's water supply environment over the coming decades.

Section 2 – Current Water Supply System

The purpose of this section is to explain the physical components of the existing TRWD raw water transmission system. The physical components include:

- Pump Stations – described by pumping capacity and number of pumps
- Pipelines – described by size, length, location, capacity
- Reservoirs – described by yield, capacity, water right
- Other water supply rights/contracts – described by annual yield
- Water Treatment Plants (WTPs) – described by treatment capacity and location

TRWD owns and operates raw water transmission infrastructure (reservoirs, pipelines, pump stations, constructed wetlands) and supplies that water to customer cities that own and operate water treatment plants and distribution system infrastructure.

2.1 Sources

Supply sources within the TRWD system include the following, which are also summarized in Table 2.1 in terms of their water rights or contracts:

- "TRWD East Texas Water Supply Reservoirs"
    - Cedar Creek Reservoir
    - Richland-Chambers Reservoir
- "TRWD Terminal Storage Reservoirs"
    - Lake Arlington
    - Lake Benbrook
    - Lake Worth
- "TRWD West Fork Water Supply Reservoirs"
    - Lake Bridgeport
    - Eagle Mountain Lake
- Richland-Chambers Constructed Wetlands

- Cedar Creek Constructed Wetlands (to be constructed in the future, but in this study assumed to be part of the current TRWD supply system – see Section 2.5 below for explanation)

Table 2.1 – Water Rights Summary – TRWD Reservoirs

Source	Certificate of Adjudi-cation No.	Certificate Holder	Annual Diversion Purpose	Author-ized (ac-ft/yr)	Max Diversion Rate (CFS)	Priority Date(s)
Cedar Creek Reservoir	08-4976	TRWD	Municipal, Mining, Industrial, Agriculture	175,000	247.54	May 28, 1956
Richland-Chambers Reservoir	08-5035	TRWD	Municipal, Mining, Industrial, Agriculture	210,000	577.78	October 18, 1954
Cedar Creek Wetlands	08-4976C	TRWD	Municipal, Mining, Industrial, Agriculture	52,500	156.5	May 5, 1987
Richland-Chambers Wetlands	05-5035C	TRWD	Municipal, Mining, Industrial, Agriculture	63,000	174.05	May 5, 1987
Lake Benbrook	5157A	TRWD	Municipal & Irrigation	72,500	310	Sept 5, 1998 COE: October 27, 1987
Eagle Mountain Lake	08-3809C	TRWD	Municipal, Mining, Industrial, Agriculture, and Recreation	159,600** acft/yr diversions	300*	July 13, 1925
Lake Bridgeport	08-3808B	TRWD	Mining, Municipal, Industrial, Irrigation	78,000** acft/yr to Lake Eagle Mountain	1,050	July 6, 1926

* Note: The 300 cfs is an extra factor used in the TRWD Riverware model to modify simulated flows from Bridgeport to Eagle Mountain.
** During normal to wet hydrologic conditions, withdrawals from the West Fork system (Eagle Mountain and Bridgeport) must be divided as follows: 100,000 acre-feet/year withdrawal from Eagle Mountain Lake to supply to City of Fort Worth, 59,600 from Eagle Mountain Lake to supply local demands, and 27,000 acre-fee/year from Lake Bridgeport (not counted against the 159,600 limit from Eagle Mountain Lake) to supply local demands on Lake Bridgeport. The contracted withdrawal to Fort Worth is limited to 46,000 acre-feet during dry conditions, though the supply to local Eagle Mountain and Bridgeport customers is not changed. A given time period is considered a dry condition if the combined storage of Lake Eagle Mountain and Lake Bridgeport is below 50% of their combined conservation storage.

The West Fork Trinity River system, defined as supply from Lake Bridgeport and Eagle Mountain Lake (passed through Lake Worth) is constrained by permit limitations, contracts, and actual supply availability. The permits and contracts specify how much water can be used by certain customers. The firm yield limits how much is actually available in critical drought periods, and serves as a real limit on availability, regardless of permits and contracts.

The Eagle Mountain permit allows TRWD to use 159,600 acre-feet/year in total from Eagle Mountain Lake. The Eagle Mountain Lake permit specifies a linkage to the Lake Bridgeport permit, making the 159,600 dependent on the release of up to 78,000 acre-feet/year from Lake Bridgeport to Eagle Mountain Lake. In normal to wet years, TRWD withdrawals from the West Fork system must be divided as follows: 100,000 acre-feet/year withdrawal from Eagle Mountain Lake to supply to City of Fort Worth, 59,600 from Eagle Mountain Lake to supply local demands on the lake, and 27,000 acre-fee/year from Lake Bridgeport (not counted against the 159,600 limit from Eagle Mountain Lake) to supply local demands on Lake Bridgeport. The contracted withdrawal to Fort Worth is limited to 46,000 acre-feet during dry conditions, though the supply to local Eagle Mountain and Bridgeport customers is not changed. A given time period is considered a dry condition if the combined storage of Lake Eagle Mountain and Lake Bridgeport is below 50% of their combined conservation storage.

TRWD has the ability to pump water from Cedar Creek and Richland-Chambers Reservoirs to Eagle Mountain Lake through the “Eagle Mountain Connection” pipeline (described below in this section). This additional supply to Eagle Mountain Lake is not counted against the 159,600 acre-feet/year.

The Lake Bridgeport permit specifies that TRWD can use 93,000 acre-feet/year. In all years, that amount is divided as follows: 78,000 acre-feet/year for release to Eagle Mountain Lake, and 15,000 acre-feet/year to supply local demands on the lake. As of a the year 2000, a change was made to the Lake Bridgeport permit that allows 12,000 of the 78,000 acre-feet/year to be used for local demands on the lake, increasing the total for local demands to 27,000 acre-fee/year. This additional 12,000 can be used for local demands without affecting the 159,600 acre-feet/year that can be used from Eagle Mountain Lake.

However, these permits are limited by the reality of actual supply availability during a drought. According to TRWD analyses[1] (see Appendix I), the firm yield of the West Fork system is decreasing (due to sedimentation) from 116,800 in 2010 and 107,200 in 2060. According to the 2011 Region C Water Plan[2], the available supply, limited to the lesser of the firm yield or the permitted amount, is decreasing (due to sedimentation) from 110,500 in 2000 and 107,200 in 2060. In graphs in this report, supply availability is shown based on the Region C numbers.

2.2 Transmission

The existing TRWD transmission system is shown in Figure 2.1. The existing TRWD Cedar Creek Pipeline is a primarily a 72-inch pipeline originating from Cedar Creek Reservoir, running parallel to the existing Richland-Chambers pipeline. The existing Richland-Chambers Pipeline is a primarily a 90-inch pipeline originating from Richland-Chambers Reservoir. Both

---

[1] Donna Stephens for Tarrant Regional Water District, *Tarrant Regional Water District Reservoir Firm Yields Accounting for Sedimentation*, August 2013.

[2] Appendix I, Table I.3

pipelines (along with others) deliver water to the TRWD Terminal Storage Reservoirs in the manner governed by TRWD operational rules.

A portion of these pipelines can operate in a bi-directional mode; water from East Texas reservoirs is delivered westward in typical conditions, but water can be delivered from western storage reservoirs eastward to supply customer water treatment plants. The section of these pipelines from the Kennedale Balancing Reservoir (not a source of supply; only used as part of transmission operations) to the Rolling Hills Water Treatment Plant was studied in both the Eagle Mountain Connection operational study[3] phase and in the Integrated Pipeline (IPL) Operations Study[4]. When demands increase in the future, this part of the system will be a “bottleneck” that restricts the hydraulic capacity of the overall system. Parallel segments are under construction as of the writing of this report to relieve this part of the system.

A 90-inch pipeline connects the Rolling Hills Water Treatment Plant and Lake Benbrook. This pipeline is also operated in a bi-directional mode depending on demand and supply conditions. The Eagle Mountain Connection is a 96-inch/84-inch pipeline connecting Lake Benbrook to Eagle Mountain Lake and the Fort Worth Westside WTP (and balancing reservoir). In the future, a lake pump station may be built on Eagle Mountain Lake to allow this pipeline to be operated in bi-directional mode as well.

2.3 Pumping

Tables 2.2 and 2.3 list details of the existing pump stations in the TRWD service area.

[3] Freese and Nichols, Inc. for TRWD, Eagle Mountain Connection Project – Operational Study Report, October 2004

[4] CDM Smith for TRWD, Integrated Pipeline Project Conceptual Design Operations Study Final Report, April 2012

Figure 2.1 – Existing TRWD System

Table 2.2 – TRWD Raw Water Conveyance Capacity

Segment No.	Pipeline	Size (inches)	Length (miles)	Max. Capacity (MGD)
Cedar Creek Line				
1	Cedar Creek Reservoir to Ennis PS	72	25.3	127
2	Ennis PS to Waxahachie PS	72	17.6	127
3	Waxahachie PS to Joe Pool Flange	72	14.3	127
4	Joe Pool Flange to Mansfield WTP	72	5.21	127
5	Mansfield WTP to John F. Kubala WTP	72	4.31	127
6	John F. Kubala WTP to Kennedale Balancing Reservoir	72	1.34	127
7	Kennedale Balancing Reservoir to Lake Arlington	84	2.71	127
8	Lake Arlington to Rolling Hills WTP	84	3.16	127
Richland Chambers Line				
1	Richland-Chambers Reservoir to Ennis PS	90	29.6	247
2	Ennis PS to Waxahachie PS	90	17.58	247
3	Waxahachie PS to Joe Pool Flange	90	14.3	247
4	Joe Pool Flange to Mansfield WTP	90	5.21	247
5	Mansfield WTP to John F. Kubala WTP	90	4.31	247
6	John F. Kubala WTP to Kennedale Balancing Reservoir	90	1.34	247
7	Kennedale Balancing Reservoir to Lake Arlington	108	2.71	247
8	Lake Arlington to Rolling Hills WTP	108	3.24	247
Benbrook Connection				
1	Rolling Hills WTP to Lake Benbrook (Including Benbrook Connection)	90	11.2	230
Eagle Mountain Connection				
1	Lake Benbrook to West Side WTP	96	11.8	350
2	West Side WTP to Eagle Mountain Lake	84	7.8	280

Notes:
1. MGD = million gallons per day
2. Max capacity shown is accepted de-rated line capacity. Max capacity shown is the system capacity as limited by other parts of the system. For example, the actual capacity of the pipelines from Kennedale Balancing Reservoir to Lake Arlington and on to Rolling Hills WTP can be as high as 430 MGD if the Rolling Hills Booster Pump Station is used to pump into the Rolling Hills WTP and if the pipelines upstream of Kennedale Balancing Reservoir were able to transmit 430 MGD to Kennedale Balancing Reservoir.

Table 2.3 – TRWD Pump Station Details

Pump Station	No. of Pumps	Pump Type	Low/High Capacity	Maximum Capacity (MGD)
Cedar Creek Intake Pump Station, CC1	6	2000 HP Flowserve	3 Low, 3 High	127
Richland-Chambers Intake Pump Station, RC1	6	5500 HP Flowserve	3 Low, 3 High	247
Booster Pump Station at Ennis (CC side), CC2	6	2500 HP Worthington	6 High	127
Booster Pump Station at Ennis (RC side), RC2	5	5000 HP Fairbanks Morse	5 High	247
Booster Pump Station at Waxahachie (CC side), CC3	9	1000 & 2500 HP Worthington	3 Low, 6 High	127
Booster Pump Station at Waxahachie (RC side), RC3	8	2000 HP IDP & 5000 HP Fairbanks Morse	3 Low, 5 High	247
Lake Benbrook Intake Pump Station, BB1	4	1500 HP Sulzer	4 High	225
Rolling Hills Booster Pump Station, RH2	6	900 HP and 2700 HP Sulzer	2 Low-Head , 4 High-Head	230 MGD High Head & 400 MGD Low Head
Benbrook Booster Pump Station, BB2	4	1, 1250 HP and 3, 3400 HP Hitachi	1 Low, 3 High	230 current 350 ultimate

Note: MGD = million gallons per day

TRWD existing pumping operations follow a low capacity and high capacity mode of pumping. The low capacity mode is when the Cedar Creek pumps deliver less than 67 million gallons per day (MGD), and the Richland-Chambers intake pumps deliver less than 144 MGD. In this condition, the Ennis Booster Pump Station is bypassed, and the flow is lifted by low capacity pumps at Waxahachie Booster pump station. The high capacity mode of pumping is when the Cedar Creek pumps deliver more than 67 MGD or the Richland-Chambers pumps deliver more than 144 MGD. In this condition, the Ennis Booster Pump Station is used together with high capacity pumps at Waxahachie Booster Pump Station. Table 2.4 gives details of how much flow is delivered in low capacity and high capacity modes.

Table 2.4 – Low Capacity/High Capacity Operating Ranges on TRWD Lake Pumps

# Pumps	Richland-Chambers Pump Station		Cedar Creek Pump Station	
	MGD		MGD	
1	65	Low	32	Low
2	114		56	
3	144		67	
3	190	High	95	High
4	225		114	
5	250		129	

2.4 Treatment (by TRWD Customers)

Table 2.5 and Figure 2.2 present the details of existing WTPs in the TRWD service area, their average and peak capacities, future expansions, and the source of raw water supply.

Table 2.5 – Treatment Plant Capacities for WTPs in TRWD Service Area

Customer	WTP	Design Capacity (MGD)	Capacity after Expansion (MGD)	Proposed Date of Expansion	Raw Water Source
City of Fort Worth	North Holly	93 MGD rated capacity (80=reliable)	NA[2]	NA[2]	Primarily supplied from Lake Worth, but may be supplemented with Lake Benbrook water pumped from the Clear Fork of the Trinity River. TRWD's Benbrook Connection allows water from East Texas to flow to Lake Benbrook and the blended water is capable of being pumped back to the RHWTP or Holly WTP. TRWD can also deliver water to the Clear Fork from the Eagle Mountain Connection Pipeline through the Clear Fork Outlet Structure.
	South Holly	100 MGD rated capacity (80=reliable)	Total capacity of Holly 200 MGD (170=reliable)	2009	
	Rolling Hills	200 MGD rated capacity	250 MGD	2013	Pipeline
	Eagle Mountain	105 MGD rated capacity	240 MGD[1]	2020[1]	Eagle Mountain
	West Side WTP	25 MGD rated capacity	35 MGD	2012	Pipeline
	Subtotal for City of Fort Worth	**523 MGD rated capacity**	**725 MGD rated capacity**		
City of Arlington	Pierce-Burch	107 MGD	build-out	NA[2]	Lake Arlington (which receives runoff from Village Creek and is supplied from CC and RC when needed)
	John F. Kubala	65 MGD	97.5 MGD	2009	Pipeline
	Subtotal for City of Arlington	**172 MGD rated capacity**	**204.5 MGD rated capacity**		

Table 2.5 – Treatment Plant Capacities for WTPs in TRWD Service Area

Customer	WTP	Design Capacity (MGD)	Capacity after Expansion (MGD)	Proposed Date of Expansion	Raw Water Source
City of Mansfield	Mansfield II	--	---	2011	Pipeline
	Mansfield I	27 MGD	45 MGD	2011	Pipeline
	Subtotal for City of Mansfield	**27 MGD rated capacity**	**45 MGD rated capacity**		
Ellis County	Mosier Valley	87 MGD	102 MGD	2015	Lake Arlington
	Ennis	9 MGD	--		Pipeline
	Midlothian I	13	36	2012	
	Midlothian II	9	36	2012	
	Sokoll WTP	20 MGD	80 MGD	2010	Pipeline
	Subtotal for Ellis County	**138 MGD rated capacity**	**254 MGD rated capacity**		

Notes:
[1] Build out capacity and proposed date of expansion are not coincident.
[2] NA implies that there are no plans of any future expansion at the treatment plants
[3] MGD = million gallons per day

Figure 2.2 – TRWD Planning Area, Reservoirs, and Customer Water Treatment Plants

2.5 Planned Sources and Transmission Already in Progress

Two TRWD supply sources and transmission infrastructure are considered "current" in this study even though they are not yet operational. The first is the Integrated Pipeline, shown in Figure 2.3 below. The second is the Cedar Creek Constructed Wetlands project, shown in Figure 2.4 below.

The purpose of the Integrated Pipeline (IPL) is to bring water from Lake Palestine, Richland-Chambers Reservoir and Cedar Creek Reservoir to Dallas and TRWD in a cost efficient way and to better ensure water supply reliability as demands grow. As the IPL connects the Dallas and TRWD raw water transmission systems it increases the redundancy in each system, making it possible to share water resources, and establishing a platform and method for integrating future water supplies, which can also be shared across the region. The IPL adds 350 MGD transmission capacity, 200 of which is dedicated to TRWD and 150 of which is dedicated to Dallas.

Though the IPL is not yet operational, it is currently in the final design phase and construction is slated to begin in 2014. Therefore, for the purposes of this 50-year water supply plan, it is considered part of the current TRWD system.

The Cedar Creek Constructed Wetlands project is an indirect reuse project that uses discharges from TRWD customers' wastewater treatment plants to add up to 52,500 acre-feet/year to Cedar Creek Reservoir, water that is then delivered through the transmission system to TRWD customers. The same concept has successfully been implemented next to Richland-Chambers Reservoir. The Richland-Chambers Constructed Wetlands project has been operational for several years and expansions that are now underway will be completed in the next few years.

Like the IPL, the Cedar Creek Constructed Wetlands project is considered part of the current TRWD system for the purposes of this 50-year water supply plan. This is assumed because the water rights permit for this water has already been secured, the time to develop this supply is short relative to other supply strategies, and TRWD has committed to this project as its next major water supply project.

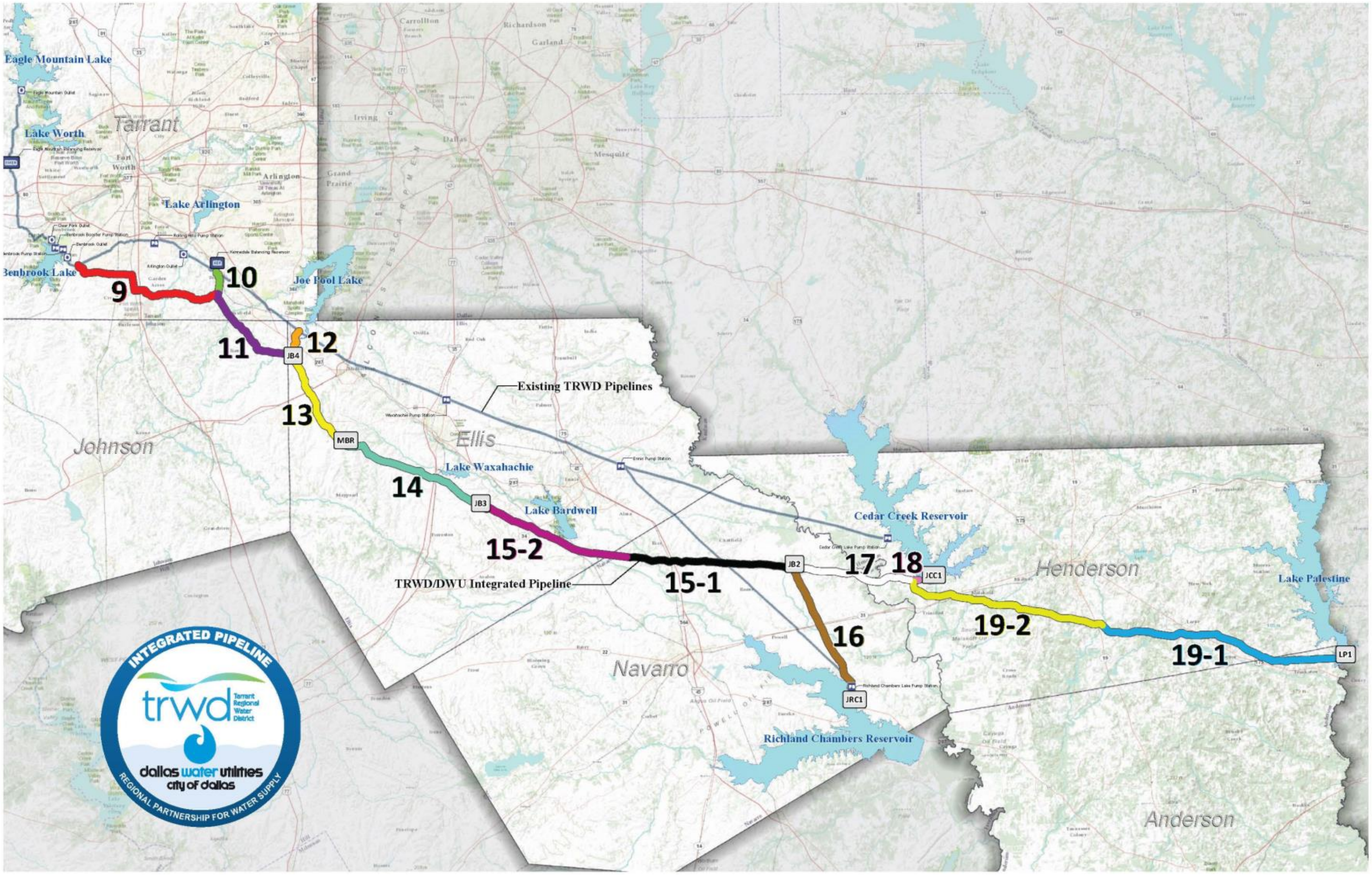


Figure 2.3 – Integrated Pipeline Project

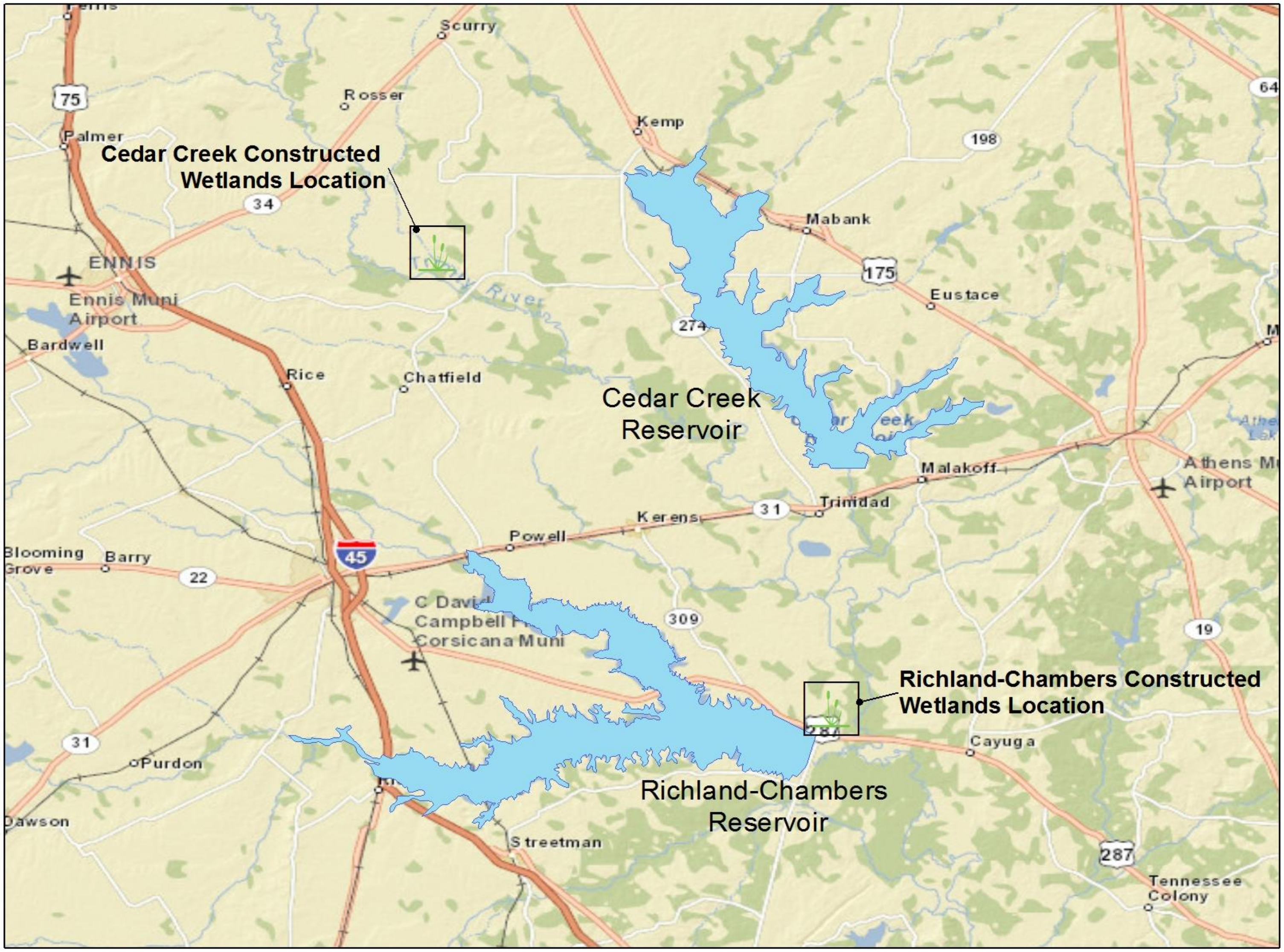


Figure 2.4 – Cedar Creek Constructed Wetlands

2.6 Current Supplies and Historic Demands

TRWD raw water supply has been under development for nearly 100 years. As Figure 2.5 shows, the District has continually added new supply sources, along with the infrastructure needed to deliver them to customers, in time to keep pace with growing demand. The demand line in Figure 2.5 is based on records of actual deliveries through the TRWD system since 1971. Though the actual annual demand is shown in Figure 2.5, the reality is that demand varies on a daily, monthly, and seasonal basis. The method used to capture that variability is described in Section 3 of this report.

Table 2.6 explains how much supply is available to TRWD customers under different conditions, such as:

- Permitted Yield – TRWD is allowed to deliver *up to* this amount of water from each supply to customers per permits with the Texas Commission on Environmental Quality (TCEQ).
- Firm Yield – defines the maximum amount of water that can be supplied with 100% reliability during a repeat of the drought of record (1949 - 1956[5]), regardless of how much is actually permitted. Cedar Creek and Richland-Chambers both have firm yields greater than permitted yield. Firm yield can be reduced over time due to sedimentation or hydrologic conditions.
- Contract Yield – a contract may limit the amount TRWD is allowed to deliver under certain conditions, regardless of what is physically available or available by permit. In TRWD's system, this applies to the West Fork. The individual yields from Lake Bridgeport and Eagle Mountain Lake are 237,600 ac-ft/year, but the TRWD amendatory contract with its customers limits the amount of water that can be used. If the combined storage in Eagle Mountain Lake and Lake Bridgeport is greater than 50% of the combined capacity, the City of Fort Worth is limited to diverting 100,000 ac-ft/year (total from combined West Fork Reservoirs). If the combined storage is less than 50%, Fort Worth can divert 46,000 ac-ft/year (total from combined West Fork Reservoirs).

  Lake Benbrook generates its own relatively small yield. However, TRWD's contract with the USACE allows it to transfer water from other sources to Lake Benbrook and then use up to 72,500 ac-ft/year, regardless of how much water is pumped to Benbrook from other sources.

---

[5] Roy Sylvan Dunn, "DROUGHTS," Handbook of Texas Online (http://www.tshaonline.org/handbook/online/articles/ybd01), accessed October 01, 2013. Published by the Texas State Historical Association

"Current Supply" is defined in this Integrated Water Supply Plan as the minimum of permitted, firm, safe, and contract yield because that minimum value will be the controlling amount during future severe droughts; to achieve full water supply reliability, TRWD must plan to develop new supplies under that critical condition.

Table 2.6 - Currrent TRWD Supply Yields

Source	Permit (ac-ft/yr)	Firm Yield in 2010 (ac-ft/yr)	Contract Limitations
Cedar Creek Reservoir	175,000		---
Richland-Chambers Reservoir	210,000		---
Cedar Creek Wetlands	52,500	52,500	---
Richland-Chambers Wetlands	63,000	63,000	---
Lake Benbrook*	72,500	6,833	---
Eagle Mountain Lake	159,600 acft/yr diversions	109,833	If combined storage of Eagle Mountain and Bridgeport is > 50% of combined capacity, City of Fort Worth is limited to diverting 100,000 ac-ft/year (total from combined West Fork Reservoirs). If < 50%, limit is 46,000 ac-ft/year
Lake Bridgeport	78,000 acft/yr to Lake Eagle Mountain		
Lake Arlington	9,100	9,100	----

*Note: The Benbrook permit allows TRWD to use up to 72,500 acre-feet for storage, and 6,833 acre-feet of water per year (569.42 acre-feet per month), when Benbrook's elevation is between 665 and 694 ft msl.

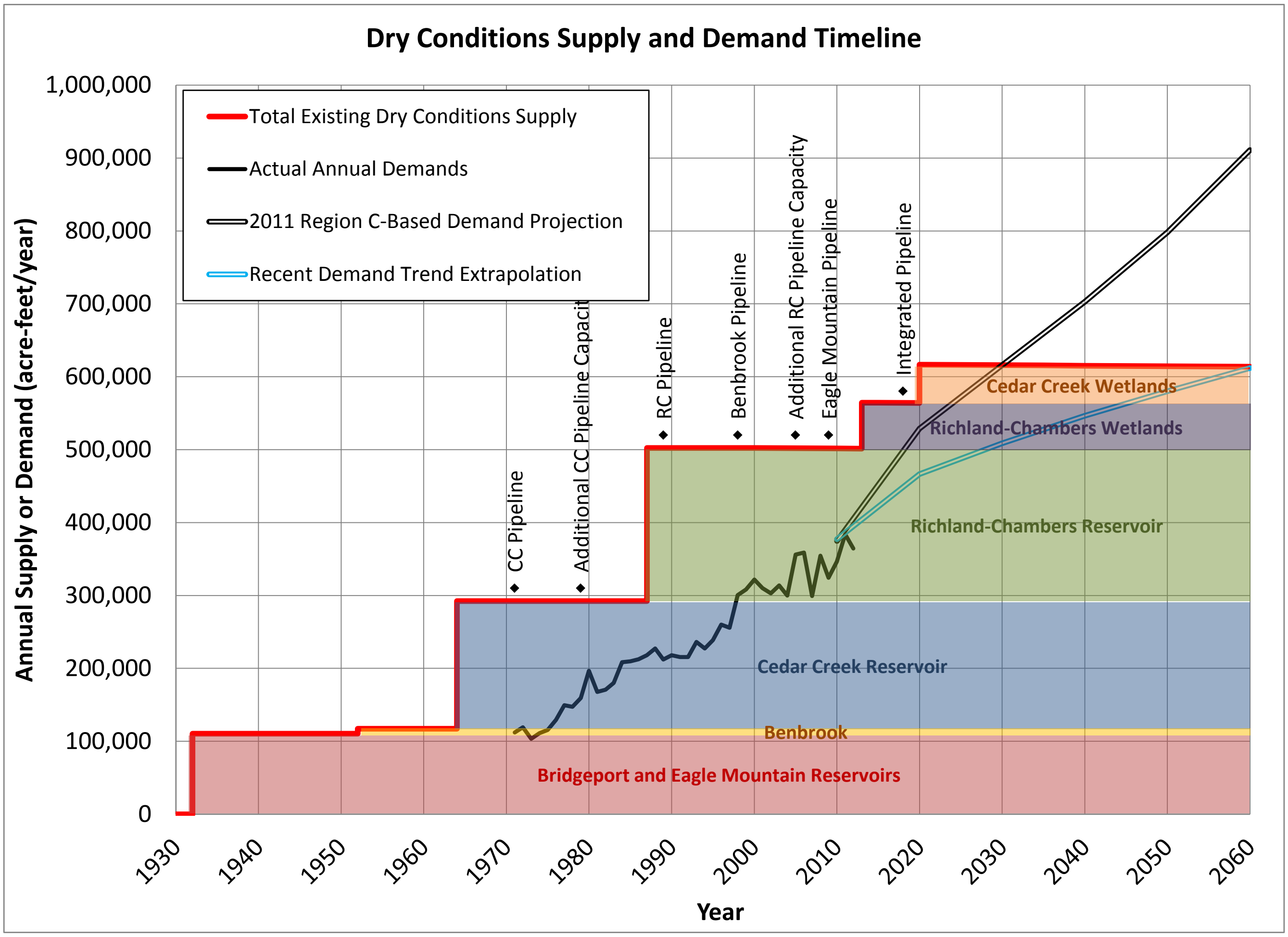


Figure 2.5 - Comparison of Current TRWD Supplies to Historic Demands

Section 3 – Water Demand Projections

North Texas has one of the highest population growth rates across the nation. According to the 2011 Region C Water Plan, “The sixteen counties that comprise Region C have been among the fastest growing areas in Texas and the nation since the 1950s.”[1] State demographers anticipate that the population will continue to grow over the next 50 years, from 5,254,722 in 2000 to 13,045,592 in 2060[2].

Demand for water is highly sensitive to changes in population but is also significantly affected by economic and industrial changes, climate, and society’s attitudes toward water conservation and water use. Forecasting future water demand is therefore an imperfect science with much uncertainty, meaning future demands cannot be predicted with a high level of confidence.

In addition to uncertainty in predicting future annual demands, there is significant fluctuation on a monthly, seasonally, and/or daily basis. The purpose of this section is to characterize the water demand projections used in this study, compare them to projections that were made in the past, and describe how demands vary at time periods smaller than a single year.

In order to reduce the risk associated with the inherent uncertainty and imprecision in demand predictions, this study relied on scenario planning: two different sets of demand projections were used to create multiple water supply plans that bracket the high and low predictions for the variables that significantly affect water demand. The first set of projections was based on the 2011 Region C Water Plan and represents a conservatively high estimate of future water demand. The second set of projections, developed by TRWD, was based on an extrapolation of the recent trends in actual water demand; it represents a low estimate of future demands, potentially achievable with aggressive conservation measures and a continuation of the recent trend towards a slower rate of growth in water usage. The methods used for computing the two sets of demands are discussed in Sections 3.2 and 3.3. Details of the factors used for developing the demand projections are discussed in Section 3.4.

3.1 Historic Projections

This section provides a historical perspective on demand projections that have been made for TRWD water supply since 1957. Figure 3.1 compares these historic demand projections with the current projections used in this study and current TRWD water supply. Appendix B includes a table summarizing the historical demand projections. Each historic projection is briefly described here.

---

[1] 2011 Region C Water Plan, p. 2.1

[2] Ibid, pp. 2.1 and 2.4

One of the earliest demand projections made for TRWD's service area was published in the 1957 report on "Water Supply for Fort Worth and Tarrant County"[3], which projected demands for a forty year period extending from 1960 to 2000. These demand estimates were developed specifically for Tarrant County, which only includes a portion of TRWD's current service area.

The 1979 report on "Sources of Additional Water Supply for TCWCID#1"[4,5] developed projections for a fifty-year future period between 1980 and 2030. The study focused on estimating minimum, maximum, and probable demands both for normal and drought conditions. (The "probable" scenario for demands during drought conditions are used in Figure 3.1). The 1987 "TCWCID#1 Conservation and Drouth Contingency Plan"[6] used the same demand projections as used in the 1979 study.

In the 1990 study, "TCWCID#1 Regional Water Supply Plan"[7], a higher projection of future demand was used than in previous studies. The projection in this study was made for the sixty year period extending from 1990 to 2050.

Historic demand projections for TRWD are also available from the Texas Water Development Board (TWDB) database of state water plans developed since 1960. The 1961 state plan[8] developed a projection of 1980 demands for the Tarrant County service area (though it is not clear how the service area was defined or how it compares to the current TRWD service area). Several water plans were produced between 1961 and 2001, but they did not include demand projections specifically for the TRWD service area.

In 1997, Senate Bill One (SB1) introduced a new approach to state and regional planning in Texas. In this process, detailed plans are developed for 16 planning regions every five years (TRWD is in Region C), and the state water plan is compiled by the TWDB based on the regional plans. Three regional plans (2001[9], 2006[10], and 2011[11]) have been produced since

---

[3] "Report on Water Supply for Fort Worth and Tarrant County". Freese and Nichols, Inc. Prepared for Tarrant County Water Control and Improvement District #1. May 1957. p. 6.

[4] Before 1990, TRWD was named the Tarrant County Water Control and Improvement District No.1

[5] "Report on Sources of Additional Water Supply". Freese and Nichols, Inc. Prepared for Tarrant County Water Control and Improvement District #1, 1979. Table 2.9.

[6] "Conservation and Drouth Contingency Plan". Freese and Nichols, Inc. Prepared for Tarrant County Water Control and Improvement District #1, 1987.

[7] "Regional Water Supply Plan". Freese and Nichols, Inc. Prepared for Tarrant County Water Control and Improvement District #1, 1990.

[8] "A Plan for Meeting the 1980 Water Requirements of Texas". Texas Board of Water Engineers. For Submittal to the Fifty-Seventh Legislature. May 1961

[9] "Region C Water Plan". Freese and Nichols, Inc., Alan Plummer Associates, Inc., Chiang, Patel &Yerby, Inc., and Cooksey Communications, Inc., January 2001.

[10] "2006 Region C Water Plan". Freese and Nichols, Inc., Alan Plummer Associates, Inc., Chiang, Patel &Yerby, Inc., and Cooksey Communications, Inc., January 2006.

SB1 was adopted. These plans include a clarified definition of the TRWD service area and a detailed discussion of its supply and demand projections. The fourth round of regional planning is currently under-way and is scheduled to be completed in 2016.

Demand projections for the 2001 regional plan were developed for a fifty-year planning cycle extending from 2000 to 2050. These demand projections were based on dry-year per capita demand. In 2002 TRWD completed a detailed operations study of the TRWD system, the "System Reliability and Enhancement Study"[12], which used the regional planning dry-year demands (2001 Region C Plan) with some adjustments. The projections were lower than the 2001 Region C Plan projections in the initial two decades of the planning cycle (2000-2010) but higher in the later decades (2020-2050).

Demand projections for the 2006 regional plan were developed for a fifty-year planning cycle extending from 2010 to 2060. Like the 2001 plan, these demand projections were based on dry-year per capita demand, though the projections were higher than the 2001 Plan in all decades except 2010.

Demand projections for the 2011 regional plan were also for the 2010 to 2060 planning horizon. Like the 2001 and 2006 plans, these demand projections were based on dry-year per capita demand. These projections account for natural conservation achieved with the installation of low-flow plumbing fixtures. However, additional conservation was treated as a new supply in the 2011 Region C Plan. For Figure 3.1, this "supply" was treated as a "demand reduction" so that the historic projections can be compared directly.

With the exception of the 1979 and 1987 projections, all other historic projections are higher than actual demand. None of the historic projections reflect any significant demand reduction due to conservation (other than the natural conservation achieved with the installation of low-flow plumbing fixtures) unless otherwise noted. It should also be noted that all of these demand projections are for a dry-year condition.

---

[11] "2011 Region C Water Plan". Freese and Nichols, Inc. Alan Plummer Associates, Inc., CP&Y, Inc., and Cooksey Communications, Inc., October 2010.

[12] "System Reliability and Enhancement Study". Camp Dresser & McKee, Inc., Power Solutions, Inc., and Freese and Nichols, Inc. Prepared for Tarrant Regional Water District. May 2002. Table 3.3.

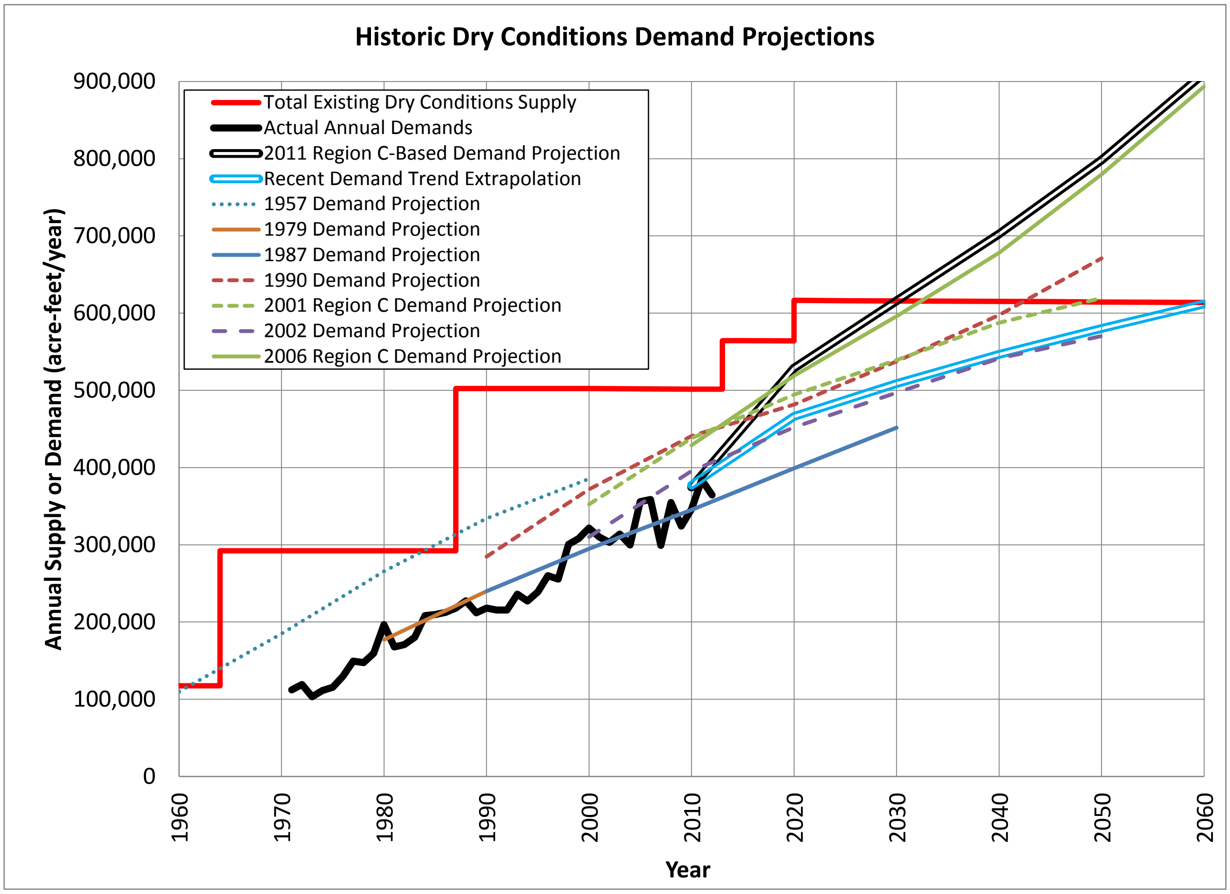


Figure 3.1 – TRWD Historic Demand Projections

3.2 2011 Region C Water Plan Based Demand Projection

The first set of projections used in the IWSP Study is based on the 2011 Region C Water Plan and represents a conservatively high estimate of future water demand. It is shown below in Figure 3.2 together with current dry conditions water supplies. The 2011 Region C Water Plan projects dry-year demands for each decade through 2060, estimated using the driest year per-capita demand information from 2000-2009. For most TRWD customers, the driest year was either 2006 or 2000. This dry-year per-capita demand for each municipal water user group (customer) was multiplied by the projected population of each customer to determine municipal demand projections. Region C also developed non-municipal demand projections for various counties in Region C based on historical information. The municipal and non-municipal demands for water users served by TRWD were combined to determine the overall dry-year demand projection for TRWD. It should be noted that the 2011 Region C demand projections were not adjusted for any conservation other than the conservation achieved through replacement of the older high-flow plumbing fixtures as mandated by current plumbing codes. The 2011 plan also has an additional “supply strategy” for TRWD to conserve 86,898 acre-feet per year (ac-ft/yr) in 2060.

TRWD staff converted these “dry-year demands” to “average year demands” by reducing each number by a factor of 1.07. This factor is calculated by TRWD using actual TRWD historical dry-year to average year comparisons. Because the 2011 Region C demands used in this study have been adjusted to represent average-year conditions, they are different from the published 2011 Region C Water Plan demand estimates.

The “average year demands” were distributed to water treatment plants by TRWD staff using data from customers’ master planning documents. Factors, such as ratios that distribute a large city’s projected population and demand among the different pressure planes in that city’s service area, and which water treatment plant serves each pressure plane, were used to then determine the projected demand for each plant’s location in the TRWD transmission system. Information on which water treatment plant will serve the secondary customers of TRWD’s primary wholesale customers is also available in these master planning documents.

In addition, demands defined as “county other”, “industrial” and “irrigation” volumes are reported in the 2011 Region C Water Plan. These annual demand projections are compared to existing TRWD contracts and to their geographic location in the the TRWD service area. Water treatment plant locations, capacities and planned expansions are also taken into consideration, and then these demands are assigned to these locations. If the demand projections are in Tarrant County or other counties served by TRWD, it is conservatively assumed that TRWD will eventually be responsible for serving these demands.

Table 3.1 lists the *average year* demand at each customer water treatment plant and the “local demands” (i.e. users close to the supply source).

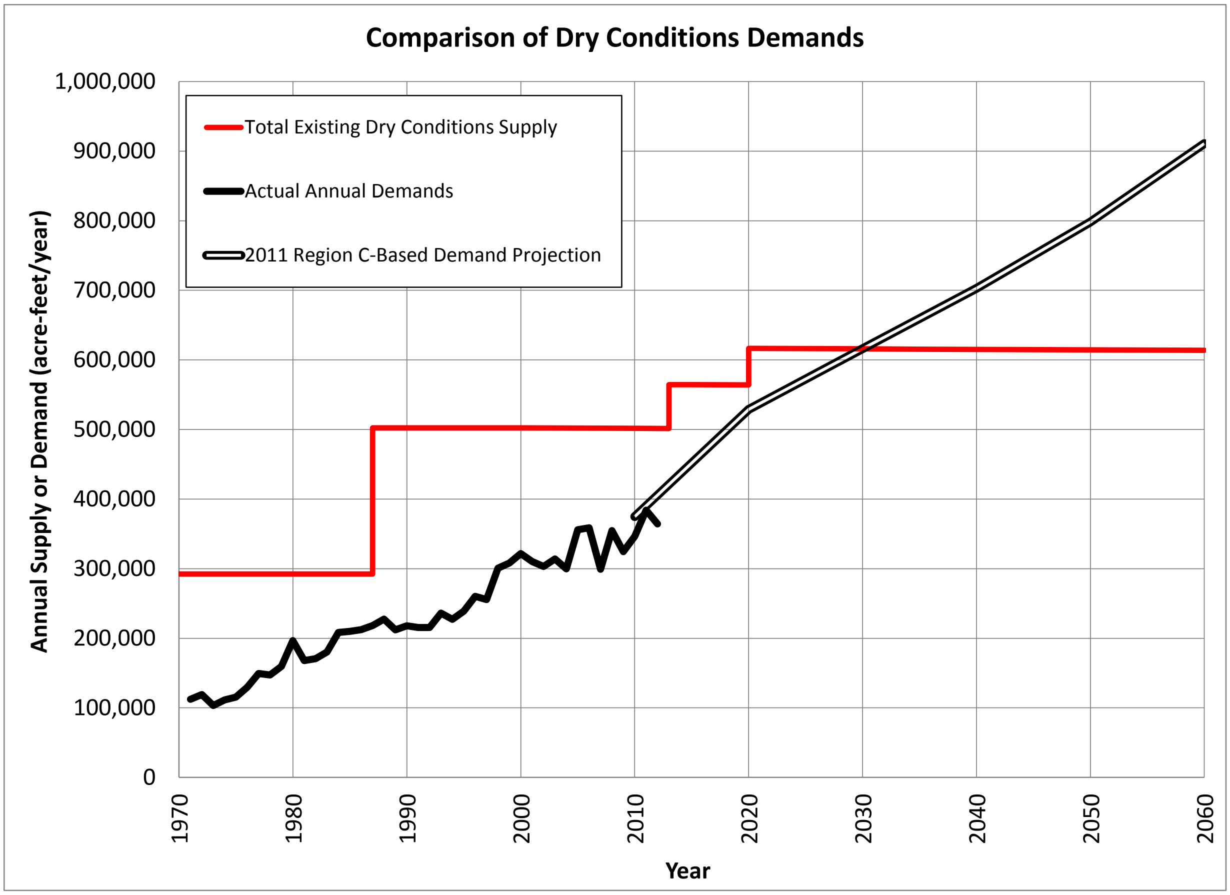


Figure 3.2 – TRWD Supply and '2011 Region C Based Demand Projection'

Table 3.1 - '2011 Region C Based Demand Projection' at WTP Level

Point of Use	2010	2015	2020	2025	2030	2040	2050	2060
Holly WTP	61,447	45,497	47,844	49,888	51,948	57,115	63,515	70,993
Eagle Mountain WTP	44,471	73,554	83,993	94,655	105,290	127,097	154,161	186,236
John F. Kubala WTP	40,610	43,305	48,035	49,372	50,710	53,025	53,217	53,819
Pierce Burch WTP	25,317	21,993	23,215	23,853	24,492	25,559	25,442	25,488
Mansfield WTP	11,023	19,517	25,578	29,455	33,331	37,641	40,855	44,069
TRA Mosier Valley	36,606	41,672	41,741	42,905	44,068	44,790	45,388	45,997
Lake Arlington (Aggregate of Pierce Burch, TRA Mosier Valley WTPs)	61,923	63,665	64,956	66,758	68,560	70,349	70,830	71,485

Point of Use	2010	2015	2020	2025	2030	2040	2050	2060
TRA Ellis (Wax/Rockett)	2,421	5,769	9,118	10,945	12,772	18,730	24,880	30,041
TRA Ellis (Midlothian)	0	4,762	9,523	10,507	11,490	13,247	15,192	17,126
TRA Ellis (Ennis)	0	499	998	1,633	2,268	3,507	3,507	4,898
Ellis County Aggregated (Existing Contracts)	2,421	11,030	19,639	23,085	26,530	35,484	43,579	52,065
Westside WTP	0	13,071	16,548	20,024	23,484	31,354	40,505	51,632
Weatherford	9	2,184	4,358	4,996	5,633	6,827	8,015	9,357
BWSA	3,079	4,403	5,125	5,368	5,610	6,665	7,921	9,394
Rolling Hills WTP	100,414	122,719	131,351	140,198	149,071	170,185	197,371	230,831
Benbrook Local Use	783	1,165	1,165	1,165	1,165	1,165	1,165	1,165
Worth Local Use	4,175	4,201	4,227	4,213	4,199	4,178	4,171	4,171
Eagle Mountain Local Use	2,921	3,742	4,149	4,662	5,174	6,281	7,459	8,534
Bridgeport Local Use	10,706	23,647	26,526	28,584	30,641	33,859	36,616	39,345
Arlington Local Use	579	621	667	715	768	884	1,017	1,171
Richland Chambers Local Use	4,018	7,014	7,305	7,336	7,367	7,428	7,482	7,544
Cedar Creek Local Use	5,097	6,416	7,390	8,528	11,670	13,302	15,192	17,400
Total	**353,676**	**445,751**	**498,856**	**539,002**	**581,151**	**662,839**	**753,071**	**859,211**

3.3 Recent Trend Extrapolation

Actual demands on the TRWD system over the past 6 or 7 years have been growing at a much slower pace than predicted in the 2011 Region C Water Plan. Demand projections being made as part of the 2016 Region C Water Plan are also lower than in the 2011 plan. Efforts to promote conservation by TRWD customers have had an enormous impact on demands, and many anticipate that this trend will continue. National trends show that demands are growing much slower than population, and much slower than previously predicted.

These factors led to the development of an alternate demand projection (an 'alternate' to the 2011 Region C Based Demand Projection). TRWD staff used actual demands on the TRWD system over the last 7 years (2005 to 2012) to predict the next 50 years of water demand.

This Recent Trend Extrapolation represents demands from all of TRWD's customers. However, the extrapolation is based on actual usage by only TRWD's four primary customers (Trinity River Authority, City of Mansfield, City of Fort Worth, and City of Arlington). It was then scaled up to represent the entire TRWD system and broken down by TRWD staff to annual average year demand at the water treatment plant level, shown in Table 3.2. This effort resulted in a set of projections much lower projection than made by Region C. Figure 3.3 shows the 'Recent Trend Extrapolation' and its comparison to the 2011 Region C demand projection.

The TRWD reservoirs also have "local demands" (i.e. users close to the supply source). These demands were also predicted by TRWD and are shown in Table 3.3. Because they impact the water supply reservoirs, they are accounted for in the IWSP System Simulation Model.

Conservation is not explicitly identified as a strategy in these implementation plans. However, it is accounted for in the TRWD water supply plan. The 2011 Region C Based demand projections used in this study are reduced over time due to TWDB's projected savings from low flow toilets, lower water use clothes washers, and other water saving appliances and plumbing fixtures. That reduction varies with the supplier and generally ranges between an 8 and 14 gallons per capita per day (gpcd) reduction from current levels by 2040. Additional savings due to conservation are considered additional "supply", not a reduction in gpcd, in the Region C planning process, so these additional conservation measures will not have an impact on the Region C water demand projections. These future conservation "supplies" are not used in the IWSP study as supply strategies. Instead, the IWSP uses this second demand projection (the Recent Trend Extrapolation), developed and provided by TRWD. This second demand projection was provided to represent a potential future result of aggressive implementation of conservation strategies; it was used in the IWSP to bracket the low side of demand projections.

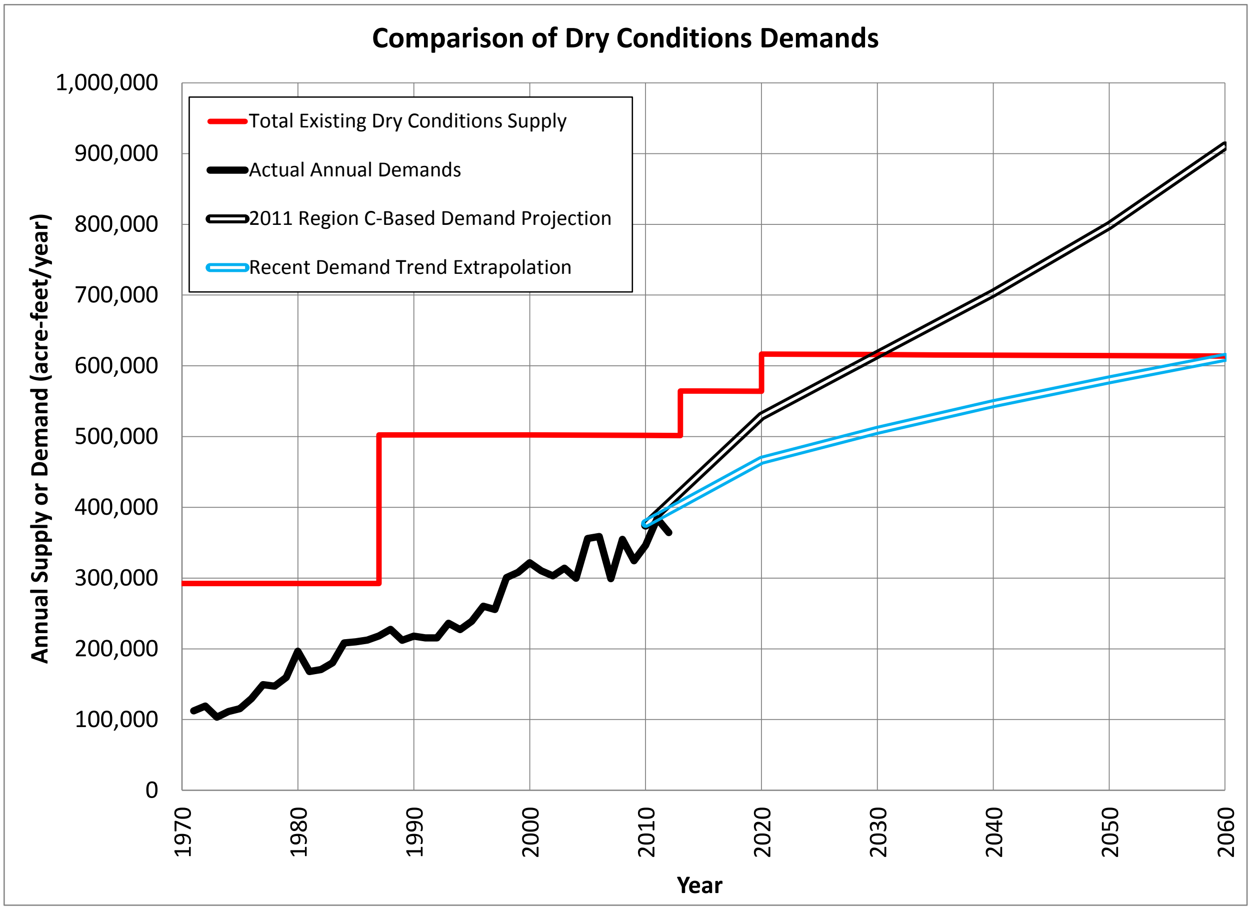


Figure 3.3 – 'Recent Trend Extrapolation' Compared to '2011 Region C Based Demand Projection'

Table 3.2 - 'Recent Trend Extrapolation' at WTP Level

Point of Use	2010	2015	2020	2025	2030	2040	2050	2060
Holly WTP	54,399	55,488	56,578	54,794	53,011	51,325	50,295	49,706
Eagle Mountain WTP	56,647	64,771	72,894	80,491	88,088	101,546	114,426	126,918
John F. Kubala WTP	42,852	44,272	45,692	46,623	47,555	48,506	49,476	50,466
Pierce Burch WTP	23,074	23,839	24,603	25,105	25,607	26,119	26,641	27,174
Mansfield WTP	11,023	12,858	14,692	15,961	17,229	19,765	22,301	24,837
TRA Mosier Valley	36,606	37,497	38,389	38,642	38,895	39,402	39,908	40,414
Lake Arlington (Aggregate of Pierce Burch, TRA Mosier Valley WTPs)	59,680	61,336	62,992	63,747	64,502	65,520	66,549	67,588

Point of Use	2010	2015	2020	2025	2030	2040	2050	2060
TRA Ellis (Wax/Rockett)	2,405	5,494	8,584	9,881	11,178	15,198	18,368	19,977
TRA Ellis (Midlothian)	0	4,482	8,965	9,510	10,056	10,749	11,216	11,389
TRA Ellis (Ennis)	0	470	940	1,462	1,985	2,846	2,589	3,257
Ellis County Aggregated (Existing Contracts)	2,405	10,446	18,488	20,853	23,218	28,793	32,172	34,623
Westside WTP	10,811	12,386	13,962	17,483	21,004	27,346	33,227	38,801
Weatherford	9	2,056	4,103	4,516	4,930	5,540	5,917	6,222
BWSA	3,058	3,941	4,825	4,867	4,910	5,408	5,848	6,247
Rolling Hills WTP	86,917	92,122	97,327	99,728	102,128	107,485	113,223	119,217
Benbrook Local Use	778	937	1,097	1,058	1,020	945	860	775
Worth Local Use	4,147	4,063	3,979	3,827	3,675	3,390	3,079	2,774
Eagle Mountain Local Use	2,901	3,404	3,906	4,217	4,528	5,097	5,507	5,675
Bridgeport Local Use	10,634	17,803	24,971	25,894	26,816	27,474	27,032	26,164
Arlington Local Use	575	602	628	650	672	717	751	779
Richland Chambers Local Use	3,991	5,434	6,877	6,662	6,447	6,027	5,524	5,017
Cedar Creek Local Use	5,063	6,010	6,957	8,585	10,213	10,794	11,216	11,571
Total	**355,889**	**397,929**	**439,968**	**459,957**	**479,945**	**515,679**	**547,402**	**577,379**

3.4 Demand Factors

There is significant fluctuation in TRWD demands on a monthly, seasonally, and/or daily basis. Because TRWD operates a raw water supply system with significant amounts of available storage, a monthly time step is appropriate for analyzing its ability to meet water demands. Using historic data, TRWD has developed factors that are used to translate annual demands to monthly demands, and to account for historic climate and typical water use patterns. These factors are described in this section.

3.4.1 "Dry" to "Average" Factor

Demand projections made as part of the Region C planning process represent projections of 'dry year demand'. "The municipal water demand projections…are based on per capita dry-year water use and the adopted population projections…. The per capita dry-year water uses are based on the per capita water uses from the 2006 Region C Water Plan, which include water savings from plumbing code requirements for low-flow fixtures. Adjustments to the per capita water uses from the 2006 Region C Water Plan were made as necessary based on recent historical per capita information from TWDB and on input from water user groups."[13] TRWD staff translates these "dry-year demands" to "average year demands" by reducing each number by a factor of 1.07. This factor is calculated by TRWD using actual TRWD historical dry-year to average year comparisons.

Appendix B includes a table summarizing the proposed demand projections used in the IWSP study.

3.4.2 Annual to Monthly Distribution Factors

Annual water treatment plant demands were converted to monthly demands using distribution factors provided by TRWD. These factors are based on historic trends.

Table 3.3 – Annual to Monthly Distribution Factors

Month	Factor
January	0.064
February	0.058
March	0.065
April	0.072
May	0.083
June	0.095
July	0.121
August	0.122
September	0.099
October	0.086
November	0.069
December	0.065

[13] 2011 Region C Water Plan, p. 2.9

3.4.3 West Fork System Customer WTP Demand Distribution Factors

Total demand placed on the West Fork Trinity River supply system was distributed between water treatment plants fed from this system (Holly, Eagle Mountain, Rolling Hills, and Westside WTPs) based on demand distribution factors developed by TRWD. Table 3.4 contains annual distribution factors for 2003 through 2030, followed by decadal factors for 2040 through 2060.

Table 3.4 – West Fork WTP Demand Distribution Factors

	Water Treatment Plants			
Year	Westside	Rolling Hills	Eagle Mountain	Holly
2003	0.00	0.48	0.19	0.33
2004	0.00	0.47	0.20	0.32
2005	0.00	0.46	0.22	0.32
2006	0.00	0.45	0.23	0.31
2007	0.00	0.45	0.24	0.31
2008	0.00	0.45	0.25	0.30
2009	0.00	0.44	0.26	0.30
2010	0.05	0.42	0.27	0.26
2011	0.06	0.42	0.27	0.26
2012	0.06	0.41	0.27	0.25
2013	0.06	0.41	0.28	0.25
2014	0.07	0.41	0.28	0.24
2015	0.07	0.41	0.29	0.24
2016	0.07	0.40	0.29	0.24
2017	0.05	0.42	0.29	0.24
2018	0.06	0.42	0.30	0.23
2019	0.06	0.41	0.30	0.23
2020	0.06	0.40	0.30	0.23
2021	0.06	0.40	0.31	0.23
2022	0.06	0.40	0.31	0.23
2023	0.07	0.40	0.31	0.22
2024	0.07	0.40	0.31	0.22
2025	0.07	0.40	0.31	0.22
2030	0.08	0.39	0.33	0.20
2040	0.10	0.37	0.35	0.18
2050	0.11	0.36	0.37	0.16
2060	0.12	0.36	0.38	0.15

3.4.4 Climatic Peaking Factors

One key input to the IWSP System Simulation Model is the period-of-record hydrology. The IWSP model uses a historical hydrologic period-of-record from 1941 to 2007. Average annual WTP demands are multiplied by a factor developed for each month of each year of the period-of-record to reflect demand fluctuations in response to climatic variation. These climatic peaking factors were developed by TRWD based on their historic demand records. These climatic factors are listed in Table 3.5.

Table 3.5 –Climatic Peaking Factors

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1941	1.048	0.988	1.025	1.005	1.029	0.935	0.896	0.897	0.979	0.972	1.007	1.029
1942	1.089	1.096	1.168	0.830	0.796	1.021	1.021	0.911	0.911	0.895	0.977	1.040
1943	1.112	1.125	1.066	0.987	0.924	0.885	0.975	1.317	0.928	0.966	1.116	1.011
1944	1.021	0.950	0.984	1.040	0.931	0.985	1.062	0.897	0.968	1.003	0.986	0.968
1945	0.984	0.934	0.914	0.921	1.064	1.026	0.904	1.125	0.970	1.023	1.032	1.069
1946	1.058	1.007	0.986	0.998	0.847	1.150	1.242	0.900	0.895	0.930	0.970	0.949
1947	0.967	1.029	1.068	0.982	1.031	1.003	1.000	0.913	0.944	0.951	1.014	0.974
1948	1.003	0.961	1.030	1.137	1.032	0.996	0.988	1.060	1.250	1.085	1.055	1.111
1949	1.021	0.950	0.924	0.976	0.865	0.850	1.037	0.906	0.979	0.919	0.983	1.097
1950	1.026	0.974	0.978	0.972	0.898	0.931	0.900	0.897	0.890	0.991	1.236	1.398
1951	1.186	1.064	1.055	1.056	0.985	0.944	0.918	1.165	1.006	1.057	1.054	1.100
1952	1.167	1.156	1.129	0.940	0.919	1.171	1.385	1.300	1.400	1.257	0.992	0.960
1953	0.989	1.048	1.077	0.951	0.947	1.111	1.246	1.150	1.033	0.982	0.985	1.019
1954	1.037	1.054	1.112	1.029	0.955	1.040	1.256	1.250	1.093	1.036	1.029	1.056
1955	1.094	1.059	1.050	1.036	0.943	0.888	1.050	1.100	0.983	1.029	1.154	1.123
1956	1.139	1.056	1.091	1.073	0.983	1.078	1.281	1.380	1.500	1.178	1.025	0.998
1957	1.021	1.020	1.000	0.844	0.850	0.822	0.977	1.277	1.024	0.985	0.966	0.976
1958	0.996	1.049	0.994	0.863	0.911	1.275	0.990	0.906	0.873	0.942	1.035	1.021
1959	1.078	1.090	1.081	1.073	1.088	0.948	0.896	1.054	0.954	0.913	0.946	0.999
1960	1.014	0.991	1.054	1.121	1.124	1.142	0.934	0.896	0.929	1.006	1.064	0.998
1961	0.999	0.960	0.987	1.001	1.142	0.990	0.897	1.313	0.985	1.007	0.996	0.996
1962	1.031	1.030	1.064	0.948	0.975	0.949	0.872	0.899	0.864	0.927	0.968	0.995
1963	1.032	1.142	1.245	0.964	0.939	1.181	1.099	0.897	0.952	1.034	1.098	1.034
1964	1.023	1.009	0.994	0.978	1.028	1.168	1.372	0.901	0.875	0.913	0.980	0.967
1965	0.975	0.954	0.960	1.056	0.894	0.908	1.237	0.906	0.939	0.949	1.013	1.006
1966	1.031	1.007	1.036	0.883	0.855	0.947	0.896	0.901	0.889	0.951	1.075	1.068
1967	1.147	1.157	1.150	0.981	0.959	1.077	1.093	1.162	0.919	0.933	1.002	1.023
1968	1.015	0.989	0.948	0.925	0.945	0.926	0.944	0.897	0.944	0.976	0.981	0.984
1969	1.012	1.046	1.015	0.957	0.904	0.968	1.262	0.898	0.931	0.910	0.978	1.009
1970	1.053	0.977	0.979	0.936	0.948	1.104	1.242	0.800	0.858	0.886	1.039	1.092
1971	1.188	1.113	1.210	1.080	1.066	1.215	0.986	0.849	0.872	0.882	0.957	0.957
1972	0.978	0.976	1.250	1.067	1.026	1.126	1.176	1.079	1.030	0.938	0.958	1.029

Table 3.5 –Climatic Peaking Factors

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1973	1.024	1.016	1.004	0.933	0.928	0.936	0.800	1.317	0.826	0.901	0.961	1.031
1974	1.054	1.070	1.107	1.069	0.944	0.890	1.100	0.913	0.889	0.885	0.958	0.990
1975	0.992	0.968	0.983	1.004	0.908	0.942	0.906	1.216	1.250	1.229	1.209	1.060
1976	1.017	1.141	1.065	0.906	0.871	0.905	0.734	1.035	0.745	0.789	0.896	0.981
1977	1.038	0.951	0.968	0.872	0.945	1.122	1.130	0.876	1.041	0.981	0.959	1.010
1978	0.997	0.941	0.962	1.018	0.962	1.106	1.271	0.969	0.889	1.070	0.980	1.054
1979	1.120	1.014	0.984	0.926	0.862	1.011	0.826	0.832	1.021	1.047	0.984	1.027
1980	0.999	1.057	1.088	1.007	0.929	1.391	1.459	1.357	1.188	0.955	1.078	1.085
1981	1.102	1.100	1.060	1.070	0.931	0.906	1.006	1.023	0.893	0.893	0.977	1.029
1982	1.099	1.056	1.054	0.944	0.841	0.799	0.874	1.041	1.093	0.936	0.989	1.047
1983	1.078	1.052	1.023	1.023	0.939	0.843	0.890	0.921	1.011	0.943	0.996	1.219
1984	1.168	1.089	1.005	1.045	1.125	1.203	1.131	1.092	1.143	0.910	1.000	1.040
1985	1.077	1.105	1.063	1.046	1.013	1.083	1.107	1.256	1.176	0.956	1.046	1.114
1986	1.189	1.155	1.286	1.053	0.931	0.876	1.187	1.036	0.968	0.977	1.078	1.094
1987	1.039	1.007	1.038	1.215	1.009	0.865	0.932	1.226	0.996	1.140	1.079	0.979
1988	1.047	1.043	1.099	1.097	1.231	1.146	1.027	1.113	1.026	0.917	0.930	0.961
1989	0.932	0.969	0.992	1.045	0.955	0.880	0.874	0.837	0.975	1.054	1.037	1.218
1990	1.040	0.981	0.924	0.835	0.887	1.179	0.971	0.887	1.002	0.934	0.941	1.024
1991	0.992	1.129	1.078	0.977	0.861	0.920	0.996	0.821	0.732	0.997	0.925	0.941
1992	0.946	0.937	0.919	0.952	0.894	0.776	0.838	0.754	0.838	0.896	0.894	0.968
1993	0.911	0.902	0.891	0.871	0.929	0.955	1.149	1.120	0.987	0.813	0.875	0.922
1994	0.941	0.934	0.939	1.005	0.781	1.028	0.825	0.939	0.818	0.832	0.865	0.921
1995	0.867	0.923	0.895	0.832	0.756	0.937	0.910	0.833	0.902	1.035	1.016	1.050
1996	1.031	1.151	1.075	1.000	1.300	1.084	0.932	0.742	0.729	0.900	0.821	0.888
1997	0.973	0.932	0.939	0.845	0.885	0.854	0.936	0.862	1.124	0.928	0.947	0.947
1998	0.927	0.918	0.917	1.020	1.212	1.264	1.338	1.085	1.117	0.955	0.947	0.972
1999	1.026	1.017	1.019	1.021	0.925	0.940	1.046	1.355	1.120	1.167	1.188	1.079
2000	1.067	1.149	1.007	0.962	1.038	0.836	1.151	1.406	1.528	1.105	0.917	1.015
2001	0.979	0.948	0.916	1.014	1.027	1.179	1.110	1.114	0.844	1.016	1.062	0.978
2002	1.019	0.982	1.014	0.926	0.974	1.050	0.852	1.018	1.066	0.926	0.982	0.965
2003	0.943	0.912	0.976	1.099	1.079	0.943	1.104	1.023	0.879	1.017	1.079	1.066
2004	0.995	0.956	1.001	1.051	1.055	0.838	0.915	0.852	1.016	0.898	0.880	0.966
2005	0.942	0.918	1.004	1.162	1.118	1.237	1.049	1.017	1.298	1.292	1.257	1.162
2006	1.256	1.067	1.098	1.227	1.260	1.345	1.153	1.192	1.028	1.089	1.102	0.995
2007	0.944	0.976	1.058	0.871	0.812	0.736	0.647	0.869	0.929	1.021	1.094	0.967

Section 4 – Water Management Strategies

The IWSP is an integration of the discrete planning that has been done over many years by TRWD and its customers and identifies the new water supplies with the greatest potential benefit for water supply reliability. The IWSP is not an endpoint (i.e., a final comprehensive plan), but is rather a *platform* that will be constantly built upon by integrating new opportunities (e.g. local sources, reuse of treated wastewater effluent), technologies (e.g. aquifer storage and recovery, advanced conservation), and strategies (e.g. groundwater) with the plan presented here. This enables TRWD to innovate and maximize value for its customers.

TRWD has been developing water supplies for North Central Texas for decades. Previous water supply plans have been implemented by building reservoirs, transmission pipelines, and reuse projects, and by encouraging conservation. Because of good planning and timely implementation, TRWD can reliably supply water to its customers for another 15 or more years even assuming rapid population and water demand growth. The current sources of supply for TRWD include four supply reservoirs (Lake Bridgeport, Eagle Mountain Lake and the Cedar Creek and Richland-Chambers Reservoirs), three terminal storage reservoirs (Lake Arlington, Lake Benbrook, and Lake Worth), and permitted reuse projects associated with Cedar Creek and Richland-Chambers Reservoirs.

The following water management strategies were analyzed in this plan and considered for inclusion in the final implementation plan:

- Conservation
- Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs (often shortened to “Unpermitted CC/RC Firm Yield” or “CC/RC Firm”)
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (often shortened to “Unpermitted CC/RC Wetlands Yield” or “CC/RC Wetlands”)
- Lake Columbia
- Excess Flow Optimization for Eagle Mountain Lake and Lake Benbrook (EXFLO)
- Kiamichi River
- Marvin Nichols Reservoir
- Lake Ringgold
- Lake Tehuacana
- Temple Reservoir
- Lake Texoma
- Toledo Bend Reservoir
- Lake Wright Patman

These water management strategies are illustrated on Figures 4.1 and 4.2.

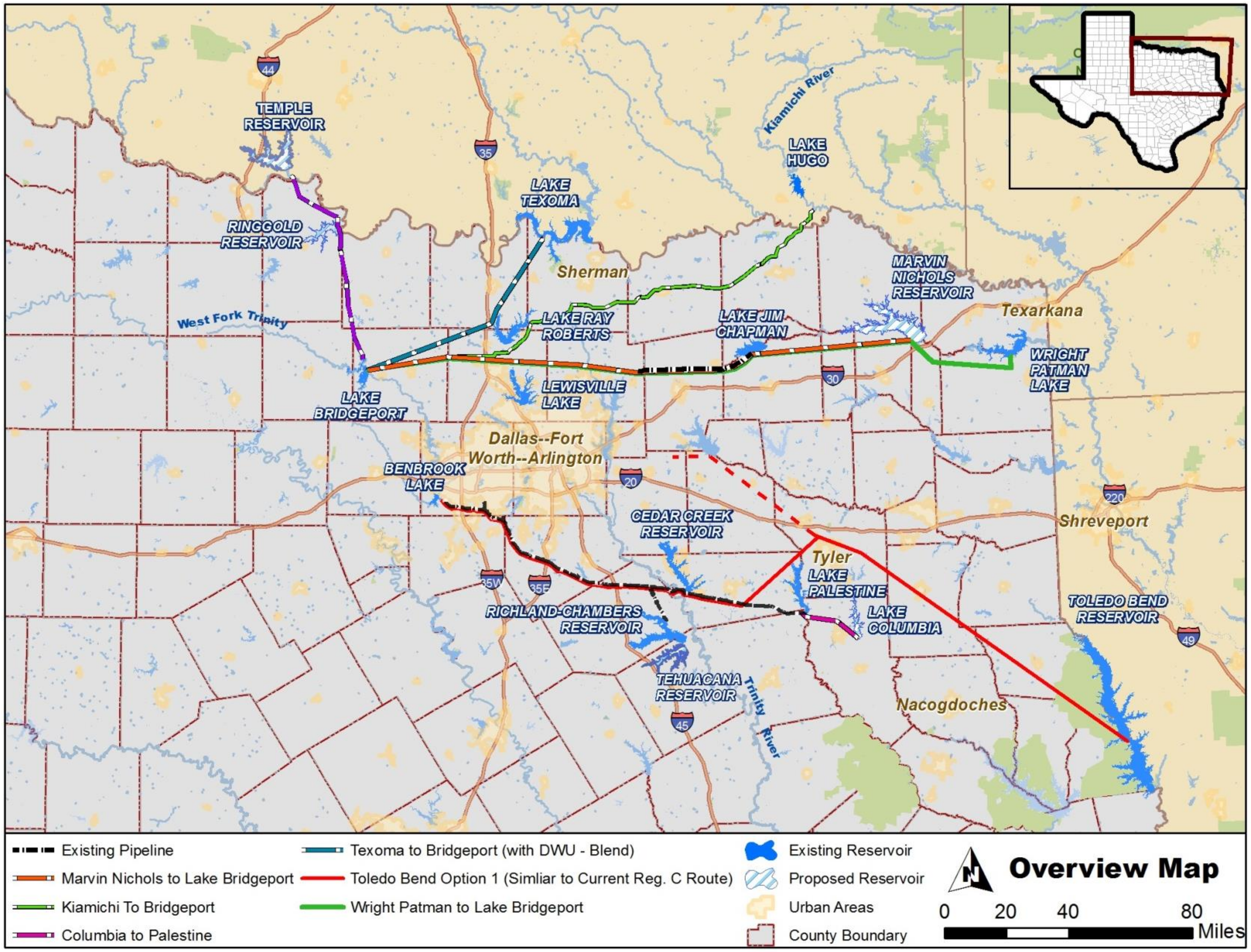


Figure 4.1 – Water Management Strategies Included in IWSP

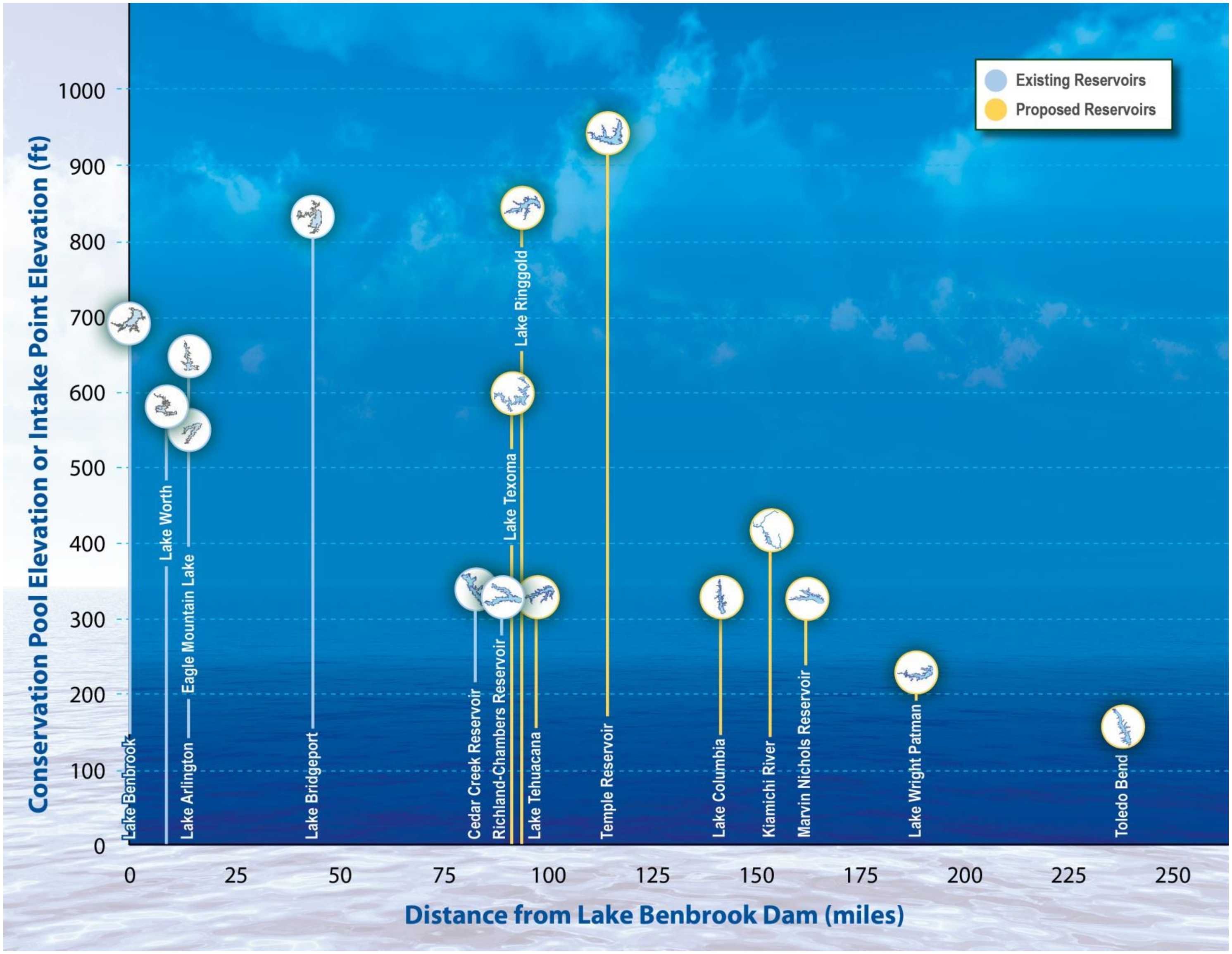


Figure 4.2 –Water Management Strategies, Relationship between Elevation and Distance

Table 4.1 – Summary of Water Management Strategies

Supply Option	Existing or New Reservoir / System	Total Yield / TRWD Yield (acre-feet/year)*	Probable Number of Years Required to Make Operational	Probable Capital Cost (2012 Dollars)
Unpermitted CC Firm Yield	Existing	17,201 in 2020, decreasing to 7,223 in 2060	3	$0 (short term) New Pipeline for 'CC/RC Firm': $415 M New Pipeline for 'CC/RC Unpermitted Wetlands': $465M New Pipeline for 'CC/RC Firm' and 'CC/RC Unpermitted Wetlands': $725M New Pipeline for 'CC/RC Firm', and 'CC/RC Unpermitted Wetlands', and Tehuacana: $1.44B
Unpermitted RC Firm Yield	Existing	46,831 in 2020, decreasing to 38,444 in 2060		
Unpermitted CC Wetlands Yield	Existing	35,559	3	
Unpermitted RC Wetlands Yield	Existing	37,465		
Lake Columbia	New	40,188	10.5	$250,165,000**
EXFLO Benbrook	Existing	78,653 Interruptible (Firm Yield = 0)	<5	$0
EXFLO Eagle Mtn	Existing	63,899 Interruptible (Firm Yield = 0)		
Kiamichi River	New	310,000 / 155,000	18.5	$1,810,696,000
Marvin Nichols Reservoir	New	612,300 / 142,850	19	$1,695,867,000
Lake Ringgold	New	28,600	12.5	$397,735,000
Lake Tehuacana	New	41,900	11	$580,790,000 (short term***) New Pipeline for 'CC/RC Firm', and 'CC/RC Unpermitted Wetlands', and Tehuacana: $1.44B
Temple Reservoir	New	125,000	15	$972,530,000
Texoma	Existing	Average 21,050 Interruptible Yield in 2060 (at 10:1 Blending Ratio)	14	$313,065,000
Toledo Bend	Existing	700,000 / 200,000	17	$2,751,751,000
Wright Patman	Existing	180,000	15.5	$2,394,849,000

** Environmental flow requirements were considered in all strategies. The TWDB's guidelines for regional water planning require that yield analysis for water management strategies be in accordance with Senate Bill 3 environmental flow standards and associated TCEQ rules, In most cases, the 1997*

Consensus Criteria for Environmental Flow Needs is used. However, modeling of new environmental flow criteria is still underway and will likely impact the yield of several water supply strategies.

*** Assumed Columbia will flow through IPL and Toledo Bend pipeline. Cost attributed to Columbia is the amount needed to increase Toledo Bend transmission system capacity enough to carry Columbia flows plus costs specific to Columbia (reservoir, portion of the pipeline to TRWD). A pipeline to convey only Lake Columbia is assumed to be cost prohibitive and is not considered here.)*

****These costs do not include the new pipeline that will eventually be needed to convey flows from Lake Tehuacana. It is most probable that the new pipeline would be built to carry Tehuacana and another supply (such as Unpermitted Yields from Cedar Creek and Richland-Chambers).*

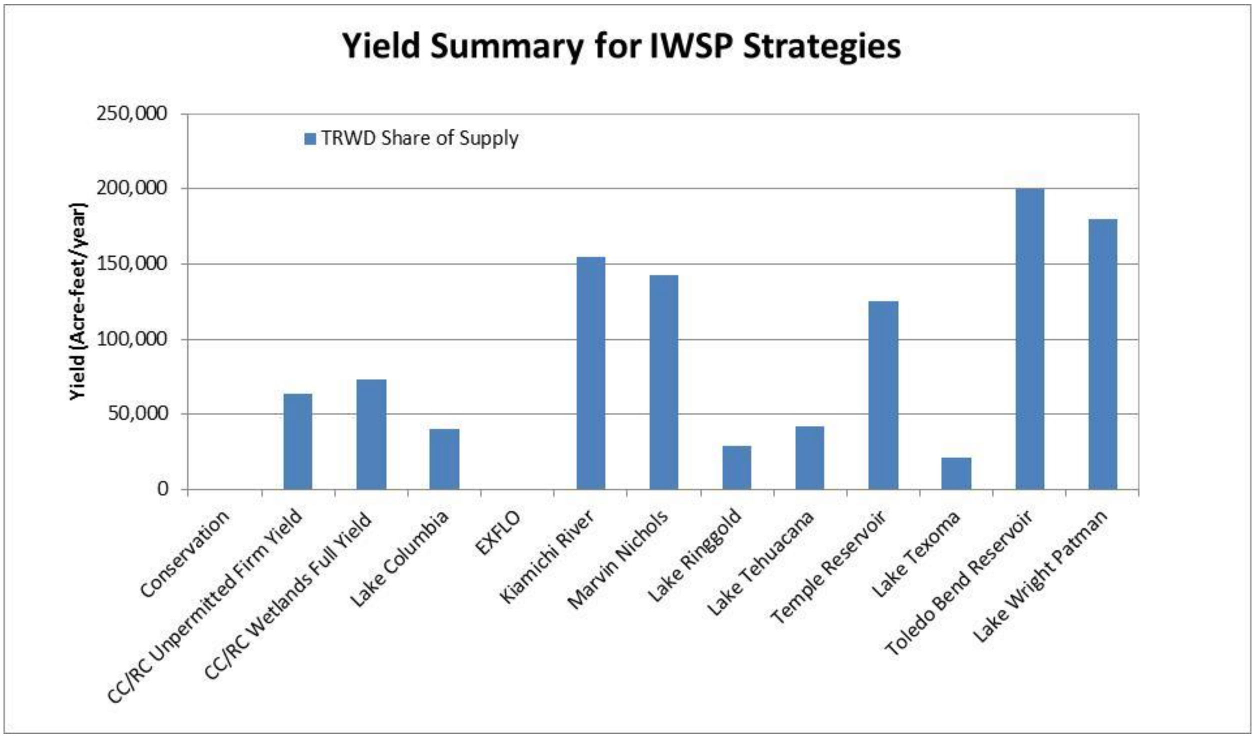


Figure 4.3 – Yield Summary for IWSP Water Management Strategies

Characterization of Water Management Strategies (i.e. water supply strategies) was done by building on data from the 2011 Region C Water Plan and other previous studies. Strategies were characterized using the following information: 1) Annual yield estimates, 2) Capital and annual costs, 3) Transmission system hydraulic grade line, used to determine pipe size, pumping facility requirements, and to calculate pumping costs, 4) Risk Assessment, and 5) Implementation Schedule. This section includes a discussion for each one of these items, and Appendix A contains a full description of each water management strategy in an individualized 'Fact Sheet'.

Water supply strategies are configured by combining three primary variables – *Supply, Transmission,* and *Partnering/Other Options*.

The *Supply* variable includes options such as:

- On-channel Reservoir
- Groundwater Supply
- Run-of-River Diversion
- Run-of-River Diversion with an Off-Channel Storage Facility
- Indirect Reuse/Constructed Wetland

The *Transmission* variable options include:

- Different pipeline routes with the same start and end points
- Different pipeline routes with different end points or intermediate delivery points
- Variations in transmission system sizing, depending on the number of supplies conveyed through one transmission system or depending on the supply configuration (e.g. run-of-river supply as compared to a reservoir)

The *Partnering/Other* variable includes options such as:

- The number of entities partnering in a supply/transmission system, thereby changing the yield to each partner
- Phasing the infrastructure needed to deliver new supply to TRWD or other partners

An example configuration would be an on-channel reservoir (the *Supply* variable) delivering through its own pipeline to TRWD's western reservoirs (the *Transmission* variable), shared with two other water suppliers (the *Partnering/Other* variable). Each strategy can be configured several different ways; the configuration that seemed to best meet TRWD's needs is used in this study.

Several strategies have been studied over the years and with corresponding published reports. In some cases, there are several different published water supply yields for a given strategy because the strategy has been defined in different ways or analyzed differently in a given study. It is important to note this distinction when IWSP strategies are compared to similar strategies from other reports.

Opportunities for new water supply to TRWD can be grouped using "geographic supply zones" - *Northwest, Northeast,* and *Southeast*. Strategies in each zone are closely related and will have commonalities in their transmission systems, timing, phasing, and partnering. Lists 1 through 3 describe the variables selected to make up the water management strategy configurations described in this IWSP. Note that all transmission system options assume intermediate reservoirs and delivery points can be bypassed. Water can be delivered to the intermediate reservoirs and delivery points listed, but it is not assumed that all water is dropped into intermediate reservoirs and pumped back out.

List 1: Northwest Geographic Supply Zone

Supply Options:

- Temple Reservoir on Cache Creek
- Lake Ringgold, 271,600 acre-feet storage, 28,600 acre-feet/year firm yield, no additional supply augmentation
- Lake Texoma, blended with other supplies

Transmission Options:

- Cache Creek (Temple Reservoir) → Bridgeport
- Ringgold → Bridgeport
- Texoma → Lake Ray Roberts (drop off Dallas' share) → Bridgeport

Partnering/Other Options:

- Share Temple Reservoir with Southwest Oklahoma. Firm yield 125,000 AFY.
- Augment Lake Ringgold with water from Temple Reservoir (Transmission Option: Cache → Ringgold → Bridgeport)
- Permit Oklahoma water supply yield from Lake Texoma and share 50% with other Wholesale Water Providers. Amount actually delivered to TRWD will be determined based on quantity that can be blended without requiring advanced treatment.

List 2: Northeast Geographic Supply Zone

Supply Options:

- Kiamichi Run-of-River diversion with off-channel storage facility, 310,000 acre-feet/year permitted yield (155,000 acre-feet/year to TRWD)
- Marvin Nichols, 142,850 acre-feet/year to TRWD (assuming Lake Ralph Hall has a senior water right to Marvin Nichols, and Marvin Nichols is operated as a system with Wright Patman)
- Wright Patman – 180,000 acre-feet/year by changing the existing rule curve, raising the flood pool, and generating the greatest yield possible without flooding the White Oak Creek mitigation area.

Transmission Options:

- Kiamichi River supply → Lake Chapman → Lake Lavon → Lake Lewisville → Lake Bridgeport

- New Sulphur Basin Supply (Marvin Nichols, Wright Patman) → Lake Chapman → Lake Lavon → Lake Lewisville → Lake Bridgeport

Partnering/Other Options:

- Share Kiamichi 25% North Texas Municipal Water District (NTMWD), 25% Dallas, 50% TRWD
- Marvin Nichols shared between Dallas, Irving, NTMWD, TRWD, Upper Trinity Regional Water District (UTRWD). TRWD @ 29.166% of the 80% of Marvin Nichols after Region D takes 20%
- Wright Patman not shared with other Region C providers
- Kiamichi River transmission built in conjunction with Sulphur River Basin Options (Marvin Nichols, Wright Patman)

List 3: Southeast Geographic Supply Zone

Supply Options:

- Cedar Creek Firm Yield Differential
- Richland-Chambers Firm Yield Differential
- Tehuacana, 41,900 acre-feet/year yield
- Toledo Bend, 200,000 acre-feet/year yield to TRWD
- Lake Columbia - 47% of 85,507 acre-feet/year permitted (40,188 acre-feet/year)[1]

Transmission Options:

- Cedar Creek and Richland-Chambers Firm Yields through Integrated Pipeline until capacity limited, then incorporate those yields into new pipeline for this yield and a new source (e.g. Toledo Bend, Lake Columbia, Lake Tehuacana)
- Lake Tehuacana through IPL until capacity limited, then incorporate into new pipeline for this yield and a new source (e.g. Toledo Bend, Lake Columbia, CC and RC unpermitted firm yields)
- Toledo Bend → Pipeline Parallel to IPL
- Lake Columbia → Lake Palestine and then through IPL until capacity limited, then incorporate into new pipeline for this yield and a new source (e.g. Toledo Bend)

---

[1] 47% is the minimum and may grow after local partners finalize their commitments

Partnering/Other Options:

- Toledo Bend – 100,000 acre-feet/year to Sabine River Authority, 200,000 acre-feet/year to Dallas (50,000 acre-feet/year at Tawakoni, 150,000 acre-feet/year near Joe Pool Lake), 200,000 acre-feet/year to NTMWD at Lake Tawakoni, 200,000 acre-feet/year to TRWD at Lake Benbrook.

4.1 Description of Strategies

This section includes an abbreviated description of each water management strategy considered in the IWSP. Appendix A contains a full description of each water management strategy in an individualized 'Fact Sheet'.

4.1.1 Conservation

In planning and developing new water supplies, water conservation strategies across Texas will play a vital role in meeting the projected water needs throughout the state. The 2012 State Water Plan reports that 12 percent of future water needs in Region C will be met through municipal conservation. From a cost standpoint, water conservation is the most cost-effective alternative for meeting new water demands.

The Texas Water Code defines water conservation as "those practices, techniques, and technologies that will reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling and reuse of water so that a water supply is made available for future or alternative uses" (§11.002 (a) (8) (B)). The end result is lower per capita demands and less pressure on existing water supplies. Meaningful reductions in water loss and water waste, and improvements in water efficiency can help TRWD in many ways. Over time, conserving water on a daily basis:

- extends the life of existing supplies to meet new water demands
- slows the drain on reservoirs making more water available during times of drought
- reduces peak supply requirements, which reduces wear and tear on existing infrastructure
- defers increases in capital and operating cost for existing systems, and
- delays the need for developing new water supplies.

TRWD recognizes the benefits of using water and energy resources more efficiently. In order to maximize the use of existing water resources, TRWD is pursuing a menu of active water conservation measures, not just in times of drought but year-round. Some of the savings TRWD is observing today are due to passive measures that are occurring naturally, such as the replacement of older fixtures and appliances in existing homes with newer, more efficient models. The water district anticipates that the combination of active and passive conservation measures will lead to long-term, permanent reductions in per capita demand. Lower per capita demands is a trend being observed across the country. A national study found that residential water use over the last 30 years has declined at an average rate of 0.44 percent annually[2].

TRWD is committed to water conservation and has established a program that is generating an annual savings that can be measured in billions of gallons. Water conservation will continue to play a vital role in the district's long-term water supply strategy.

4.1.2 Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs

The original water right permits for Cedar Creek Reservoir and Richland-Chambers Reservoir authorizes TRWD to make annual diversions that are less than the actual firm yield of the reservoirs. This strategy is to obtain a permit for the difference between the current water rights and the firm yields. A vicinity map showing the project location is included in Figure 4.4.

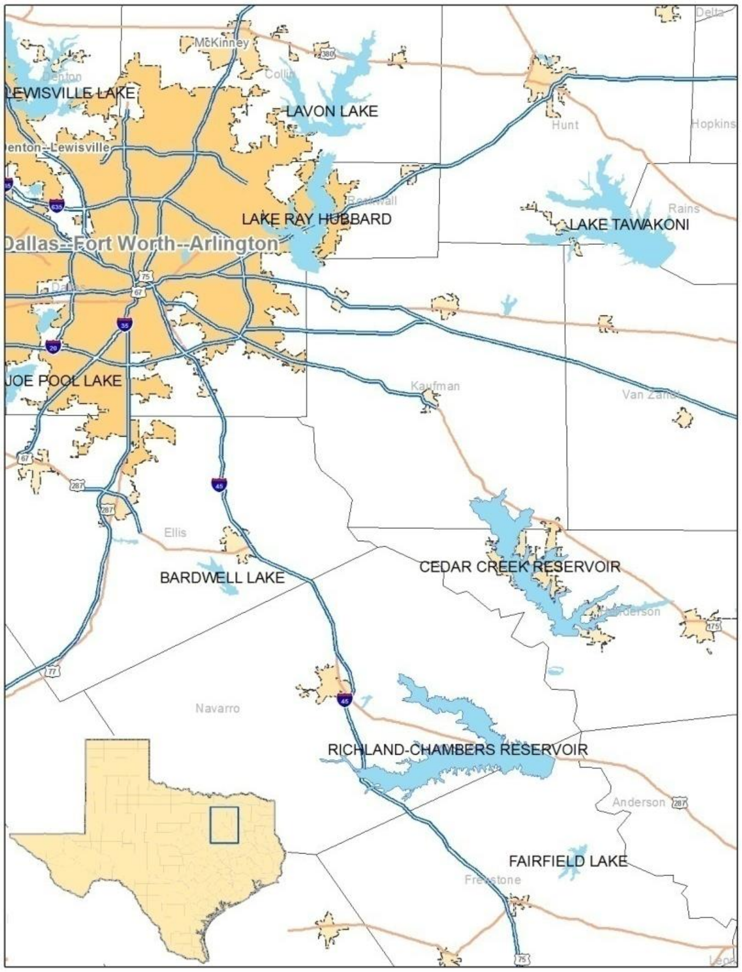


Figure 4.4 – CC/RC Reservoirs Vicinity Map

Two transmission configurations were analyzed:

1. Deliver additional Cedar Creek and Richland-Chambers supplies through the Integrated Pipeline (IPL) to Benbrook Lake. Because the Integrated Pipeline will not be operated at full capacity in the near term, unpermitted firm yield from Cedar Creek and Richland-Chambers reservoirs could initially be delivered through the IPL. In the future, the IPL will become fully utilized by current supply sources it has been designed to deliver and a new pipeline will be required. Figure 4.5 illustrates the pipeline route for transmission of flows from Cedar Creek and Richland-Chambers to Lake Benbrook using IPL.

---

[2] Coomes, Paul, Tom Rockaway, Josh Rivard, Barry Kornstein, 2010. North America Residential Water Use Trends Since 1992, Water Research Foundation. Retrieved August 1, 2013 from: http://www.waterrf.org/PublicReportLibrary/4031.pdf

2. Deliver additional Cedar Creek and Richland-Chambers supplies through a new pipeline constructed parallel to the IPL to carry this additional supply, possible additional supply from Cedar Creek and Richland Chambers wetlands (a separate strategy), and water from Lake Tehuacana (a separate strategy). Figure 4.6 illustrates the proposed pipeline route for transmission of flows from Cedar Creek and Richland-Chambers and Lake Tehuacana to Lake Benbrook using a new pipeline.

Table 4.2: Cedar Creek and Richland-Chambers Unpermitted Reservoir Firm Yield Estimates

Reservoir	Existing Permit (ac-ft/yr)	Proposed New Supply (ac-ft/yr) by Decade					
		2010	2020	2030	2040	2050	2060
Richland-Chambers	210,000	19,679	17,201	14,715	12,221	9,724	7,223
Cedar Creek	175,000	48,928	46,831	44,734	42,637	40,540	38,444

*Note: Existing permits for yield from the Cedar Creek (63,000 ac-ft/year) and Richland-Chambers (52,500 ac-ft/yr) Constructed Wetlands are not included in these numbers (though they are accounted for in the appropriate places of the TRWD Integrated Water Supply Plan).

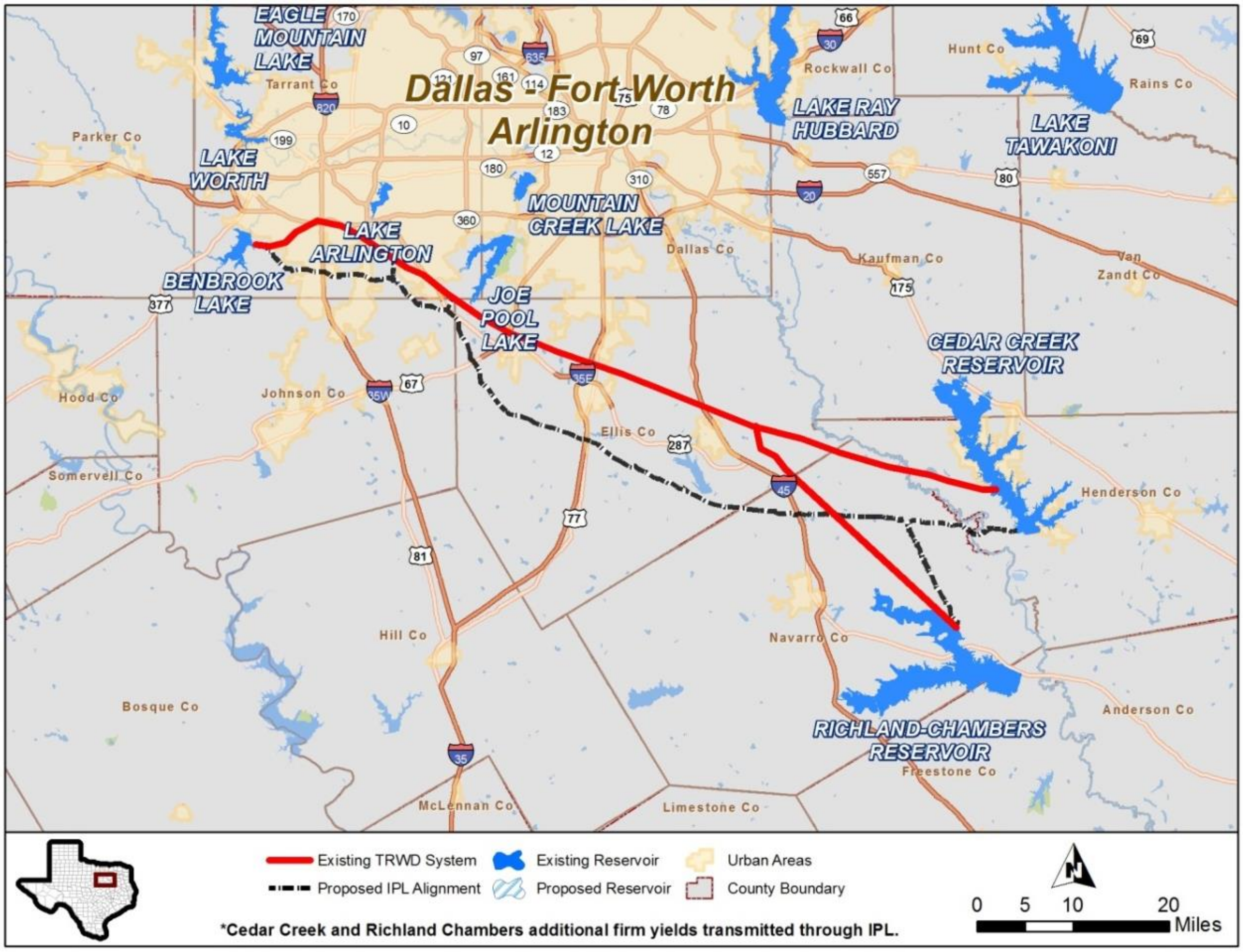


Figure 4.5 – Pipeline Route to Lake Benbrook (Transmitted through IPL)

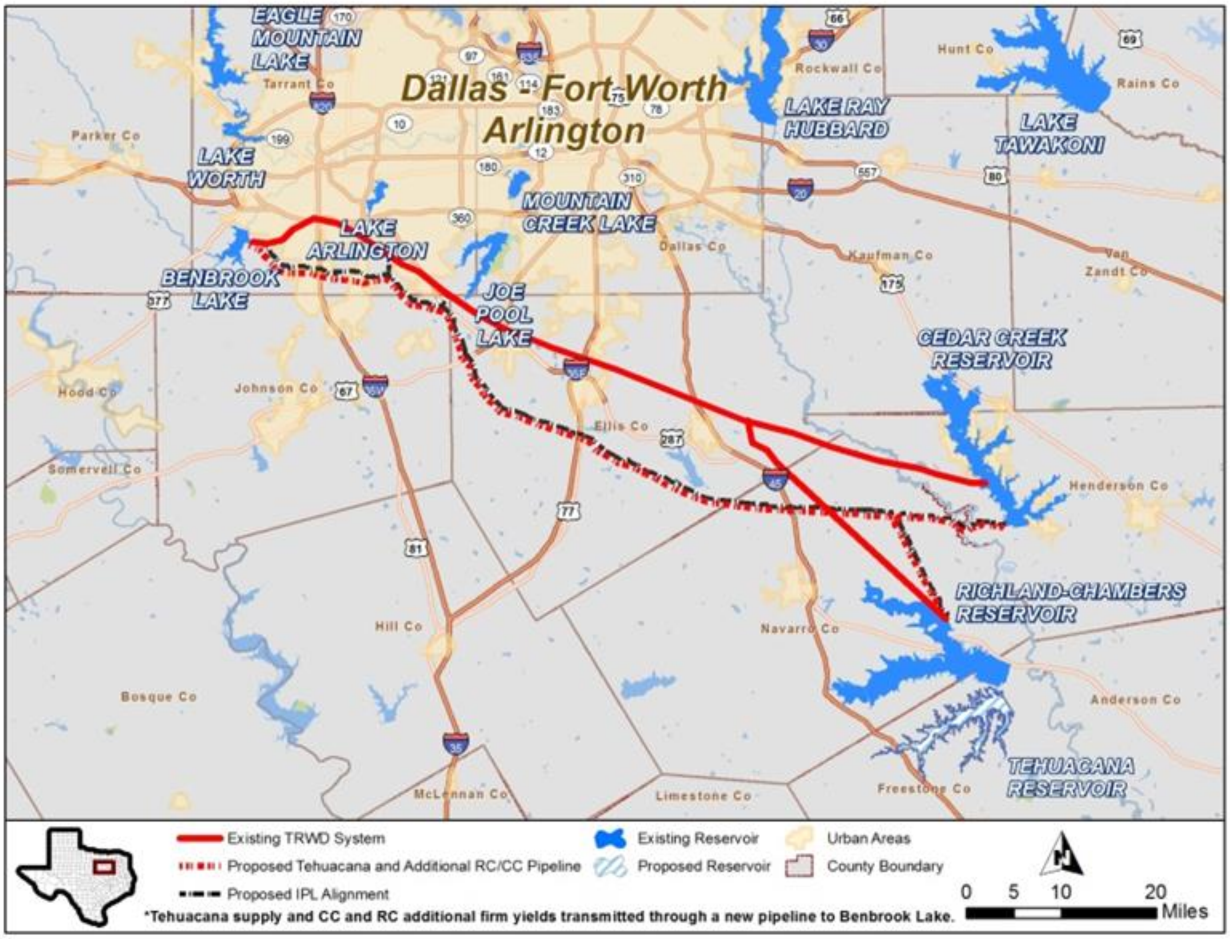


Figure 4.6 – Pipeline Route to Lake Benbrook (Tehuacana and Additional Richland-Chambers & Cedar Creek in a new Pipeline Parallel to IPL)

4.1.3 Cedar Creek and Richland Chambers Reservoirs Constructed Wetlands Full Yield Permits

TRWD has constructed and is operating wetlands adjacent to Richland-Chambers Reservoir and is planning to construct similar wetlands adjacent to Cedar Creek Reservoir. Water from the Trinity River is pumped into these constructed wetland systems where it is treated naturally in a series of sedimentation ponds and wetland cells (to remove nutrients and sediment) and then put back into the reservoir for use as a water supply. TRWD has permits from the Texas Commission on Environmental Quality (TCEQ) to divert water from the Trinity River into constructed wetlands, deliver that water to Cedar Creek and Richland-Chambers Reservoirs, and then deliver to TRWD customers. TRWD customers' wastewater treatment plant discharges are a source of water permitted for delivery to the constructed wetlands. A vicinity map showing the project location is included in Figure 4.7.

On February 8, 2005 the TCEQ granted Certificates of Adjudication for the Cedar Creek Wetlands (08-4976C for 52,500 acre-feet/year) and Richland-Chambers Wetlands (05-5035C for 63,000 acre-feet/year). These permitted amounts are not equal to the full volume of water available for delivery to the wetlands or permitted for delivery to the reservoirs (each permitted amount is different in this three step process). The difference exists because it was previously decided that at any point of time, the total volumetric contribution to Cedar Creek and Richland-Chambers Reservoirs from their respective wetlands should not be greater than 30% of the reservoir storage volume. This decision was meant to protect reservoir water quality. The 30% rule was chosen based on engineering judgment, but actual operations of the wetlands system have shown that this rule is not required to maintain acceptable water quality.

This water supply strategy is to secure a permit from the TCEQ to use all water delivered to the reservoirs from the constructed wetlands. The strategy is to pump water out of the reservoirs and to TRWD customers on the same day as it is delivered from the wetlands. This eliminates evaporative losses and will not impact reservoir storage that could be otherwise used (such as to permit the difference between the current water rights in Cedar Creek and Richland-Chambers and their firm yields). See Table 4.3 for additional details on yield estimates.

Table 4.3: Cedar Creek and Richland-Chambers Reservoir and Wetlands Yield Estimates

Reservoir	Permitted Delivery from Trinity River to Wetlands (ac-ft/yr)	Permitted Delivery from Wetlands to Reservoir (ac-ft/yr)	Permitted Supply of Wetland Water from Reservoir to Customers (ac-ft/yr)	**Proposed Additional Supply of Wetland Water from Reservoir to Customers** (ac-ft/yr)
Richland-Chambers	105,019	100,465	63,000	**37,465**
Cedar Creek	90,799	88,059	52,500	**35,559**

Two transmission configurations were analyzed:

1. Deliver additional Cedar Creek and Richland-Chambers supplies through the Integrated Pipeline (IPL) to Benbrook Lake. Because the Integrated Pipeline will not be operated at full capacity in the near term, wetlands supply could initially be delivered through the IPL. In the future, the IPL will become fully utilized by current supply sources it has been designed to deliver.

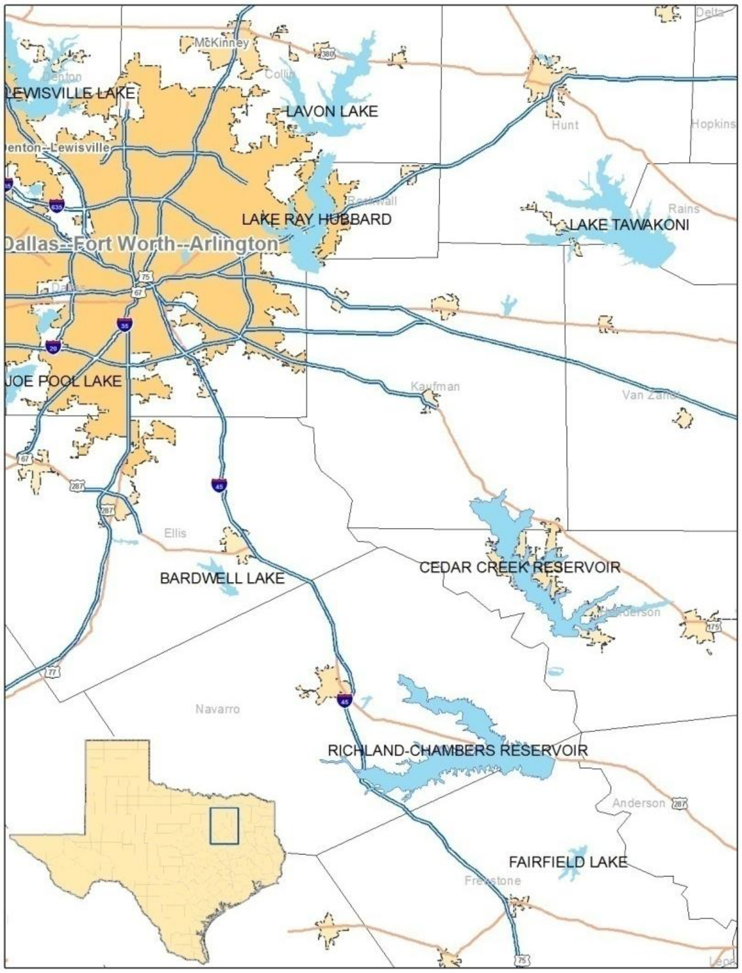


Figure 4.7 – CC/RC Reservoir Vicinity Map

2. Deliver additional Cedar Creek and Richland-Chambers supplies through a new pipeline constructed parallel to the IPL to carry this additional supply and water from Cedar Creek and Richland Chambers unpermitted reservoir firm yield (a separate strategy), and water from Lake Tehuacana (a separate strategy). Figure 4.8 shows the proposed pipeline route for transmission of flows from Cedar Creek and Richland-Chambers and Lake Tehuacana to Lake Benbrook using a new pipeline.

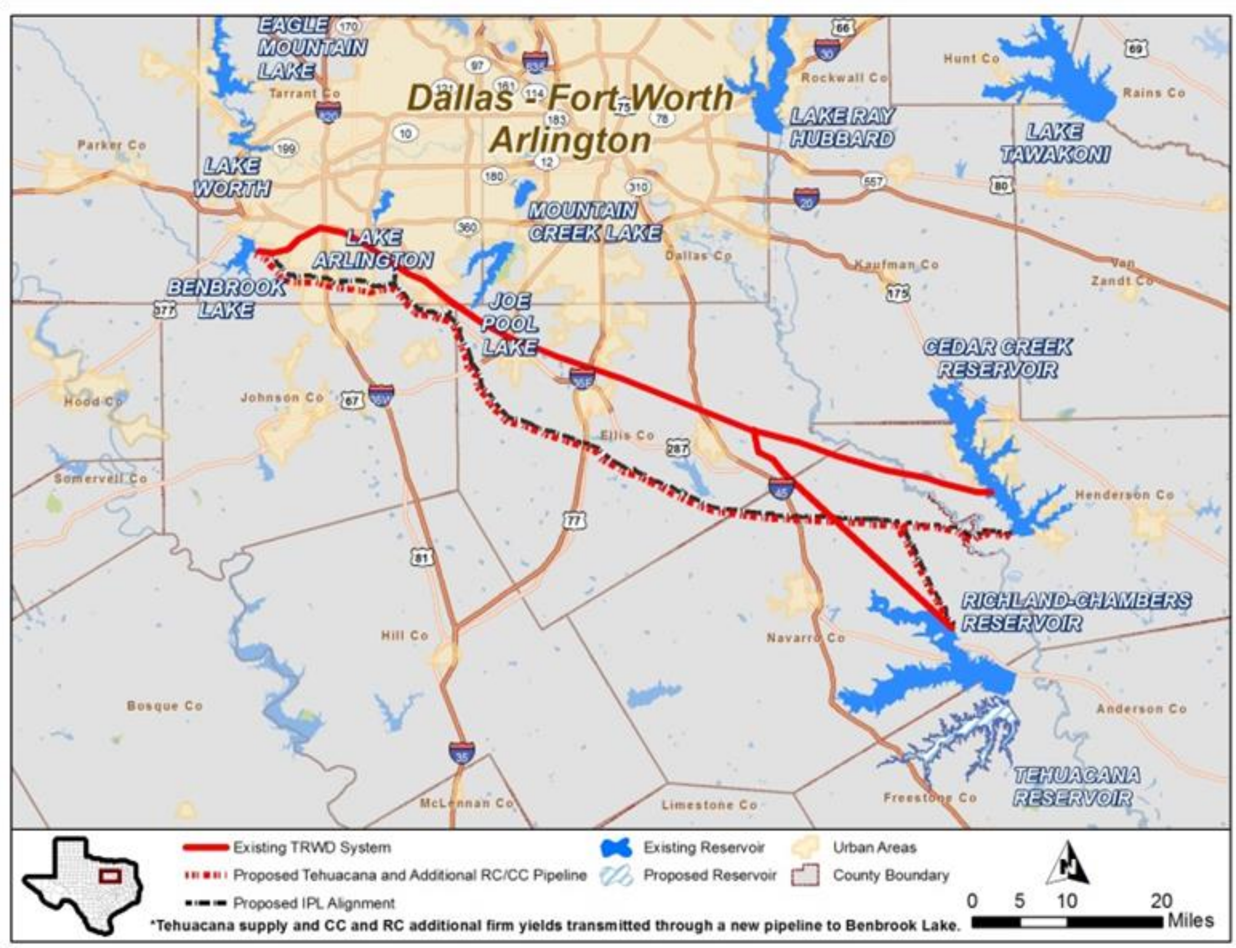


Figure 4.8 – Pipeline Route to Lake Benbrook (Tehuacana and Richland-Chambers & Cedar Creek Constructed Wetlands Supply in a New Pipeline Parallel to IPL)

4.1.4 Lake Columbia

The Angelina and Neches River Authority (ANRA) has a Texas water right for the development of the proposed Lake Columbia on Mud Creek in the Neches River Basin. ANRA is pursuing development of the reservoir and is working toward a Section 404 permit from the U.S. Army Corps of Engineers. Lake Columbia would inundate approximately 10,133 acres.

The Lake Columbia dam could be designed, constructed, and begin filling within six years of 404 permit issuance. Water would be available to meet identified demands once the lake fills and an interbasin transfer permit is issued. A vicinity map is included in Figure 4.9.

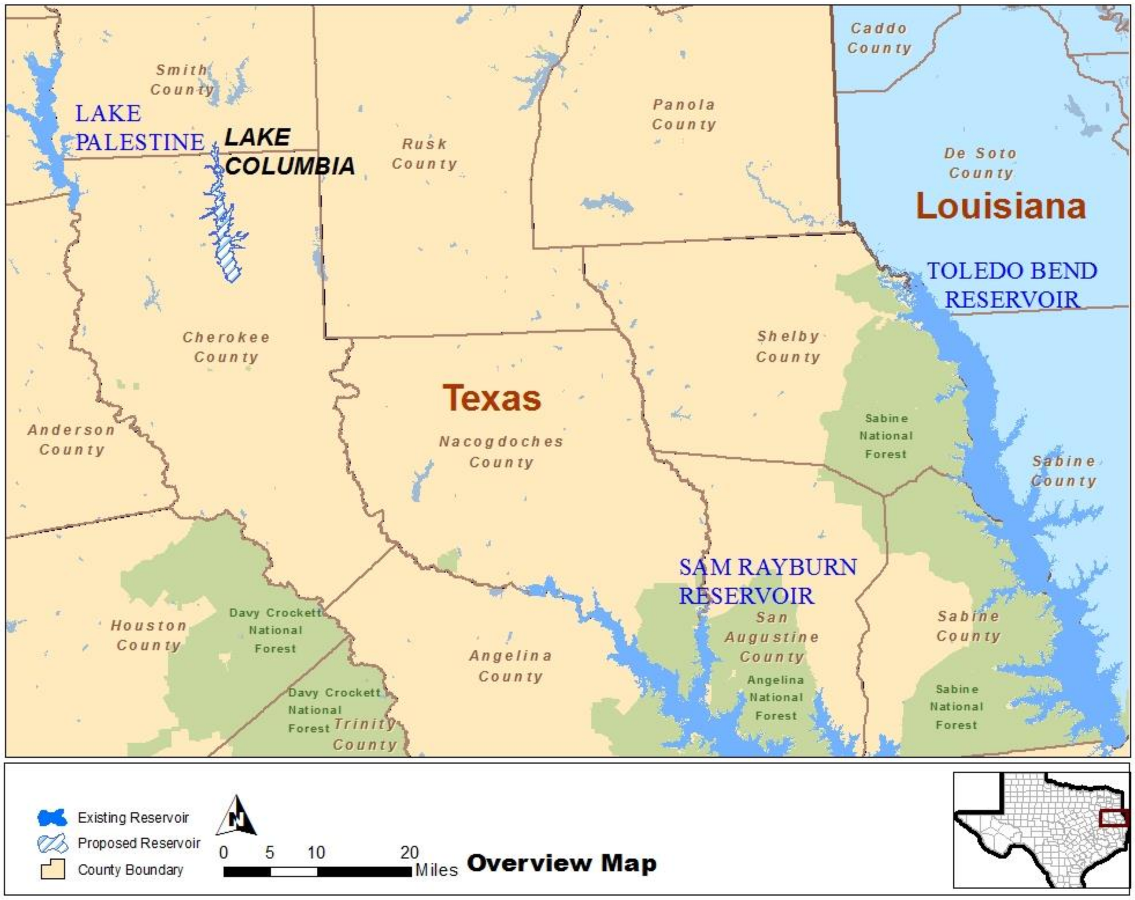


Figure 4.9 – Vicinity Map

Facilities Required

- Dam/Reservoir - the Lake Columbia dam would be an earthen fill structure approximately 6,800 feet long with a maximum height of 67 feet.
- One intake structure and 4,200 HP pump station located on the west side of Lake Columbia.
- One 2,500 HP booster pump station and a 9 MG open storage tank.
- 23-miles of 54-inch diameter pipe from Lake Columbia to the Integrated Pipeline (IPL) on the west side of Lake Palestine (This configuration assumes water will be transported around Lake Palestine.)
- Because the Integrated Pipeline will not be flowing at full capacity initially, Lake Columbia supply could initially be delivered through the Integrated Pipeline (IPL). Once the IPL becomes fully utilized by TRWD and Dallas, delivery of Lake Columbia will require a new pipeline. As configured here, Columbia would flow through a pipeline

designed to convey Toledo Bend supply and Columbia supply. A pipeline to convey only Lake Columbia is assumed to be cost prohibitive and is not considered here.

Yield

Of the permitted yield for Lake Columbia (85,507 acre-feet per year), 47 percent (40,188 acre-feet per year) would be available for use by TRWD or other entities in Region C. There could be more available in the future if local partners do not contract for the full 53% of Columbia's yield that is currently planned for in-basin use.

4.1.5 Excess Flow Optimization (EXFLO), Eagle Mountain Lake and Lake Benbrook[3]

The Excess Flow Optimization (EXFLO) strategy is, in essence, the District is seeking authorization to divert unappropriated water flowing through Eagle Mountain Lake and Lake Benbrook when they are in a defined state of flood stage and to account for these diversions under the authority of the new water rights rather than the existing water rights that authorize these impoundments and their associated diversions. Under certain circumstances, this mode of operation will alleviate the need for the District to pump water from its eastern reservoirs, Richland-Chambers and Cedar Creek, to satisfy the demands of its customers, thereby reducing overall pumping and energy costs. Operation of the EXFLO project will not alter in any way current flood operating procedures for either Eagle Mountain Lake or Lake Benbrook.

Figure 4.10 – Lake Benbrook and Eagle Mountain Lake Vicinity Map

The EXFLO project will allow the District to take advantage of available high flows when they occur, with cost savings realized because of reduced pumping that otherwise would be necessary to delivery water to the District's customers from the District's distant eastern reservoirs (Richland-

---

[3] Water Availability Analysis, Excess Flow Optimization Project – EXFLO, Atkins, 2011

Chambers and Cedar Creek). A net benefit of this type of operation is that it extends the District's existing sources of supply, effectively making more water available during more extreme drought periods. In the most basic sense, the EXFLO strategy will be an integral part of the District's overall water supply and delivery system, and it will be operated as such. Unlike, other strategies, EXFLO is not intended to produce a 100 percent reliable supply for the drought of record,

No new facilities are required to make use of this strategy. Supplies will be delivered through existing infrastructure. A map showing the project location is included in Figure 4.10.

The maximum annual diversion under the EXFLO permit is 78,653 acre-feet. The maximum annual diversion from Eagle Mountain Lake is 63,899 acre-feet. "It should be noted that the proposed EXFLO project is not intended to produce a firm supply of water [i.e. 100% reliable even in drought of record] for the District, nor does it need to with the availability of the District's other existing sources of supply. It is also not expected to be utilized often, since diversions under the EXFLO permits will be limited to only those times when Eagle Mountain Lake and Lake Benbrook are in flood stage." (Atkins, 2011)

4.1.6 Kiamichi River

In 2006 TRWD applied to the Oklahoma Water Resources Board for a 310,000 acre-feet/year water right permit on the Kiamichi River in Southeastern Oklahoma. The permit application was subject to the result of litigation in the federal courts, which has concluded with a decision that supports Oklahoma's refusal to grant the permit. Therefore, water supply from Southeastern Oklahoma is subject to on-going efforts to negotiate a contract for the sale of water to TRWD. A run-of-river supply with an off-channel storage facility (OCSF) is planned close to the Red River confluence. Transmission facilities will deliver water from the Kiamichi River to a nearby OCSF and then on to TRWD and regional partners (in this case NTMWD and Dallas). The breakdown of assumed percent of yield (in acre-feet per year) available to each entity is 50% TRWD, 25% NTMWD, and 25% Dallas. Project location is shown in Figure 4.11.

Facilities Required

- Channel dam and one 46,630 HP run-of-river intake and pump station
- Approximately 2 miles of 144-inch pipe from Kiamichi River to an off-channel storage facility
- One 80,000 acre-foot off-channel storage facility (OCSF)

- One 50,000 HP intake pump station to deliver from OCSF to TRWD and partners
- One 35,000 HP Intake Pump Station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.
- 167 miles of transmission pipeline to Lake Bridgeport if built independently of the Sulphur River transmission system and in a separate route. Approximately 15 additional miles would be required if the Kiamichi pipeline were re-routed to be in the same right of way as the Sulphur River system transmission lines. The pipeline lengths are detailed below.
- Approximately 52 miles of 120-inch pipe, 54 miles of 108-inch pipe, and 61 miles of 90-inch pipe
- Three booster pump stations along the pipeline route: 38,840 HP, 29,200 HP and 25,200 HP
- Three earthen storage reservoirs: 69 MG, 52 MG, and 35 MG
- 207 MGD discharge structure at Lake Bridgeport

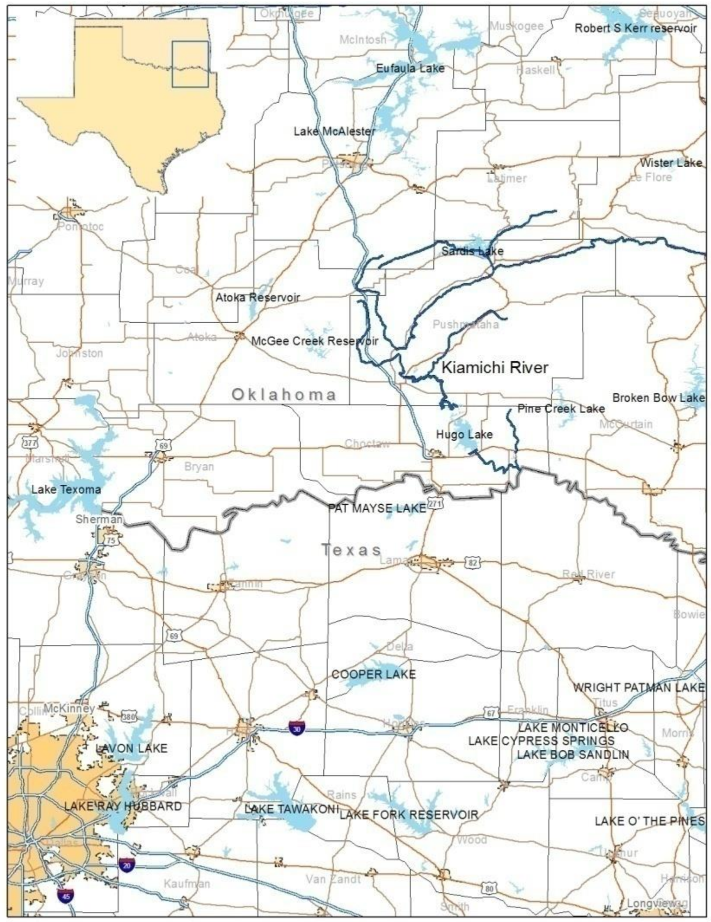


Figure 4.11 – Kiamichi River Vicinity Map

Yield

A run-of-river diversion has a variable annual yield because of its dependency on available river flow without storage. The Kiamichi River water right permit application sought 310,000 acre-feet/year; it is assumed that this quantity could be obtained through a negotiated sale. A 1,050 mgd run-of-river diversion with OCSF and 350 mgd delivery pump station could supply 310,000 acre-feet/year with 90% reliability, and could supply a long-term average 300,000 acre-feet/year. Approximately 300,000 acre-feet per year could be supplied on an annual average during the North Texas drought of record, which occurred between 1949 and 1956.

Based on the period-of-record, the minimum one-year supply could drop as low as 164,000 acre-feet/year.

The 310,000 acre-feet/year total yield would be shared among TRWD and regional partners. In the current configuration under consideration, 50% is delivered to TRWD, 25% to NTMWD, and 25% Dallas.

Preliminary water availability estimates indicate that the same infrastructure (a 1,050 mgd run-of-river diversion with OCSF and 350 mgd delivery pump station) could yield an average of about 350,000 acre-feet/year at 83% reliability if deliveries were only limited by available supply (assuming no permit restrictions), and a maximum of almost 400,000 acre-feet/year.

4.1.7 Marvin Nichols Reservoir

The proposed Marvin Nichols Reservoir is located on the Sulphur River in the Sulphur River Basin in Texas' Regional Water Planning Group D ("Region D – North East Texas"). The 80th Texas Legislature designated the Marvin Nichols Reservoir site as a site of unique value for reservoir development (Senate Bill 3, Section 4.01). The proposed reservoir would be about 115 miles from the Dallas-Fort Worth Metroplex and would inundate approximately 67,000 acres. Figure 4.12 includes an illustration of the proposed project location. This strategy assumes that NTMWD, TRWD, Dallas, Irving, and UTRWD would collaborate to construct Marvin Nichols Reservoir and transmission facilities. Below is a breakdown of the assumed percent of yield (in acre-feet per year) available to each entity.

- NTMWD – 142,850 (29.167%)*
- TRWD – 142,850 (29.166%)*
- DWU – 142,850 (29.167%)*
- Irving – 26,451 (5.4%)*
- UTRWD – 34,779 (7.1%)*

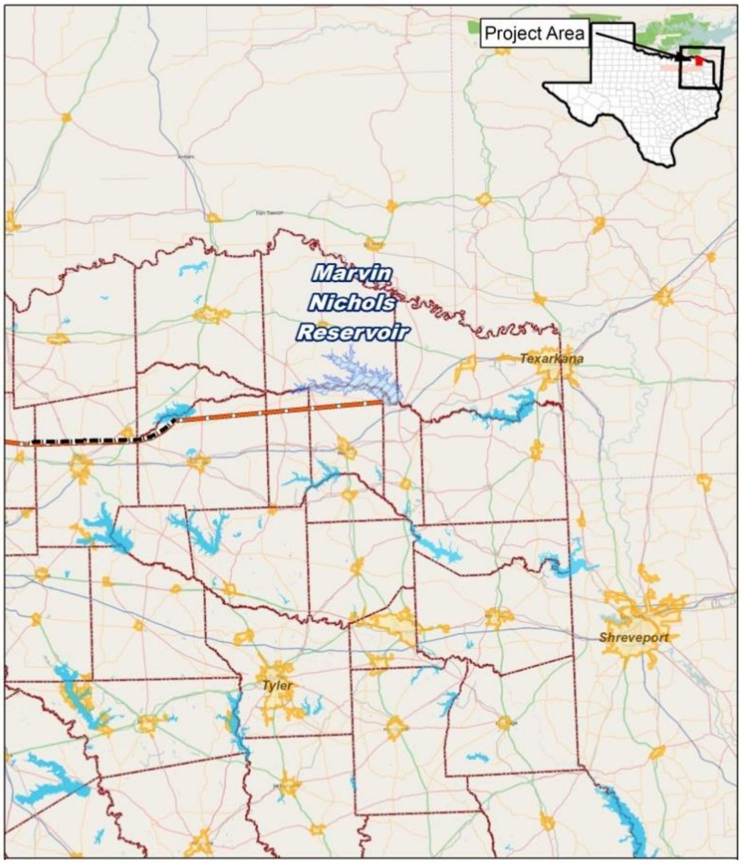


Figure 4.12 – Vicinity Map

- Local Users – 122,521

*Percentages are based on water going to the Metroplex and do not include the water taken by local users.

Facilities Required

New reservoir:

- Dam height: 82 feet
- Normal Pool Elevation: 328 feet-msl
- Normal Pool Surface Area: 67,392 acres
- Normal Pool Storage: 1,562,669 acre-feet

Transmission Facilities:

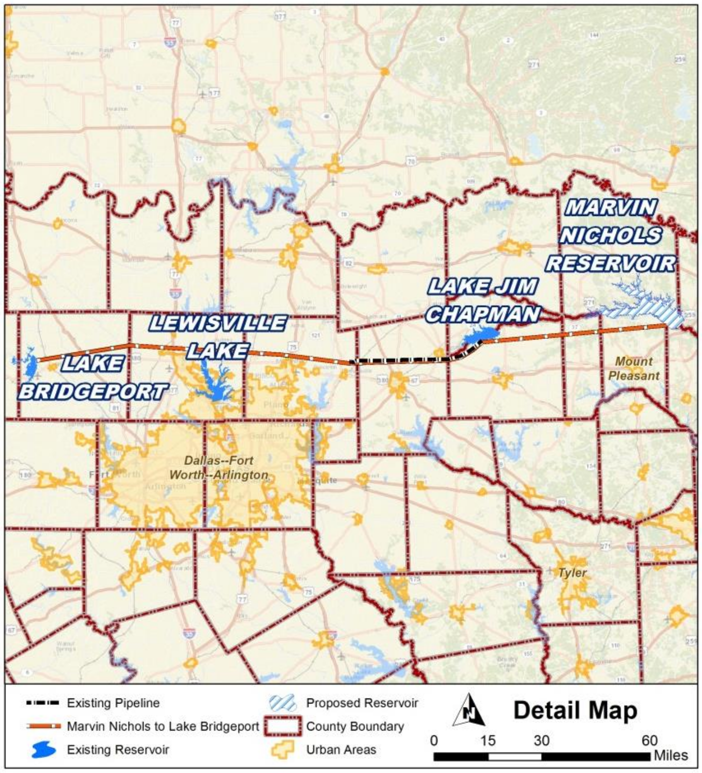


Figure 4.13 – Proposed Pipeline Route Map for Marvin Nichols Reservoir Supply

- Approximately 110 miles of two parallel 108-inch pipes,30 miles of two 96-inch pipes, and 60 miles of single 96-inch pipe. The assumed pipeline route runs from Marvin Nichols Reservoir to Lake Bridgeport. Along the route, it passes Jim Chapman Lake, Lake Lavon, and Lewisville Lake. Figure 4.13 includes a representation of the proposed pipeline route.
- One 35,000 HP Intake Pump Station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.
- One 58,500 HP Intake Pump Station at Marvin Nichols
- Three booster pump stations along the pipeline route: 68,800 HP, 76,300 HP, and 20,500 HP.
- Two 109 MG earthen storage reservoirs and one 77 MG earthen storage reservoir
- One 191 MGD discharge structure at Lake Bridgeport.

Yield

The yield of Marvin Nichols Reservoir is 602,000 acre-feet/year, assuming stand-alone reservoir operations. The proposed Lake Ralph Hall will likely have a senior water right to

Marvin Nichols, and would reduce the firm yield of Marvin Nichols by 17,900 acre-feet/year to 584,100 acre-feet/year (TWDB, 2008). However, if Marvin Nichols Reservoir is operated as a system with Lake Wright Patman, the yield can be increased to 612,300 acre-feet/year, even if Lake Ralph Hall's water rights are senior to Marvin Nichols Reservoir.

The yield used in the *2011 Region C Water Plan* and in this study is 612,300 acre-feet/year. Assuming twenty percent of the supply would go to local users in Region D, 489,840 acre-feet per year would be available for use by TRWD and other entities in Region C.

4.1.8 Lake Ringgold

The 80th Texas Legislature designated the Lake Ringgold site as a site of unique value for reservoir development (Senate Bill 3, Section 4.01). It is located on the Little Wichita River just upstream of the confluence with the Red River in Clay County and is a water supply strategy for the City of Wichita Falls. Vicinity Map is included in Figure 4.14. Wichita Falls needs an additional 4,200 to 4,900 acre-feet of annual supply to be fully reliable on a safe yield basis in 2060. Their current plan is to meet this gap by constructing Lake Ringgold. Wichita Falls also lists wastewater reuse as an alternative supply that could provide approximately 11,000 acre-feet/year. TRWD and Wichita Falls have agreed to study the feasibility of jointly developing Lake Ringgold.

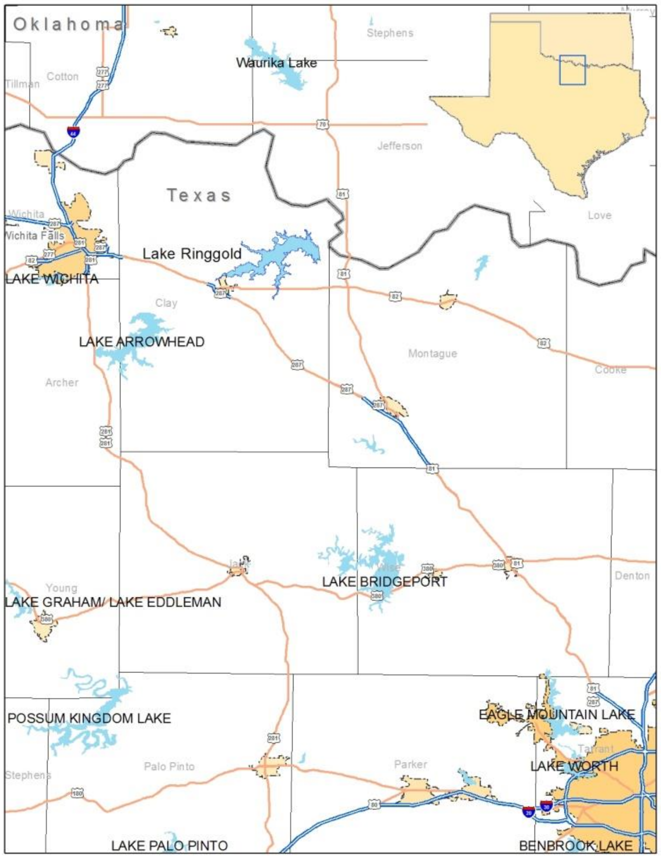


Figure 4.14 – Vicinity Map for Ringgold

This strategy is to build Lake Ringgold for two purposes: 1) water supply to TRWD and Wichita Falls; and 2) to integrate with the Southwestern Oklahoma water supply system.

Facilities Required

- Dam – 9,350-ft long zoned earthen embankment at 871 foot elevation with gated spillway. 844 foot elevation conservation pool; 271,600 acre-feet capacity; 14,980 acres inundated at top of conservation pool.
- One 3,400 HP intake pump station at Ringgold
- Approximately 42 miles of single 48-inch pipe

- 32 mgd discharge structure at Lake Bridgeport
- One 35,000 HP intake pump station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline. Pipeline route is illustrated in Figure 4.15.

Yield

The Red River Water Availability Model – the Texas Commission on Environmental Quality's (TCEQ) Water Rights Analysis Package (WRAP) – estimates the firm yield at 33,000 acre-feet/year. However, previous studies estimated a lower firm yield. To be conservatively low, the Texas Regional Water Planning Group B 2011 Water Plan used these older yield estimates; 27,000 acre-feet/year was used as the reservoir firm yield and 24,000 was used as the safe yield (reserves a one-year supply of water at all times).

This study uses 28,600 acre-feet/year as the stand-alone Lake Ringgold firm yield. However, the yield can be increased if operated jointly with Southwestern Oklahoma water, and the Ringgold flows can similarly increase Lake Bridgeport yield. These joint operations have not yet been simulated. This strategy assumes primary use of Ringgold yield by TRWD within the timeframe of this study (50 years). Therefore, all capital and annual costs are attributed to TRWD.

Figure 4.15 – Pipeline Route for Ringgold

4.1.9 Lake Tehuacana

Tehuacana Reservoir is a proposed reservoir on Tehuacana Creek in Freestone County, a tributary to the Trinity River, immediately south of Richland-Chambers Reservoir. Tehuacana Reservoir would inundate approximately 15,000 acres adjacent to Richland-Chambers Reservoir and the two would be hydraulically connected with a small channel. Water from Tehuacana would be transported from Richland-Chambers Reservoir into TRWD transmission facilities.

Tehuacana Reservoir has been part of the TRWD water supply portfolio since the 1950's, but mineral issues in the reservoir footprint have made the project expensive to develop.

The existing spillway for Richland-Chambers Reservoir has capacity to handle Probable Maximum Flood flows from the additional storage created by Tehuacana Reservoir. The Tehuacana Reservoir dam can be constructed without an additional spillway and can function as an extension of Richland-Chambers Reservoir. Project Location is depicted in Figure 4.16.

The yield from Lake Tehuacana is 41,900 acre-feet/year.

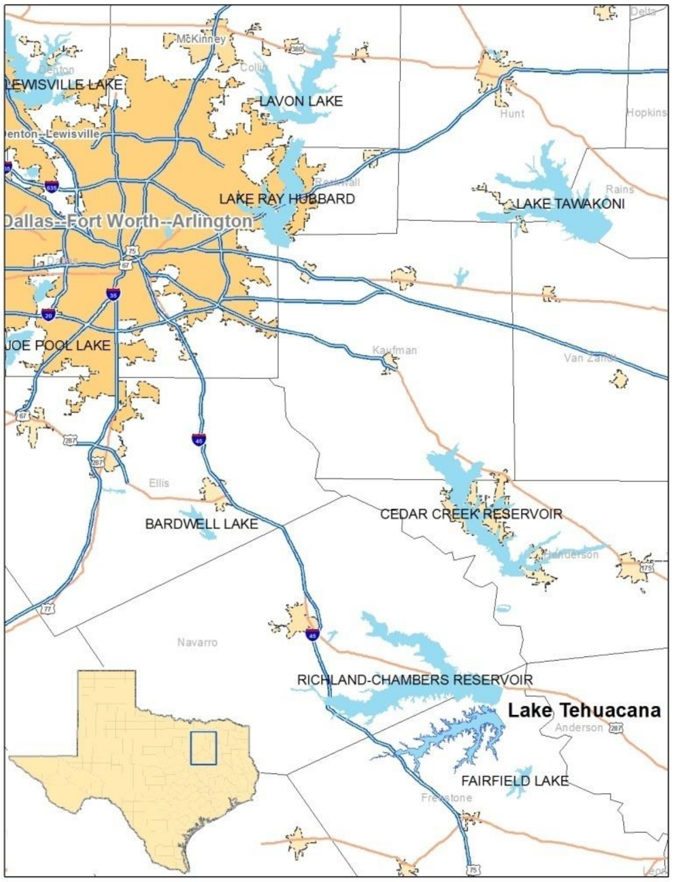


Figure 4.16 – Vicinity Map for Tehuacana

Facilities Required

- Zoned earthen embankment with a maximum height of 81 feet.
- 9,000-foot channel at elevation 290' connecting to Richland-Chambers Reservoir and a 60 HP booster pump station*[4] to access the full yield of Tehuacana down to elevation 270'.
- Because the Integrated Pipeline will not be operated at full capacity in the near term, Tehuacana supply will initially be delivered through the IPL. In the future, the IPL will become fully utilized by current supply sources it has been designed to deliver. At that point it will not have unused capacity and a new pipeline will be needed to deliver Lake Tehuacana flows. This new pipeline will be built within the IPL right of way and will be designed to also carry other supply sources from Southeast of Dallas/Fort Worth. Two configurations were analyzed:
  1. Deliver Lake Tehuacana supplies through the Integrated Pipeline (IPL) to Benbrook Lake (Figure 4.17)

[4] Sized based on July 11, 2013 conversation with Woody Frossard of TRWD based on on-going work to quantify Lake Tehuacana yield.

2. Deliver Lake Tehuacana through a new pipeline constructed parallel to the IPL to carry Tehuacana and water from additional Cedar Creek and Richland-Chambers unpermitted supplies and wetland full yield supplies (separate strategies). Pipeline route is included in Figure 4.18.

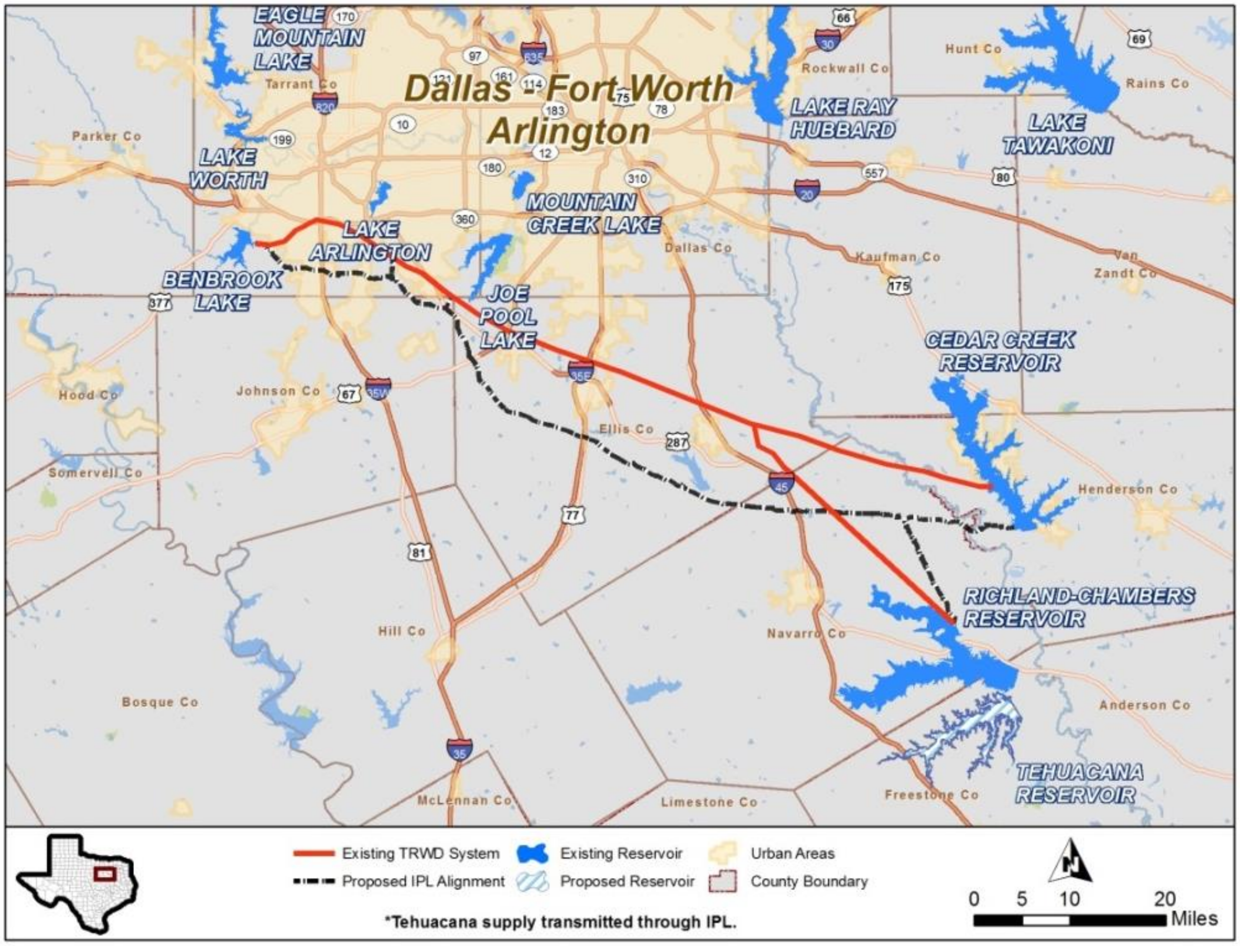


Figure 4.17 – Pipeline Route to Lake Benbrook (Tehuacana supply transmitted through IPL)

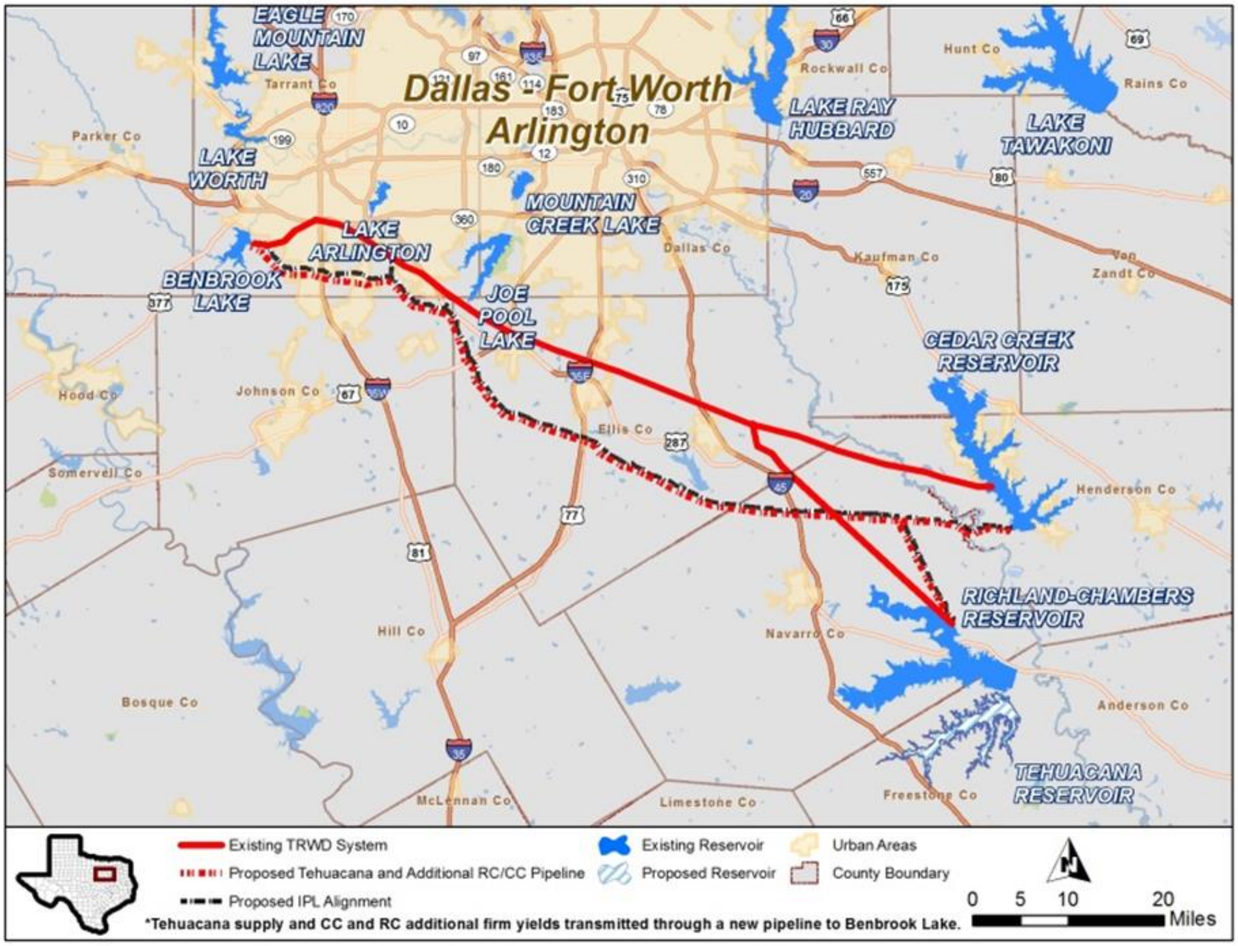


Figure 4.18 – Pipeline Route to Lake Benbrook (Tehuacana Supply and Additional Richland- Chambers & Cedar Creek Unpermitted Supplies in a new Pipeline)

4.1.10 Temple Reservoir

In 2006 TRWD applied to the Oklahoma Water Resources Board (OWRB) for water right permits on stream systems in Southwestern Oklahoma: 125,000 acre-feet/year on Cache Creek and 25,000 acre-feet/year on Beaver Creek. The permit applications were subject to the result of litigation in the federal courts, which has concluded with a decision that supports Oklahoma's refusal to grant the permits. Therefore, water supply from Southwestern Oklahoma is subject to on-going efforts to negotiate a contract for the sale of water to TRWD. Several supply configurations from these sources have been evaluated (run-of-river diversion, on-channel reservoir, off-channel storage facility) and the most reliable is construction of a reservoir on the main stem of Cache Creek close to its confluence with the Red River. In 1966, the OWRB identified a potential reservoir sited in this location – the "Temple Reservoir".

A new reservoir at this site could be constructed to store 383,000 acre-feet of water at an average depth of 20 feet and could supply a firm yield of 125,000 ac-ft/yr. Transmission facilities would be designed to take water from Temple Reservoir to Lake Ringgold and/or to TRWD's Lake Bridgeport on the West Fork Trinity River. Though water supply from Beaver Creek (25,000 acre-feet/year from the stream system that includes Lake Waurika) is not included in this strategy, the transmission system is configured so that Beaver Creek supply could be added later. Project location is illustrated in Figure 4.19.

Facilities Required

- 84' high, 17,300' long earthen dam. 383,000 acre-foot conservation pool.
- 68 mile, 84" transmission pipeline. The assumed configuration does not combine Temple Reservoir with Lake Ringgold. If they are combined, approximately 43 miles of pipeline would be upsized to also carry Ringgold water.
- 8,400 HP intake pump station at Temple Reservoir
- 9,700 HP booster pump station along the pipeline route
- One 28 MG earthen storage reservoir
- 139 mgd discharge structure at Lake Bridgeport
- One 35,000 HP intake pump station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.

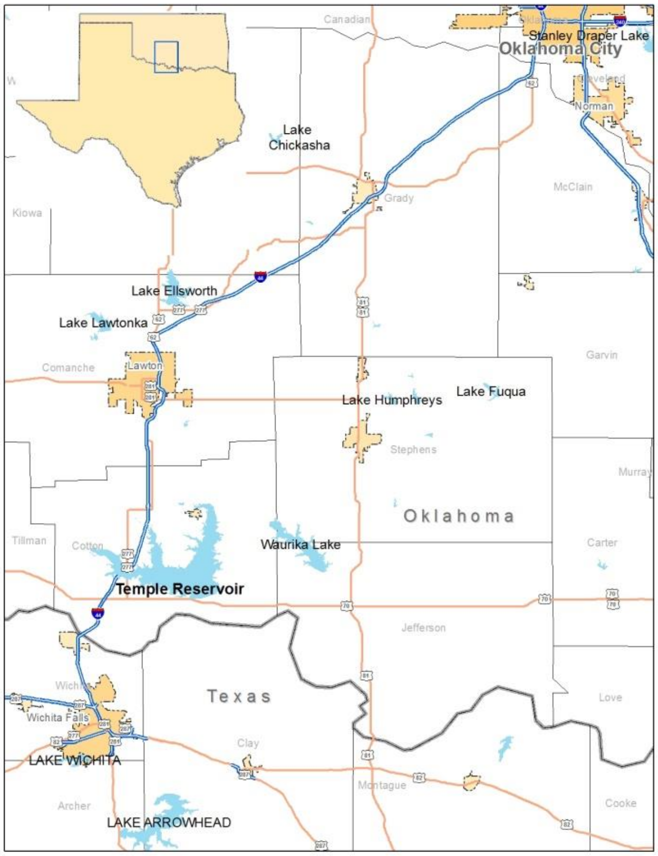


Figure 4.19 – Vicinity Map for Temple Reservoir

Yield

The water right permit applications sought 125,000 acre-feet/year from Cache Creek and 25,000 acre-feet/year from Beaver Creek; it is assumed that these quantities could be obtained through a negotiated sale. The Temple Reservoir strategy only includes the Cache Creek yield but is configured so that Beaver Creek supply could be added in the future.

This configuration of Temple Reservoir is sized for a *firm yield* of 125,000 acre-feet/year. It is possible that a contract for more than the firm yield could be secured through negotiations with Oklahoma. Preliminary water availability estimates indicate that Temple Reservoir could supply an *average* of roughly 320,000 acre-feet/year if the transmission infrastructure were upsized accordingly, but as configured, modeled, and priced here, the infrastructure is sized only for the firm yield of 125,000 acre-feet/year (with a peaking factor of 1.25).

Figure 4.20 – Temple Reservoir Pipeline Route to Lake Bridgeport

4.1.11 Lake Texoma

Lake Texoma is an existing Corps of Engineers reservoir on the Red River on the border between Texas and Oklahoma, located approximately 50 miles from the Dallas-Fort Worth Metroplex. Under the terms of the Red River Compact, the yield of Lake Texoma is divided equally between Texas and Oklahoma. Figure 4.21 shows the project location. As stated in the TWDB 2011 Region C Water Plan, the current storage amount available to Texas is 300,000 acre feet. This includes the original 150,000 acre feet that was allocated for municipal supply when Lake Texoma was constructed and the additional 150,000 acre feet that was authorized by Congress in 1986 to be reallocated from hydropower storage. Of the reallocated water, 50,000 acre feet was reserved for the Greater Texoma Utility Authority, and the remaining water was contracted to the North Texas Muncipal Water District. The total permitted yield is 316,550 acre-feet/year. The firm yield of the total storage amount allocated to Texas has already been permitted to the following entities by the TCEQ:

- North Texas Municipal Water District (NTMWD): 197,000 acre-feet/year (including their original 84,000 and the additional 113,000 from hydropower reallocation)
- Greater Texoma Utility Authority (GTUA): 83,200 acre-feet/year (including their original 25,000; the additional 56,500 from hydropower reallocation; and 1,700 that was recently added to their permit).
- City of Denison: 24,400 acre-feet/year
- TXU: 16,400 acre-feet/year

- Red River Authority (RRA): 2,250 acre-feet/year

According to the Corps of Engineers and stated in the TWDB 2011 Region C Water Plan, an additional supply of 220,000 acre-feet per year may be available to Texas entities if the U.S. Congress authorizes the reallocation of additional hydropower storage in Lake Texoma to municipal water supply. This is in addition to hydropower storage that has already been reallocated. However, this possible supply is not considered a viable strategy at this time due to the probability that an additional reallocation will not be approved. Texas' entire share of the municipal water supply in Texoma has been permitted and there is therefore no additional water available for TRWD from Texas.

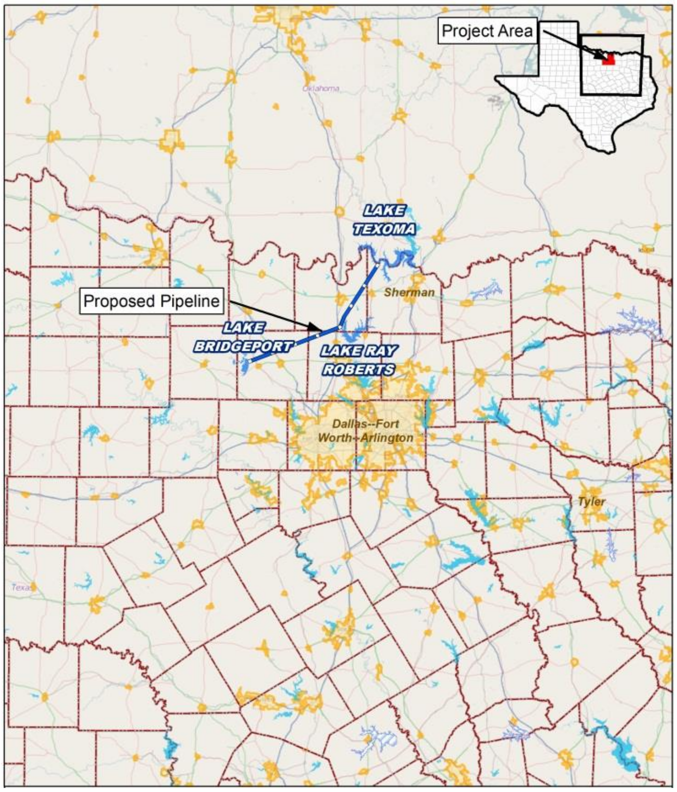


Figure 4.21 – Lake Texoma Vicinity Map

To obtain water supply from Lake Texoma, TRWD would require a contract or permit from Oklahoma. According to the 2011 Oklahoma Comprehensive Water Plan, there is 162,271 acre-feet/year available from Oklahoma's share of Lake Texoma. This does not include the additional 150,000 acre-feet of storage representing Oklahoma's share of the water reallocated from hydropower storage.

Although Lake Texoma water cannot currently be transmitted directly to other reservoirs across state lines due to the presence of zebra mussels in Lake Texoma, this strategy assumes that conditions change, allowing the transfer of water between reservoirs. The lake has elevated levels of dissolved solids, and the water must be blended with higher quality water or desalinated for municipal use. While desalination is an alternative for Lake Texoma water, this configuration of the Lake Texoma supply strategy focuses on blending Lake Texoma water with other water supplies, allowing conventional treatment. The Lake Texoma water will be delivered to Lake Bridgeport and blended in TRWD's West Fork system.

Facilities Required

Yield from Lake Texoma will be blended with Lake Bridgeport water at a 10:1 (Bridgeport:Texoma) ratio, making the annual supply from Texoma highly variable because it depends on the amount of water supply in Bridgeport. A significant modeling effort would be required to determine the optimal monthly delivery rate from Lake Texoma because it depends on the ability to forecast future reservoir levels so that peak flows can be reduced and spread over a period of several months; that modeling will not be done unless Texoma is selected as a preferred strategy and that detail becomes needed to help implement the project. In this study's Lake Texoma strategy configuration, the transmission system is sized such that the unit cost of delivering Lake Texoma water is equivalent to TRWD's most expensive surface water supply strategy: Toledo Bend Reservoir. This assumption helps put an upper limit on Lake Texoma – it tells us the largest transmission system, the one most likely to deliver TRWD's possible supply at a 10:1 ratio, that could be built for Lake Texoma without being more expensive than Toledo Bend. Facilities for this configuration were therefore sized for a maximum delivery rate of 67 million gallons per day (MGD). The pipeline route is illustrated in Figure 4.22.

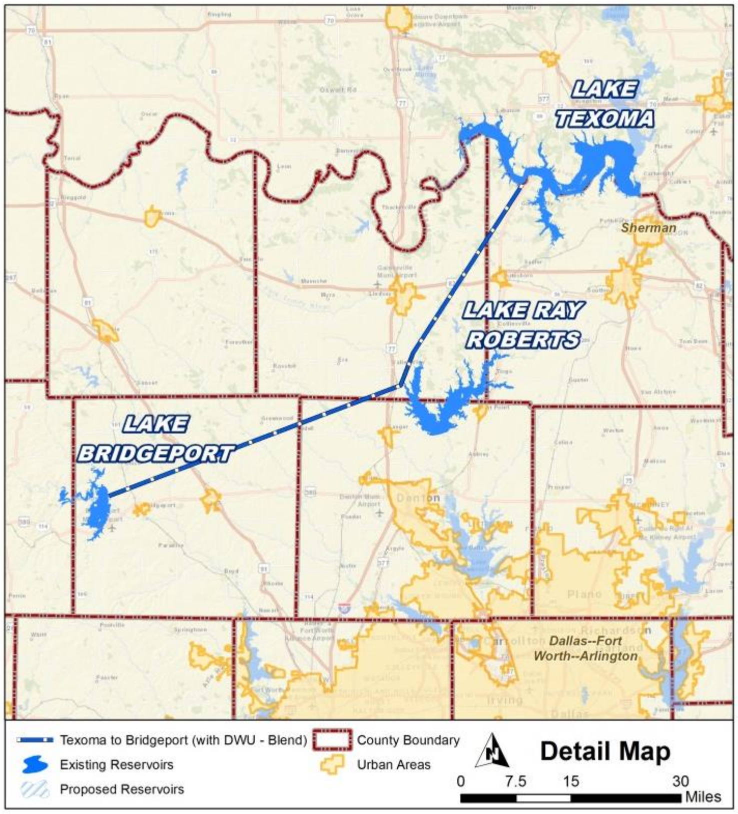


Figure 4.22 – Pipeline Route for Texoma

- Pipeline from Lake Texoma to Lake Bridgeport. The pipeline is aligned in anticipation of future delivery to Lake Ray Roberts, assuming TRWD will partner with the City of Dallas to bring part of Texoma supply to Dallas. However, in this configuration the transmission system is sized only for TRWD supply.
- Intake and 6,000 HP Lake Pump Station at Lake Texoma, one 7,800 HP mgd Booster Pump Station, and a 9 MG storage tank.

Supply

According to the 2011 Oklahoma Comprehensive Water Plan, there is 162,271 acre-feet/year available from Oklahoma's share of Lake Texoma. If that water were secured by TRWD and blended in Lake Bridgeport, a 10:1 (Bridgeport to Texoma) blending ratio is required to meet a total dissolved solids (TDS) standard of 625 mg/L, which is a revision from the current standard of 300 mg/L in Lake Bridgeport. Using 2060 demand assumptions, this ratio would result in an average annual supply of 21,050 acre-feet/year and a maximum annual supply of 72,000 acre-feet/year from Lake Texoma. (This also leaves a substantial amount of Texoma's 162,271 acre-feet/year to share with Dallas).

4.1.12 Toledo Bend Reservoir

Toledo Bend Reservoir is an existing reservoir located in the Sabine River Basin on the border between Texas and Louisiana. It was built in the 1960s by the Sabine River Authority of Texas (SRA) and the Sabine River Authority of Louisiana. Project Map is included in Figure 4.23. The yield of the project is split equally between Texas and Louisiana, and Texas' share of the yield is slightly over 1,000,000 acre-feet per year. The SRA holds a Texas water right to divert 750,000 acre-feet per year from Toledo Bend and is seeking the right to divert an additional 293,300 acre-feet per year.

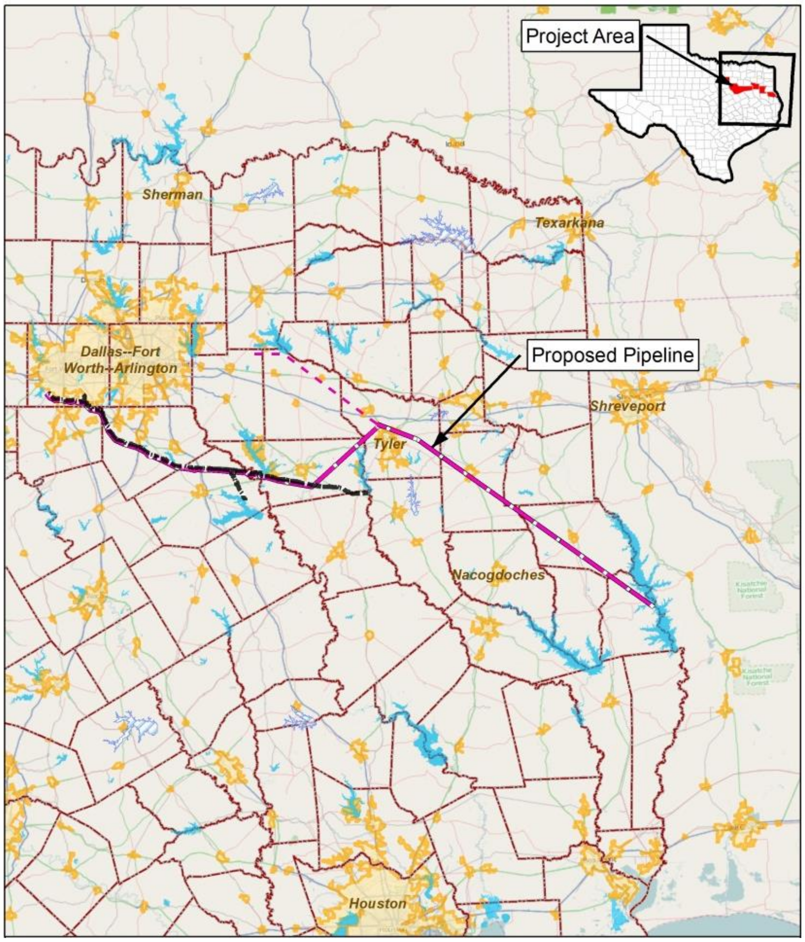


Figure 4.23 – Vicinity Map for Toledo Bend

This configuration assumes that the SRA and Dallas-Fort Worth Metroplex water suppliers, (TRWD, NTMWD, and Dallas) would collaborate on a project to deliver 100,000 acre-feet per year of Toledo Bend water to SRA customers in the upper Sabine River Basin and up to 600,000 acre-feet per year to the Metroplex. Recent agreements between the SRA and other entities in Southeastern Texas have reduced the amount of water available to the Metroplex by approximately 200,000 acre-feet/year. This configuration of the Toledo Bend supply strategy assumes that amount could be secured by including a portion of Louisiana's share of Toledo Bend. The assumed supply available to each entity is listed below in acre-feet per year.

- TRWD – 200,000
- NTMWD – 200,000

- DWU – 200,000
- SRA – 100,000

The cost estimate for this configuration of the Toledo Bend supply strategy assumes that a new pipeline is required the entire distance between Toledo Bend and Benbrook Lake.

Because the Integrated Pipeline will not be flowing at full capacity initially, Toledo Bend supply could be delivered through the Integrated Pipeline (IPL). Once the IPL becomes fully utilized by TRWD and Dallas, delivery of Toledo Bend will require a new pipeline. This new pipeline will be built within the IPL right of way and will be designed to also carry other supply sources from Southeast of DFW. Proposed pipeline route is depicted in Figure 4.24.

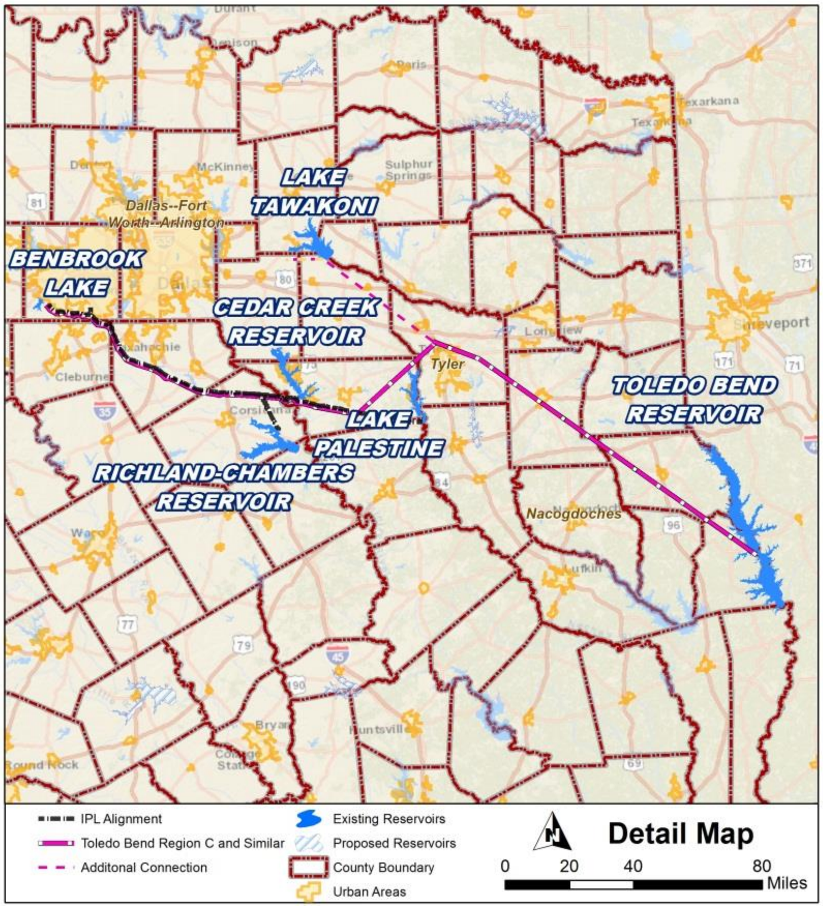


Figure 4.24 – Proposed Pipeline Route for Toledo Bend Reservoir

Facilities Required (Assuming a New Pipeline from Toledo Bend to Lake Benbrook)

- One 75,200 HP Intake Pump Station at Toledo Bend
- Approximately 132 miles of one 120-inch pipe and one 132-inch pipe in parallel (An additional 23 miles of 120-inch pipeline is needed for Lake Tawakoni branch for other partners)
- Approximately 151 miles of two 96-inch pipes (An additional 6.5 miles of 96-inch pipe is needed for Lake Tawakoni branch for other partners)
- Approximately 10 miles of single 102-inch pipe
- Nine booster pump stations ranging in size from 11,300 HP to 77,600 HP (seven of which would be partially owned/operated by TRWD)

- Nine earthen storage reservoirs ranging in size from 45 million gallons to 156 million gallons (seven of which would be partially owned/operated by TRWD)
- Discharge structure at Lake Benbrook

4.1.13 Lake Wright Patman

Wright Patman Lake is an existing reservoir in the Sulphur River Basin, approximately 150 miles from the Dallas-Fort Worth Metroplex. It is owned and operated by the U.S. Army Corps of Engineers (USACE). The City of Texarkana has contracted with the USACE for storage in the lake and holds a water right to use up to 180,000 acre-feet per year. According to the 2011 Region C Water Plan, the top of conservation storage in Wright Patman Lake could potentially be raised from the current top of conservation pool (which ranges from 220.6 feet-msl to 227.5 feet-msl depending on the month) to elevation 228.64 feet msl. Raising the conservation pool elevation to 228.64 and using 5 feet of storage below the bottom of the conservation pool (normally reserved for sediment storage) would increase the reservoir yield to 364,000 acre-feet per year, approximately 180,000 acre-feet per year of additional supply that could be used for TRWD or others in Region C. Some form of consideration to acquire the water right held by Texarkana for a portion of this water would be expected to be included in the final project. A project map is included in Figure 4.25.

Raising the conservation pool above elevation 228.64 feet msl could increase the yield to much more than 364,000 acre-feet per year, but could inundate portions of the White Oak Creek mitigation area, located upstream from Wright Patman Lake. The White Oak Creek Mitigation Area (WOCMA) is approximately 25,000 acres of land owned in fee title by the USACE and managed by the Texas Parks and Wildlife Department (TPWD) under contract to the USACE in fulfillment of the USACE's obligation to mitigate for terrestrial wildlife impacts caused by the construction of Jim Chapman Reservoir. Raising the conservation pool to elevation 228.64 ft msl is also a long-term water supply alternative for the City of Dallas.

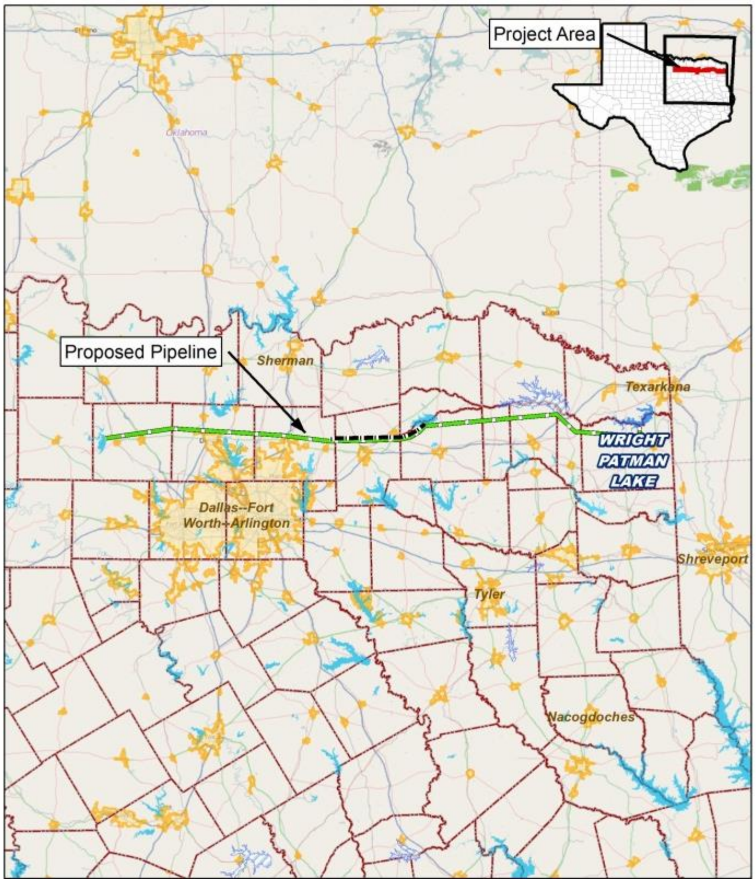


Figure 4.25 – Wright Patman Vicinity Map

Facilities Required

- A 96-inch pipeline from Wright Patman Lake to Lake Bridgeport (approximately 216 miles): assumed route goes from Wright Patman Lake to Jim Chapman Lake then parallel to North Texas Municipal Water District's existing Chapman Pipeline, then continues to a point just north of Lake Lewisville, and then on to Lake Bridgeport.
- One 35,000 HP Intake Pump Station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.
- One 19,600 HP Intake Pump Station at Wright Patman Lake
- Four booster pump stations along the pipeline route: two 18,500 HP, one 17,500 HP, and one 14,700 HP
- Four 40 MG earthen storage reservoirs
- 201 mgd discharge structure at Lake Bridgeport

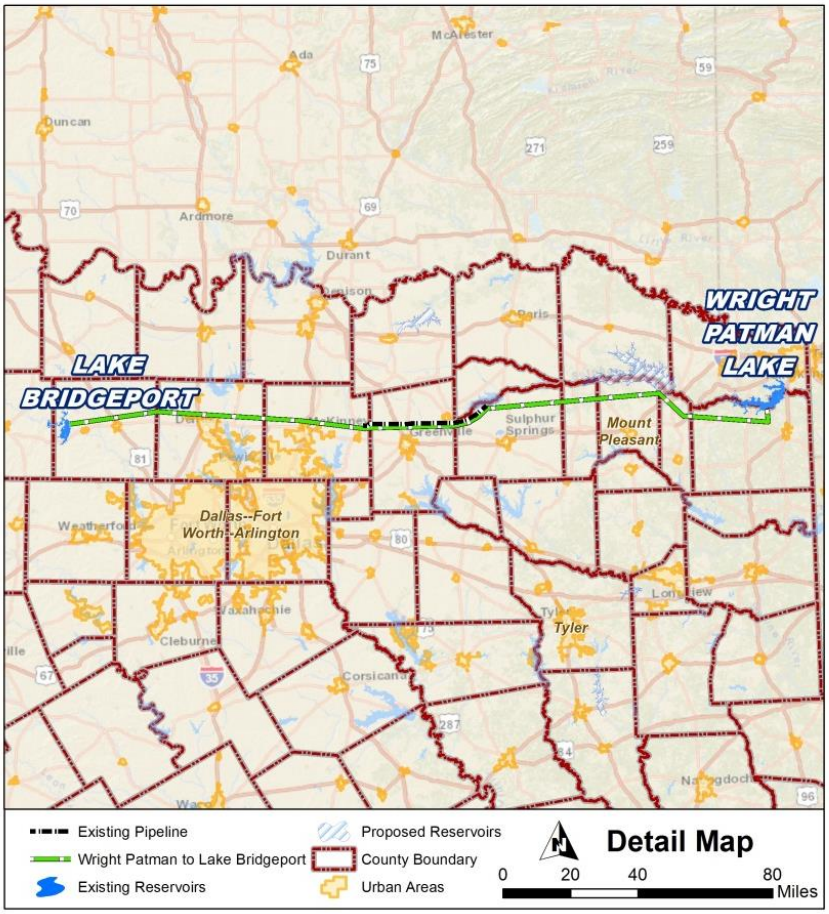


Figure 4.26 – Proposed Pipeline Route for Lake Wright Patman

4.2 Implementation Schedules

Implementation schedules were developed for each strategy in order to estimate the duration from project initiation to operational status. Schedules were based on the anticipated length of time needed for planning tasks (conceptual design/planning, necessary contract negotiations, state permitting, Federal permitting); design-related tasks (embankment design, relocations, route selection and preliminary design for transmission facilities, preparation of bid packages); and construction-related tasks (real estate acquisition, relocations, embankment construction, pipeline and pump station construction, etc.). A common template of tasks was developed and durations for each task were standardized as much as possible. However, not all tasks are applicable to each strategy, and the overall implementation schedules vary based on which tasks are included for a given strategy. In addition, the implementation schedules vary between strategies based on the degree to which certain tasks were allowed to overlap. Factors affecting the duration of the implementation schedules are discussed in more detail below.

A Risk Assessment (see Section 4.3) was performed for each strategy to reflect the team's assessment of the probability that institutional, legal, or environmental factors would adversely affect the schedule. To avoid double-counting the impact of these risks on the implementation schedules, standard durations for tasks were employed wherever possible. For example a standard duration of 4 years was assumed to obtain a Section 404 permit for a strategy involving construction of a new reservoir (this assumption is true for all reservoirs except Marvin Nichols); the relative likelihood that this schedule would actually be met for a given water management strategy was assessed as part of the Risk Assessment. Within the schedule, strategies involving an interbasin transfer were assigned longer durations for water rights permitting than water rights not requiring approval of interbasin transfers. As another example, the standardized construction duration for any given 100-mile length of pipeline was assumed to be 5.5 years; the construction duration is determined based on the estimated length of pipeline required.

Assumptions regarding the start/finish relationships between tasks were also largely standardized. For example, design activities are allowed to begin prior to completion of permitting tasks by slightly varying amounts based on an assessment of the relationship between the two for the specific strategy in question. Under no circumstances was construction allowed to start prior to completion of all permitting and design tasks for that strategy. Some variation in overlap was allowed, however. In general, for strategies involving multiple partners and/or interstate negotiations, planning activities were assumed to be at a higher level of completion prior to initiation of detailed design in comparison to strategies with less complex institutional parameters.

Each implementation schedule therefore represents the specific planning, design, and construction tasks required to implement that specific strategy. The duration of each task and the degree of overlap between tasks was largely considered to be a function of the scale or complexity of that task for that strategy, and the overall implementation duration is a function of all three variables.

Implementation schedules for individual strategies are included along with the strategy fact sheets in Appendix A. The specific assumptions for each strategy are included on the implementation schedules themselves. Below are the general assumptions.

Planning Task Assumptions

1. Three years are built into the schedule to negotiate an agreement for the transfer of water from Oklahoma to TRWD.
2. Texas water right permitting times vary for different strategies.

Design Task Assumptions

1. Whenever possible, the design overlaps with the permitting process.
2. The time required for the design of transmission facilities was based on the length of the pipeline.

Construction Task Assumptions

1. The embankment/spillway construction includes two years for reservoir filling.
2. Some construction activities can start before the real estate acquisition is complete.
3. The time required for construction of the transmission facilities was based on the length of the pipeline.

4.3 Risk Assessment

Each water supply strategy has factors that affect the probability it can be successfully developed. Put another way, 'risks' are issues or conditions that influence uncertainty in project performance or viability. Three types of risk have been defined (and quantified) in this IWSP:

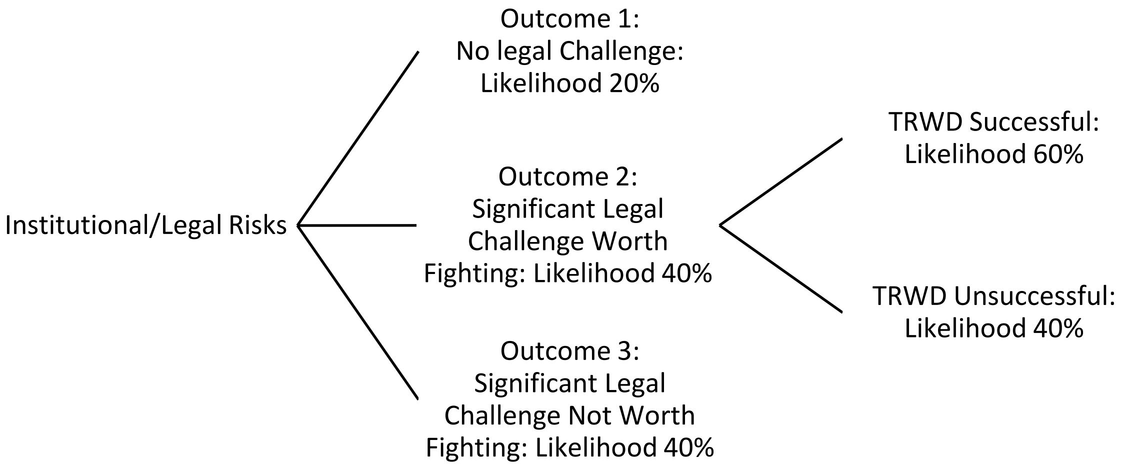
1. *System-wide Risks*: there are many system-wide risks in any water supply system (natural disasters, contamination, etc.), but the following three are considered in this study because they can be quantified and modeled and because they contribute clearly to the choice between final water supply portfolios:
   - Population/Demand Growth – the risk that growth is significantly greater than or less than projections.
   - Climate Variability – the risk that future droughts exceed the severity of the 1950's drought of record or that dry conditions persist for unprecedented durations.
   - Power Cost Variability – the risk that future power costs are higher than current projections.
2. *Strategy-specific Risks*, which impact project viability and schedule:

- Institutional/Legal
- Regulatory/Environmental
- Capital Cost Variability/Water Quality – though water quality could affect project viability on its own in some cases, it is combined with capital cost variability because, in the TRWD system, the primary impact of water quality is to change the overall project cost and therefore its cost comparison to other supplies.

3. *Water Supply Risk:* the probability that demand cannot be met under particular supply and demand conditions. These risks were calculated using the IWSP System Simulation Model that was built in the STELLA platform. Section 4.3 below describes the modeling effort.

Risk was assessed for each water supply strategy in five steps:

1. Define an appropriate range for each **System-wide Risk**. For example, what is the range of demand variability, +50% to -20%? What is an appropriate range of climate variability?
2. Assess the likelihood of each **Strategy-specific Risk** as it relates to project viability, using probable "outcomes". These likelihoods are also known as the 'score'. For example, if we were to consider Institutional/Legal risk, the outcomes and likelihoods/scores may be defined in this way:



3. Assess the possible schedule impact of each Strategy-specific Risk.
4. Calculate the probability of water supply risks under 2010, 2020, 2030, 2040, 2050, and 2060 projected water supply demand conditions in combination with either current supply conditions or (current supplies + one new water management strategy). These calculations define how much each new supply could impact TRWD water supply reliability. (See Section 4.3 below.)

5. Repeat step 4 for each *portfolio* (combination of strategies based on a theme, such as 'low risk') of water management strategies and for each potential implementation plan (see Section 5 of this report for a full explanation).

Table 4.4 defines the outcomes, or range of outcomes, that were analyzed for each *system-wide risk*. Figures 4.27a through 4.27c illustrate the possible outcomes considered for each *strategy-specific risk* for each water supply strategy.

Scores represent the likelihood that a particular outcome will occur, and these were assigned to each possible outcome by TRWD staff and the IWSP consulting team using professional judgment. A total of 100 points was available for each level of possible outcomes and the team divided the 100 points between possible outcomes by assigning the most points to the most probable outcomes. Each water management strategy's risk assessment scores and a brief explanation of those scores are included in its fact sheet (see Appendix A) and a summary of the scoring is shown below in Table 4.5.

The *impact* of each possible outcome was also assessed by assigning a probable number of years that the outcome could delay development of a water management strategy. These impacts are shown in the far left column of Table 4.5.

Table 4.4 – System-Wide Risk Outcomes

System-Wide Risks	Possible Outcomes to Analyze
Population / Demand Growth	2011 Region C based demand projections
	Projection based on extrapolation of recent trends
Climate Variability	No change to historic flows and evaporation
	-15% of historic flows and +15% of evaporation
Power Cost	-25% of projections made during the IPL planning studies[5]
	+25% of projections made during the IPL planning studies

[5] During the Integrated Pipeline planning phase, also known as the Raw Water Transmission System Integration Study, J. Stowe & Co. developed a projection of power costs. This report is included here as Appendix I.

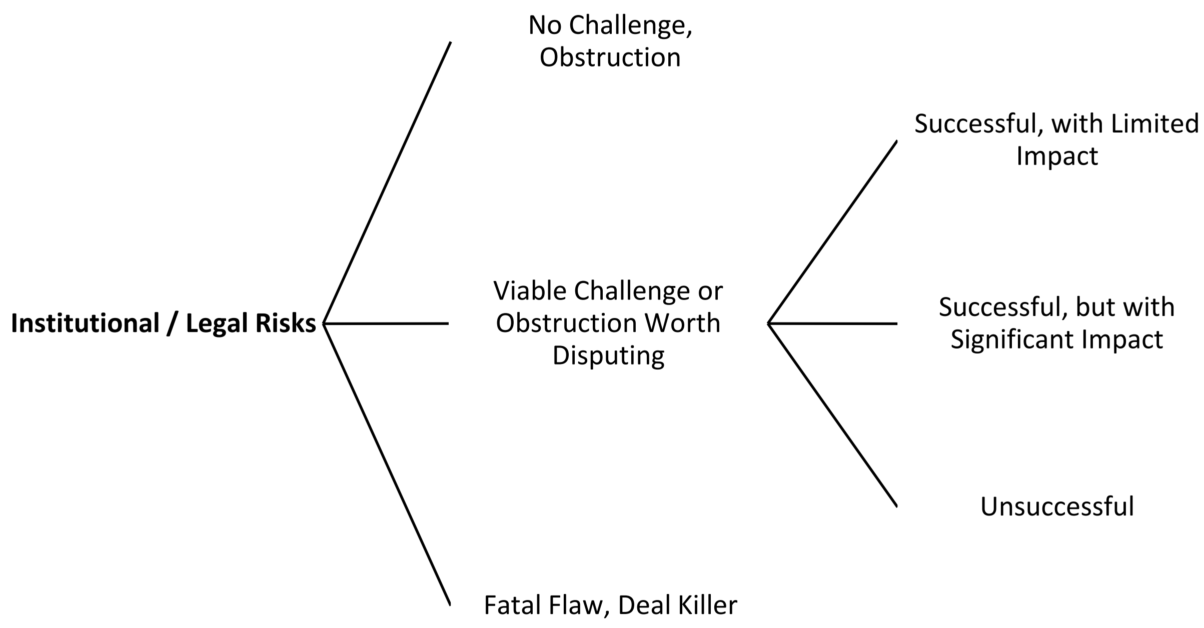


Figure 4.27a – Institutional/Legal Risks, Possible Outcomes

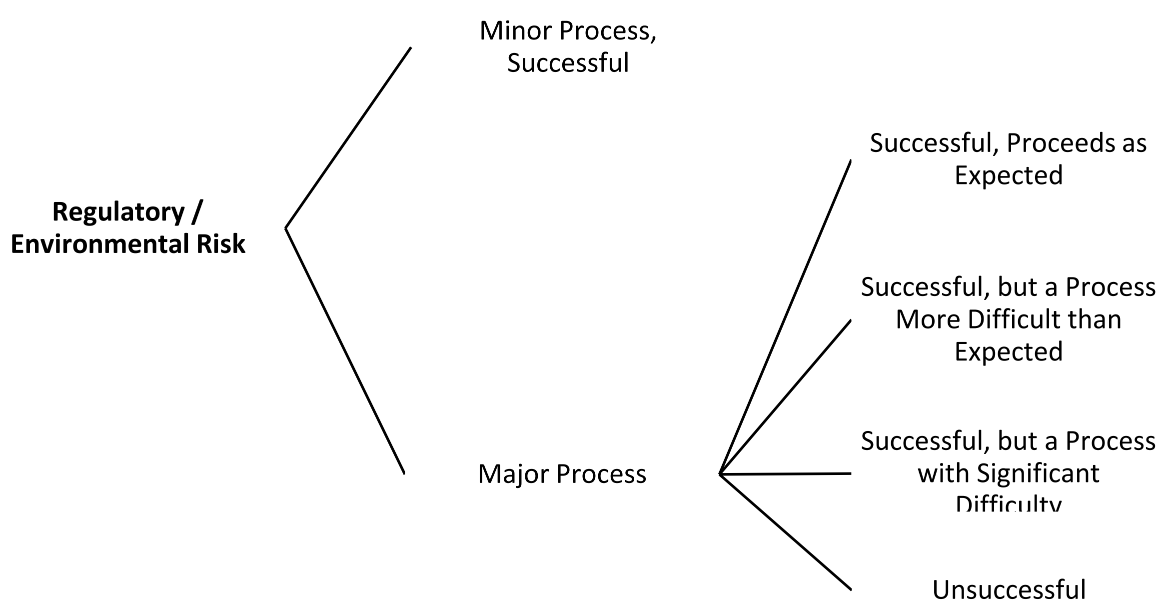


Figure 4.27b – Regulatory/Environmental Risks, Possible Outcomes

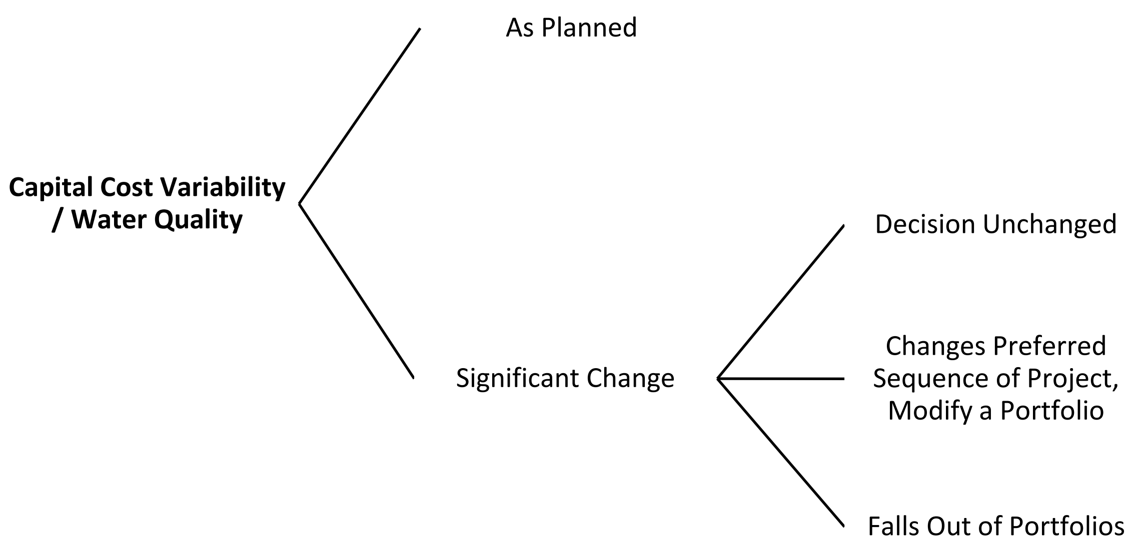


Figure 4.27c – Capital Cost Variability / Water Quality Risks, Possible Outcomes

Table 4.5– Strategy-Specific Risk Assessment Scoring

Schedule Impact (Years)	Risk	Outcome Level 1	Outcome Level 2	Temple	Ringgold	Texoma (blended w/ Bridgeport)	Kiamichi	Marvin Nichols	Wright Patman	EXFLO	CC/RC Wetlands Permits	CC/RC Firm	Tehuacana	Toledo Bend	Columbia
0	Institutional/ Legal	No Challenge, Obstruction		0	20	0	0	5	5	80	80	80	30	10	10
		Viable Challenge or Obstruction Worth Disputing		40	70	70	25	70	75	15	15	15	60	70	50
1-4			Successful, with Limited Impact	5	60	50	5	30	45	80	80	80	60	30	40
6-10			Successful, but with Significant Impact	35	30	40	20	60	50	15	15	15	30	50	40
N/A			Unsuccessful	60	10	10	75	10	5	5	5	5	10	20	20
N/A		Fatal Flaw, Deal Killer		60	10	30	75	25	20	5	5	5	10	20	40
0	Regulatory/ Environmental	Minor Process, Successful		0	0	0	0	0	0	40	40	40	0	0	0
		Major Process		100	100	100	100	100	100	60	60	60	100	100	100
0			Successful, Proceeds as Expected	40	50	10	40	10	30	70	70	70	20	60	20
2-6			Successful, but a Process More Difficult than Expected	40	30	30	40	20	40	20	20	20	40	30	30
8-12			Successful, but a Process with Significant Difficulty	10	15	30	10	60	20	5	5	5	30	5	40
N/A			Unsuccessful	10	5	30	10	10	10	5	5	5	10	5	10
0	Capital Cost Variability/ Water Quality	As Planned		10	60	40	10	70	30	80	80	80	50	20	70
		Significant Change		90	40	60	90	30	70	20	20	20	50	80	30
0-3			Decision Unchanged	80	80	60	40	60	40	90	90	90	60	60	70
5-15			Changes Preferred Sequence of Project, Modify a Portfolio	15	15	25	40	20	40	5	5	5	30	20	20
N/A			Falls Out of Portfolios	5	5	15	20	20	20	5	5	5	10	20	10

Risk Assessment Application

Selecting the appropriate risks and scoring their relative probability are only precursors to applying the risk assessment, which was done in two ways. First, water management strategies were ranked according to their Strategy-specific Risk overall score and this ranking was used to select strategies for the "Low Risk" portfolio, described more fully in Section 5. Second, the overall score was used to calculate a probable impact to the strategy's development schedule (time required for planning, design, and construction), which was used to develop implementation plans and the decision tree, also described in Section 5.

An overall Strategy-specific Risk score was calculated for each strategy. The first step was to normalize the impacts, the probable number of years that the outcome could delay development of a water management strategy, of each probable outcome. The following rules were applied:

Impact (years)	Normalized Risk Score
0	5
1 to 3	4
4 to 6	3
7 to 9	2
10+	1
Fatal Flaw	0

The product of these normalized values and the risk scores (i.e. likelihoods) were used to calculate the summary risk score for each category (Institutional/Legal, Regulatory/Environmental, Capital Cost Variability/Water Quality). Each category was then assigned a weight, which is the relative effect each category has on the probable schedule impact. The product of the categories' summary risk scores and the categories' weights is the *overall risk score* for each water management strategy. This risk score was translated into the probable number of years that each water management strategy could be delayed, and that number of years is based on the full risk assessment. The end result is shown in Table 4.6.

Table 4.6– Final Strategy-Specific Risk Overall Risk Scores and Schedule Impacts

Strategies (ranked highest → lowest risk)	Potential Schedule Impact	Overall Risk Score
EXFLO	2	4.6
CC/RC Wetlands	2	4.6
CC/RC Firm	2	4.6
Lake Ringgold	5	3.5
Lake Tehuacana	7	3.1
Toledo Bend Reservoir	7	3.0
Lake Wright Patman	9	2.7

Table 4.6– Final Strategy-Specific Risk Overall Risk Scores and Schedule Impacts

Strategies (ranked highest → lowest risk)	Potential Schedule Impact	Overall Risk Score
Lake Columbia	9	2.5
Marvin Nichols Reservoir	10	2.3
Lake Texoma (blended)	10	2.2
Temple Reservoir	10	2.2
Kiamichi River	11	1.8

4.4 Modeling Water Supply Strategies

4.4.1 Modeling Goals

In order to evaluate the effectiveness and the cost-effectiveness of water management strategies, simulation of the performance of water management strategies over the 50-year planning period (to 2060) was done using complex computer models. The goals of the computer modeling were the following:

- Evaluate each strategy over a historic range of hydrologic conditions, including the drought of record
- Consider how each new water management strategy could operate in conjunction with existing sources and conveyance infrastructure – that is, identify where existing infrastructure or practices may limit newly available water, and conversely, where newly available water could help reduce overall operating costs by distributing supplies toward this objective before their full capacities are needed.
- Transfer the knowledge gained about system operations and sensitivities during the Integrated Pipeline (IPL) Study to the long-term planning of new supplies (issues such as hydraulic balancing of parallel pipes, West Fork operations, etc.)
- Answer the fundamental questions about the water management strategies as listed in the following section.

Whether or not the new sources directly connect to existing storage and transmission facilities, the opportunity to spread demand among existing and new sources has profound impact on ability to save costs in the future. This could be an important differentiating factor between alternatives, and therefore it was imperative to simulate the strategies within an integrated modeling platform.

One important consideration from the outset of this study was that the modeling goals were NOT to establish optimized operating rules for the new alternatives. Rather, the objective was to examine the suitability of new source alternatives with planning level resolution in a platform that already accounts for the dynamics of a well-defined system and its current operating protocols and lessons learned.

4.4.2 Modeling Questions

Through simulation modeling of the alternative water management strategies and their interactions with TRWD's existing system, the following questions were addressed as part of the Integrated Planning study:

1. How does each strategy and the timing of its connection to TRWD impact water supply reliability over time?
2. Under what future conditions will the supply system be limited by capacity, permits, or actual water availability?
3. Does interconnection with the existing and planned transmission and storage infrastructure limit the accessible yield of the alternatives in any way (or in any time of year)?
4. What are the expected transmission costs for each water management strategy as an integrated element of the supply system?
5. How can total demand be distributed among all available supplies to help avoid unnecessarily high operating costs?

4.4.3 Modeling Methodology

In order to evaluate the strategies in a way that would identify distinguishing characteristics of integration with the existing TRWD system (cost efficiencies, capacity constraints, etc.), the model had to represent the complete existing TRWD supply and transmission systems. This included the East Texas Reservoirs, West Fork System, terminal reservoirs, existing pipelines, and the planned Integrated Pipeline (IPL). As a fully integrated model, it was used as an operational test platform to examine how well different future strategies interact with the system as a whole.

Specifically, it was essential to examine where there might be unforeseen constraints that are not apparent when evaluating options as standalone supplies. Also, the opportunity to spread demand among existing and new sources will have a profound impact on the ability to reduce costs in the future. This could be an important differentiating factor between alternatives, but it can only be estimated if future supplies are evaluated as integral elements of a complete system. For example, if existing lines are being operated at full capacity when a new source and transmission pipeline are brought into service, it may make sense initially to distribute total demand between the existing and new sources so that none of them are operating at full capacity. This could offer operational cost savings over a condition, for example, where existing sources were operated at 100% capacity, and a new source operated at only 5%.

To provide an integrated platform in which new water management strategies could be simulated in the context of existing supplies and infrastructure, the computer model of the TRWD system (developed using the STELLA[6] programming system) to evaluate operations of the IPL was adapted for this study. While this model was equipped with detailed operational capabilities, the new sources were added in with planning-level detail, as described below. The objective of this analysis was not to develop optimized operating rules for new alternatives, but rather, to examine the suitability of new alternatives within the context of a well-defined system and its operating practices.

The IWSP model simulates historical hydrologic conditions from 1941 through 2006 at monthly intervals and can superimpose any projected future demand year (in decadal increments) over this hydrology to estimate the system's expected reliability. The period of record includes the drought of record (generally defined as 1950-1957), as well as other excessively dry periods, such as those that occurred during the 1960s. In this way, the model can establish firm supply, as well as probable supply.

New sources of supply were added to the model as separate submodels, whose outflow was then linked into the existing network of demand nodes and transmission pipelines. Some new strategies were represented simply by the availability of their permitted yield, and no additional hydrology or operations of these sources were necessary. Other sources, whose yield remained indeterminate, were simulated with estimated hydrology and very generalized operating rules in order to help quantify their water availability for TRWD on both firm and probabilistic bases.

The sources were connected into the network of supply lines and TRWD demand nodes through one of three transmission routes:

- Utilization of the Integrated Pipeline (IPL)
- Utilization of a conceptual pipeline parallel to the IPL
- Via the West Fork System

Sources that were connected via the West Fork System are expected to deliver water to Lake Bridgeport, and flow through the system to the water treatment facilities it services. However, to simplify the modeling, the water was routed directly to the four water treatment plants directly, and constraints were applied to existing pipelines when this occurred. The rationale for this was that the modeling was not attempting to optimize supply operations, and therefore water was not being moved from new sources into Bridgeport Reservoir to augment storage, or to pre-empt drought conditions. Rather, it was delivered into the system on an as-needed basis, based on demand in the current month. However, the sequence in which water would move from Bridgeport to the water treatment facilities was represented accurately, such that

[6] STELLA, Systems Thinking for Education and Research, isee Systems, www.iseesystems.com

water from new sources was delivered first to the Eagle Mountain WTP, then Westside WTP, then Holly WTP, and finally Rolling Hills WTP.

Because many of the treatment plants serviced by the West Fork water sources are also serviced by TRWD's existing sources in East Texas (Cedar Creek and Richland Chambers), it was important to compare the expected operating costs of new sources flowing through the West Fork to the costs of water from existing sources in East Texas. Ideally, if a new source is less expensive to deliver to the West Fork system than pumping from existing sources in East Texas, the availability of such a source should include its priority usage over existing East Texas water in order to save operating costs. The model, therefore, divided the new sources that pass through the West Fork system into two categories:

- Sources introduced via the West Fork System that are likely to be less operationally expensive than pumping from existing sources in East Texas
- Sources introduced via the West Fork System that are likely to be more operationally expensive than pumping from existing sources in East Texas

Sources that were deemed less expensive than pumping from existing sources in East Texas by virtue of proximity and elevation change (see Figure 4.2) were prioritized in the model so that they are used first before existing East Texas water is pumped. These included Ringgold, Texoma, and Temple Reservoirs. Likewise, sources deemed to be more expensive than existing sources in East Texas by virtue of greater distance and/or elevation change were prioritized to be delivered after, or concurrently with, existing East Texas water. These included Marvin Nichols, Wright Patman, and the Kiamichi River Basin.

The only significant change to the West Fork logic originally built into the model when it was developed for the IPL studies, then, was to assume bidirectional utilization of the Eagle Mountain Connection. Currently, this pipeline flows from the Benbrook Pump Station to Eagle Mountain Reservoir, but not in reverse. To deliver water from Eagle Mountain to West Side and Holly Water Treatment Plants, the line was assumed to be used in the opposite direction. During such operations, the line was designated for use in only one direction at a time in any given month. While the water from new sources was delivered "virtually" to the various treatment facilities (that is, it was not mathematically routed through pipelines simulated in the model), the Eagle Mountain Connection was disabled in any reach that would have required it to flow in the opposite direction to deliver the new water. Clearly, new infrastructure in the future could eliminate the need for the conversion of this pipeline into a bidirectional pathway, but for this study, it was assumed that new water would use existing infrastructure within the West Fork network.

4.4.4 Modeling Output

The model was used for three different purposes:

- Simulate Baseline Conditions – in which existing sources (which include the IPL and Cedar Creek constructed wetlands) are simulated, but no additional new water sources. This establishes comparative information on supply reliability, timing of new supply needs, and operating energy costs.

- Model Impact of Individual Water Management Strategies – used to quantify expected improvements in reliability by decade, as well as associated operating energy cost.
- Develop Implementation Plans – groups of new sources strategically combined to satisfy future demand as well as an institutional theme, such as low cost, low risk, or regional cooperation (Section 5 discusses these plans in more detail).

The model directly outputs pipe flows, reservoir water levels, and deliveries to water treatment plants. With the aid of post-processing spreadsheets, this information was formatted to indicate total TRWD system reliability by decade, as well as total system operating cost by decade. These graphs were used for all three purposes above, and examples are shown below in Figures 4.28 through 4.31.

Reliability is measured two ways. One measurement is the average volume of demand that could not be satisfied during the simulated period of record (1941-2007). It is presented as a percentage of total demand for each corresponding decade. The other measurement represents the frequency, or number of months, in the period of hydrologic record (1941-2007) in which demand could not be fully satisfied, regardless of the magnitude of the simulated shortfall. It should be noted, per IPL documentation[7], that in 1-2 percent of the simulated timesteps, demand cannot be satisfied in the model even though the water and transmission lines are available. This is because the model was simplified to avoid complex representation of bidirectional flow pathways in the existing system and these simplifications introduce a low level of modeling error that is acceptable for water supply planning purposes..

The operating costs represent expected energy costs for pumping water through the entire system. Calculation techniques are discussed further in this section.

[7] TRWD Integrated Pipeline Project Conceptual Design Operations Study Final Report, CDM Smith, April 2012.

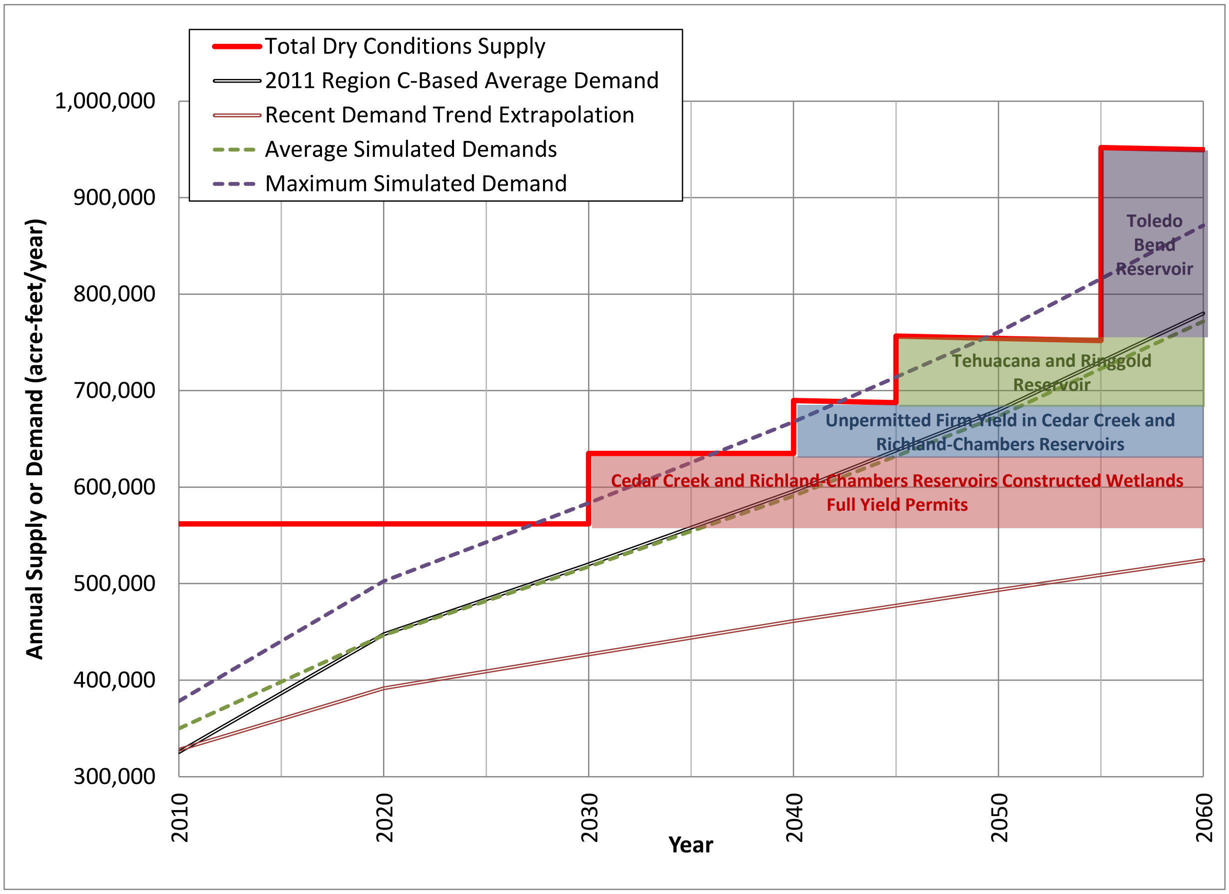


Figure 4.28 – Supply and Demand Graph for an Implementation Plan (Example Only)

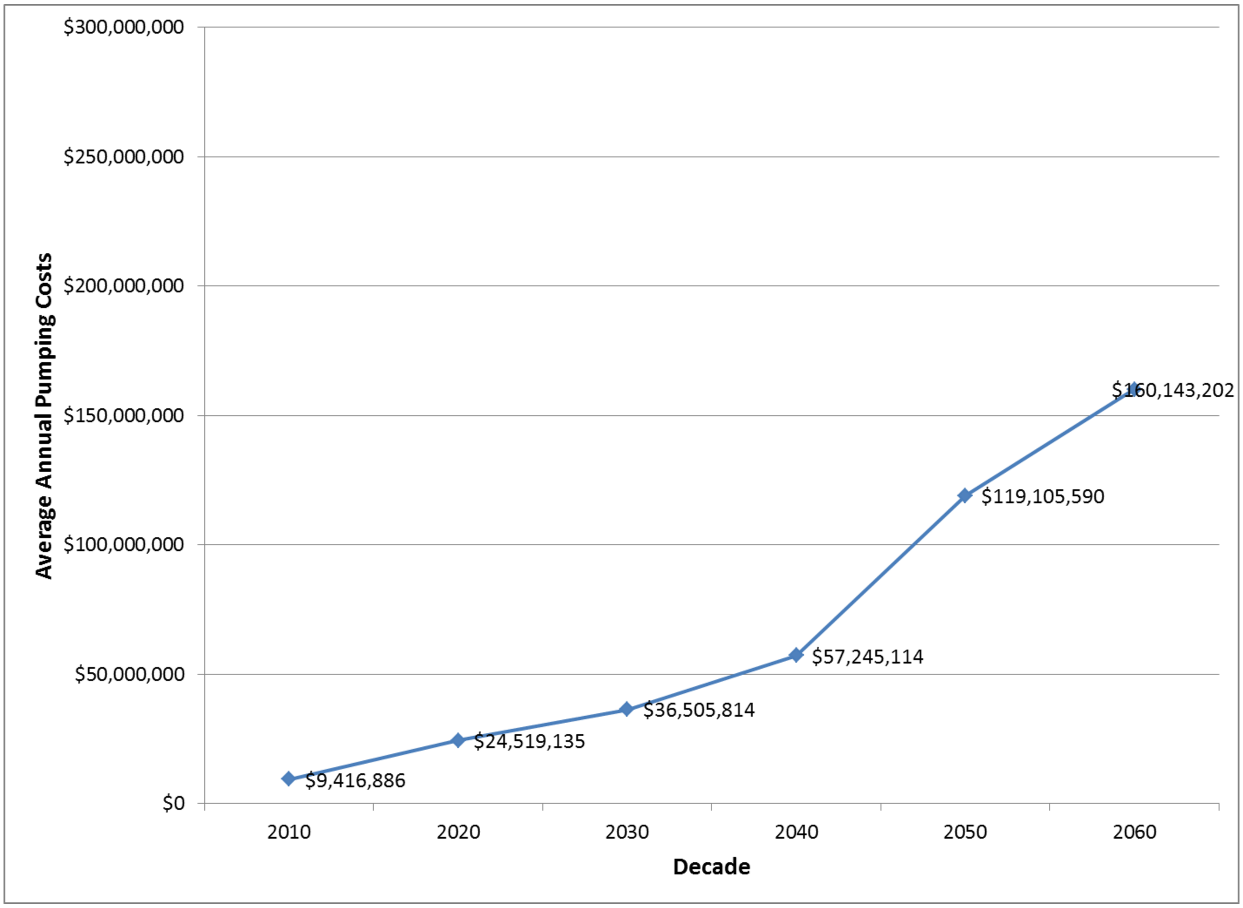
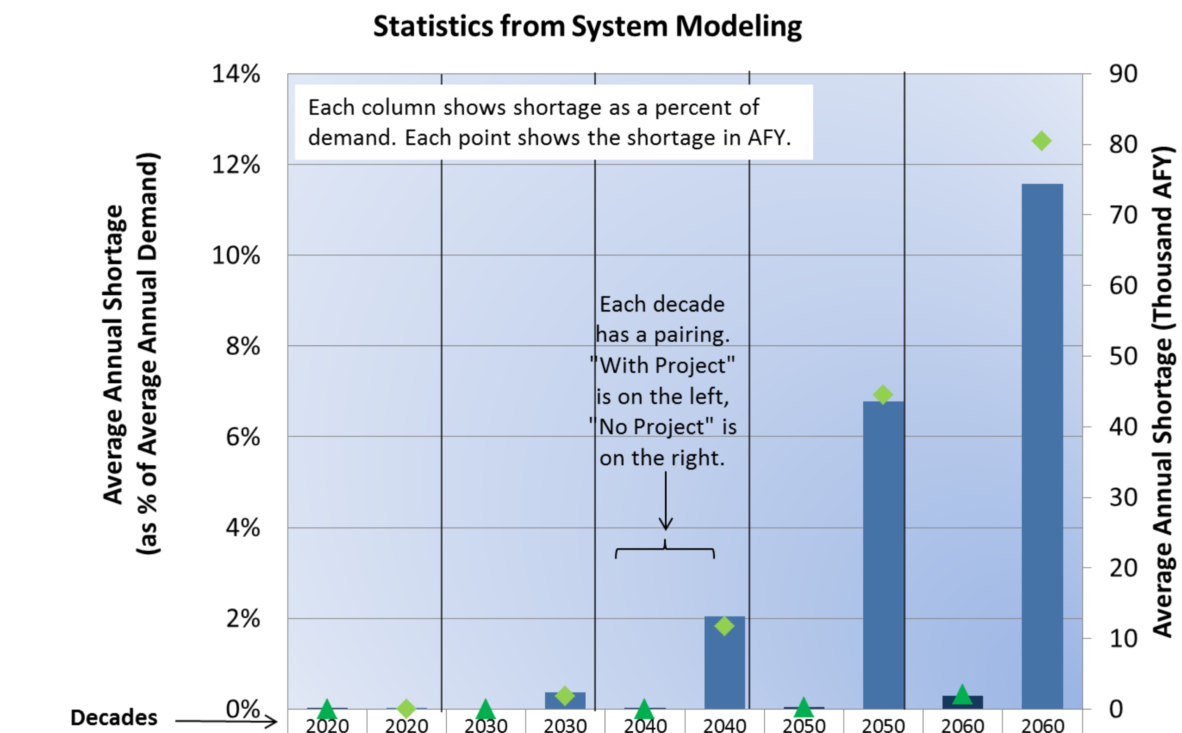
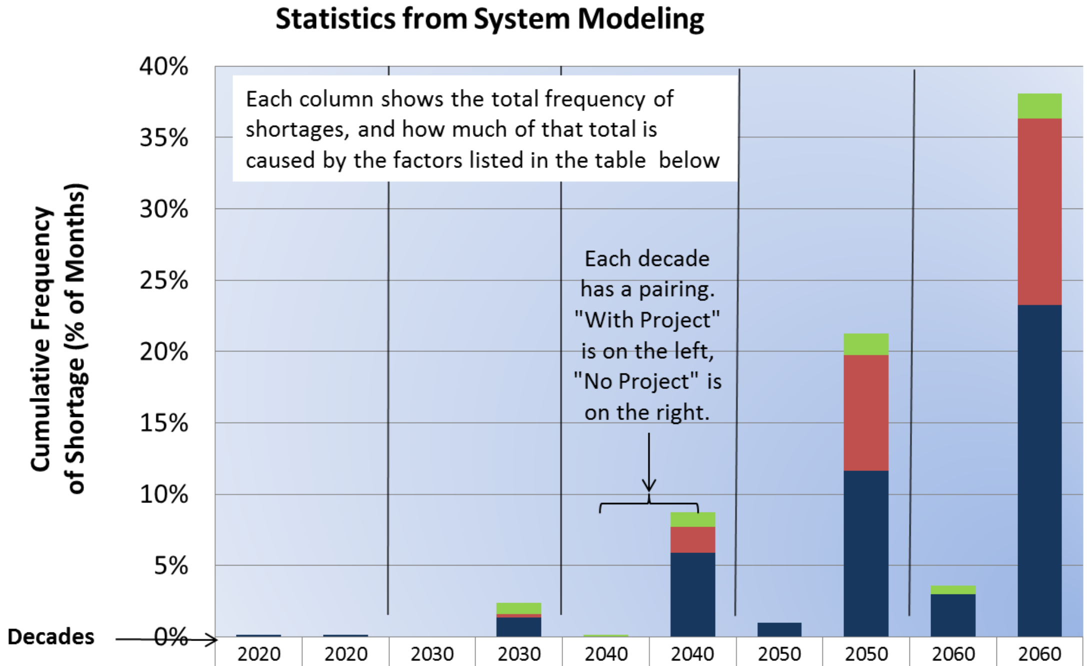


Figure 4.29 – Annual Operating Costs for Example Implementation Plan (Example Only)



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
As % of Demand	0.0%		0.0%		0.0%		0.0%		0.3%	
As % of Demand (No Project)		0.0%		0.4%		2.0%		6.8%		11.6%
Avg. in AFY	1		0		18		231		2,063	
Avg. in AFY (No Project)		1		1,850		11,686		44,460		80,441

Figure 4.30 – Average Annual Shortage With and Without New Water Management Strategies in Example Implementation Plan (Example Only)

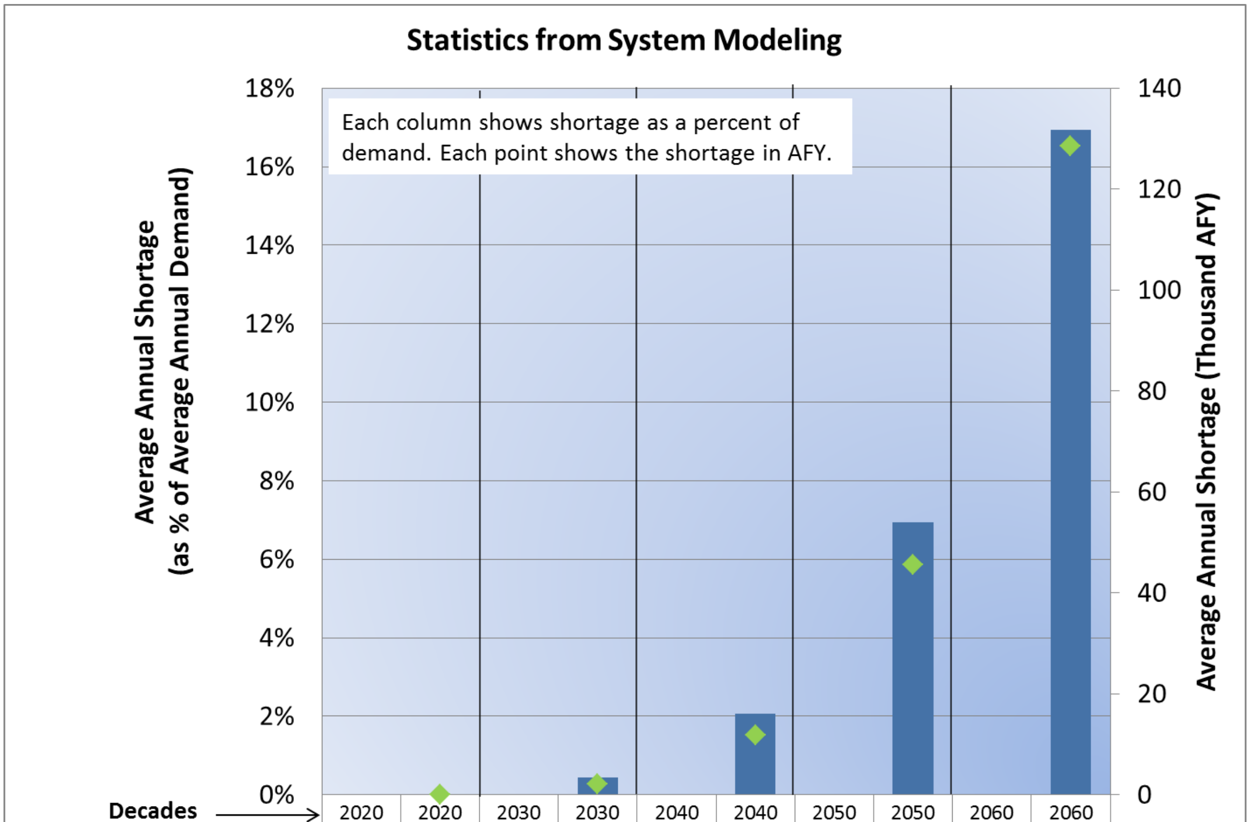


	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.8%		1.0%		1.5%		1.7%
Permitted Amount (No Project)		0.0%		0.2%		1.8%		8.2%		13.1%
Pipeline Capacity (No Project)		0.1%		1.4%		5.9%		11.6%		23.3%
Water Levels	0.0%		0.0%		0.1%		0.0%		0.6%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.0%	
Pipeline Capacity	0.1%		0.0%		0.0%		1.0%		3.0%	

Figure 4.31 – Frequency of Shortage With and Without New Water Management Strategies in Example Implementation Plan (Example Only)

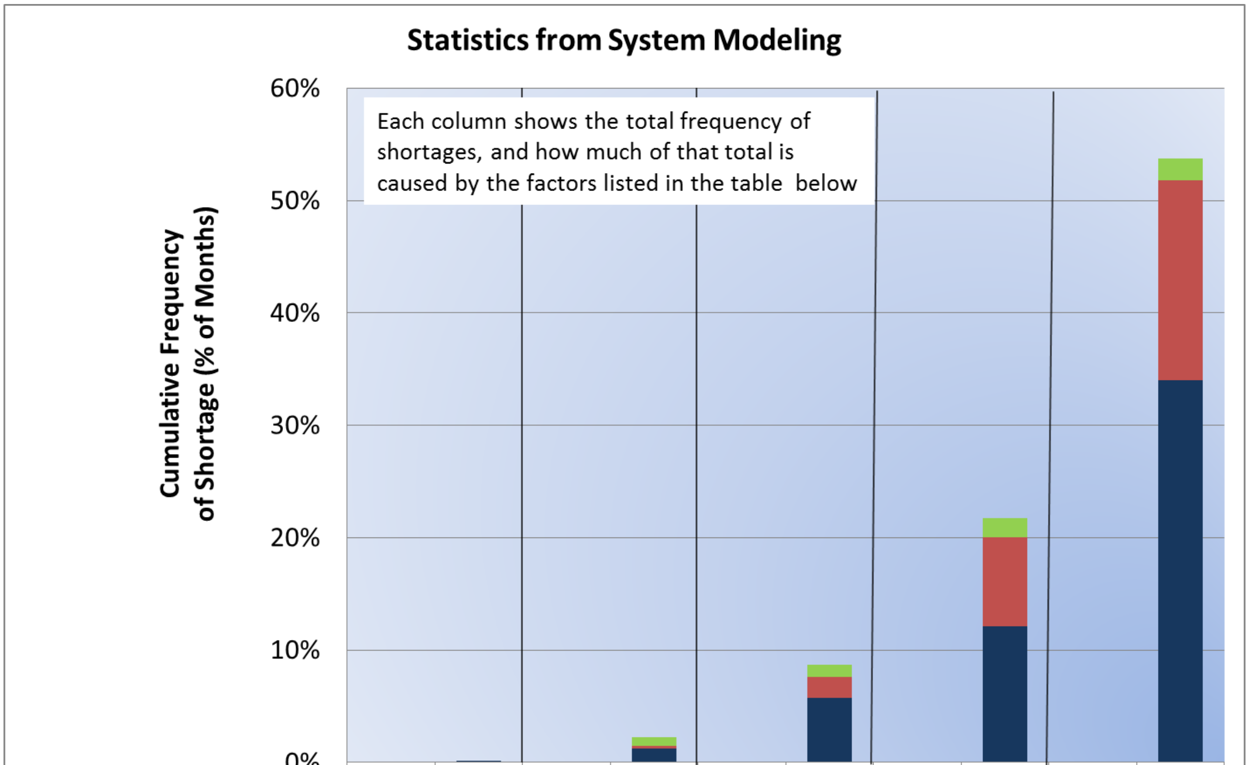
4.4.5 Baseline Condition

Before it was employed to model the impact of new water management strategies, the model was used to determine the “baseline condition”, the water supply reliability metrics based on the TRWD supply system in its current condition. The following figures identify the frequency and magnitude of shortages without new water management strategies in place. Figures 4.32 and 4.33 define the baseline condition using the 2011 Region C Based Demand Projection. Figures 4.34 and 4.35 define the baseline condition using the Recent Trend Extrapolation Demand Projection. And Figures 4.36 and 4.37 define the baseline condition using the 2011 Region C Based Demand Projection *and* the assumption that system inflows are reduced by 15% while evaporation increases by 15%. Each of these conditions represents a particular scenario, which are described in Section 5.



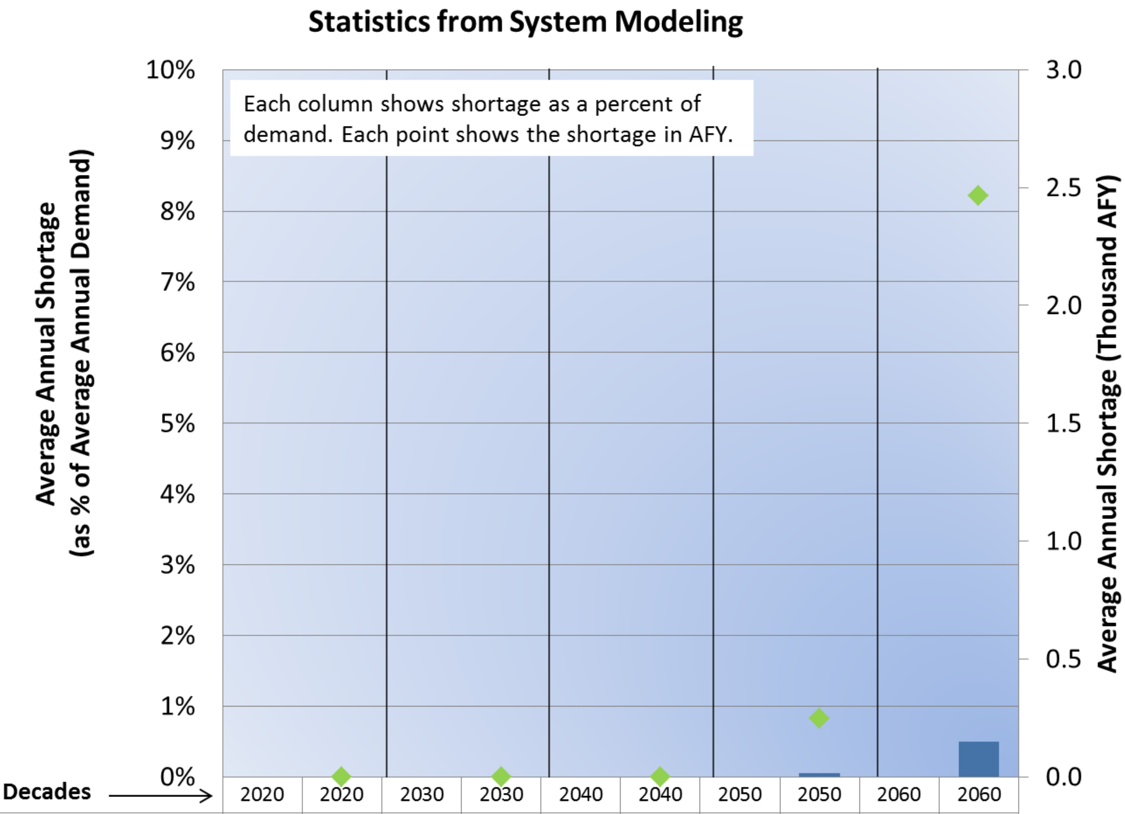
Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
As % of Demand (No Project)		0.0%		0.4%		2.1%		6.9%		16.9%
Avg. in AFY (No Project)		1		2,159		11,827		45,530		128,570

Figure 4.32 – Average Annual Shortage for Baseline Condition using 2011 Region C Based Demand Projection



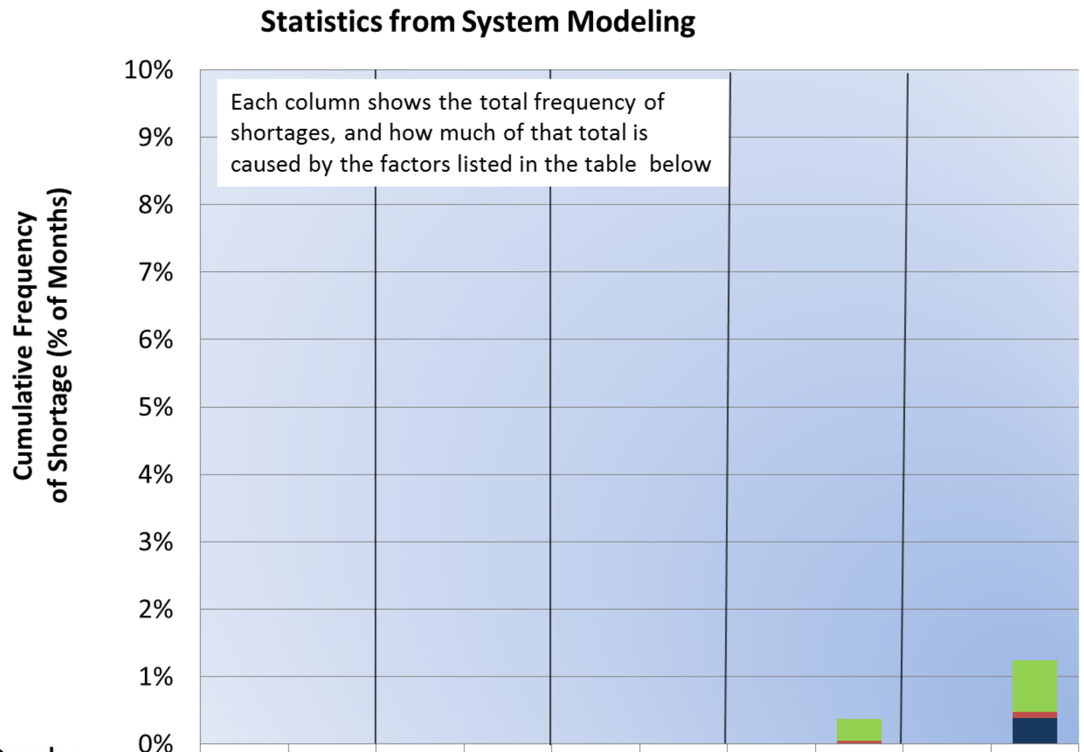
Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.8%		1.1%		1.7%		2.0%
Permitted Amount (No Project)		0.0%		0.2%		1.8%		8.0%		17.8%
Pipeline Capacity (No Project)		0.1%		1.2%		5.8%		12.1%		34.0%

Figure 4.33 –Frequency of Shortage for Baseline Condition using 2011 Region C Based Demand Projection



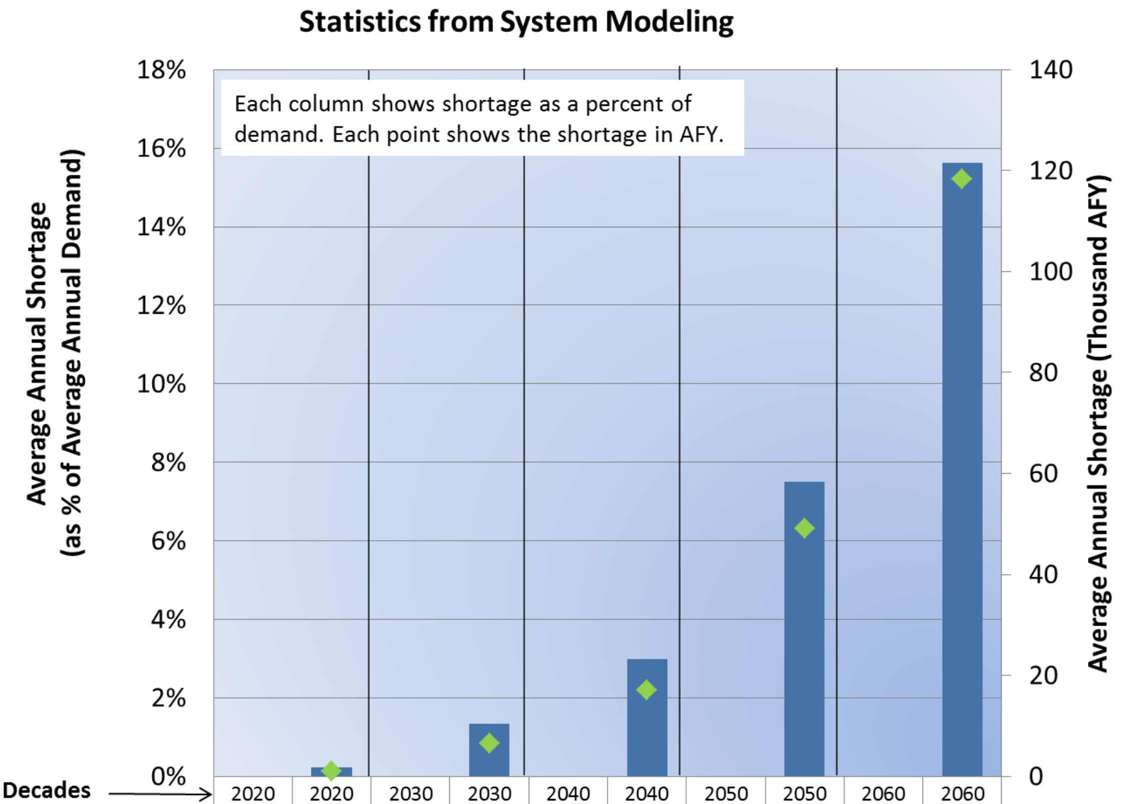
Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
As % of Demand (No Project)		0.0%		0.0%		0.0%		0.1%		0.5%
Avg. in AFY (No Project)		0		0		0		247		2,465

Figure 4.34 – Average Annual Shortage for Baseline Condition using Recent Trend Extrapolation Demand Projection



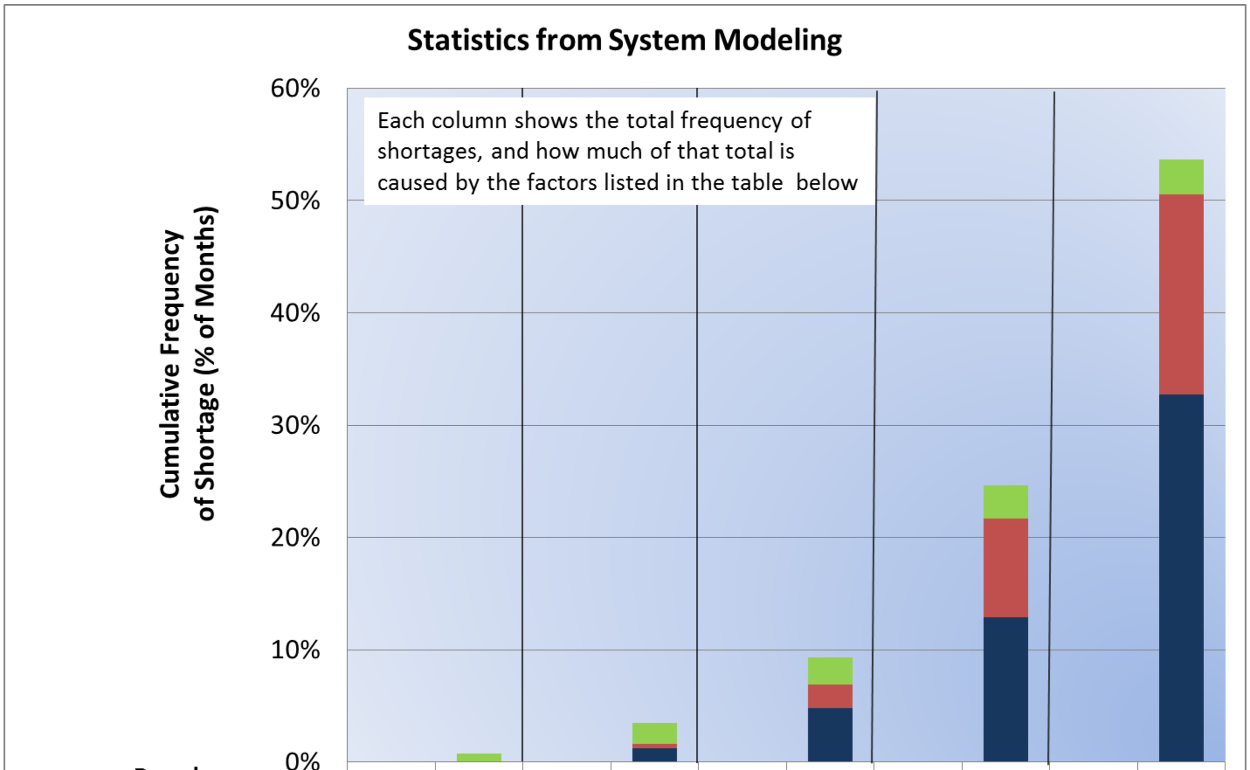
Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.3%		0.8%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.1%		0.1%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.4%

Figure 4.35 –Frequency of Shortage for Baseline Condition using Recent Trend Extrapolation Demand Projection



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
As % of Demand (No Project)		0.2%		1.3%		3.0%		7.5%		15.6%
Avg. in AFY (No Project)		977		6,587		17,009		49,102		118,388

Figure 4.36 – Average Annual Shortage for Baseline Condition using 2011 Region C Based Demand Projection with Reduced Inflows and Increased Evaporation



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.7%		1.8%		2.4%		2.9%		3.1%
Permitted Amount (No Project)		0.0%		0.4%		2.1%		8.8%		17.8%
Pipeline Capacity (No Project)		0.1%		1.2%		4.8%		12.9%		32.7%

Figure 4.37 –Frequency of Shortage for Baseline Condition using 2011 Region C Based Demand Projection with Reduced Inflows and Increased Evaporation

4.5 Cost Analyses

This section summarizes how capital, annual, unit, and operating costs were estimated. In general, opinions of probable capital costs were developed using the methodology, level of detail, and parameters outlined in the Texas Water Development Board's (TWDB) Regional Water Planning Guidelines[8] so that the costs developed in this study can be compared to the cost of strategies listed in the *2011 Region C Water Plan* or other regions' water plans. However, it is important to note that the configurations (yield, transmission system) of the IWSP water management strategies differ from the configuration of these same water supply sources as used in the regional water plans, so the cost estimates *will not be the same*. Also note that the *2011 Region C Water Plan* estimates were reported in September 2008 dollars while the IWSP estimates are reported in March 2012 dollars.

[8] Texas Water Development Board, August 2012. Updated General Guidelines for Development of 2016 Regional Water Plans.

Annual costs were also estimated using these same Regional Water Planning Guidelines, though a second, more detailed method was also employed. Both methods are described below. And unit costs, defined as the annual cost divided by the yield, were calculated both during the period of debt repayment for money borrowed to develop the water management strategy, and after the debt has been retired. Unit costs are calculated by dividing the annual costs that were estimated using Regional Water Planning Guidelines by TRWD's share of each strategy's yield, as defined in Section 4.1, and are reported in dollars per 1,000 gallons and dollars per acre-foot of water supply.

A spreadsheet "costing model" was developed using the Regional Water Planning Guidelines and contains capital costs, annual costs, and hydraulic calculations for each water management strategy. A summary of the methodologies and assumptions used in the costing model is included in Appendix D and the model itself is included in digital form with this report. This section provides an abbreviated summary of the methodologies and assumptions.

4.5.1 Capital Costing Methodologies and Assumptions

Unit construction costs (such as price per foot of pipe) that were developed for the TWDB Unified Costing Tool (developed in 2012 for use in regional water planning) were used for the IWSP cost estimates unless more detailed costs were available. In regional water planning and in this study, large dams and other facilities that have been evaluated in greater detail in other studies were evaluated at a greater level of detail than is used in the Unified Costing Tool. Table 4.7 includes a list of strategies for which more detailed costs were available, and for which TWDB unit construction costs were not used.

Table 4.7 – Strategies Using Unit Construction Costs Different from TWDB Unified Costing Tool

Strategy	Facility	Source of Information
Kiamichi River	Intake at OCSF, Channel Dam, ROR Intake and Pump Station	*Evaluation of Water Supply Alternatives for the Kiamichi River, Cache Creek, and Beaver Creek*, Dec. 2010
Marvin Nichols	Dam and Reservoir	TWDB Report 370, Reservoir Site Protection Study, 2005
Wright Patman	Raw Water Improvements (e.g. storage purchase, relocation costs, NEPA evaluation, etc.)	USACE
Columbia	Dam and Reservoir	2011 Region I Water Plan
Tehuacana	Dam and Reservoir	2011 Region C Water Plan
Temple	Dam and Reservoir	Technical Memorandum: *Southwest Oklahoma - Preliminary Cost Estimate for Temple Reservoir and Four Water Supply Options*, Feb 2012
Ringgold	Dam and Reservoir	TWDB Report 370, Reservoir Site Protection Study, 2005

To size pump stations and associated facilities, the following assumptions were made (some exceptions to these assumptions are discussed in Appendix D):

1. Peaking factor of 1.5 for strategies with multiple partners sharing the transmission system; peaking factor of 1.25 when the transmission system only serves TRWD. As a comparison, the *2011 Region C Water Plan* used the following peaking factors: 1.2 to 1.5 times the average demand was used for strategies with terminal storage; 2 times the average demand was used for strategies pumped directly to a water treatment plant.

2. Pump station "wire-to-water" efficiency of 0.72.

3. Storage at each booster pump station in an earthen reservoir or open ground storage tank with a capacity of 0.25 times the average daily flow.

4. The pipelines were sized using a Hazen Williams C factor of 120 for a headloss not to exceed 0.8 feet per thousand feet of pipe length.

A 35,000 horsepower intake pump station at Eagle Mountain Lake for pumping southward through the Eagle Mountain Connection pipeline was included for all strategies delivering into the TRWD system at Lake Bridgeport. The pump station was sized based on the maximum capacity of the existing Eagle Mountain Connection pipeline operating in "reverse flow" from north to south.

Some other general assumptions used in the IWSP study are listed below:

- In this study, all raw water purchase prices were set at an assumed value of $0.10 per thousand gallons, consistent with what is used in Region C water planning. The actual purchase price is unknown at this time and will depend on negotiations with the water supply owner.

- All unit construction costs were indexed to March 2012 dollars and all capital costs are reported in March 2012 dollars.

- Debt service for all transmission and reservoir facilities is annualized over 30 years and calculated using a 6% interest rate.

- The total capital costs include costs for pipeline right-of-way, engineering and contingencies, and permitting. Pipeline lengths were assumed to be the straight-line distance increased by 10 percent to account for slope distances and routing around obstacles.

- Engineering and contingencies are assumed to be 35% of pump station and reservoir construction costs and 30% of pipeline construction costs. Permitting and mitigation for transmission facilities are assumed to be one percent of the total construction cost. However, a 20% allowance for construction contingencies was included for permitting.

- For reservoirs, mitigation and permitting costs are assumed equal to twice the land purchase cost, unless site specific data was available.

4.5.2 Capital Cost Results

The capital cost and yield for each TRWD water management strategy is listed in Table 4.8, along with a comparison to what was used in previous studies, such as the *2011 Region C Water Plan* (indexed to March 2012 dollars so that they can be compared to IWSP costs). As stated above, the IWSP estimates are different than previous studies because their configurations (yield, transmission system) are different.

Supply from the *Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs*, *Cedar Creek and Richland Chambers Reservoirs Constructed Wetlands Full Yield Permits*, and *Lake Tehuacana* can be delivered through the IPL until it reaches maximum capacity. A new pipeline will be needed at that time, but it is not known with complete certainty at this point if one pipeline will convey the water from all three strategies jointly, or if some other combination of strategies will be conveyed jointly. Therefore, costs were computed for all combinations of the three strategies. A summary of all combinations analyzed for strategies delivered through the IPL or through a new pipeline parallel to the IPL is shown in Table 4.9.

Table 4.8 – Comparison of Supply and Capital Costs in IWSP and Previous Studies

Strategy	TRWD Share of Supply (acre-feet/year)		Capital Cost ($)	
	Previous Studies	IWSP	Previous Studies	IWSP
Conservation[1]	---	---	---	---
Unpermitted Firm Yield in Cedar Creek and Richland-Chambers	n/a	64,032 (in 2020)	n/a	Refer to Table 4.9
Cedar Creek and Richland-Chambers Wetlands Full Yield Permits	n/a	73,024	n/a	Refer to Table 4.9
Lake Columbia[2]	n/a	40,188	n/a	250,165,000
EXFLO	0 firm supply	0 firm supply	0	0
Kiamichi River	155,000	155,000	1,551,778,000	1,810,696,000
Marvin Nichols	163,676	142,850	1,586,158,000	1,695,867,000
Lake Ringgold	28,600	28,600	340,649,000	397,735,000
Lake Tehuacana	56,800	41,900	808,348,000	Refer to Table 4.9
Temple Reservoir	125,000	125,000	853,920,000	972,530,000
Lake Texoma[2]	n/a	21,050[3]	n/a	313,065,000
Toledo Bend Reservoir	200,000	200,000	2,014,539,000	2,751,751,000
Lake Wright Patman	180,000	180,000	1,834,881,000	2,394,849,000

[1] See *Tarrant Regional Water District Strategic Water Conservation Plan*, Alan Plummer Associates, Inc., January 2013.
[2] Not listed in 2011 Region C Water Plan for TRWD
[3] Average 20,200 Interruptible Yield in 2060 (at 10:1 Blending Ratio)

Table 4.9 – Cost Summary for Strategies Delivered Through IPL or New Pipeline Parallel to IPL

Supply Option	TRWD Share of Supply (AFY)	Capital Cost		Annual Cost		With Debt Service (DS) Unit Cost (per 1,000 gal)		Without Debt Service Unit Cost (per 1,000 gal)	
		Total	TRWD Share	TRWD	TRWD w/out DS	Total	TRWD Share	Total	TRWD Share
Unpermitted RC & CC Firm yield (FY) through new pipeline	64,032	$415,460,000	$415,460,000	$40,329,000	$10,146,000	$1.93	$1.93	$0.49	$0.49
Unpermitted RC & CC wetlands through new pipeline	73,024	$465,373,000	$465,373,000	$44,840,000	$11,031,000	$1.88	$1.88	$0.46	$0.46
Tehuacana through new pipeline	41,900	$868,331,000	$868,331,000	$71,308,000	$8,225,000	$5.22	$5.22	$0.60	$0.60
Unpermitted RC & CC FY + Tehuacana though new pipeline	105,932	$1,152,482,000	$1,152,482,000	$101,039,000	$17,312,000	$2.93	$2.93	$0.50	$0.50
Unpermitted RC & CC wetlands + Tehuacana though new pipeline	114,924	$1,217,707,000	$1,217,707,000	$106,410,000	$17,945,000	$2.84	$2.84	$0.48	$0.48
Unpermitted RC & CC wetlands + FY though new pipeline	137,056	$725,528,000	$725,528,000	$72,470,000	$19,761,000	$1.62	$1.62	$0.44	$0.44
Unpermitted RC & CC wetlands + FY + Tehuacana though new pipeline	178,956	$1,440,491,000	$1,440,491,000	$131,799,000	$27,149,000	$2.26	$2.26	$0.47	$0.47
Unpermitted RC & CC wetlands + FY though IPL	137,056	$0	$0	$28,832,000	$28,832,000	$0.65	$0.65	$0.65	$0.65
Unpermitted RC & CC FY through IPL	64,032	$0	$0	$8,841,000	$8,841,000	$0.42	$0.42	$0.42	$0.42
Unpermitted RC & CC wetlands through IPL	73,024	$0	$0	$10,700,000	$10,700,000	$0.45	$0.45	$0.45	$0.45
Tehuacana through IPL	41,900	$580,790,000	$580,790,000	$48,781,000	$6,587,000	$3.57	$3.57	$0.48	$0.48

4.5.3 Operating Cost Calculations

Operating (i.e. pumping, electricity) costs were computed in the IWSP study using two methods, each of which is described in this section:

1. The Region C Method: the method employed by the Texas Water Development Board's guidelines for regional water planning, where electricity costs are calculated assuming an annual delivery of the full annual yield of a water management strategy.

2. Using Simulated Pumping: where operating costs are calculated using a simulation of probable deliveries from various supplies rather than the assumption of delivery of the full yield in every year.

The "Region C Method" was used so that the unit cost of each water management strategy could be compared before water supply portfolios were built. This information was necessary to construct the "Low Cost Portfolio", described in Section 5.

The "Simulated Pumping" method was used to produce a more accurate prediction of annual pumping costs, which are used as input to the rate analysis described in Section 6. These pumping costs can also be used for additional cost analyses, such as present worth costing, at the discretion of TRWD.

Operating Cost Calculations Using the Region C Method

Per the regional planning guidelines, it was assumed that TRWD's full yield of any new water supply is delivered to TRWD every year, regardless of demand on that supply and regardless of how the existing supply system operates. The cost to pump that amount of water to the designated TRWD delivery point was calculated using a constant $0.09 per kilowatt-hour for electricity. These estimates only represent the annual operating cost for the individual water management strategy and do not include operating costs for the existing TRWD transmission system.

Table 4.10 shows energy costs as calculated using the Region C method, which assumes that TRWD's full share of any given supply is delivered to TRWD every year, regardless of demand.

Table 4.10 – Annual Pumping Costs using Region C Methodology

Water Supply Strategy	Annual Pumping Cost, New Supply Only	TRWD Share of Supply (AFY)
Conservation	0	---
CC/RC Unpermitted Firm Yield (through IPL)	$8,841,000	64,032
CC/RC Wetlands + CC/RC Firm Yield (through IPL)	$28,832,000	137,056
Lake Columbia	$9,456,000	40,188

Water Supply Strategy	Annual Pumping Cost, New Supply Only	TRWD Share of Supply (AFY)
EXFLO	0	0 firm supply
Kiamichi River	$23,762,000	155,000
Marvin Nichols Reservoir	$23,248,000	142,850
Lake Ringgold	$1,548,000	28,600
Tehuacana through IPL	$5,593,000	41,900
Temple	$7,671,000	125,000
Texoma	$1,430,000	21,050
Toledo Bend	$38,769,000	200,000
Wright Patman	$37,060,000	180,000

IWSP Operating Cost Calculations Using Simulated Pumping

Operating costs were also calculated using an alternative method to the Region C method described above. This alternative method was used to estimate annual operating costs based on simulation of probable deliveries from various supplies rather than the assumption of delivery of the full yield in every year. Output from the IWSP System Simulation Model was used as input to a spreadsheet model that calculates the average annual operating costs based on the associated pipeline systems and projected unit energy costs. The following procedure was used to calculate the average annual operating costs:

- The IWSP System Simulation Model was used to simulate deliveries anticipated from different supplies on a monthly basis under selected conditions.
- The simulated flows were transferred to an operations cost spreadsheet model.
- Post-processing of the flows was conducted as needed depending on the supply.
- The cost of energy was calculated for each water supply (or portion of a pipeline as needed) at each monthly timestep for the simulation period.
- The cost of all the supplies were added up to create a predicted timeseries of monthly operating costs.
- The monthly operating costs were averaged and multiplied by 12 to arrive at an average annual operations cost.

The IWSP System Simulation Model was used to simulate deliveries for individual water management strategies and for implementation plans under different future scenarios (see Section 5). The resulting annual operating costs are presented in Section 5 and organized according to possible portfolios of water management strategies.

Through direct input or post-processing of the IWSP System Simulation Model simulated deliveries, the operations cost spreadsheet model accounts for the following:

- Pumping through the existing Cedar Creek and Richland-Chambers pipelines
- Pumping through new transmission facilities, as planned for each water management strategy
- Distribution of flow between the Integrated Pipeline (IPL) and a new parallel pipeline for supplies from Cedar Creek, Richland-Chambers, and Tehuacana (discussed more below)
- Conversion of simulated deliveries to exhaust existing Cedar Creek and Richland-Chambers supply before pumping supplies that are more operationally expensive than Cedar Creek and Richland-Chambers. Those more expensive sources include Marvin Nichols, Wright Patman, and the Kiamichi River (discussed more below)

Pumping costs associated with use of the IPL and a new pipeline parallel to the IPL were estimated based on the assumption that if both pipelines were available for use by TRWD, flow would be divided between them to minimize pumping costs. The flows were divided proportionally based on capacity. The capacity of a new pipeline parallel to the IPL was dependent on the strategies incorporated, e.g. if Tehuacana was not included in the implementation plan, the pipeline was only sized for the new supplies from Cedar Creek and Richland-Chambers.

As discussed in Section 4.4.3, there are sources that are more operationally expensive compared to the existing East Texas supplies (Cedar Creek and Richland-Chambers). Even though they are more expensive, the IWSP System Simulation Model is coded to maximize reliability rather than minimize operating costs; therefore, there are times when pumping will be simulated from these new supplies before the lower-cost supplies are exhausted. Post-processing of the model output was conducted to adjust for this in order to minimize the operating costs.

The operating costs are based on the amount of energy required to pump the simulated monthly deliveries. The amount of energy is based on the rate that energy is used, or the power. The power required for pumping is calculated based on the following equation:

$$P = \frac{QH}{3960\mu}$$

Where P is power in Horsepower, Q is flow in gpm (simulated deliveries), H is the total dynamic head in feet, μ is efficiency, and 3960 is a conversion factor. The total dynamic head is the made up of the friction head and the static head. The friction head is calculated using the empirical Hazen-Williams formula. The static head is the maximum height that the water must be lifted. Power is converted to an amount of energy by multiplying by time.

To calculate the total dynamic head, information regarding the infrastructure required for the different water supply strategies was used. Infrastructure requirements were developed to develop the capital costs for each water supply strategy as discussed in Section 4.5.2. This information included pipeline lengths and diameters, friction, efficiency, and overall static lift for sections of pipelines.

The cost of energy is applied based on the planning year and a selected scenario. A baseline cost of energy was projected out to 2060 (see Appendix H). This baseline is adjusted up or down depending on the scenario. The scenarios are discussed further in Section 5.

Section 5 – Recommended Plan

This section describes the recommended 50-year TRWD water supply plan. The inputs to the decision making process are described in Sections 2, 3, and 4. This section explains how the individual water management strategies were combined into portfolios, tested against possible future scenarios, and then synthesized into implementation plans. This section concludes with the recommended TRWD water supply decision tree.

Though also provided in Section 1, a definition of terms used in this section, and throughout this document, is useful at this point.

- **Water Management Strategy (or simply "Strategy")**: a discrete water supply source, such as a new reservoir, groundwater, reuse water, or conservation (which is considered either as a strategy or a demand reduction, depending on the context).
- **Risk**: the chance that TRWD will be adversely impacted in its efforts to deliver water to customers reliably and economically.
- **System-wide Risks**: defined in this study as Population/Demand Growth Rate, Climate Variability, and Power Costs. These risks impact water supply reliability and cost for the entire TRWD system.
- **Strategy-specific Risks**: defined in this study as Institutional/Legal Risks, Regulatory/Environmental Risks, and Capital Cost Variability/Water Quality Risks. These risks impact project viability and schedule of individual projects.
- **Scenario**: alternative future conditions that address system risks; a combination of system risks that together define a possible future. An example scenario would be "stressed system" in which demands and power costs are on the high end of projections and climate variability reduces available supplies.
- **Portfolios**: a combination of strategies based on a theme (e.g. low cost, low risk) and built to ensure system reliability under a specific scenario.
- **Implementation Plans**: a plan for the order in which strategies should be developed and the schedule of when they should be connected to the TRWD system to maintain supply reliability.
- **Decision Tree**: an adaptive management plan based on major triggers that result in actions on selection and sequencing of strategies.
- **Performance Measure**: water supply reliability is the performance measure used to determine when new water supply strategies should be completed. The following conditions were evaluated to determine when new supplies are needed (also see Section 4.4):
    - Simulated frequency of water supply shortages. Less than a 2% shortage frequency is considered "modeling error" because no model can fully capture all of the supply

system redundancies and capabilities. A shortage frequency greater than 2% is considered a trigger for evaluating the need for new supply in conjunction with the following two conditions;

- The risk profile (probability of simulated shortage plotted over time). The profile should exhibit a break in the slope such that risks begin growing at a faster rate beyond the year being considered as the target for new supplies;

Exhibit 5.1 describes the sequence employed to arrive at a final 50-year TRWD water supply planning decision tree. TRWD selected a group of strategies for this IWSP, focusing primarily on surface water strategies that have already been part of District planning. The team then analyzed each strategy independently to assess the implementation risk, capital and annual cost, individual impact on supply reliability, project development (planning, design, construction) schedule, and yield. Demand projections were also selected and system-wide risks were defined.

Using those analyses as input, we next developed scenarios and portfolios. Implementation plans were then built for scenario/portfolio combinations. Supply reliability performance measures (frequency and magnitude of simulated shortages) were calculated using the IWSP System Simulation Model. The implementation plans provided the building block for an adaptive management plan, a decision tree that can be used by TRWD decision makers as they develop additional TRWD water supply.

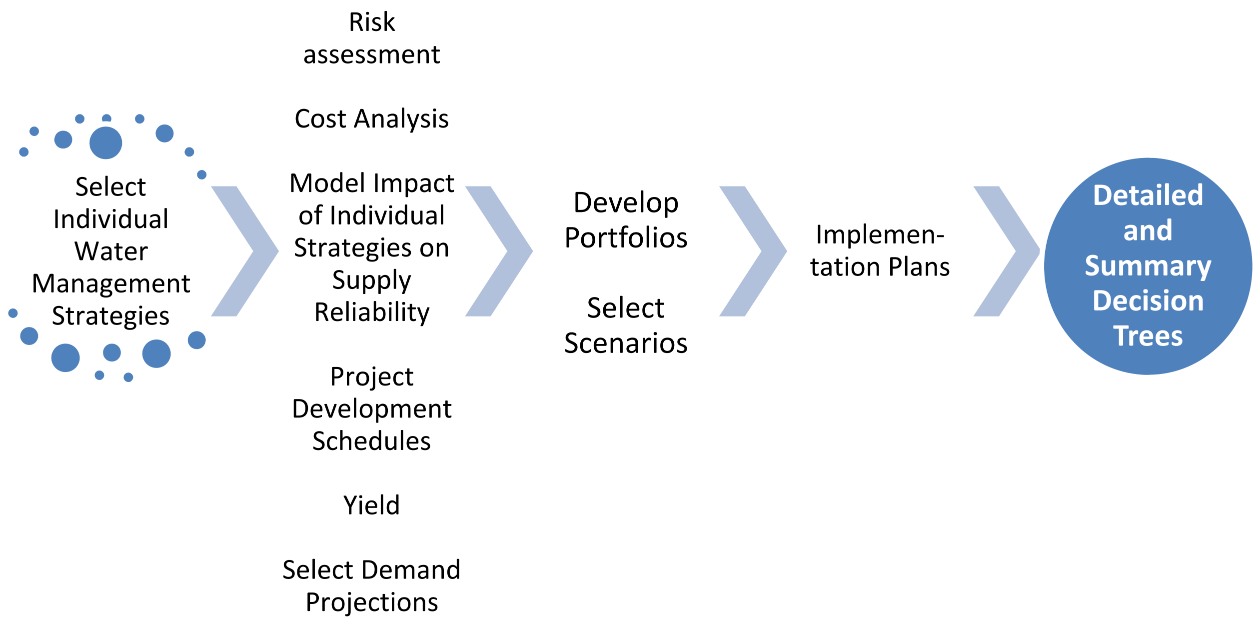


Exhibit 5.1 – Integrated Water Supply Planning Analysis Sequence

5.1 Portfolios of Water Management Strategies

A portfolio is a combination of water management strategies based on a theme and built to promote system reliability under a specific scenario. Three portfolio themes were selected for the IWSP: Low Cost, Low Risk, and Regional Partnerships/High Yield. Each portfolio was built by ranking water management strategies according to their metrics for that theme and then adding strategies to that portfolio in order of highest to lowest preference. Implementation plans are then built for each portfolio by connecting new supplies in the order of preference.

Low Risk Portfolio

The Low Risk theme represents the strategies with the highest overall risk score (with a high score representing low risk),as shown below in Table 5.1 (explained in Section 4.3). The Low Risk portfolio contains the following water management strategies, listed in order of implementation preference:

- Conservation
- Excess Flow Optimization for Eagle Mountain Lake and Lake Benbrook (EXFLO)
- Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs (often shortened to “Unpermitted CC/RC Firm Yield” or “CC/RC Firm”)
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (often shortened to “CC/RC Wetlands Full Yield” or “CC/RC Wetlands”)
- Lake Ringgold
- Lake Tehuacana
- Toledo Bend Reservoir
- Marvin Nichols or Wright Patman

Table 5.1– Final Strategy Specific Risk Overall Risk Scores and Schedule Impacts

Strategies (ranked highest → lowest risk)	Potential Schedule Impact*	Overall Risk Score
EXFLO	2	4.6
CC/RC Wetlands	2	4.6
CC/RC Firm	2	4.6
Lake Ringgold	5	3.5
Lake Tehuacana	7	3.1
Toledo Bend Reservoir	7	3.0

Table 5.1– Final Strategy Specific Risk Overall Risk Scores and Schedule Impacts

Strategies (ranked highest → lowest risk)	Potential Schedule Impact*	Overall Risk Score
Lake Wright Patman	9	2.7
Lake Columbia	9	2.5
Marvin Nichols Reservoir	10	2.3
Lake Texoma (blended)	10	2.2
Temple Reservoir	10	2.2
Kiamichi River	11	1.8

*See Section 4 for definition and explanation

Low Cost Portfolio

The Low Cost theme represents the strategies with the lowest annual unit costs,as shown below in Figure 5.1. Professional judgment was applied to select preferred strategies for the Low Cost portfolio because if the strategies are ranked according to their unit cost (annual cost divided by maximum permitted annual yield) while construction debt is being paid and then again according to their unit cost after the debt is paid (when annual costs are only pumping and O&M), the two rankings are not the same. Lake Columbia illustrates this point: though it has a relatively low unit cost while construction debt is being paid (if developed as part of the Toledo Bend pipeline), it has a high unit cost after the debt is paid. The unit cost after debt payment is high enough that the IWSP team judged it should not be part of the Low Cost portfolio.

TRWD is committed to developing projects with the lowest life-cycle cost because they represent the best long-term investment and lowest long-term impact on rates, but a gradual increase in rates is also preferred over large spikes, which are necessary when strategies with high capital costs are developed. In an effort to balance these two goals, the following water management strategies were selected for the Low Cost portfolio (listed in order of implementation preference):

- Conservation
- Excess Flow Optimization for Eagle Mountain Lake and Lake Benbrook (EXFLO)
- Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs (often shortened to “Unpermitted CC/RC Firm Yield” or “CC/RC Firm”)
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (often shortened to “CC/RC Wetlands Full Yield” or “CC/RC Wetlands”)

- Temple Reservoir
- Lake Tehuacana
- Marvin Nichols Reservoir
- Lake Ringgold
- Kiamichi River

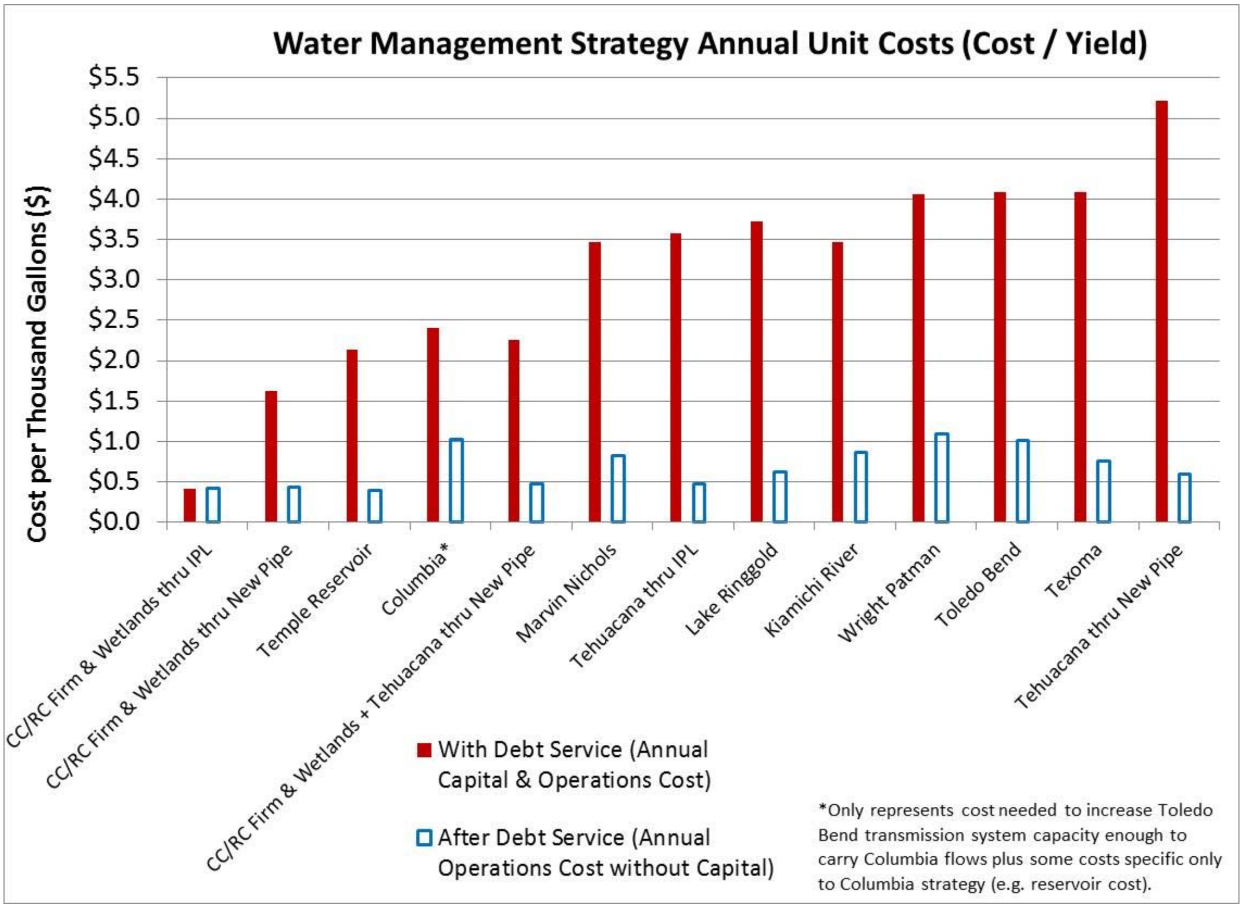


Figure 5.1 – Water Management Strategy Annual Unit Costs

Regional Partnerships/High Yield Portfolio

The Regional Partnerships/High Yield portfolio was built using strategies that will benefit multiple water supply agencies in North Texas, such as the North Texas Municipal Water District and City of Dallas, and that have a high potential yield when compared to other strategies. TRWD is committed to partnering with other water suppliers to develop large regional supplies. These partnerships can create significant cost savings and may make successful implementation more likely from a political standpoint. Strategies with high yield are also preferable in some respects because they ensure water supply system reliability for a much longer timeframe.

The Regional Partnerships/High Yield portfolio contains the following water management strategies, listed in order of implementation preference:

- Conservation
- Excess Flow Optimization for Eagle Mountain Lake and Lake Benbrook (EXFLO)
- Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs (often shortened to "Unpermitted CC/RC Firm Yield" or "CC/RC Firm")
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (often shortened to "CC/RC Wetlands Full Yield" or "CC/RC Wetlands")
- Marvin Nichols Reservoir
- Toledo Bend Reservoir
- Lake Wright Patman
- Kiamichi River

No Regret Strategies

Four strategies are common to every portfolio because they are low cost, low risk, and in three cases already under development. It is recommended that these four strategies be developed regardless of the future scenario:

- Conservation
- Excess Flow Optimization for Eagle Mountain Lake and Lake Benbrook (EXFLO)
- Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs (often shortened to "Unpermitted CC/RC Firm Yield" or "CC/RC Firm")
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (often shortened to "CC/RC Wetlands Full Yield" or "CC/RC Wetlands")

Conservation is a water management strategy that has long been part of TRWD's water supply portfolio. Because the District is committed to being a good steward of natural resources and to optimizing the cost of operations, it has developed strategic water conservation plans that are already being implemented and will continue in the future.

EXFLO is a permitting strategy that will not significantly impact water supply reliability, but it will reduce system pumping costs under certain conditions. It does not provide a reliable source of new supply, but it is recommended as an operational strategy, and the permits should be pursued.

CC/RC Wetlands and CC/RC Firm are low risk, low cost permitting strategies that make full use of existing, already connected TRWD supplies, and just require additional transmission infrastructure. It is recommended that these permits be secured without delay, regardless of when the additional water is required to maintain water supply reliability.

5.2 Possible Future Scenarios

Scenarios are alternative future conditions that involve various system risks; in other words, a combination of system-wide risks that together define a possible future. The system-wide risks were described in Section 4.3 and Table 5.2 serves as a reminder of what those system-wide risks are.

Table 5.2 – System-Wide Risk Outcomes

System-Wide Risks	Possible Outcomes to Analyze
Population / Demand Growth	2011 Region C based demand projections
	Projection based on extrapolation of recent trends
Climate Variability	No change to historic flows and evaporation rates
	-15% of historic flows and +15% of evaporation
Power Cost	-25% of projections made during the IPL planning studies
	+25% of projections made during the IPL planning studies

It is necessary to limit the number of scenarios used in this study so that the results can be useful and digestible, so the following scenarios were selected for analysis:

1. Accepted Projections Scenario:
    a. 2011 Region C based demand projections
    b. No change to historic flows
    c. Use current power cost projections, as developed during the Integrated Pipeline Project planning phase by J. Stowe & Co. (included here as Appendix H).
2. Stressed System Scenario:
    a. 2011 Region C based demand projections
    b. -15% of historic flows and +15% of historic evaporation
    c. Power cost projections increasing at a rate 25% greater than current projections

3. Optimistic Projections Scenario:
    a. Demand projection based on extrapolation of recent trends
    b. No change to historic flows
    c. Power cost projections increasing at a rate 25% less than current projections

5.3 Implementation Plans

Implementation plans define the order in which strategies should be developed and the schedule of when they should be connected to the TRWD system to maintain supply reliability. Supply reliability performance measures (frequency and magnitude of simulated shortages) determine when each new strategy should be connected. Each plan is essentially how to implement each portfolio under a possible future scenario.

Table 5.3 defines which implementation plans were developed. Though some implementation plans did not become part of the final decision tree, they were all useful input, used to inform decision-makers as the decision tree was developed. To provide extra information, each portfolio was considered with and without three of the No Regret Strategies (EXFLO, CC/RC Wetlands, CC/RC Firm; Conservation is never excluded). Implementation plans that include these No Regret Strategies are plan A, those without these strategies are plan B.

Conservation is not explicitly identified as a strategy in these implementation plans. However, it is accounted for in the TRWD water supply plan. The 2011 Region C-based demand projections used in this study are reduced over time due to TWDB's projected savings from low flow toilets, lower water use clothes washers, and other water saving appliances and plumbing fixtures. That reduction varies with the supplier and generally ranges between an 8 and 14 gpcd reduction from current levels by 2040. Additional savings due to conservation are considered additional "supply", not a reduction in per capita demand, in the Region C planning process, so these additional conservation measures will not have an impact on the Region C water demand projections. These future conservation "supplies" are not used in the IWSP study as supply strategies. Instead, the IWSP uses a second demand projection (the Recent Trend Extrapolation), developed and provided by TRWD, in which demands are projected using a trendline based on recent years of actual water usage. This second demand projection was provided to bracket the low side of demand projections.

Figures 5.2 through 5.13 show each implementation plan developed for the IWSP. Some explanatory notes relevant to the figures:

1. Demand projections shown on these figures cannot be compared to other figures in this report for two reasons. First, in the figures below, they represent annual *average* demands. In other parts of this report, *dry year* demand projections are shown in several figures. Second, demands by customers that pull directly from District reservoirs (i.e. "local demands" on Lake Benbrook, Lake Bridgeport, Eagle Mountain Lake, and etc.) are not included in the figures below. This is simply due to how the

model output divides demands on the reservoirs from demands on the pumped transmission system. However, it is important to note that the implementation plans are not based on the demand projection lines shown in the figures; the IWSP System Simulation Model simulates a full range of supply and demand conditions and those results are used to develop the implementation plans.

2. Average Simulated Demand and Maximum Simulated Demand are output from the IWSP System Simulation Model. The Maximum line indicates how demand can peak on an annual basis based on the factors described in Section 3.

3. The supply line is based on current supplies (including the Cedar Creek Constructed Wetlands and Integrated Pipeline) under dry conditions, not including supply to customers that pull directly from District reservoirs (i.e. "local demands" on Lake Benbrook, Lake Bridgeport, Eagle Mountain Lake, and etc.). Therefore, supply from the West Fork is limited to 46,000 acre-feet/year in these figures. See Sections 2 and 3 of this report for a full description of supply and demand.

4. The colors of the water management strategy are not consistent between implementation plans; they are only used for differentiation.

Table 5.3– Implementation Plans, Combinations of Portfolios and Future Scenarios

Scenario	Portfolio
Optimistic Projections	All Portfolios
Accepted Projections	Low Risk, Plan A
Accepted Projections	Low Risk, Plan B
Accepted Projections	Low Cost, Plan A
Accepted Projections	Low Cost, Plan B
Accepted Projections	Regional Partnerships, Plan A
Accepted Projections	Regional Partnerships, Plan B
Stressed System	Low Risk, Plan A
Stressed System	Low Risk, Plan B
Stressed System	Low Cost, Plan A
Stressed System	Regional Partnerships, Plan A
Stressed System	Regional Partnerships, Plan B

**Recall that Plan A includes the No Regret strategies, while Plan B does not.*

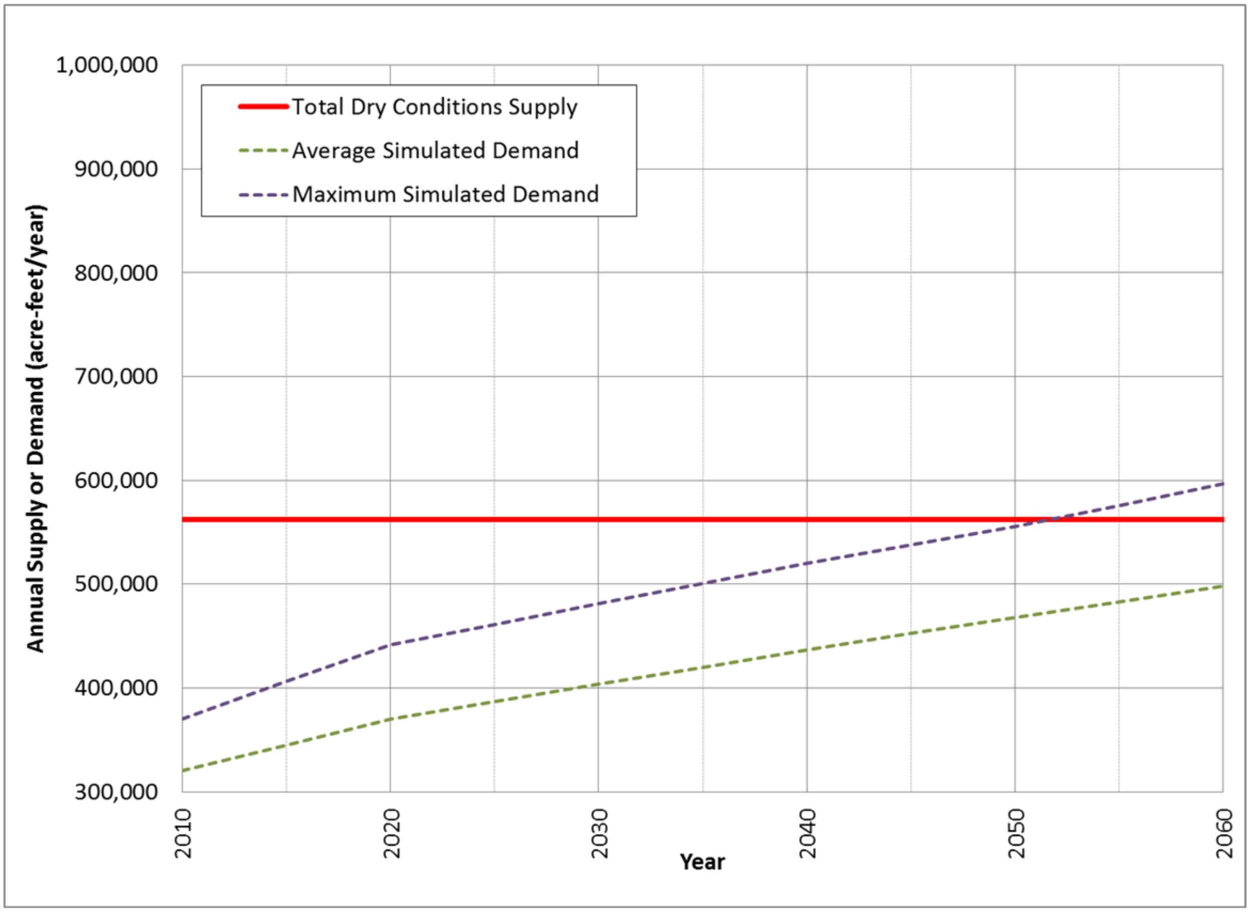


Figure 5.2 – Implementation Plan: Optimistic Projections, All Portfolios

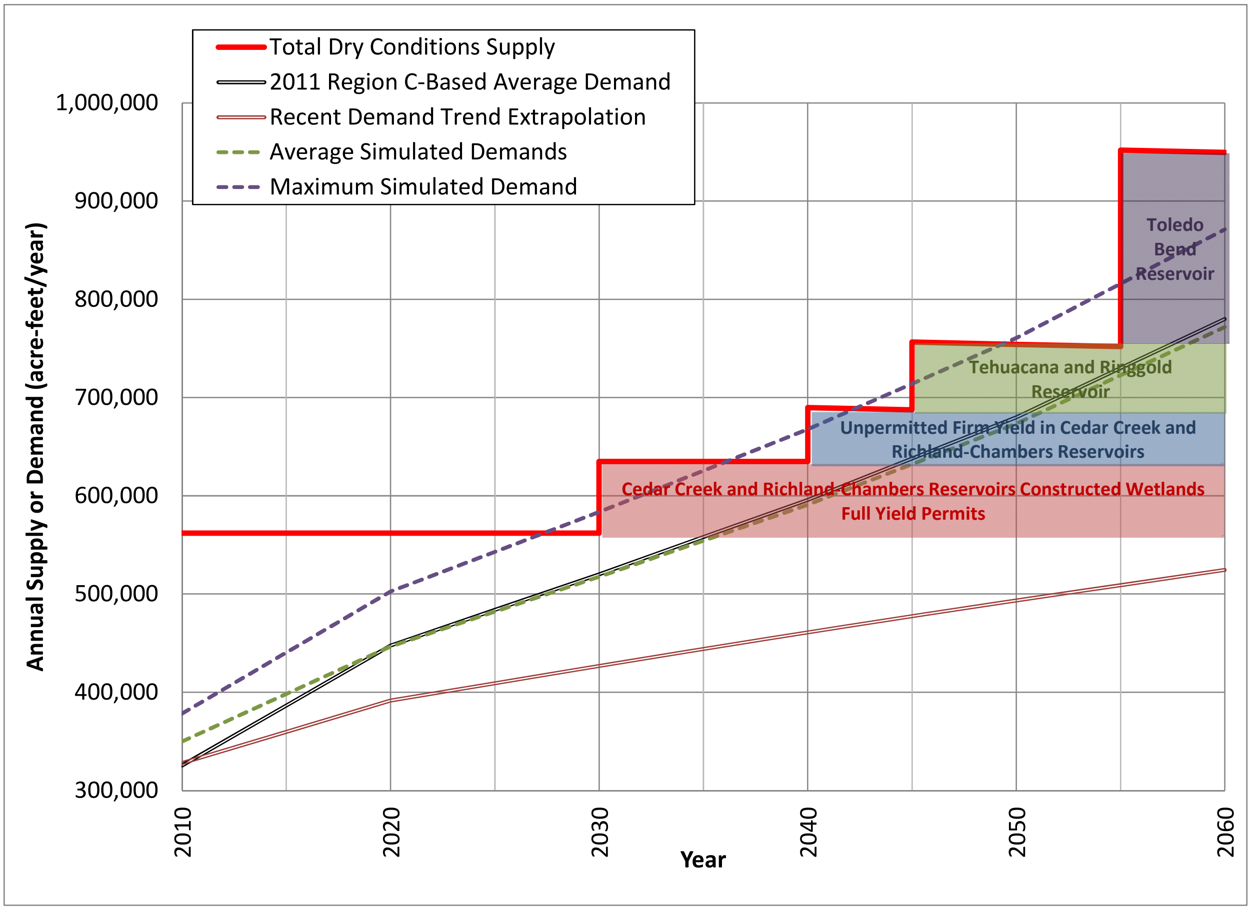


Figure 5.3 – Implementation Plan: Accepted Projections, Low Risk A

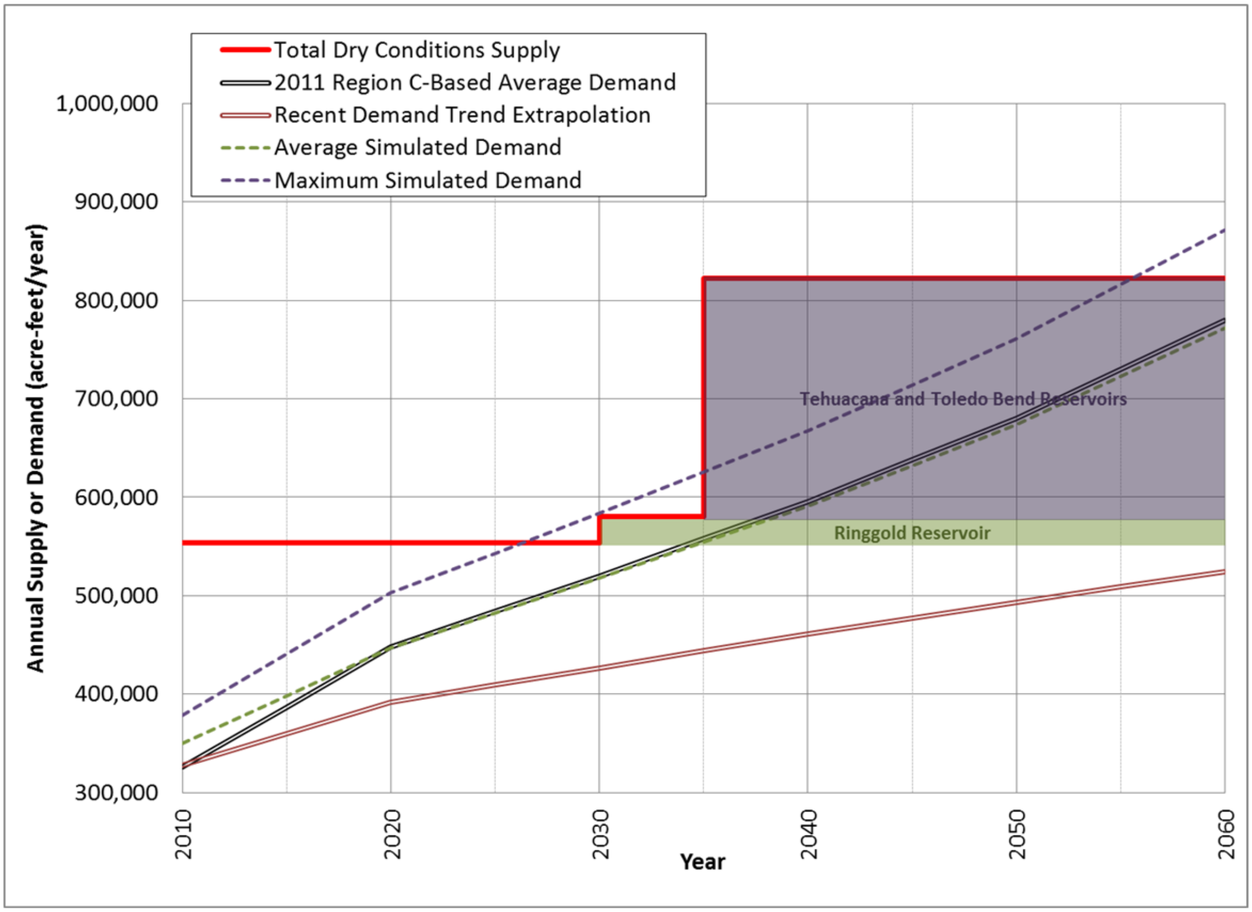


Figure 5.4 – Implementation Plan: Accepted Projections, Low Risk B

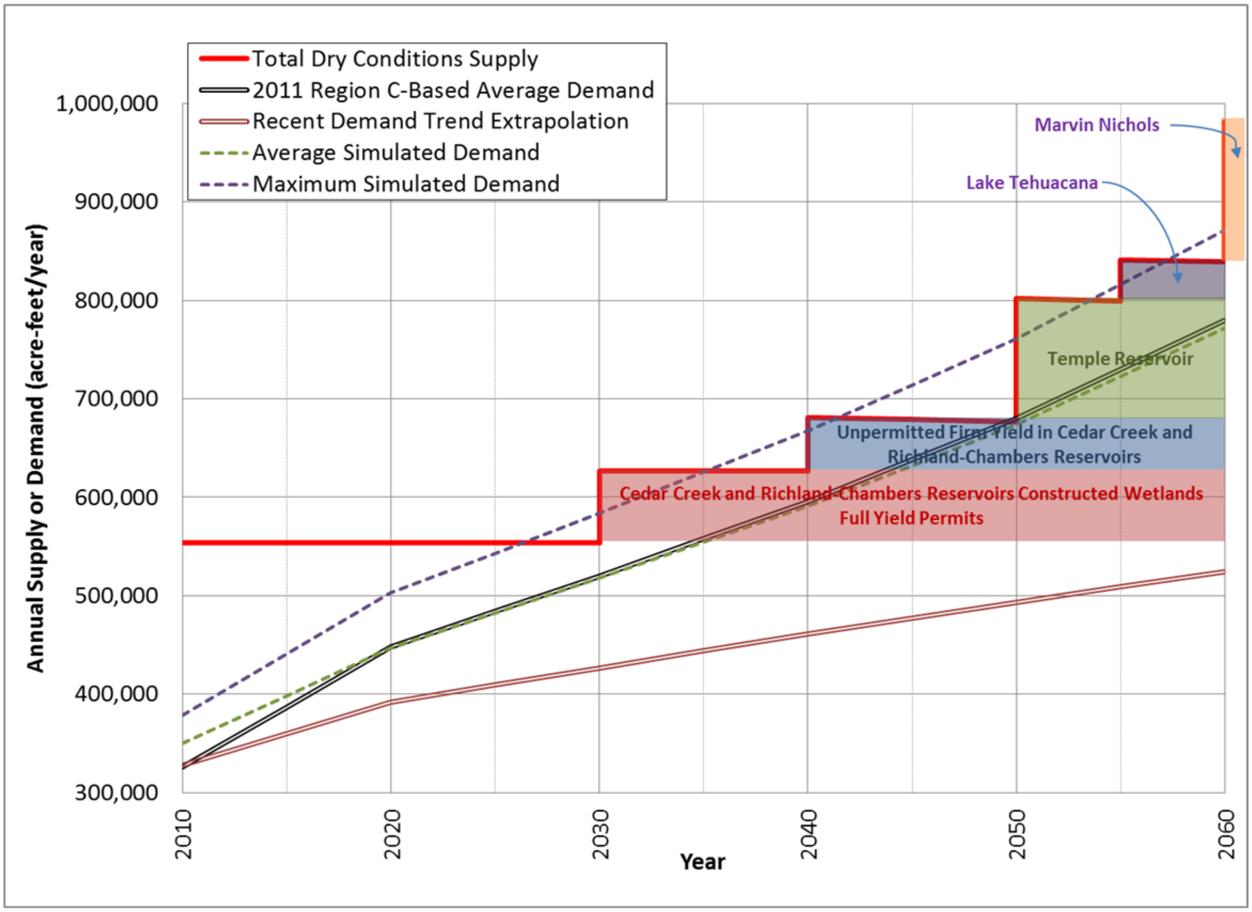


Figure 5.5 – Implementation Plan: Accepted Projections, Low Cost A

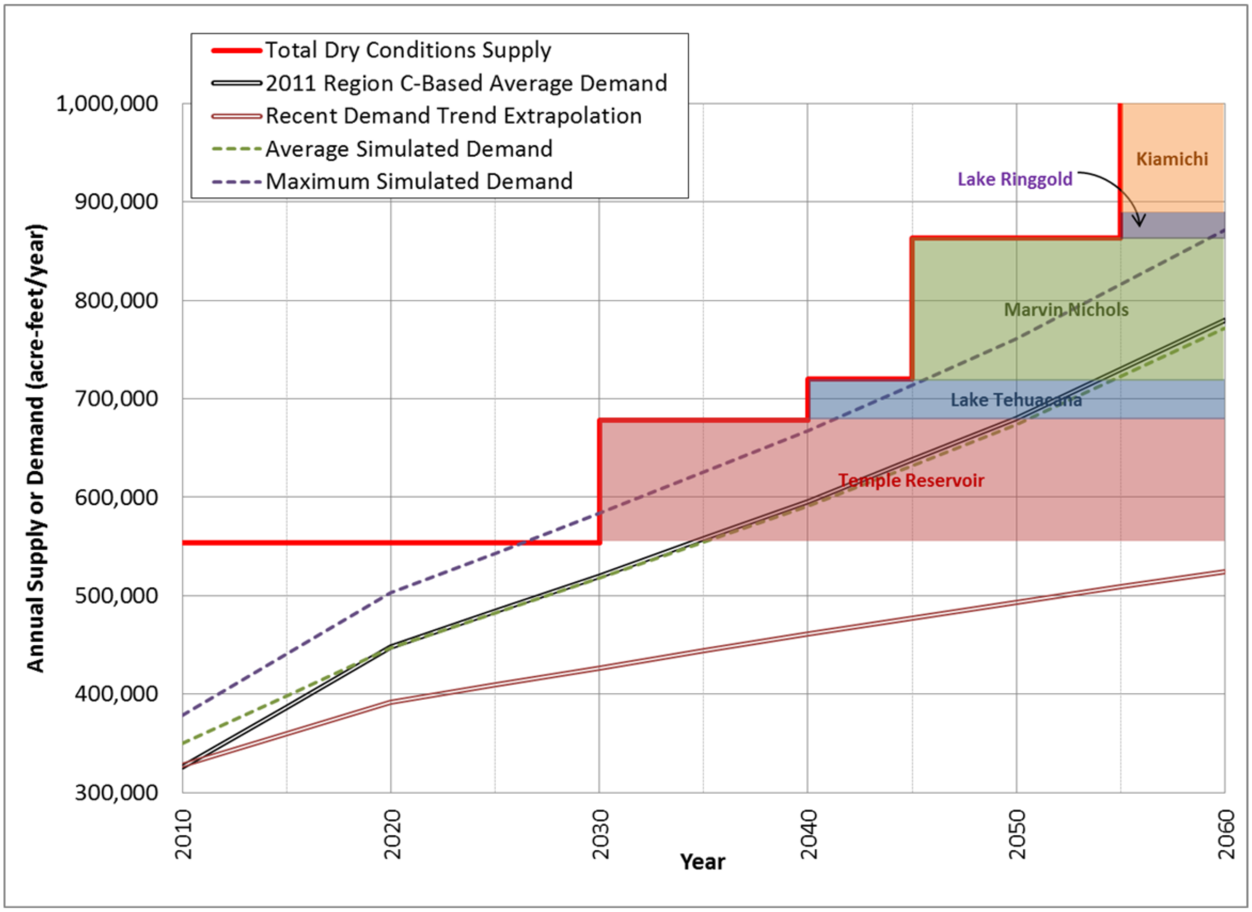


Figure 5.6 – Implementation Plan: Accepted Projections, Low Cost B

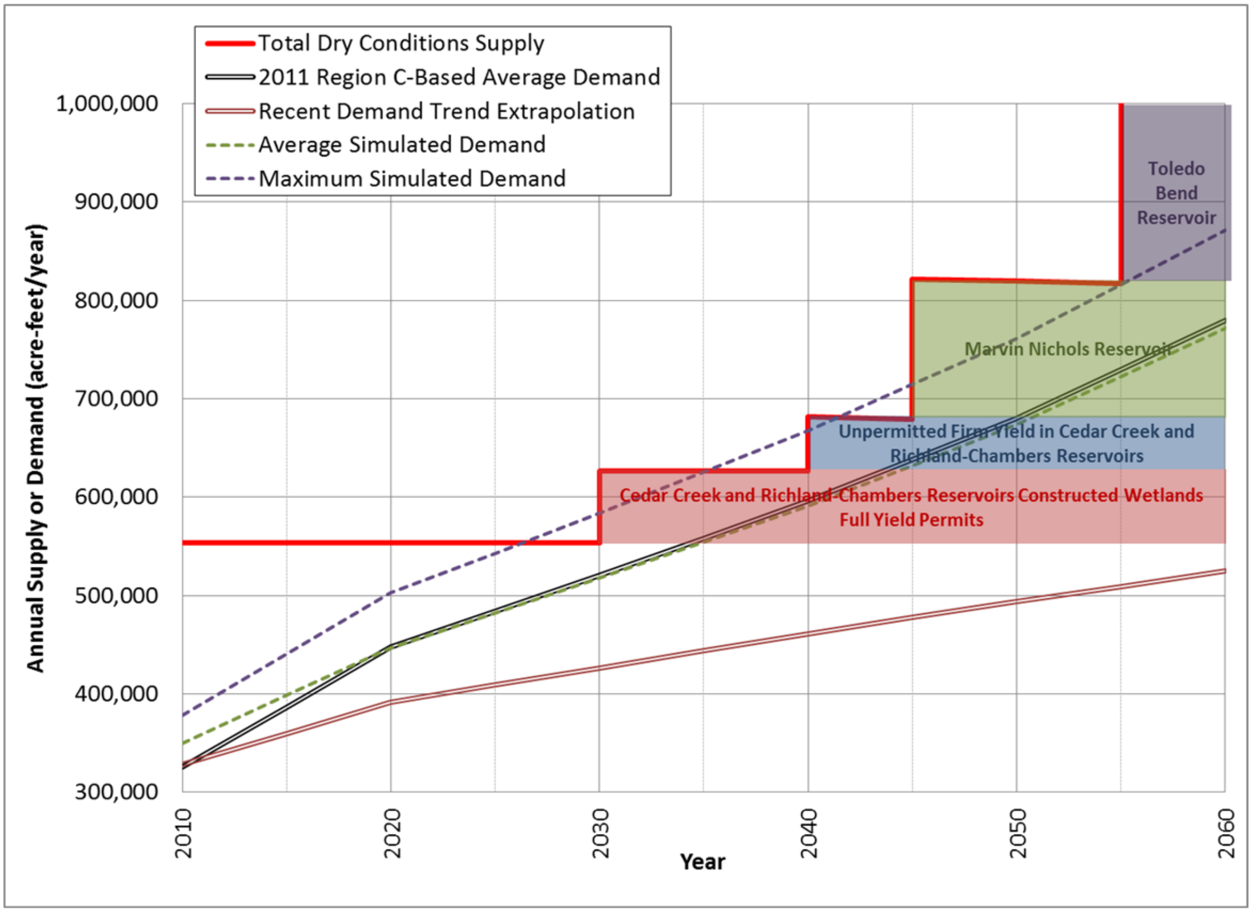


Figure 5.7 – Implementation Plan: Accepted Projections, Regional Partnerships, Plan A

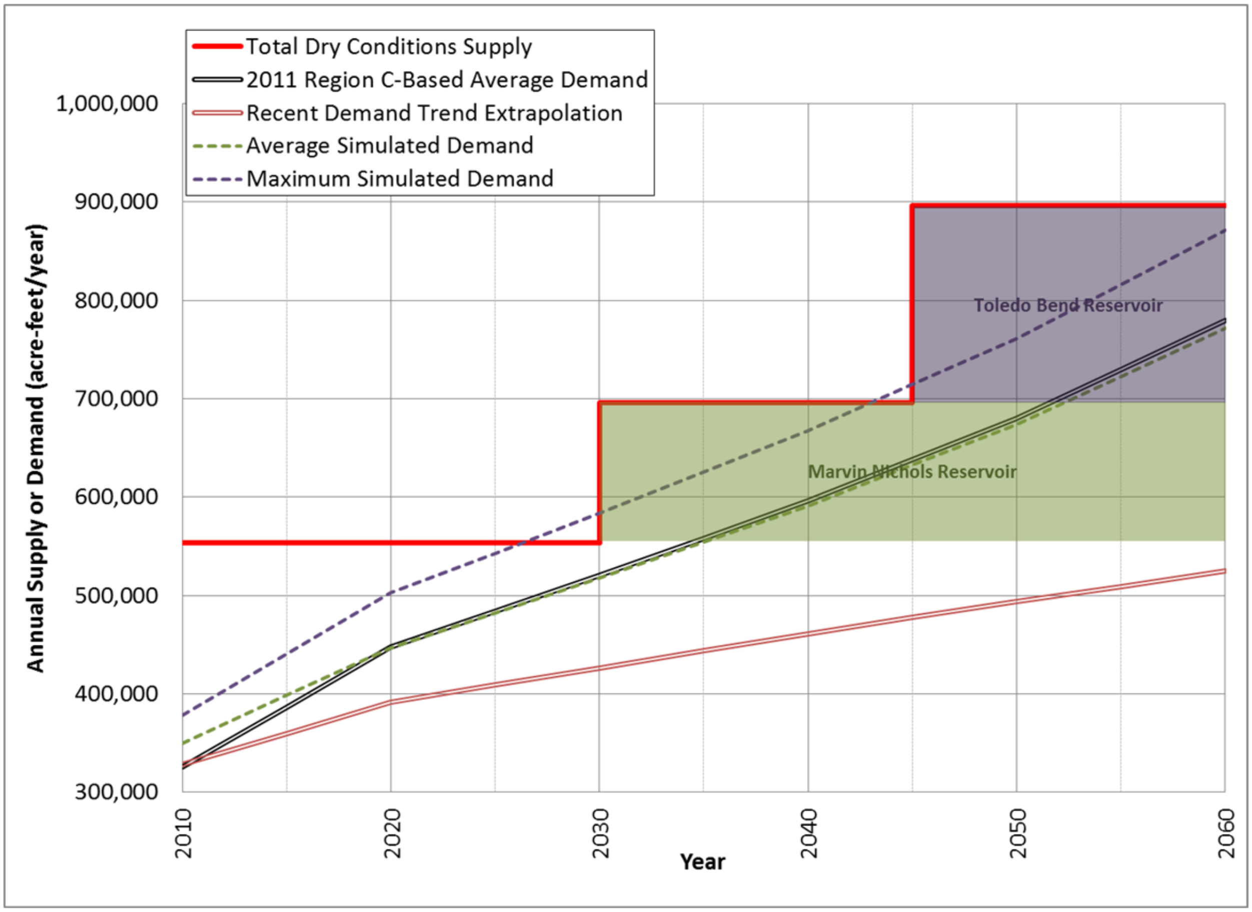


Figure 5.8 – Implementation Plan: Accepted Projections, Regional Partnerships, Plan B

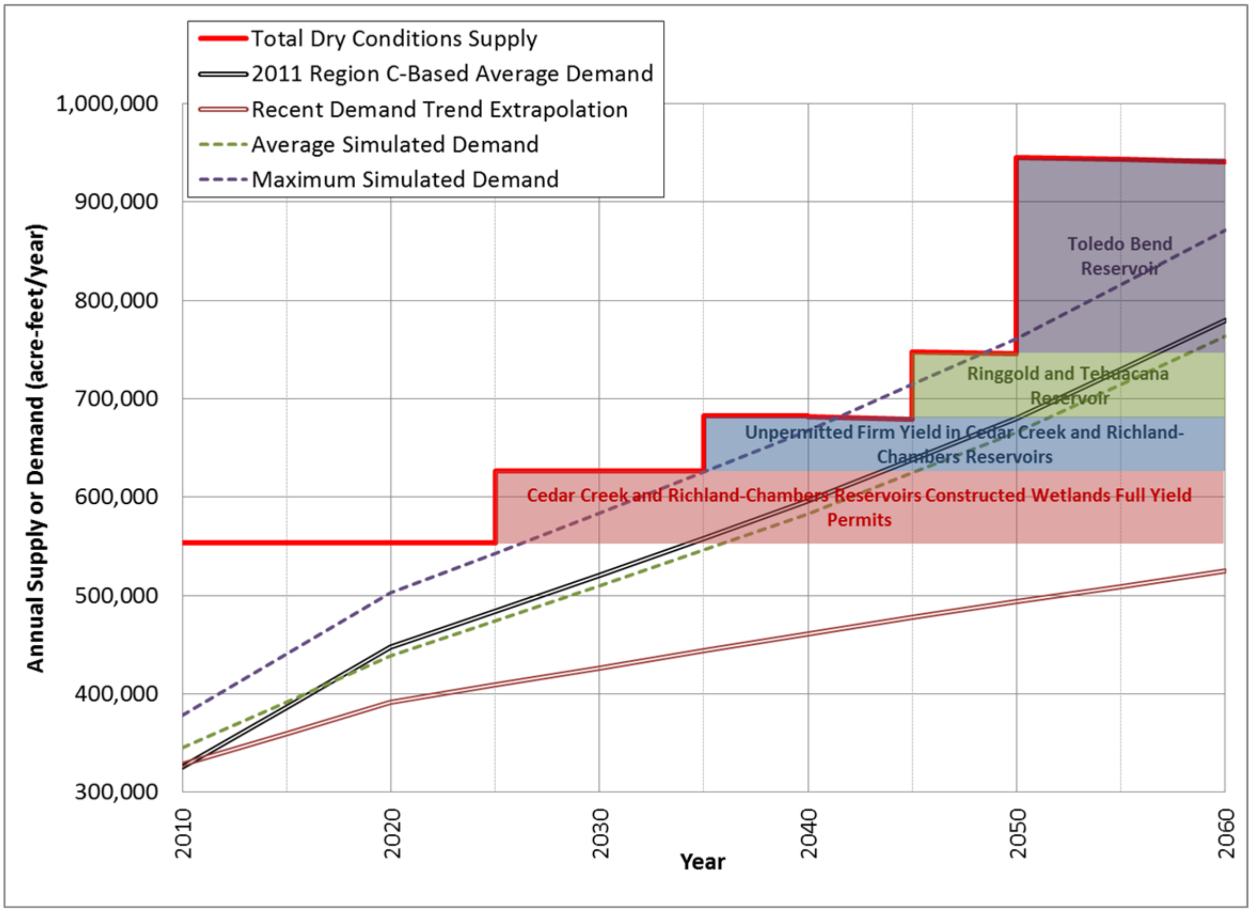


Figure 5.9 – Implementation Plan: Stressed System, Low Risk, Plan A

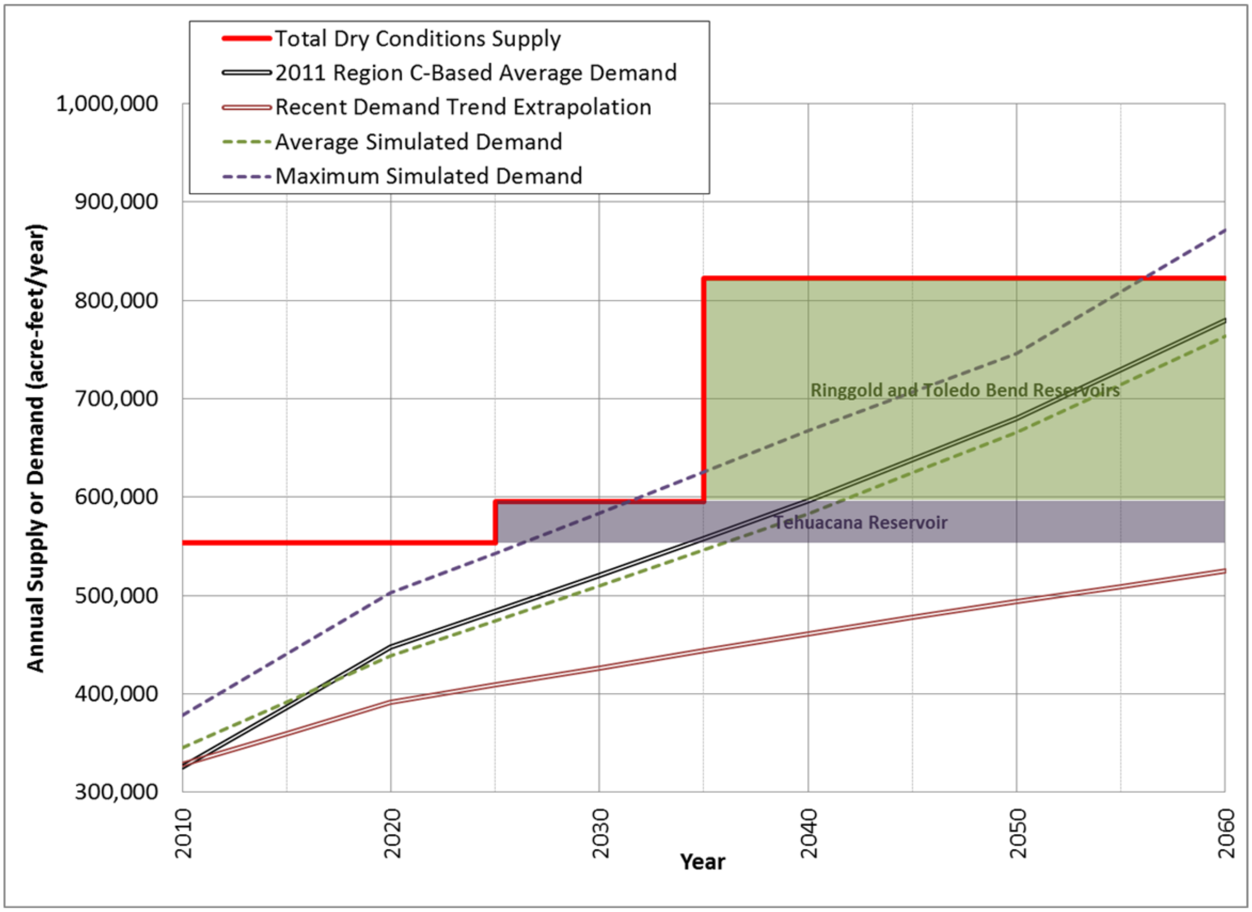


Figure 5.10 – Implementation Plan: Stressed System, Low Risk, Plan B

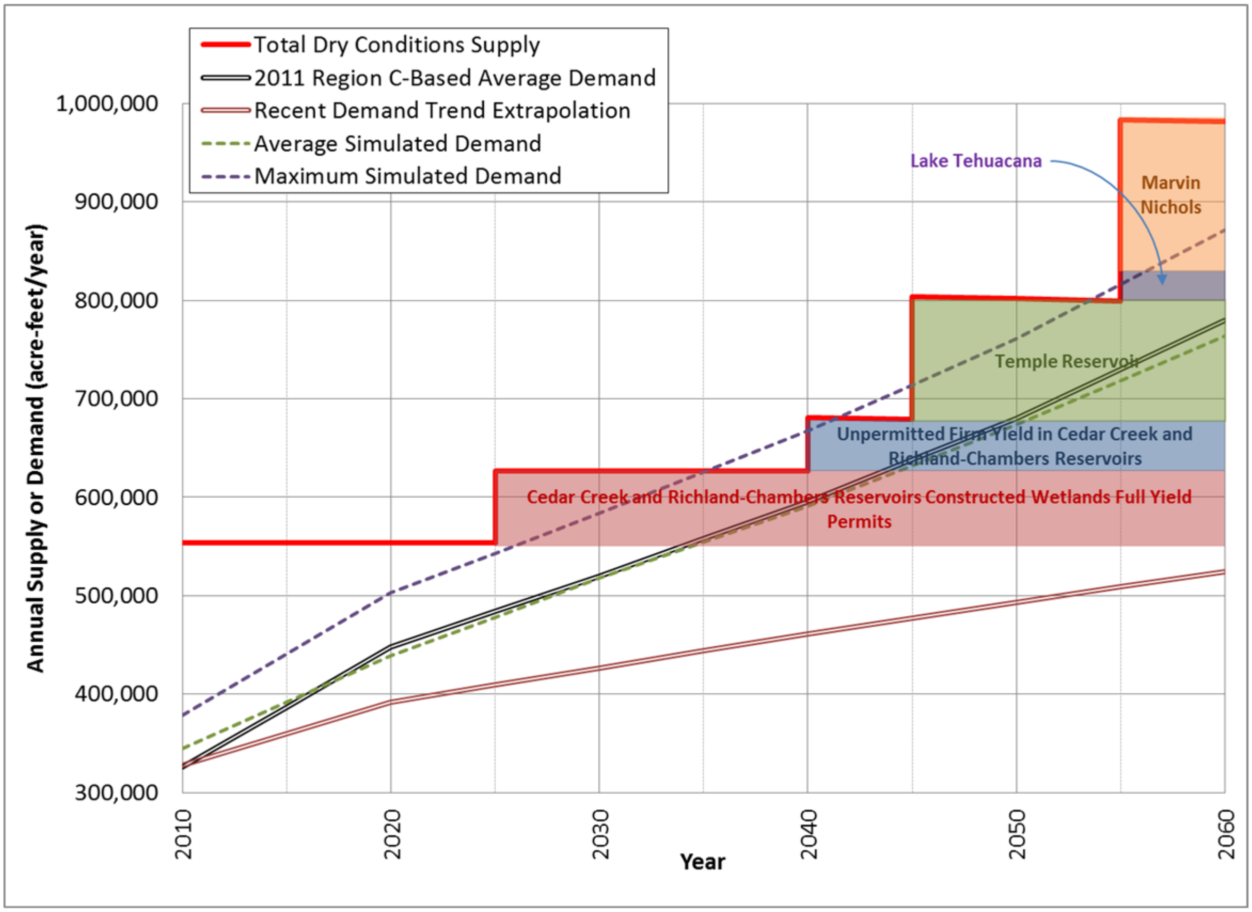


Figure 5.11 – Implementation Plan: Stressed System, Low Cost, Plan A

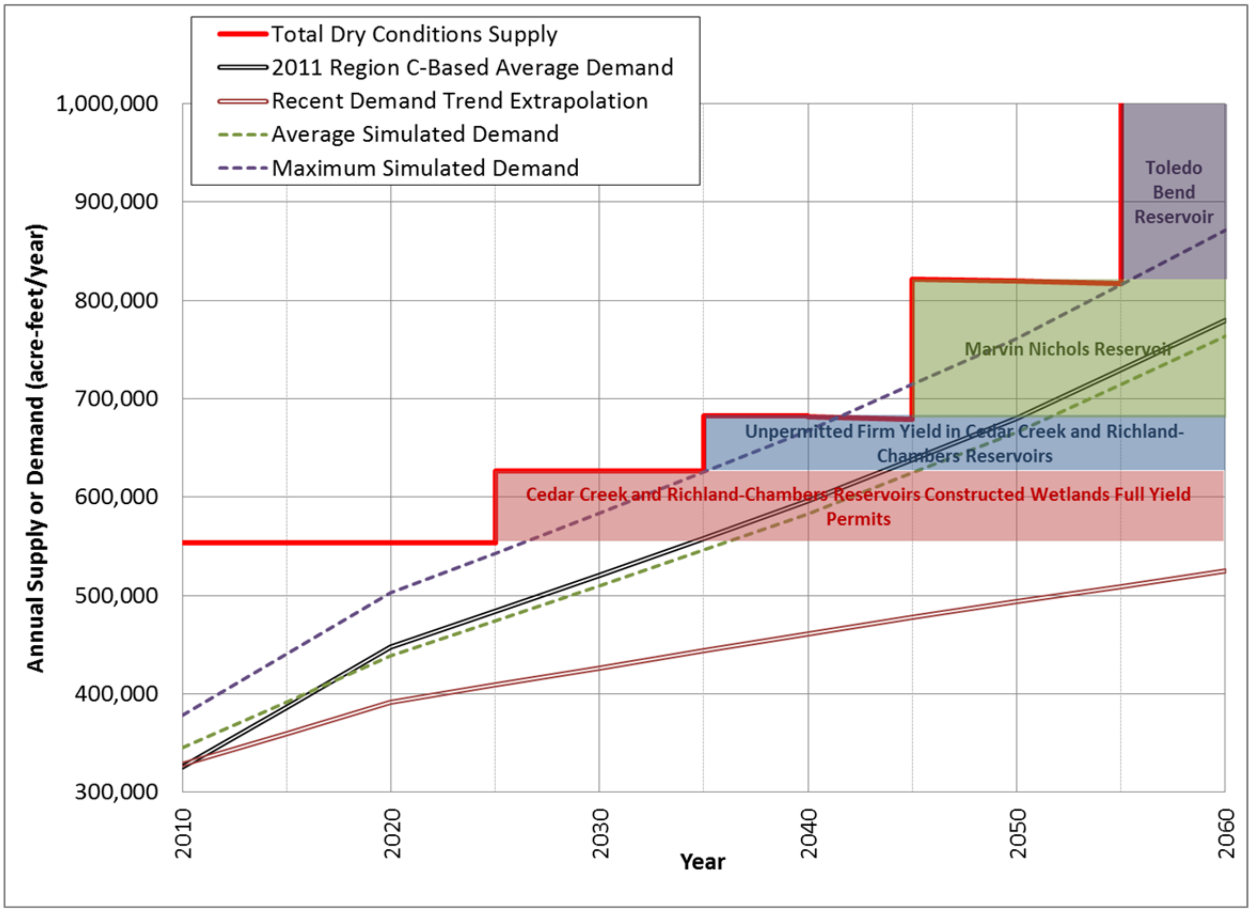


Figure 5.12 – Implementation Plan: Stressed System, Regional Partnerships, Plan A

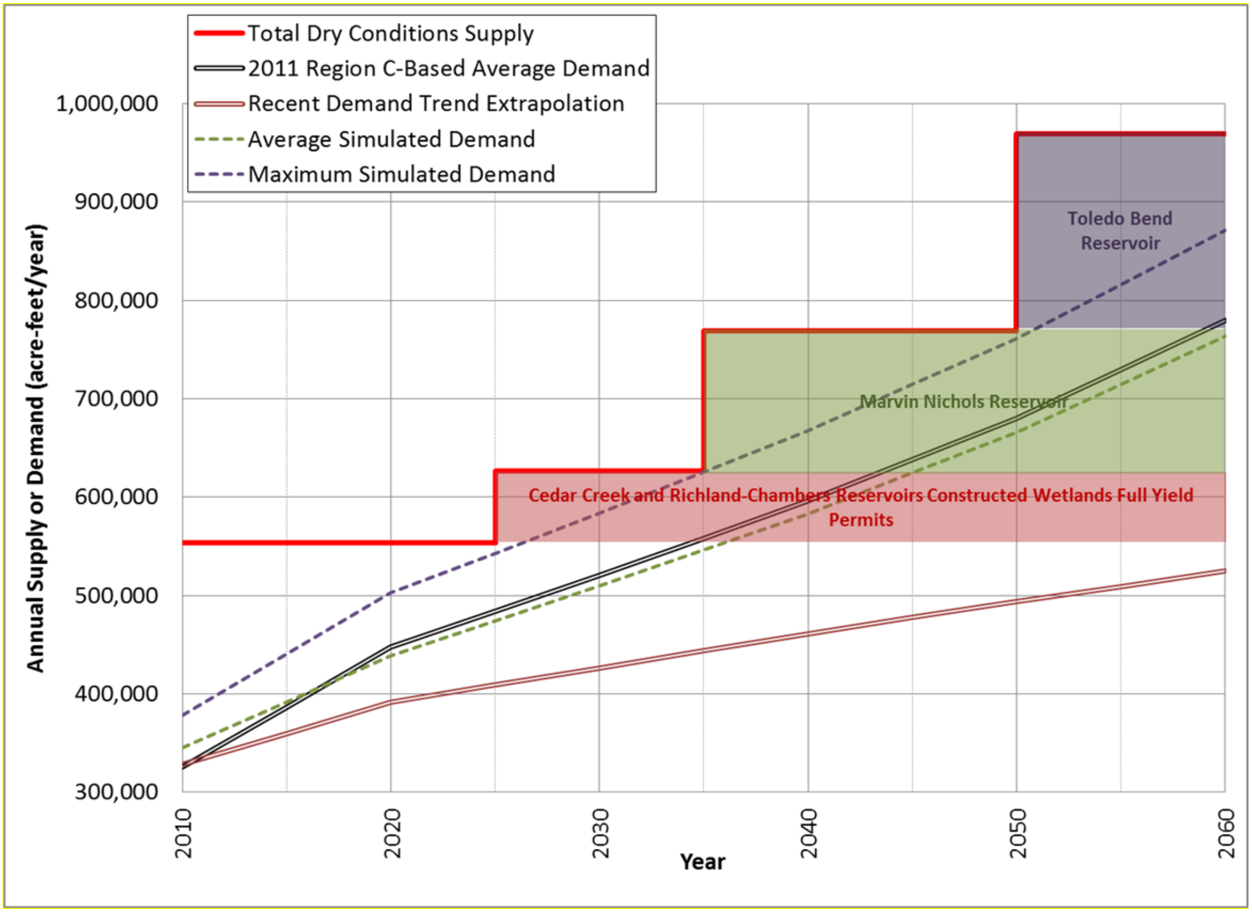


Figure 5.13 – Implementation Plan: Stressed System, Regional Partnerships, Plan B

*Note that in this "Plan B" implementation plan, a No Regret strategy (CC/RC Wetlands) is required to make it a feasible plan because it is not possible to develop Marvin Nichols by 2025, when additional supply is required.

Operating costs were calculated for each implementation plan using the methodology described in Section 4.5.3. The operating costs were summarized for each portfolio and plan (A versus B) in graphical form. Each graph shows the baseline projected operating costs (no new strategies) and the accepted and stressed scenarios. The implementation plan is also shown as a bar graph to indicate the timing of strategies, provided as a reference in these figures to help understand the increases in operational costs. These graphs are shown in Figures 5.14 through 5.19.

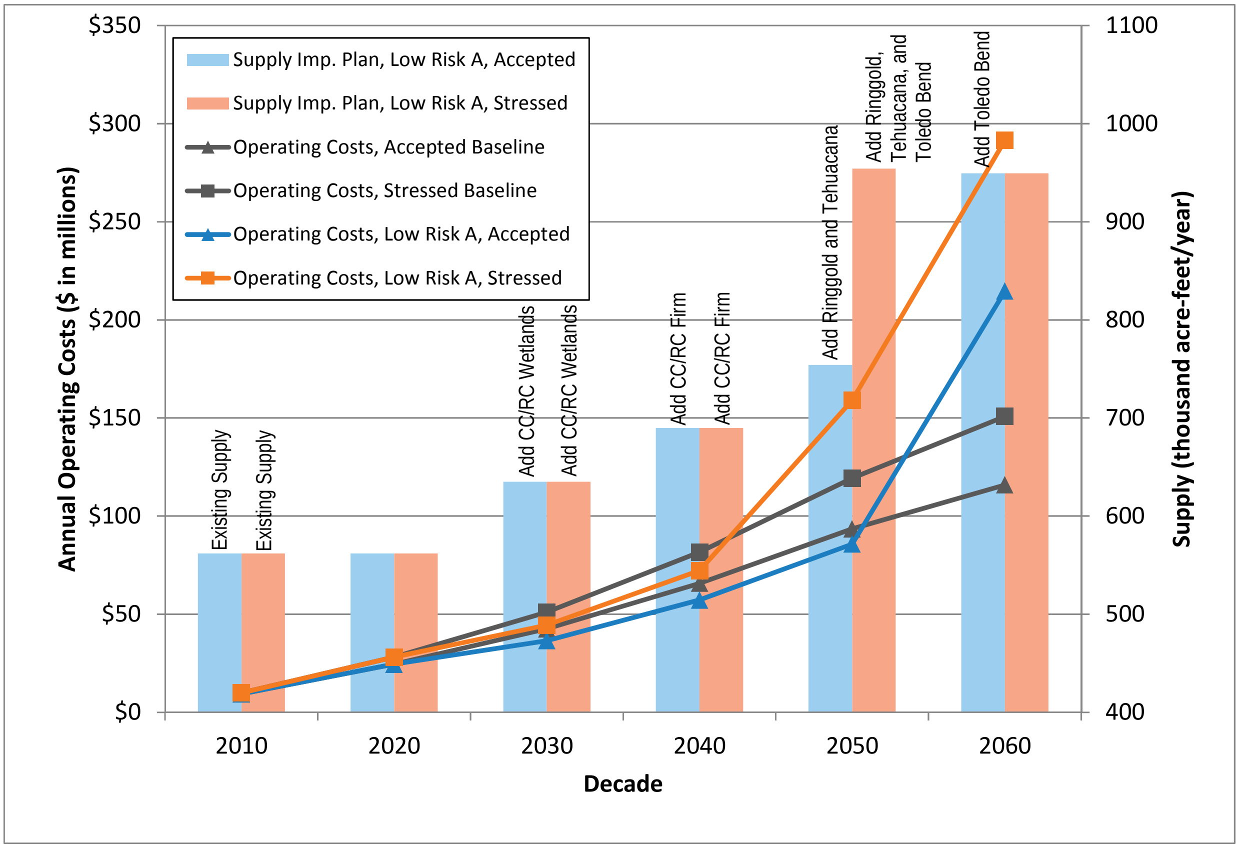


Figure 5.14 – Annual Operating Costs, Low Risk Portfolio, Plan A

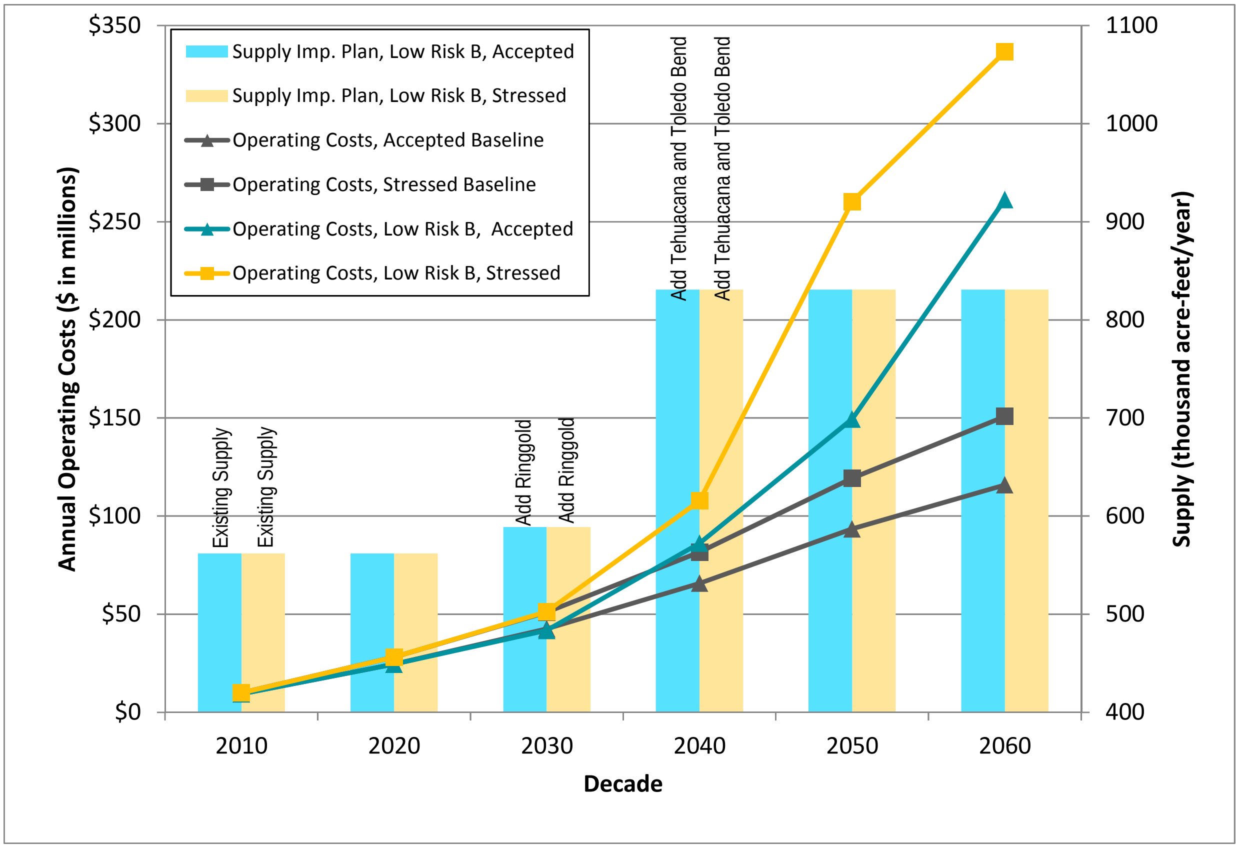


Figure 5.15 – Annual Operating Costs, Low Risk Portfolio, Plan B

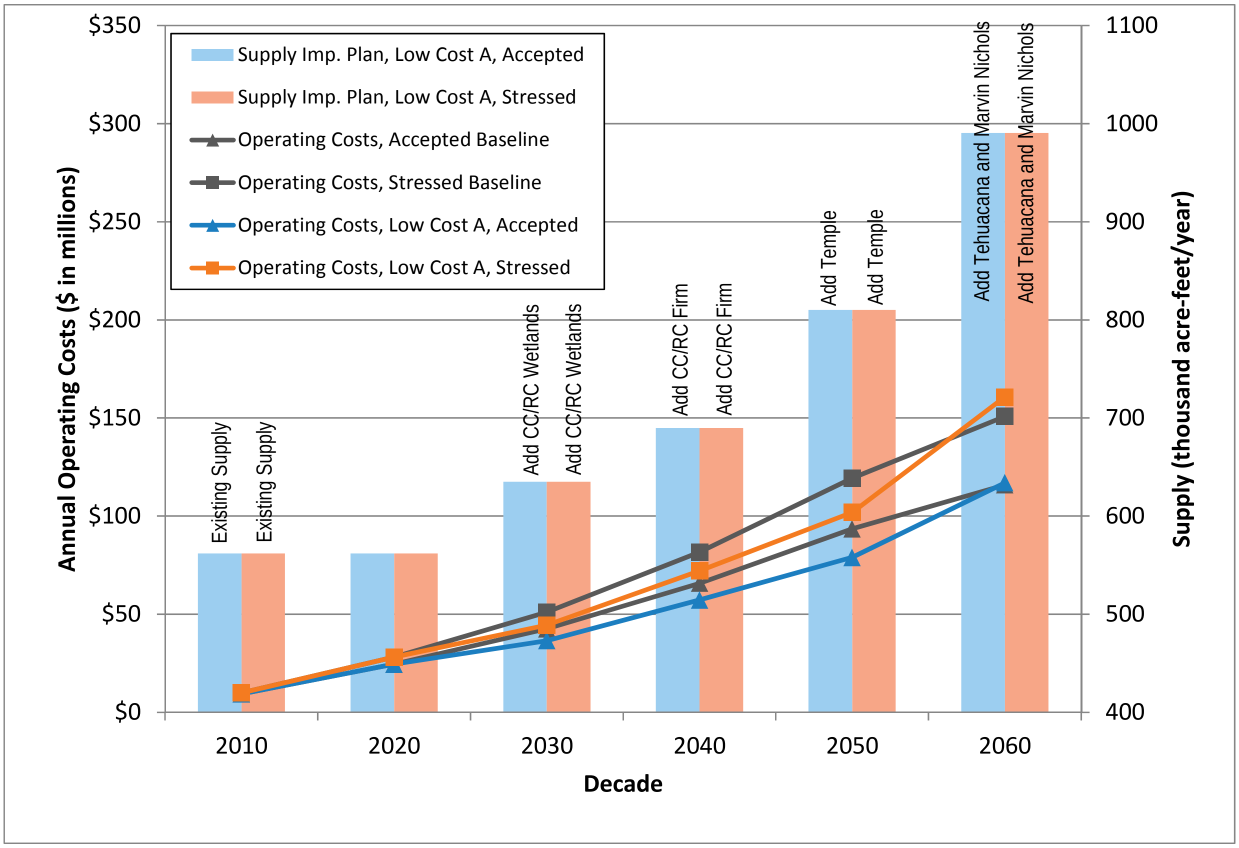


Figure 5.16 – Annual Operating Costs, Low Cost Portfolio, Plan A

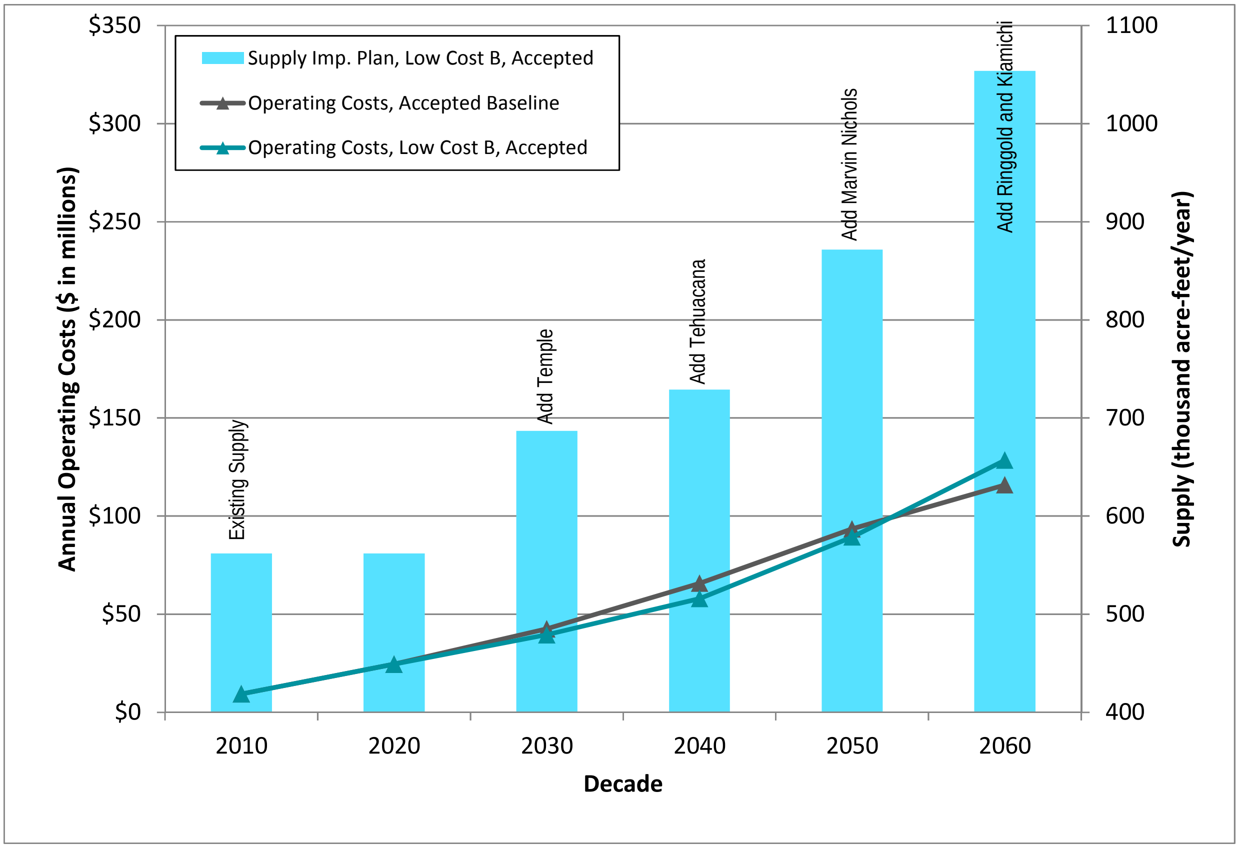


Figure 5.17 – Annual Operating Costs, Low Cost Portfolio, Plan B

*Note – Stressed System Scenario was not calculated for this portfolio because this portfolio is not part of the recommended TRWD water supply plan.

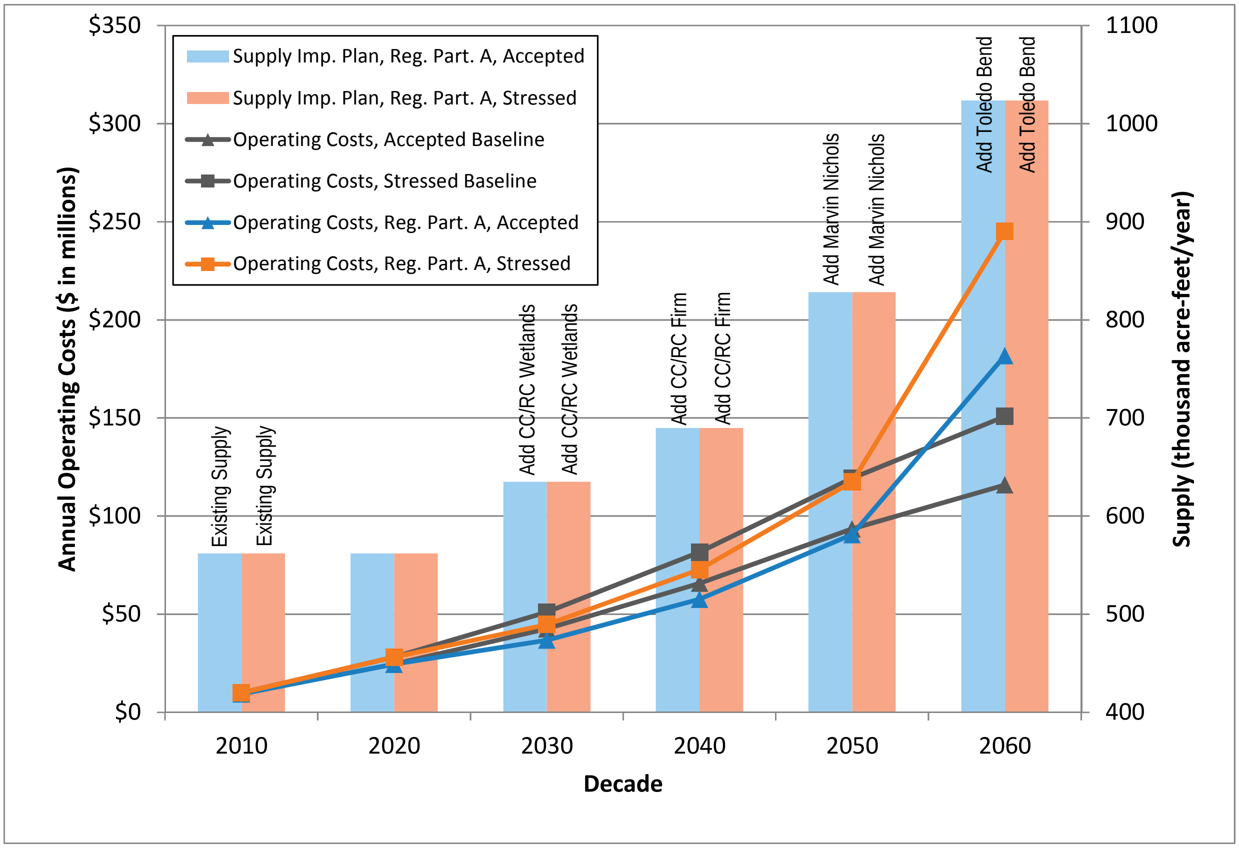


Figure 5.18 – Annual Operating Costs, Regional Partnerships Portfolio, Plan A

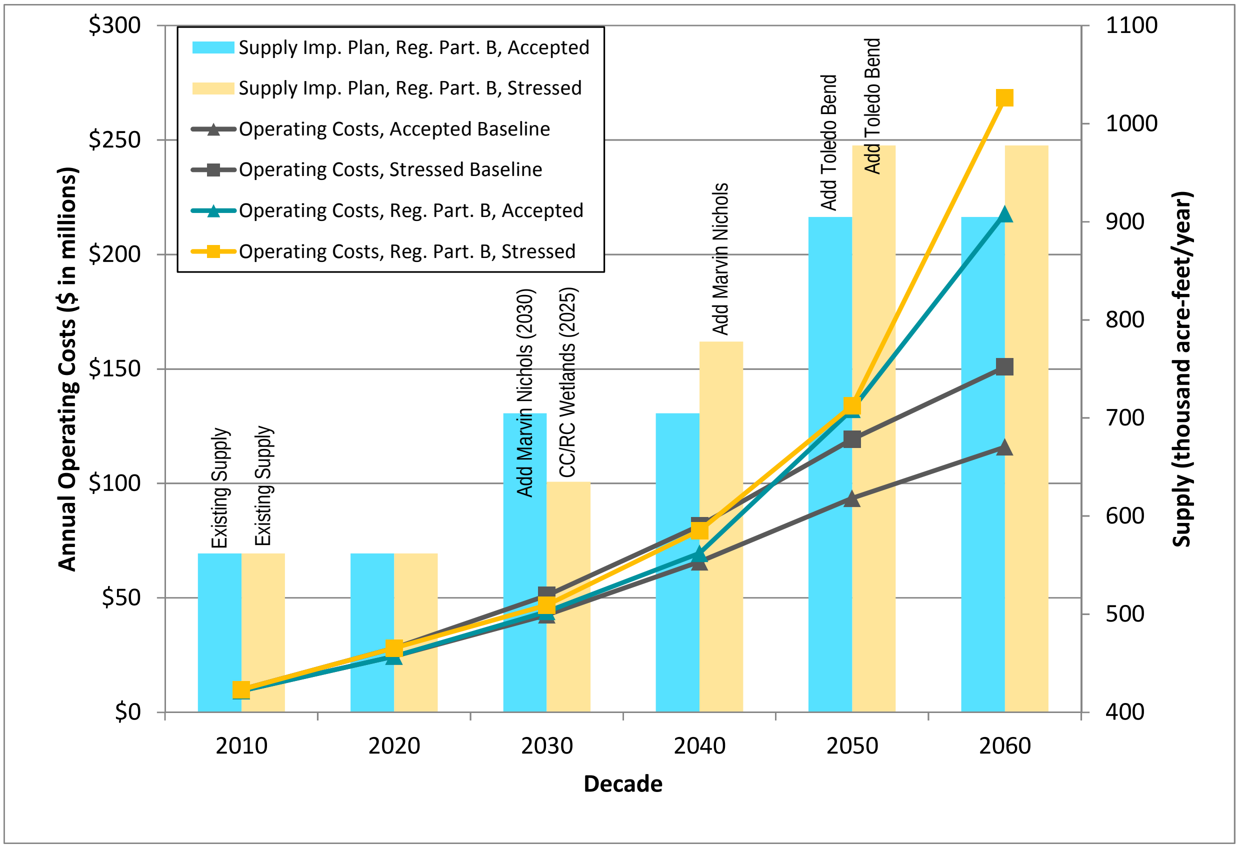


Figure 5.19 – Annual Operating Costs, Regional Partnerships Portfolio, Plan B

5.4 Decision Tree

The implementation plans described above in Section 5.3 provide the building block for an adaptive management plan, a decision tree that can be used by TRWD decision makers to answer questions such as:

- What is the next preferred water management strategy?
- When does the next water management strategy need to be connected to the TRWD water supply system?
- When does TRWD need to begin developing the next water management strategy?
- If conditions change and a strategy is no longer viable, what is the next best alternative?
- When must the decision be made to substitute the existing plan for new strategies?

A detailed decision tree was built for the Accepted Projections Scenario and is available in Appendix G. A separate decision tree is not necessary for the Optimistic Projections Scenario because no additional water supply is needed in the 50-year planning timeframe if demand grows according to this scenario. Section 5.4.2 describes modifications needed to the decision tree under the Stressed System Scenario.

This decision tree does not include every possible future scenario, decision point, or alternative branch because there are infinite possibilities. Instead, the most likely and the recommended paths are included. Two primary decision triggers were used:

1. Yes/No decision to prioritize the timing of a major regional water management strategy over the recommended TRWD implementation plan. As stated earlier, TRWD is committed to partnering with other water suppliers to develop large regional supplies. This decision point does not question whether or not TRWD will partner with other suppliers, instead it questions the *timing* of when those strategies need to be developed. Under almost every possible future scenario, at least one major regional water management strategy is recommended for TRWD; this decision trigger would only accelerate the timing of that strategy.

2. Project Viability – the decision tree recommends alternate strategies should any recommended implementation path become unfeasible.

5.4.1 Recommended TRWD Water Supply Plan

It is recommended that TRWD implement water management strategies based on the Accepted Projections Scenario. The recommended TRWD water supply plan, based on the detailed decision tree in Appendix G, is shown in Figure 5.20 below. This section also describes the plan in narrative form. The recommendations from the decision tree are as follows:

- If demand, supply and power cost trends follow the Optimistic Projections Scenario, develop the No Regrets strategies, which include *Conservation, EXFLO, Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits* (i.e. “CC/RC Wetlands”), and *Unpermitted Firm Yield in Cedar Creek and Richland-Chambers Reservoirs* (i.e. “CC/RC Firm”). Though the additional supply is not needed until after 2060, it is recommended that the permits for these strategies be secured without delay because of their very low cost, low risk, and benefits to TRWD reliability and operational cost. However, if trends follow the Optimistic Projections Scenario, TRWD can delay building infrastructure to convey these sources until 2060.

- If demand, supply and power cost trends follow the Accepted Projections Scenario, develop the No Regrets strategies now, followed by the necessary transmission system by 2030. Conservation should be an on-going strategy. At the latest, develop EXFLO and CC/RC Wetlands permits by 2030 (including a new pipeline sized to carry CC/RC Wetlands permit water and CC/RC Firm permit water and Lake Tehuacana supply), followed by CC/RC Firm permits by 2040.

- **Decision Point 1**: Were the No Regrets strategies successfully developed?
    - If No Regrets strategies were successfully developed, it is recommended that TRWD continue to develop the Low Cost portfolio of strategies.

- **Decision Point 2**: Should TRWD prioritize the timing of a major regional water management strategy over the recommended TRWD implementation plan?

    - If yes, develop Marvin Nichols Reservoir and its transmission system to Lake Bridgeport by 2045 and Lake Tehuacana, without a new pipeline since the additional pipeline added for CC/RC Wetlands and CC/RC Firm will be sized to also convey Lake Tehuacana supply, by 2055. **(Branch 1)**

    - If no, develop Temple Reservoir and its transmission system to Lake Bridgeport by 2045 and Lake Tehuacana, without a new pipeline since the additional pipeline added for CC/RC Wetlands and CC/RC Firm will be sized to also convey Lake Tehuacana supply, by 2055. If Temple Reservoir and/or Lake Tehuacana development is not possible, Marvin Nichols should be used as a substitute strategy for Temple Reservoir and Lake Ringgold as a substitute for Lake Tehuacana. **(Branch 2)**

o If No Regrets permitting strategies are not successfully developed, it is recommended that TRWD develop the Low Risk portfolio of strategies because the timeframe for developing new supply will be more compressed and because the unsuccessful development of the lowest risk strategies signals that the risk of developing all other strategies has also grown and TRWD should place priority on their lowest risk options.

- **Decision Point 2**: Should TRWD prioritize the timing of a major regional water management strategy over the recommended TRWD implementation plan?

    - Even if the answer to this decision point is yes, there is not sufficient time to develop a major regional water management strategy by 2030, when new supply is required to maintain system reliability. (The lowest risk major regional strategy is Toledo Bend Reservoir.)

    - If no, develop Lake Ringgold and its transmission system to Lake Bridgeport by 2030. Next develop Lake Tehuacana and a new pipeline to Lake Benbrook by 2035 *and* Toledo Bend Reservoir and its transmission system to Lake Benbrook . Development of the Lake Tehuacana and Toledo Bend projects will be concurrent so the transmission systems should be combined. **(Branch 3)**

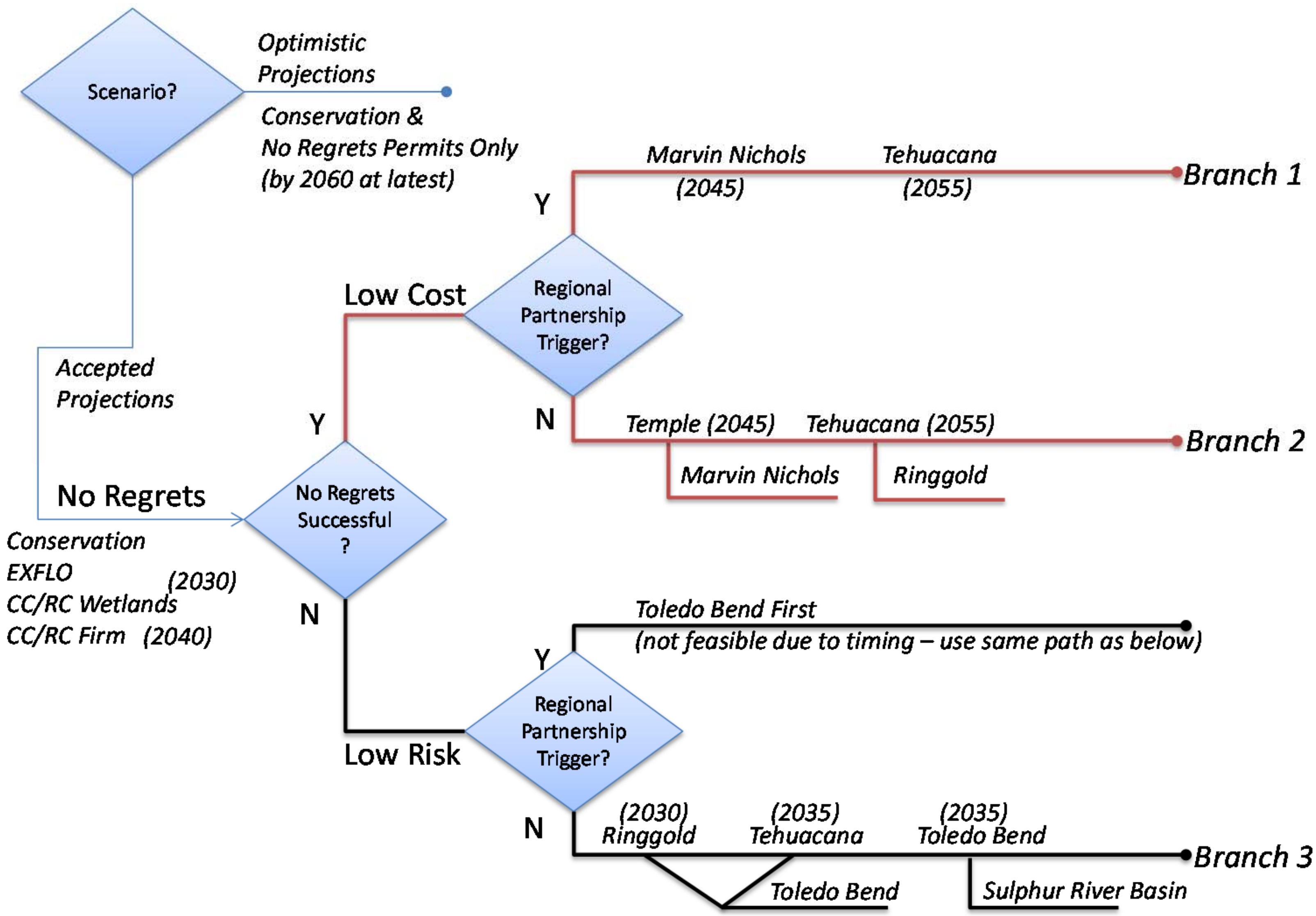


Figure 5.20 – Recommended TRWD Water Supply Plan

The detailed decision tree in Appendix G specifies several other possible paths TRWD could take to developing water management strategies. It also specifies the year by which decisions must be made to change paths should individual strategies become unviable. This section does not provide a narrative of all those possible decision points and the reader is instead directed to Appendix G.

5.4.2 Recommended Stressed System Scenario TRWD Water Supply Plan

A separate decision tree was not created for the Stressed System Scenario because it is nearly identical to the Accepted Projections Scenario decision tree. However, should TRWD demands grow, supplies diminish, and power costs grow as predicted in the Stressed System Scenario, some modifications are required.

- Branch 1 – accelerate the No Regret strategies by 5 years, which is feasible based on their implementation schedules. The timing of Marvin Nichols Reservoir and Lake Tehuacana are not significantly altered.
- Branch 2 – accelerate all strategies by by 5 years, which is feasible based on their implementation schedules. The system simulation modeing showed that some strategies need to be accelerated by five years while others may not need to be. To be conservative, a five year acceleration is recommended for all strategies..
- Branch 3 – replace development of Lake Ringgold in 2030 with development of Lake Tehuacana by 2025. Lake Ringgold and Toledo Bend would then be developed in 2035 under this scenario, instead of Lake Tehuacana and Toledo Bend by 2035, as recommended in the Accepted Projections scenario.

It is recommended that TRWD track key indicators as recommended in Section 7 to determine if these modifications, or additional modifications, are needed to the recommended TRWD water supply plan.

Section 6 – Financial Impacts

Each Implementation Plan described in Section 5 develops new water supplies so that the TRWD water supply system meets minimum reliability standards. Though system water supply reliability is not a differentiator between implementation plans, financial performance is. This section describes the financial impact of each of four implementation plans on TRWD customers using the metrics of capital cost, annual cost, and the resulting impact on customer rates. The recommended implementation plans are shown below in Figure 6.1 (the recommended TRWD water supply plan) as "branches" of the decision tree.

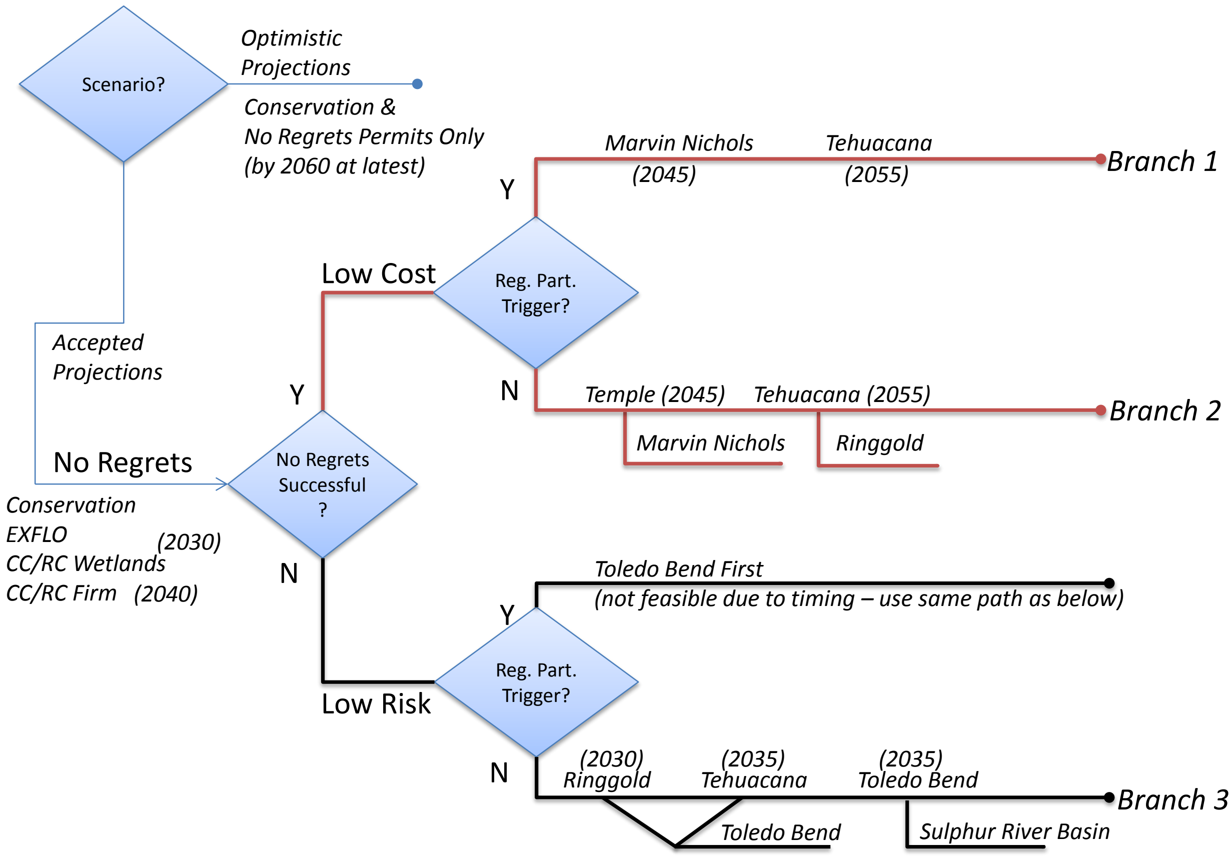


Figure 6.1 – Recommended TRWD Water Supply Plan

Financial impacts can be quantified using several metrics: capital cost, annual cost, present worth (i.e. life-cycle cost) value/cost, unit cost during the repayment of debts issued for project development, unit cost after the retirement of those same debts, levelized costs, or impact on customer water rates. The scope of this analysis is limited to calculating capital cost, annual cost, and the impact on TRWD customer rates. However, a description of potential metrics is included here along with some recommendations for further analysis:

- Capital Costs – the cost of developing (planning, design, and construction) each water management strategy in 2012 dollars. Each implementation plan consists of several water management strategies developed over the course of the 50-year planning horizon. Cumulative capital cost is provided in this report for each of the branches in Figure 6.1, but this metric should be used with caution when comparing the plans because each plan differs in terms of how long it maintains TRWD reliability beyond the 50-year planning horizon. In other words, ‘Plan X’ (an example only) may require an additional water management strategy by 2065 while Plan Y may provide system reliability until 2080. This is therefore an incomplete picture of the system life cycle cost.

- Annual Costs – quantified in 2012 dollars as the annual debt service payments, maintenance costs, and average annual operating costs (predominantly pumping costs) over the 67 years of historical hydrology at a future demand level (2020, 2030….2060). A comparison of annual costs provides a more complete picture of the financial impact at any given future year, but like cumulative capital cost, it fails to give a complete picture of the system life cycle cost and also suffers from being limited to the 50-year planning horizon.

- Unit Cost – the annual cost divided by the available water supply, calculated both during the period of debt repayment for debt issued during project development, and after the retirement of those same debts, when annual costs are only operations and maintenance. Unit costs are useful for comparing individual water management strategies and constructing water supply portfolios, using available water supply as the denominator. Unit costs are also one of the primary cost outputs in the Texas Water Development Board’s State Water Plan and Regional Plans (e.g. Region C Water Plan), so calculating unit costs facilitates comparison to the regional water plan results. However, they do not provide a useful comparison if the denominator is equal to the actual water deliveries needed to meet demands, as calculated by the IWSP System Simulation Model, because all implementation plans deliver essentially the same quantity of water, though at different costs. So the denominator (supply) is constant and can be eliminated, leaving only a comparison of annual costs.

- Levelized Cost – the annual cost divided by the water supply actually delivered (as opposed to the reliable supply available). This method provides a useful comparison of individual water management strategies and is useful in constructing water supply portfolios. Though not within the scope of this study, levelized cost comparison can be built using the information and tools developed in this study.

- Rate Analysis – calculation of the impact on future TRWD customer water rates. A rate analysis is a useful comparison. Though it also provides an incomplete picture of the system life cycle cost, it provides information of critical importance to TRWD customers, and at a timeframe of sufficient length for comparison and decision making.

- Present Worth Analysis – analysis of capital and annual costs over a defined period (i.e. 100 years), brought to a present value for comparison. Though a present worth analysis was not included in the IWSP scope of services, we recommend that TRWD supplement the rate analysis with a present worth (i.e. life-cycle cost) analysis.

This section describes the capital costs, annual costs, and the financial impact of each of four implementation plans on TRWD customers in terms of their impact on customer rates. This information is provided for each implementation plan shown on Figure 6.1 for each of the three following scenarios:

1. Accepted Projections Scenario:
   a. 2011 Region C based demand projections
   b. No change to historic flows or evaporation rates
   c. Use current power cost projections, as developed during the Integrated Pipeline Project planning phase by J. Stowe & Co. (included here as Appendix H).
2. Optimistic Projections Scenario:
   a. Demand projection based on extrapolation of recent trends
   b. No change to historic flows or evaporation rates
   c. Power cost projections increasing at a rate 25% less than current projections
3. Stressed System Scenario:
   a. 2011 Region C based demand projections
   b. -15% of historical flows and +15% of historical evaporation
   c. Power cost projections increasing at a rate 25% greater than current projections

6.1 Parameters and Definitions

All capital and annual cost numbers represent March 2012 dollars; they are not inflated to represent costs at the anticipated time of implementation. Annual operating costs are calculated only at each decade (2020, 2030…2060) because demand projections are made on a decadal level. Operating costs at intermediate years are linearly interpolated. Annual costs include annual debt service payments (assuming a 30-year debt repayment period), maintenance costs, and average annual pumping costs.

As noted above, cumulative capital cost and annual costs should be used with caution when comparing implementation plans because each plan differs in terms of how long it maintains TRWD reliability beyond the 50-year planning horizon. In other words, ‘Plan X’ (an example only) may require an additional water management strategy by 2065 while Plan Y may provide system reliability until 2080. This is therefore an incomplete picture of the whole system life cycle cost.

The following assumptions were used:

- Planning costs are assumed to be 15% of the design cost and are attributed to the year in which planning begins.

- Design costs are assumed to be 10% of construction cost and are attributed to the year in which design begins.
- Construction costs are the difference between Total Capital Cost and (Design Costs + Planning Costs) and are attributed to the mid-point of construction.
- Annual Debt Service and Annual O&M begin at the end of construction.

It is important to note that except for "Pumping Costs", all costs should be *added* to existing TRWD system costs and debts; pumping costs are different in that they represent the cost of operating the entire (existing and future) TRWD system.

A rate analysis provides information of critical importance to TRWD customers, at a timeframe of sufficient length for comparison and decision making. This rate analysis should only be used for high-level planning purposes because the underlying data is not precise enough to rely on the projected rates over a 50-year timeframe for detailed or short-term (e.g. annual) decision making. However, the information is useful for master planning and strategy development.

All results should be viewed through the lens of the following assumptions and constraints:

- Pumping Costs were calculated for the overall TRWD system in the IWSP System Simulation Model for each decade beginning in 2010 and ending in 2060. However, TRWD uses its customers' demand annual demand projections to make a projection of each year's pumping costs as input to the TRWD budget. Those estimates made for budgeting differ from the system simulation model because the budget numbers are based on more detailed, up-to-date demand and weather information while the system simulation model estimates pumping costs based on 50-year demand projections and historic hydrology. This difference explains some of the non-intuitive results between the years 2010 and 2020.
- Existing bond debt service, and upcoming, planned bond debt service are included in the rate model. All TRWD system operations costs and District income is included.
- Proposed debt issuances for the Integrated Pipeline Project and the Cedar Creek Wetlands project are also included in the rate model. It is assumed that bonds needed to pay for the Cedar Creek Wetlands project are secured in 2016.
- Timing of debt issuance for new water supply strategies follows the results shown in Section 6.1 above.
- The rate model calculates projected water use and the system water rate for seven customer classes: Fort Worth (in-district), Fort Worth (out of district), Arlington, Trinity River Authority, Mansfield, Other (in-district), and Other (out of district). The results presented below are based on the "Other (in-district)" customer class; they are

representative of all customer class results, which only vary by less than $0.02 when compared to the Other (in-district) results.[1]

6.2 Results

6.2.1 Accepted Projections Scenario

If demand, supply and power cost trends follow the Accepted Projections Scenario, it is recommended that TRWD implement the decision tree as shown in Figure 6.1. The cost breakdown for each branch of the decision tree is shown below in Tables 6.1 through 6.3 and in Figures 6.2, 6.4, and 6.6, all of which use the same extents on the vertical axis so that they can be more easily compared. Figures 6.3, 6.5, and 6.7 display projected system rates and costs for each of the three primary branches of the decision tree.

Branch 1

Branch 1 is the low cost implementation plan with a regional partnership project on the critical path. This plan includes securing the No Regrets Permits and construction of Marvin Nichols Reservoir and Lake Tehuacana.

Table 6.1a – Capital and Annual Cost Breakdown, Accepted Projections Scenario, Branch 1 (Low Cost implementation plan with a regional partnership project on the critical path)

Metric	Exflo+Wetlands+CC/ RC Firm+Tehuacana Pipeline		Marvin Nichols		Tehuacana (Reservoir Only)	
	Cost	Year	Cost	Year	Cost	Year
Total Capital Cost	$859,701,000	--	$1,695,867,000	--	$580,790,000	--
Planning Cost	$12,895,515	2018	$25,438,005	2026	$8,711,850	2044
Design Cost	$85,970,100	2022	$169,586,700	2035	$58,079,000	2049
Construction Cost	$760,835,385	2027	$1,500,842,295	2040	$513,999,150	2051
Annual Debt Service	$62,456,000	2030	$123,203,000	2045	$42,194,000	2055
Annual O&M	$8,778,000	2030	$15,154,000	2045	$994,000	2055

*The costs for the Richland-Chambers and Cedar Creek Wetlands Full Yield strategy are combined with the costs for RC/CC Additional Firm Yield. The cost estimate includes a pipeline with sufficient capacity to carry the total yield from the RC/CC Wetlands Full Yield, RC/CC Unpermitted Firm Yield, and Lake Tehuacana.

[1] TRWD will have only one rate class beginning in 2022 when the initial 40-year term of the 1982 Amendatory Contract lapses.

Table 6.1b – Capital Cost Summary, Accepted Projections Scenario, Branch 1

Metric	Cost ($ Millions)
Planning Cost	$47.0
Design Cost	$313.6
Construction Cost	$2,775.7
Total Capital Cost	$3,136.4

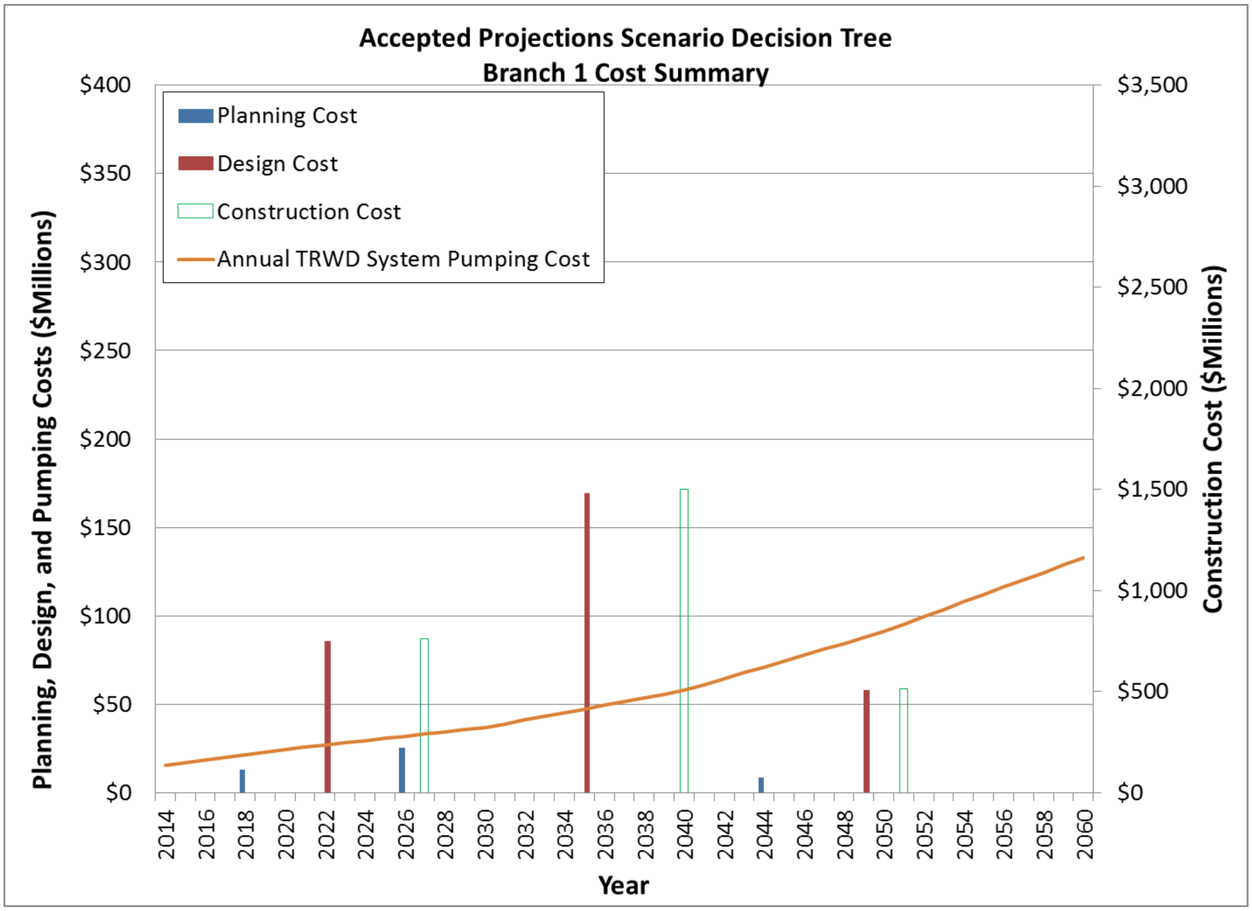


Figure 6.2 – Capital and Annual Cost Breakdown, Accepted Projections Scenario, Branch 1

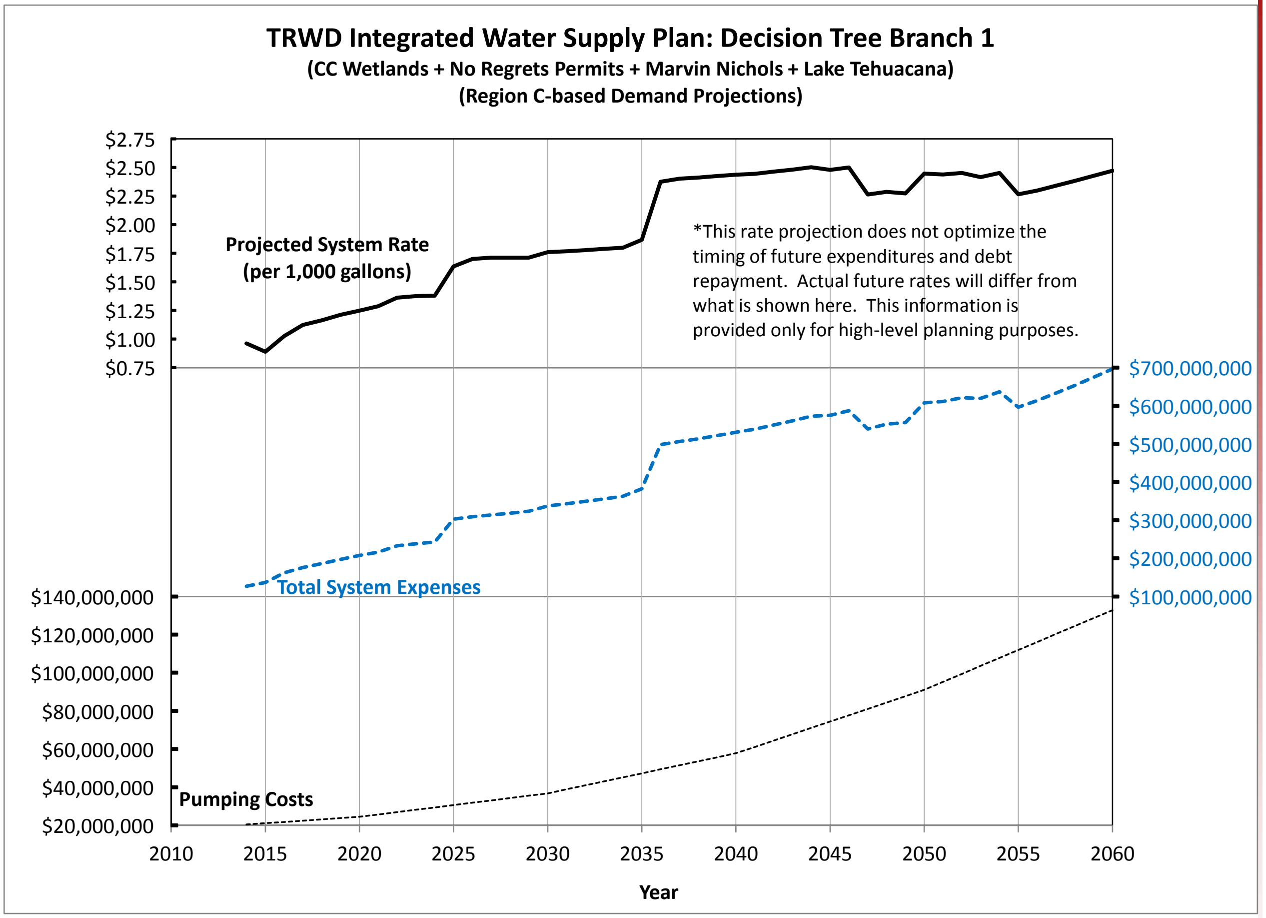


Figure 6.3 – Projected System Rate and Costs, Accepted Projections Scenario, Branch 1

Branch 2

Branch 2 is the low cost implementation plan, which includes securing the No Regrets Permits and construction of Temple Reservoir and Lake Tehuacana.

Table 6.2a – Capital and Annual Cost Breakdown, Accepted Projections Scenario, Branch 2 (Low Cost implementation plan)

Metric	Exflo+Wetlands+CC/ RC Firm+Tehuacana Pipeline		Temple Reservoir		Lake Tehuacana (Reservoir Only)	
	Cost	Year	Cost	Year	Cost	Year
Total Capital Cost	$859,701,000	--	$972,530,000	--	$580,790,000	--
Planning Cost	$12,895,515	2018	$14,587,950	2030	$8,711,850	2044
Design Cost	$85,970,100	2022	$97,253,000	2038	$58,079,000	2049
Construction Cost	$760,835,385	2027	$860,689,050	2041	$513,999,150	2051
Annual Debt Service	$62,456,000	2030	$70,653,000	2045	$42,194,000	2055
Annual O&M	$8,778,000	2030	$8,607,000	2045	$994,000	2055

*The costs for the Richland-Chambers and Cedar Creek Wetlands Full Yield strategy are combined with the costs for RC/CC Additional Firm Yield. The cost estimate includes a pipeline with sufficient capacity to carry the total yield from the RC/CC Wetlands Full Yield, RC/CC Unpermitted Firm Yield, and Lake Tehuacana.

Table 6.2b – Capital Cost Summary, Accepted Projections Scenario, Branch 2

Metric	Cost ($ Millions)
Planning Cost	$36.2
Design Cost	$241.3
Construction Cost	$2,135.5
Total Capital Cost	$2,413.0

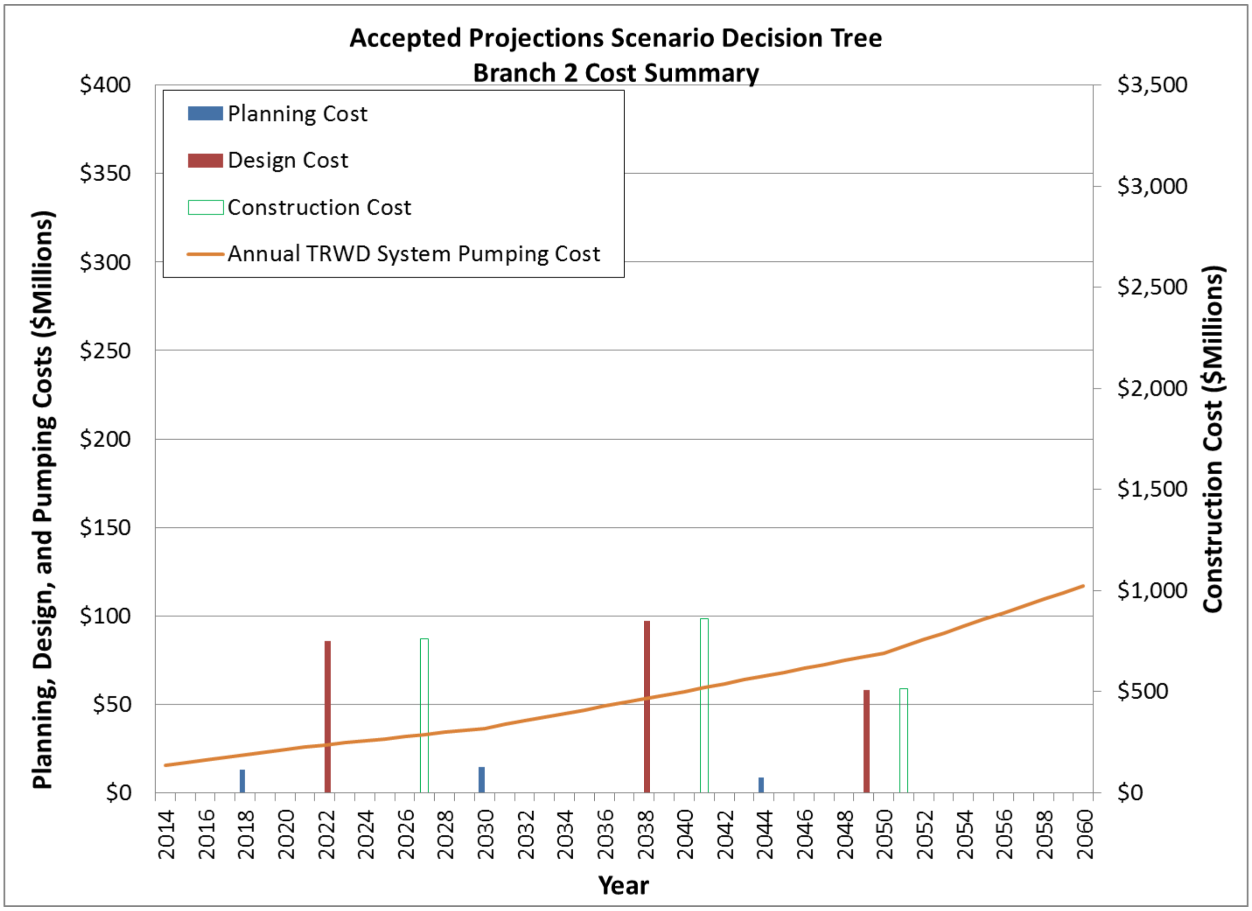


Figure 6.4 – Capital and Annual Cost Breakdown, Accepted Projections Scenario, Branch 2

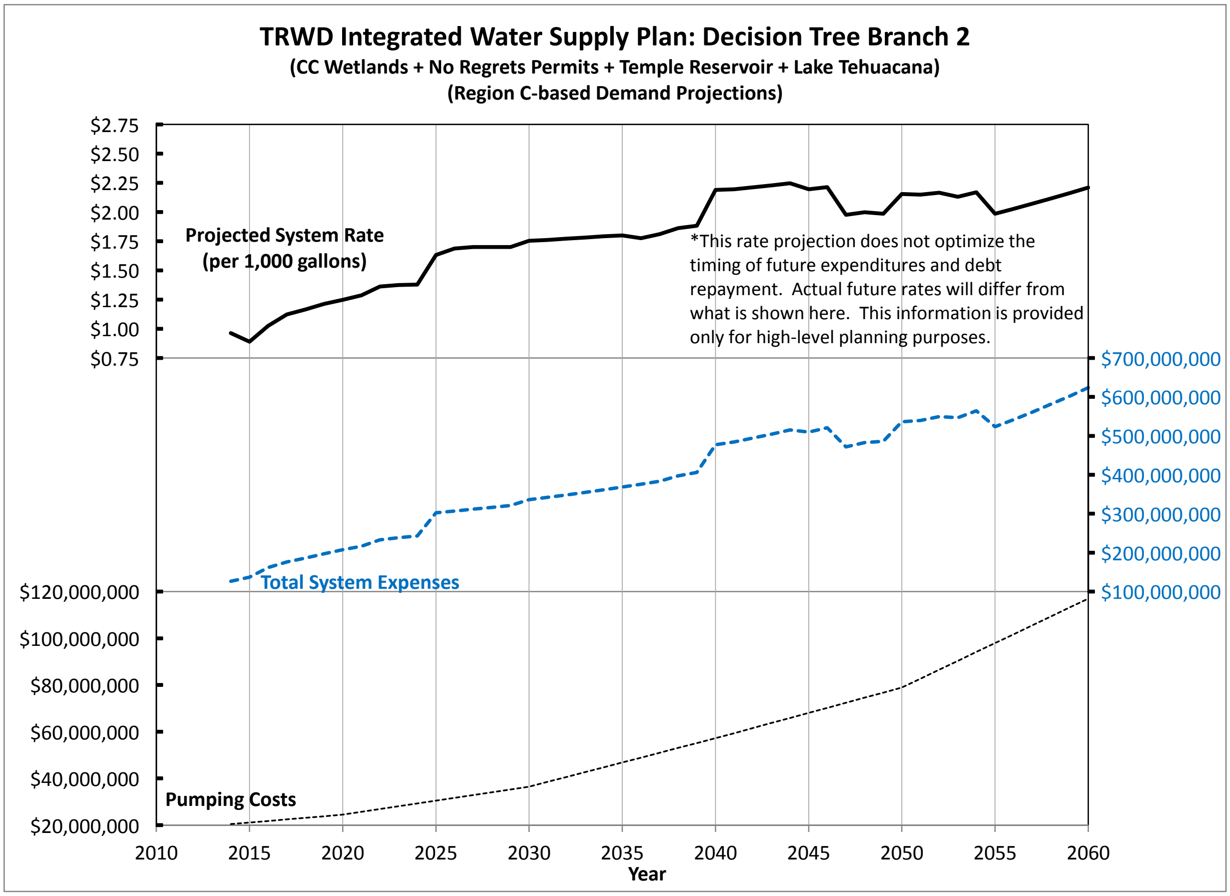


Figure 6.5 – Projected System Rate and Costs, Accepted Projections Scenario, Branch 2

Branch 3

Branch 3 is the low risk implementation plan. This plan is recommended if the District does not secure the No Regrets Permits. It includes construction of Lake Ringgold, Lake Tehuacana, and the Toledo Bend Reservoir transmission system.

Table 6.3a – Capital and Annual Cost Breakdown, Accepted Projections Scenario, Branch 3 (Low Risk implementation plan)

Metric	Lake Ringgold		Toledo Bend Reservoir + Lake Tehuacana	
	Cost	Year	Cost	Year
Total Capital Cost	$397,735,000	--	$3,553,016,000	--
Planning Cost	$1,988,675	2017	$17,765,080	2018
Design Cost	$39,773,500	2023	$355,301,600	2022
Construction Cost	$355,972,825	2026	$3,179,949,320	2030
Annual Debt Service	$28,895,000	2030	$258,123,000	2035
Annual O&M	$4,239,000	2030	$33,684,000	2035

Table 6.3b – Capital Cost Summary, Accepted Projections Scenario, Branch 3

Metric	Cost ($ Millions)
Planning Cost	$19.8
Design Cost	$395.1
Construction Cost	$3,535.9
Total Capital Cost	$3,950.8

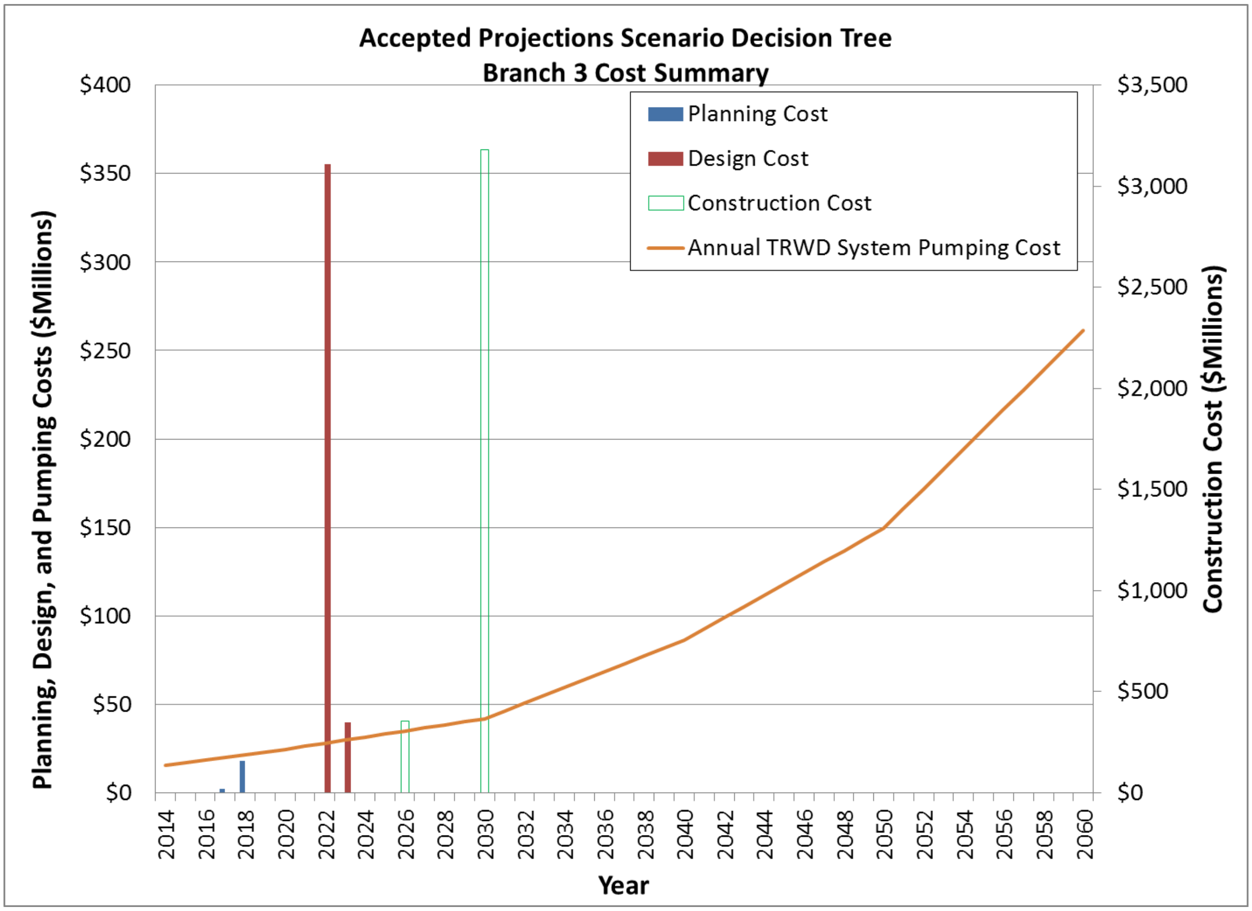


Figure 6.6 – Capital and Annual Cost Breakdown, Accepted Projections Scenario, Branch 3

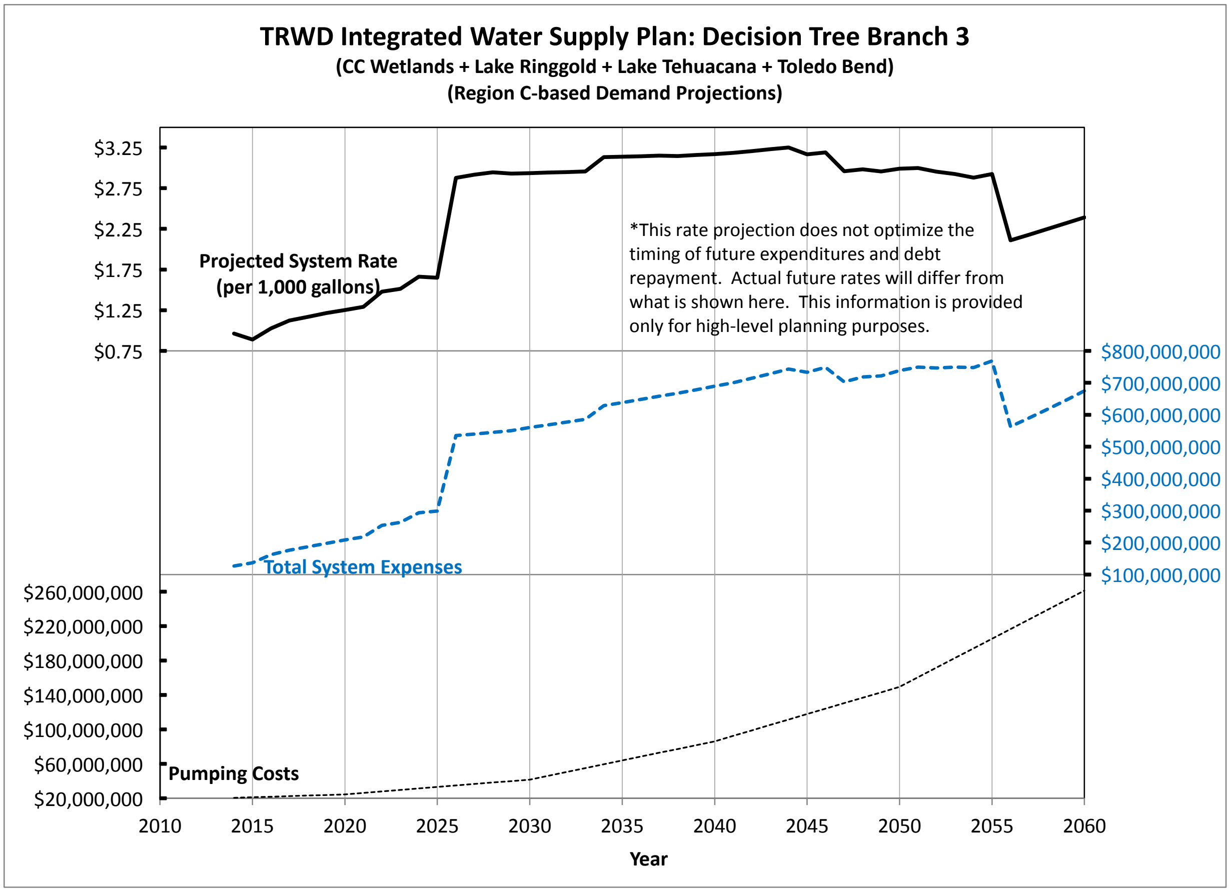


Figure 6.7 – Projected System Rate and Costs, Accepted Projections Scenario, Branch 3

6.2.2 Optimistic Projections Scenario

If demand, supply and power cost trends follow the Optimistic Projections Scenario, it is recommended that TRWD develop the No Regrets strategies, which include Conservation, EXFLO, Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (i.e. "CC/RC Wetlands"), and Unpermitted Firm Yield in Cedar Creek and Richland-Chambers Reservoirs (i.e. "CC/RC Firm"). Though the additional supply is not needed until after 2060, it is recommended that the necessary permits for these strategies be secured without delay because of their low cost, low risk, and because they add to TRWD reliability and lower TRWD operational costs. However, if trends follow the Optimistic Projections Scenario, TRWD can delay building infrastructure to convey these sources until 2060. Therefore, this scenario would require no additional capital costs within the planning period for this study.

Figure 6.8 shows the cost breakdown for the Optimistic Projections Scenario. No capital costs for new supplies are required (i.e. no capital costs are required above and beyond the costs to operate and maintain the existing TRWD system), so the graph only shows pumping costs. Though not required for system reliability, the No Regret strategies can save pumping costs (and slightly increase reliability), so Figure 6.8 shows pumping costs with and without the No

Regret strategies. Figure 6.9 shows the projected system rate and costs for the Optimistic Projections Scenario.

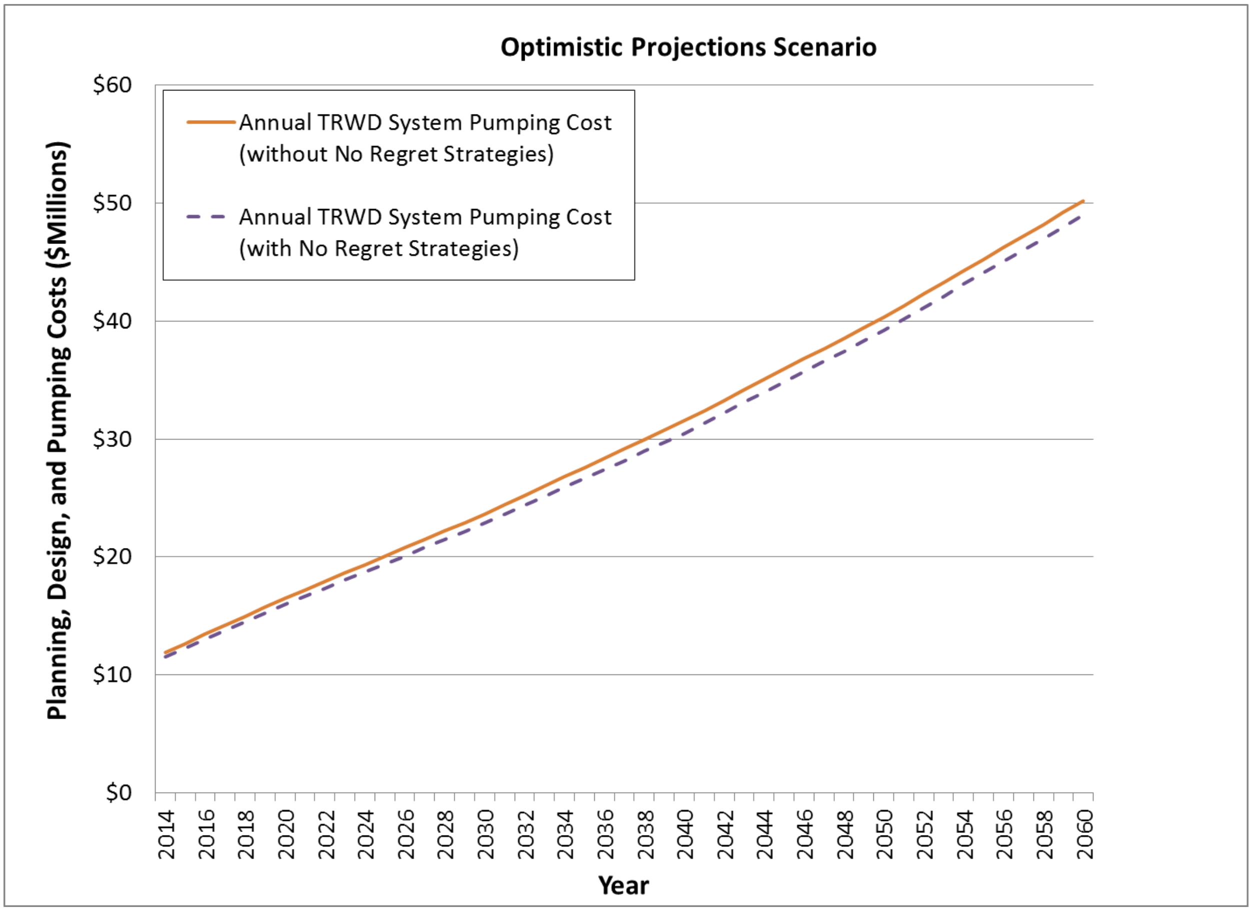


Figure 6.8 –Annual Pumping Costs, Optimistic Projections Scenario

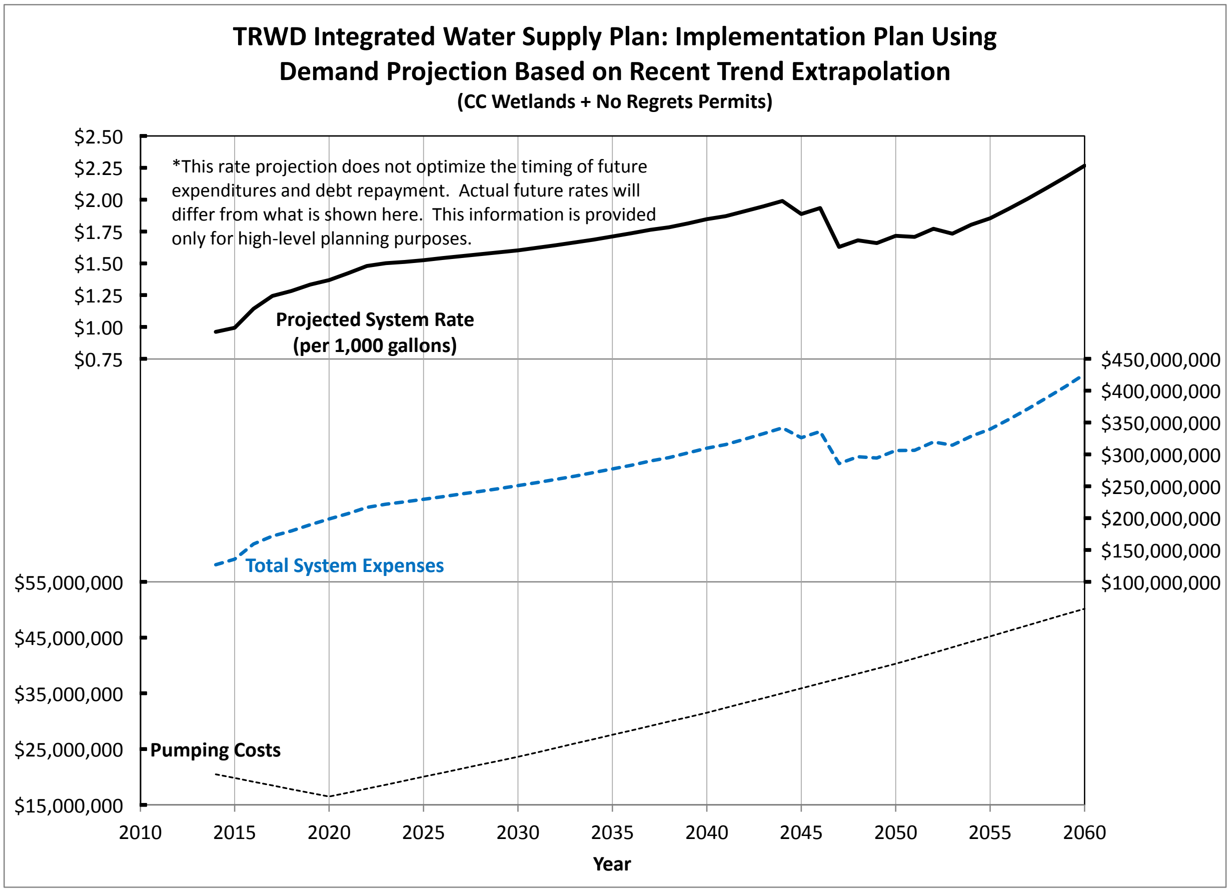


Figure 6.9 – Projected System Rate and Costs, Optimistic Projections Scenario

6.2.3 Stressed System Scenario

If demand, supply and power cost trends follow the Stressed System Scenario, it is recommended that the timing of project development be modified as explained in Section 5.4.2. The modifications to timing are not so significant that they warrant a separate rate analysis or summary of project costs; the financial impacts of the Stressed System Scenario are similar to the Accepted Projections Scenario and are therefore not included here.

6.2.4 Comparison of Projected System Rates

To simplify a direct comparison of the different impact on rates and costs, Figures 6.10 through 6.12 combine the cost information for the four primary branches of the decision tree. The “Implementation Plan Using Demand Projection Based on Recent Trend Extrapolation” line represents the lowest cost in all of the figures below because it is based on a projection of lower future demands, not because it represents a less expensive way to meet the same projected demands as the other options.

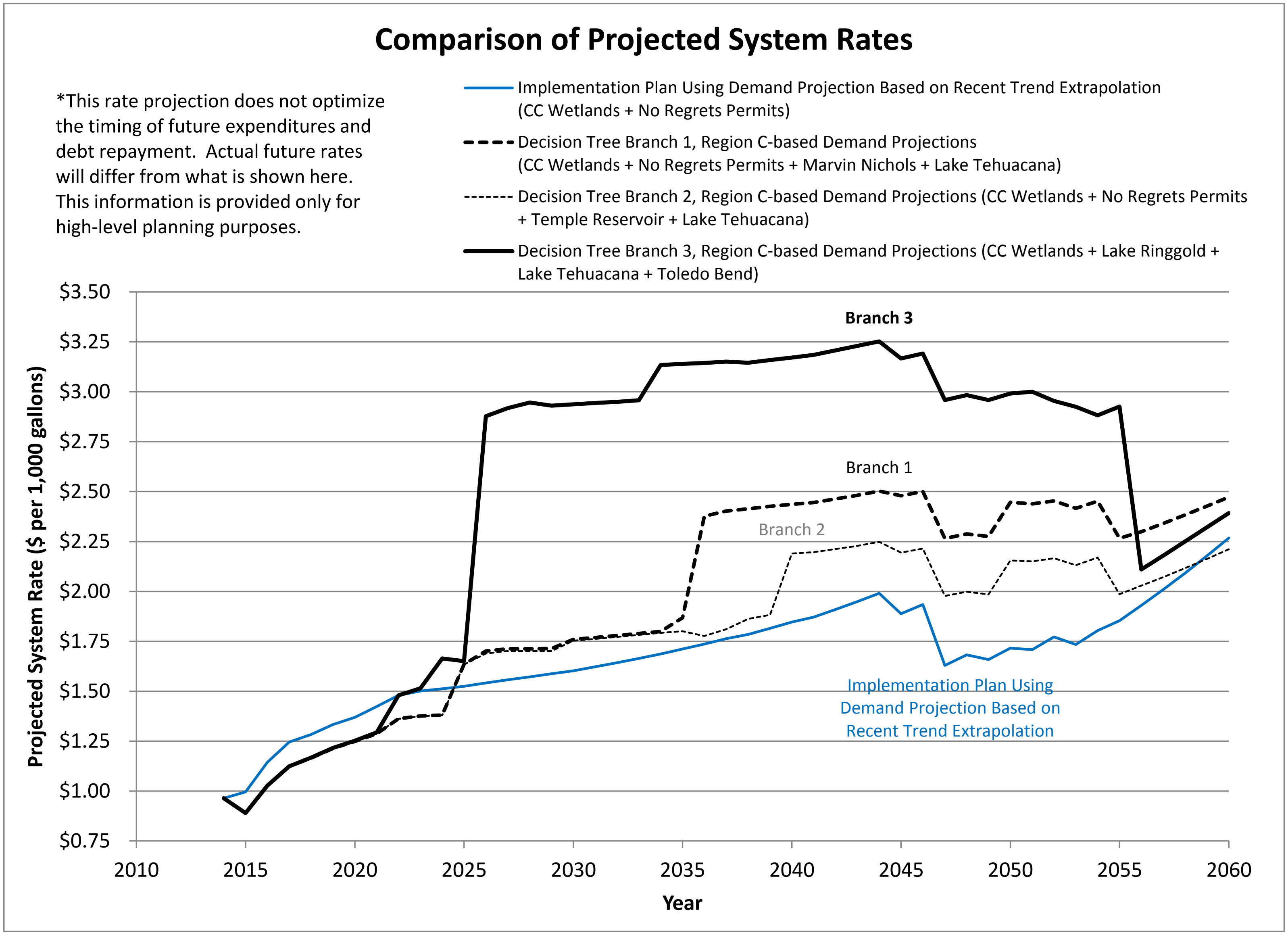


Figure 6.10 – Comparison of Projected System Rates

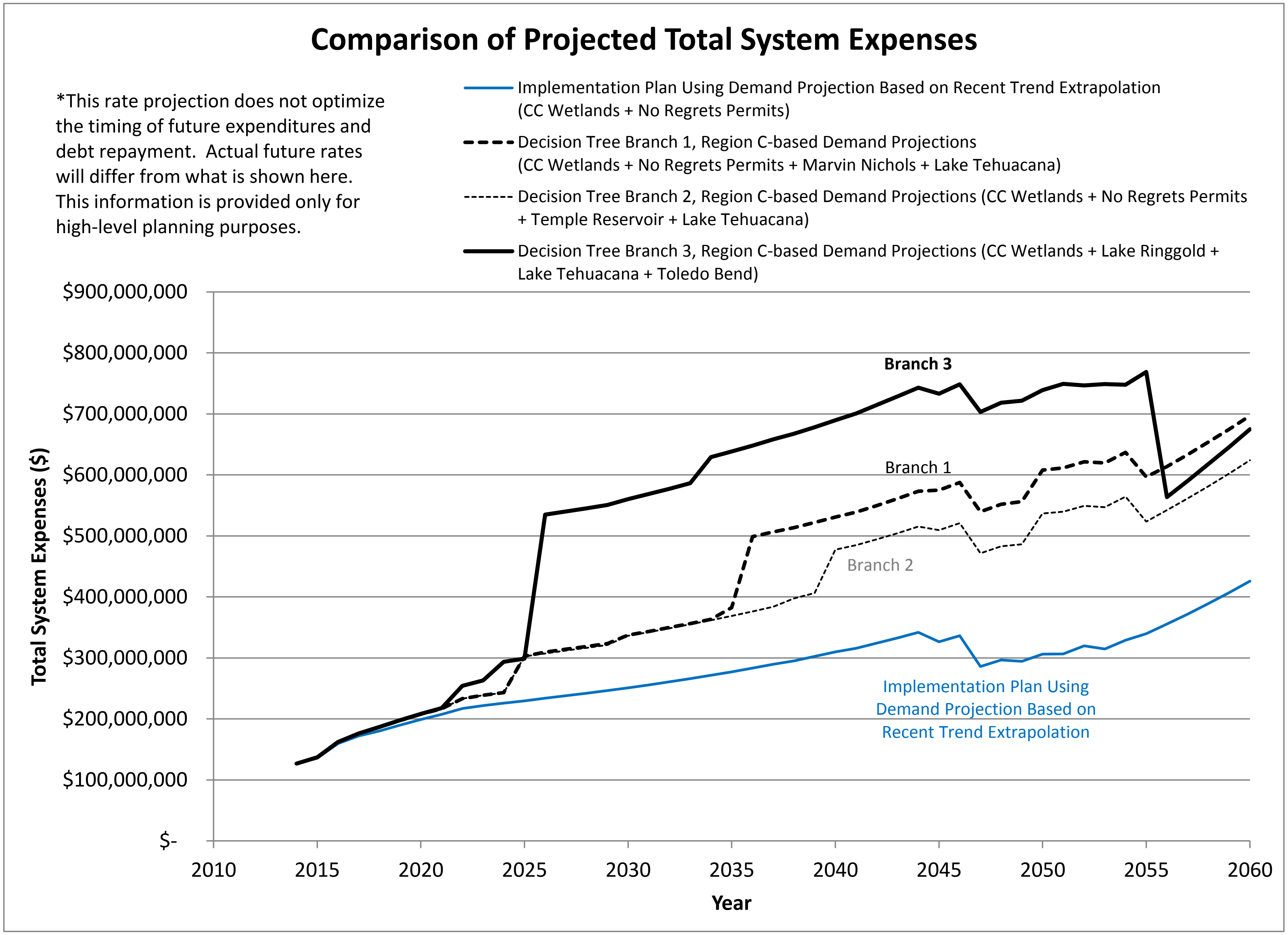


Figure 6.11 – Comparison of Total System Expenses

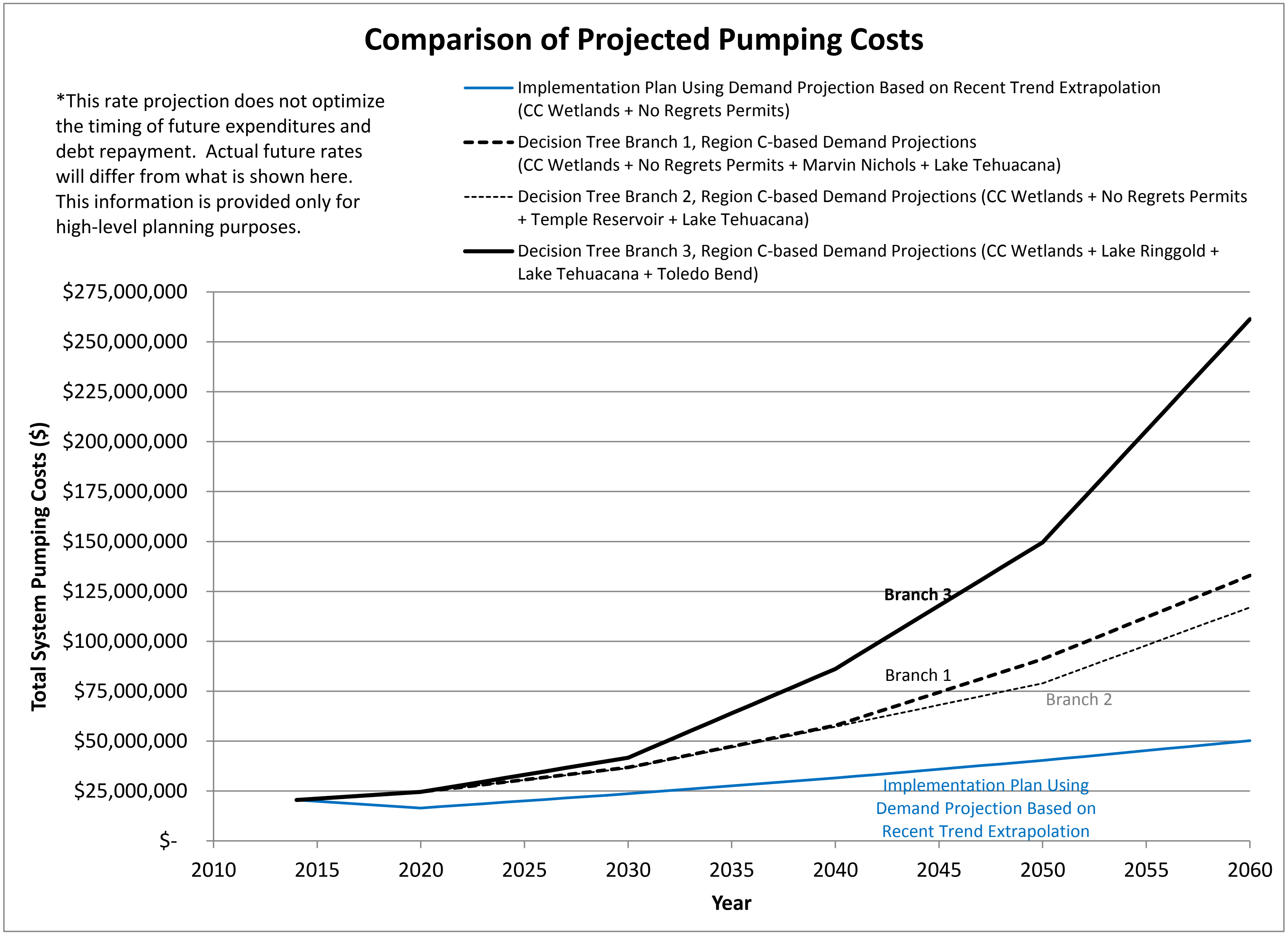


Figure 6.12 – Comparison of Projected Total System Pumping Costs

Section 7 – Moving Forward: Tracking and Logging Key Indicators

The decision tree presented in this report provides guidance toward a preferred plan of future water supply investments based on a comparative analysis of cost, risk, and reliability. The plan also includes alternative pathways toward meeting future supply needs, should recommended investments become infeasible or be abandoned for any reason.

The recommended timing of the projects is contingent upon many things. Most importantly, the timing is based on projected water demands. If demand grows at rates slower or faster than those used in this analysis, project phasing can be adjusted accordingly, or alternative solutions may become more appropriate.

It is impossible to forecast with certainty what demand levels will be in fifty years. Likewise, it is impossible to forecast economic conditions or hydrologic trends. The decision tree is based on projections of possible future conditions, but it must be adapted as conditions change. In lieu of forecasting unpredictable future trends, the Integrated Water Supply Plan proposes tracking trends as part of the implementation of the plan. These trends should be reviewed periodically, and the decision tree or other portions of the plan adjusted as needed. It is recommended that this update occur at least every five years, and would involve updating the analyses in this study as needed and revising the decision tree according to the new results.

The following list offers guidance on the hydrologic, socio-economic, and institutional trends that should be tracked as part of the implementation of this plan. The accompanying tables are templates for updating this plan on a periodic basis, and should be viewed as a "living record" of TRWD's water supply environment over the coming decades. The purpose of tracking and logging the factors that influence the system evolution is so that they can be consolidated in this single document to provide additional support and documentation for future decisions. Ultimately, decisions should be based on the decision tree and the conditions that are tracked through the planning period. While conditions may affect the timing of decisions in the decision tree, no attempt is made here to correlate the tracked information with the need to accelerate or decelerate decisions. Rather, it is expected that both the decision tree (with its manageable permutations) and the tracked information will work in tandem to support decisions.

The recommended factors to track, described on the following pages with accompanying tables for logging, are the following:

- Annual Demand
- Seasonal Demand Peaking
- Storage Capacity
- Climate Trends

- Effectiveness of Conservation Measures
- Effectiveness of Drought Response Measures
- Regional Agreements and Decisions by Other Utilities
- Energy Prices
- Instream Flow Regulations
- Status of Project Implementation

7.1 Annual Demand

System-wide water demands should be tracked each year and compared against projections. Observed trends may be factored into new projections as necessary, and/or compared against updated estimates from Region C or other sources.

Year	Actual Demand (mgd)	Region C Forecast from 2011 (mgd)	Recent Trend Extrapolation used in 2013 IWSP (mgd)	Updated Region C Demand Forecast (mgd)	Other Updates or Trend Analyses (mgd)
2014		381.2	347.5		
2015		397.6	355		
2016		407.1	362.5		
2017		416.6	370		
2018		426.1	377.5		
2019		435.5	385		
2020		445	392.5		
….					
2030		518.4	428.1		
….					
2040		591.3	460		
….					
2050		671.8	488.3		
….					
2060		766.5	515.1		

7.2 Seasonal Demand Peaking

Each year the differences in seasonal demands should be logged. This will help assess potential transmission capacity constraints, as well as possible effectiveness of conservation measures or shifts in water use sectors (from residential to commercial, for example). It is recommended that demand peaking be tracked for each Water Treatment Facility (or customer), though the table below is offered as a summary of total demand throughout the system (and can be copied for each individual plant if desired). The Peaking Factor is defined for this purpose as the highest monthly average demand divided by the lowest monthly average demand. The table includes columns for maximum and minimum daily demands as well, but these are less likely to affect assessment of transmission capacity due to the buffering storage in terminal reservoirs and balancing reservoirs.

Year	(a): Maximum Month Demand (mgd)	(b): Minimum Month Demand (mgd)	Seasonal Peaking Factor (a/b)	Reference: Max Day Demand (mgd)	Reference: Min Day Demand (mgd)
2014					
2015					
2016					
2017					
2018					
….					
2020					
….					
2030					
….					
2040					
….					
2050					
….					
2060					

7.3 Storage Availability

The water supply reliability estimates presented in this study are based on current projections of reservoir sedimentation rates for TRWD's existing reservoirs and available historical hydrology. It is recommended that bathymetric studies be done on each reservoir (existing and any new reservoirs that are added or built into the system) on a ten-year periodic basis to ascertain if supply availability may be restricted by declining storage at rates other than those upon which the recommendations in this report are based.

Decade	Cedar Creek		Richland Chambers		Bridgeport		Eagle Mountain		Lake Worth	
	Projected Capacity (AF)	Actual Capacity (AF)	Projected Capacity (AF)	Actual Capacity (AF)	Projected Capacity (AF)	Actual Capacity (AF)	Projected Capacity (AF)	Actual Capacity (AF)	Projected Capacity (AF)	Actual Capacity (AF)
2020	633,265		1,085,918		357,191		176,707		31,375	
2030	625,585		1,065,268		352,669		174,044		30,315	
2040	617,905		1,044,618		347,895		171,381		29,206	
2050	610,225		1,023,968		343,121		168,719		28,096	
2060	602,545		1,003,318		338,347		166,056		26,987	

7.4 Climate Trends

Along with demand uncertainty, climate uncertainty represents one of the greatest risks in future water supply planning. It is recommended that climate trends be evaluated on a five-year basis to help determine whether supply availability is more or less likely to become constrained in any way, thereby necessitating adjustments in the timing of new supply sources. The table below offers typical climate indicators, as well as system-specific impacts of climate conditions, both of which can guide future decisions. It is recommended that the indicators be logged as 5-year averages, unless otherwise indicated. The Table is shown for Richland-Chambers and Cedar Creek Reservoirs, but similar tables should also be developed for the West Fork reservoirs, and any new reservoirs that are integrated into the TRWD system.

Year	Annual Runoff into Cedar Creek (5-year avg. AFY)	Annual Runoff into Richland Chambers (5-year avg. AFY)	Annual Precipitation (5-year Avg. inches)	Annual Average Temperature (5-year Avg. degrees)	Annual Average Lake or Pan Evaporation (5-year Avg. inches)	Was supply constrained at less than permitted capacity?**
Historical						
2015						
2020						
2025						
2030						
2035						
2040						
2045						
2050						
2055						
2060						

**The final column should indicate whether or not the permitted capacity was not available in any year due to lack of water in the reservoir.*

7.5 Effectiveness of Conservation Measures and Drought Response Measures

Although this may in some ways overlap with demand tracking, it is recommended that TRWD specifically track indicators of the effectiveness of programs to increase water conservation in the region. Unlike other key factors presented in this study, it may not be necessary to measure and record data on conservation on a regular basis, but rather in response to any specific conservation measures that are enacted, using methods of measurement tailored to the desired effects.

It is recommended that this tracking take place as part of regular updates to the TRWD Strategic Water Conservation Plan. This should include listings of specific conservations measures, expected impact on water demand by use sector, and ultimately, the documented effectiveness of the measures.

It is also recommended that TRWD track the effectiveness of drought response measures, when employed, by tracking the percentage reduction in demand by customer and overall system.

7.6 Regional Agreements and Decisions by Other Utilities

TRWD has actively pursued cooperative agreements with other regional water providers. In addition, other water providers are exploring supply availability of sources in which TRWD has expressed interest. Such coincident interest could create opportunities for shared infrastructure (similar to the IPL), or possibly create conflicts due to mutual interest in a finite source. Even though the formalization of such agreements will be broadly recognized and understood, this report can provide a mechanism for documenting them and considering their implications on future water supply decisions. They do not lend themselves to a table format, but this section can serve as a platform in which to document these decisions.

7.7 Energy Prices

The operating cost estimates provided in this report are based on assumed projections of energy prices, as shown in Appendix I. The analysis did not factor in the complexities of tariff structures, nodal markets, etc. Although changes in energy costs could affect all supply alternatives in some way,, nodal markets, alternative energy sources in the future, and the significant differences in energy needs between strategies could affect the alternatives differently. It will be prudent to track annual energy costs in the table below, and to possibly extend this analysis to individual alternatives if their projected markets would exhibit variability. It is recommended that the costs be tabulated annually, and that trend analysis be conducted every five years.

Year	Projected Energy Cost ($/mWh)	Actual Energy Cost ($/mWh)	Total Water Pumped	Annual Cost ($)
2014	65.1			
2015	67.1			
2016	68.6			
2017	74.8			
2018	77.9			
….	80.8			
2020	81.4			
….				
2030	103			
….				
2040	121.3			

Year	Projected Energy Cost ($/mWh)	Actual Energy Cost ($/mWh)	Total Water Pumped	Annual Cost ($)
….				
2050	139.6			
….				
2060	157.9			

7.8 Instream Flow Regulations

Texas is currently developing and implementing instream flow regulations for all Texas river basins. Currently these regulations only apply to proposed projects or new water rights. There is also a process in place for modifying and updating these regulations as more information becomes available. These and other similar regulations should be documented in this plan as they are implemented and updated, as well as their impacts on the affected supplies, permitted capacity, etc. If such regulations significantly reduce the yield of a water management strategy, adjustments in the phasing or selection of new sources may be warranted.

7.9 Projects Completed, Rendered Infeasible or Abandoned

Decisions concerning the implementation of this plan should be documented below. The status of every alternative should be monitored, and dates entered when decisions are made. While these decisions are likely to be broadly publicized and understood, the purpose of this section is to serve as legacy documentation in summary form.

Supply Source	Date Permits Submitted	Date Permits Granted	Date Funded	Date Construction Started	Date Completed and Online	Date Project Abandoned or Declared Infeasible	Notes
Lake Ringgold							
Temple Reservoir							
Lake Texoma							
Wright Patman							
Marvin Nichols							
Kiamichi River							
Columbia Reservoir							
Toledo Bend Reservoir							
Tehuacana Reservoir							
Cedar Creek / Richland Chambers Wetlands Expansion							
Cedar Creek / Richland Chambers Permit Increase							

Integrated Water Supply Plan
Appendix A-I

Buhman Associates, LLC

IN COOPERATION WITH: CDM Smith   Freese and Nichols

Appendix A
Water Management Strategy
Fact Sheets

TRWD Integrated Water Supply Plan
Introduction to Water Supply Strategy Fact Sheets

The Integrated Water Supply Plan is an integration of the discrete planning that has been done over many years by TRWD and its customers and identifies the new water supplies with the greatest potential benefit for water supply reliability. The IWSP is not an endpoint (i.e., a final comprehensive plan), but is rather a *platform* that will be constantly built upon by integrating new opportunities (e.g. local sources, reuse of treated wastewater effluent), technologies (e.g. aquifer storage and recovery, advanced conservation), and strategies (e.g. groundwater) with the plan presented here. This enables TRWD to innovate and maximize value for its customers.

The purposes of the Tarrant Regional Water District integrated Water Supply Plan are:

1. Integrate what have historically been independent planning efforts for new supply strategies.
2. Develop an implementation plan for the next 50 years that is adaptive and maximizes reliability.
3. Develop a 50-year implementation plan that minimizes the effect on customer rates.
4. Communicate the implementation plans to stakeholders.
5. Support integration of District planning with other regional water providers

The following water management strategies were analyzed in this plan and considered for inclusion in the final implementation plan:

- Conservation
- Unpermitted Firm Yield in Cedar Creek and Richland Chambers Reservoirs (often shortened to "Unpermitted CC/RC Firm Yield" or "CC/RC Firm")
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits (often shortened to "Unpermitted CC/RC Wetlands Yield" or "CC/RC Wetlands")
- Lake Columbia
- Excess Flow Optimization for Eagle Mountain Lake and Lake Benbrook (EXFLO)
- Kiamichi River
- Marvin Nichols Reservoir
- Lake Ringgold
- Lake Tehuacana
- Temple Reservoir
- Lake Texoma
- Toledo Bend Reservoir
- Lake Wright Patman

Summary of IWSP Water Supply Strategies

Supply Option	Existing or New Reservoir / System	Total Yield / TRWD Yield (acre-feet/year)*	Probable Number of Years Required to Make Operational	Probable Capital Cost (2012 Dollars)
Unpermitted CC Firm Yield	Existing	17,201 in 2020, decreasing to 7,223 in 2060	3	$0 (short term) New Pipeline for 'CC/RC Firm': $415 M New Pipeline for 'CC/RC Unpermitted Wetlands': $465M New Pipeline for 'CC/RC Firm' and 'CC/RC Unpermitted Wetlands': $725M New Pipeline for 'CC/RC Firm', and 'CC/RC Unpermitted Wetlands', and Tehuacana: $1.44B
Unpermitted RC Firm Yield	Existing	46,831 in 2020, decreasing to 38,444 in 2060		
Unpermitted CC Wetlands Yield	Existing	35,559	3	
Unpermitted RC Wetlands Yield	Existing	37,465		
Lake Columbia	New	40,188	10.5	$250,165,000**
EXFLO Benbrook	Existing	78,653 Interruptible (Firm Yield = 0)	<5	$0
EXFLO Eagle Mtn	Existing	63,899 Interruptible (Firm Yield = 0)		
Kiamichi River	New	310,000 / 155,000	18.5	$1,810,696,000
Marvin Nichols Reservoir	New	612,300 / 142,850	19	$1,695,867,000
Lake Ringgold	New	28,600	12.5	$397,735,000
Lake Tehuacana	New	41,900	11	$580,790,000 (short term***) New Pipeline for 'CC/RC Firm', and 'CC/RC Unpermitted Wetlands', and Tehuacana: $1.44B
Temple Reservoir	New	125,000	15	$972,530,000
Texoma	Existing	Average 21,050 Interruptible Yield in 2060 (at 10:1 Blending Ratio)	14	$313,065,000
Toledo Bend	Existing	700,000 / 200,000	17	$2,751,751,000
Wright Patman	Existing	180,000	15.5	$2,394,849,000

** Environmental flow requirements were considered in all strategies. The TWDB's guidelines for regional water planning require that yield analysis for water management strategies be in accordance with Senate Bill 3 environmental flow standards and associated TCEQ rules, In most cases, the 1997*

Consensus Criteria for Environmental Flow Needs is used. However, modeling of new environmental flow criteria is still underway and will likely impact the yield of several water supply strategies.

*** Assumed Columbia will flow through IPL and Toledo Bend pipeline. Cost attributed to Columbia is the amount needed to increase Toledo Bend transmission system capacity enough to carry Columbia flows plus costs specific to Columbia (reservoir, portion of the pipeline to TRWD). A pipeline to convey only Lake Columbia is assumed to be cost prohibitive and is not considered here.)*

****These costs do not include the new pipeline that will eventually be needed to convey flows from Lake Tehuacana. It is most probable that the new pipeline would be built to carry Tehuacana and another supply (such as Unpermitted Yields from Cedar Creek and Richland-Chambers).*

Water supply strategies are configured by combining three primary variables – *Supply, Transmission,* and *Partnering/Other Options*.

The *Supply* variable includes options such as:

- On-channel Reservoir
- Groundwater Supply
- Run-of-River Diversion
- Run-of-River Diversion with an Off-Channel Storage Facility
- Indirect Reuse/Constructed Wetland

The *Transmission* variable options include:

- Different pipeline routes with the same start and end points
- Different pipeline routes with different end points or intermediate delivery points
- Variations in transmission system sizing, depending on the number of supplies conveyed through one transmission system or depending on the supply configuration (e.g. run-of-river supply as compared to a reservoir)

The *Partnering/Other* variable includes options such as:

- The number of entities partnering in a supply/transmission system, thereby changing the yield to each partner
- Phasing the infrastructure needed to deliver new supply to TRWD or other partners

An example configuration would be an on-channel reservoir (the *Supply* variable) delivering through its own pipeline to TRWD's western reservoirs (the *Transmission* variable), shared with two other water suppliers (the *Partnering/Other* variable). Each strategy can be configured several different ways; the configuration that seemed to best meet TRWD's needs is used in this study.

Several strategies have been studied over the years and with corresponding published reports. In some cases, there are several different published water supply yields for a given strategy because the strategy has been defined in different ways or analyzed differently in a given study. It is important to note this distinction when IWSP strategies are compared to similar strategies from other reports.

Opportunities for new water supply to TRWD can be grouped using “geographic supply zones” - *Northwest, Northeast,* and *Southeast*. Strategies in each zone are closely related and will have commonalities in their transmission systems, timing, phasing, and partnering. Lists 1 through 3 describe the variables selected to make up the water management strategy configurations described in this IWSP. Note that all transmission system options assume intermediate reservoirs and delivery points can be bypassed. Water can be delivered to the intermediate reservoirs and delivery points listed, but it is not assumed that all water is dropped into intermediate reservoirs and pumped back out.

List 1: Northwest Geographic Supply Zone

Supply Options:

- Temple Reservoir on Cache Creek
- Lake Ringgold, 271,600 acre-feet storage, 28,600 acre-feet/year firm yield, no additional supply augmentation
- Lake Texoma, blended with other supplies

Transmission Options:

- Cache → Bridgeport
- Ringgold → Bridgeport
- Texoma → Lake Ray Roberts (drop off Dallas’ share) → Bridgeport

Partnering/Other Options:

- Share Temple Reservoir with Southwest Oklahoma. Firm yield 125,000 AFY.
- Augment Lake Ringgold with water from Cache Creek (Transmission Option: Cache → Ringgold → Bridgeport)
- Permit Oklahoma water supply yield from Lake Texoma and share 50% with other Wholesale Water Providers. Amount actually delivered to TRWD will be determined based on quantity that can be blended without requiring advanced treatment.

List 2: Northeast Geographic Supply Zone

Supply Options:

- Kiamichi Run-of-River diversion with off-channel storage facility, 310,000 acre-feet/year permitted yield (155,000 acre-feet/year to TRWD)

- Marvin Nichols, 142,850 acre-feet/year to TRWD (assuming Lake Ralph Hall has a senior water right to Marvin Nichols, and Marvin Nichols is operated as a system with Wright Patman)
- Wright Patman – 180,000 acre-feet/year by changing the existing rule curve, raising the flood pool, and generating the greatest yield possible without flooding the White Oak Creek mitigation area.

Transmission Options:

- Kiamichi River supply → Lake Chapman → Lake Lavon → Lake Lewisville → Lake Bridgeport
- New Sulphur Basin Supply (Marvin Nichols, Wright Patman) → Lake Chapman → Lake Lavon → Lake Lewisville → Lake Bridgeport

Partnering/Other Options:

- Share Kiamichi 25% North Texas Municipal Water District (NTMWD), 25% Dallas, 50% TRWD
- Marvin Nichols shared between Dallas, Irving, NTMWD, TRWD, Upper Trinity Regional Water District (UTRWD). TRWD @ 29.166% of the 80% of Marvin Nichols after Region D takes 20%
- Wright Patman not shared with other Region C providers
- Kiamichi River transmission built in conjunction with Sulphur River Basin Options (Marvin Nichols, Wright Patman)

List 3: Southeast Geographic Supply Zone

Supply Options:

- Cedar Creek Firm Yield Differential
- Richland-Chambers Firm Yield Differential
- Tehuacana, 41,900 acre-feet/year yield
- Toledo Bend, 200,000 acre-feet/year yield to TRWD
- Lake Columbia - 47% of 85,507 acre-feet/year permitted (40,188 acre-feet/year)[1]

[1] 47% is the minimum and may grow after local partners finalize their commitments

Transmission Options:

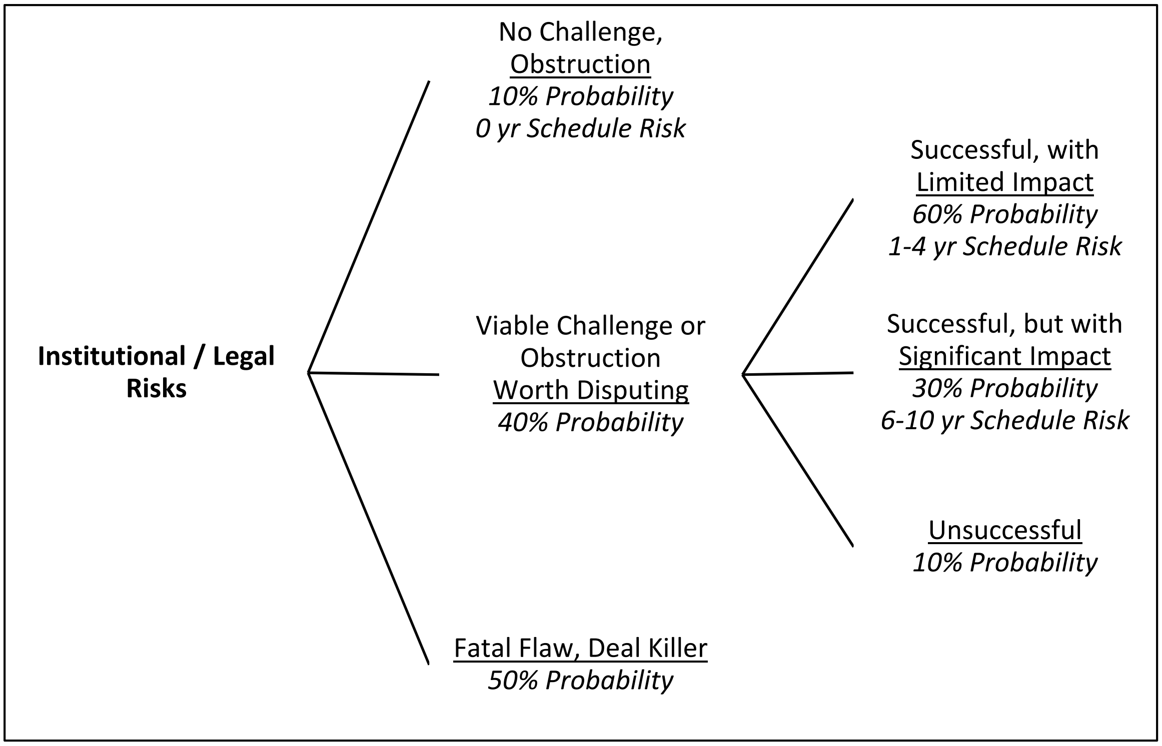
- Cedar Creek and Richland-Chambers Firm Yields through Integrated Pipeline until capacity limited, then incorporate those yields into new pipeline for this yield and a new source (e.g. Toledo Bend, Lake Columbia, Lake Tehuacana)
- Lake Tehuacana through IPL until capacity limited, then incorporate into new pipeline for this yield and a new source (e.g. Toledo Bend, Lake Columbia, CC and RC unpermitted firm yields)
- Toledo Bend → Pipeline Parallel to IPL
- Lake Columbia → Lake Palestine and then through IPL until capacity limited, then incorporate into new pipeline for this yield and a new source (e.g. Toledo Bend)

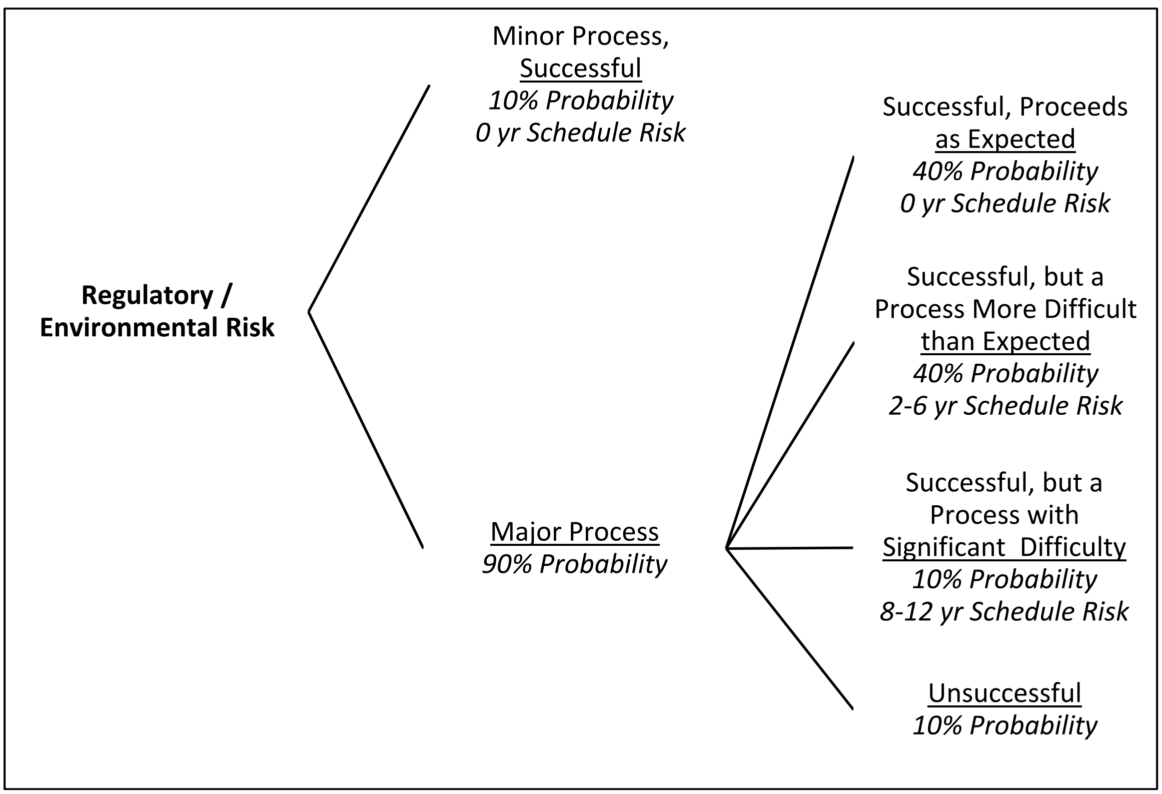
Partnering/Other Options:

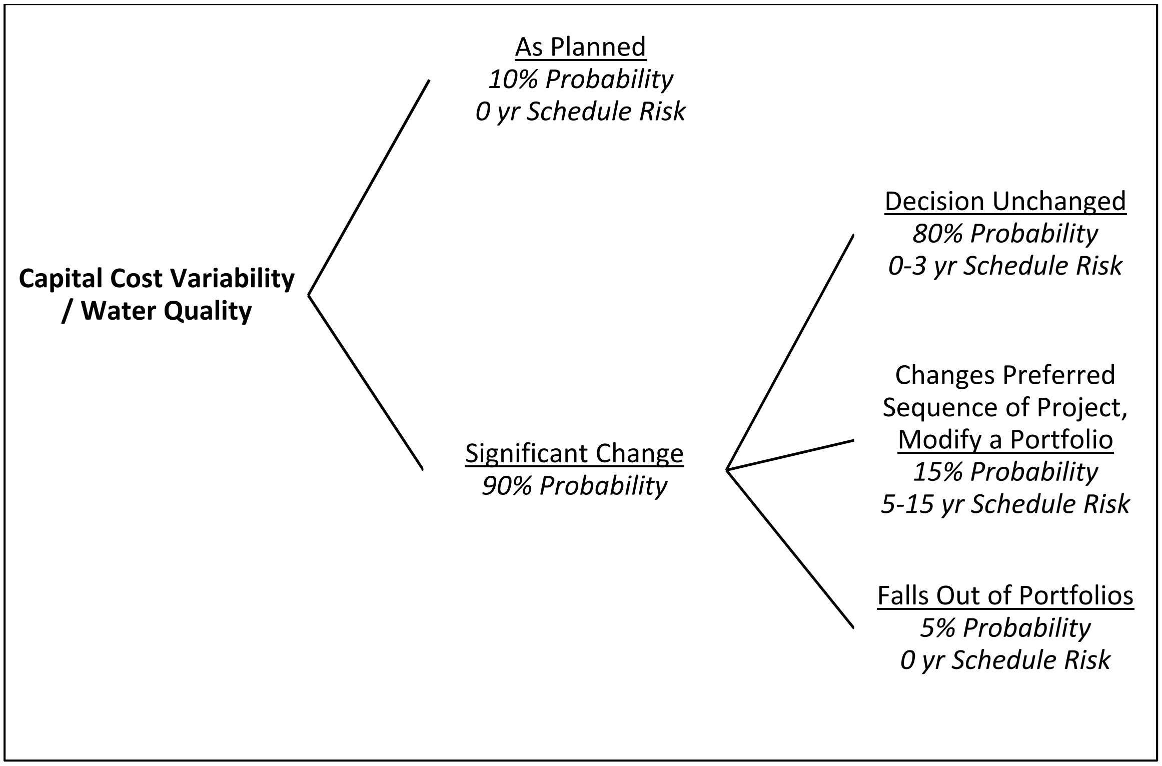
- Toledo Bend – 100,000 acre-feet/year to Sabine River Authority, 200,000 acre-feet/year to Dallas (50,000 acre-feet/year at Tawakoni, 150,000 acre-feet/year near Joe Pool Lake), 200,000 acre-feet/year to NTMWD at Lake Tawakoni, 200,000 acre-feet/year to TRWD at Lake Benbrook.

Risk Assessment

Three categories of risk have been assessed for each water supply strategy: 1) *Institutional / Legal Risks,* 2) *Regulatory / Environmental Risks, and 3) Capital Cost Variability / Water Quality Risks*. Three risk assessments are shown below, illustrating how risk is quantified for each strategy (numbers are only given as an example). A summary of the full risk assessment for all strategies is then provided below.


Institutional / Legal Risks
No Challenge, Obstruction
10% Probability
0 yr Schedule Risk
Viable Challenge or Obstruction Worth Disputing
40% Probability
Successful, with Limited Impact
60% Probability
1-4 yr Schedule Risk
Successful, but with Significant Impact
30% Probability
6-10 yr Schedule Risk
Unsuccessful
10% Probability
Fatal Flaw, Deal Killer
50% Probability

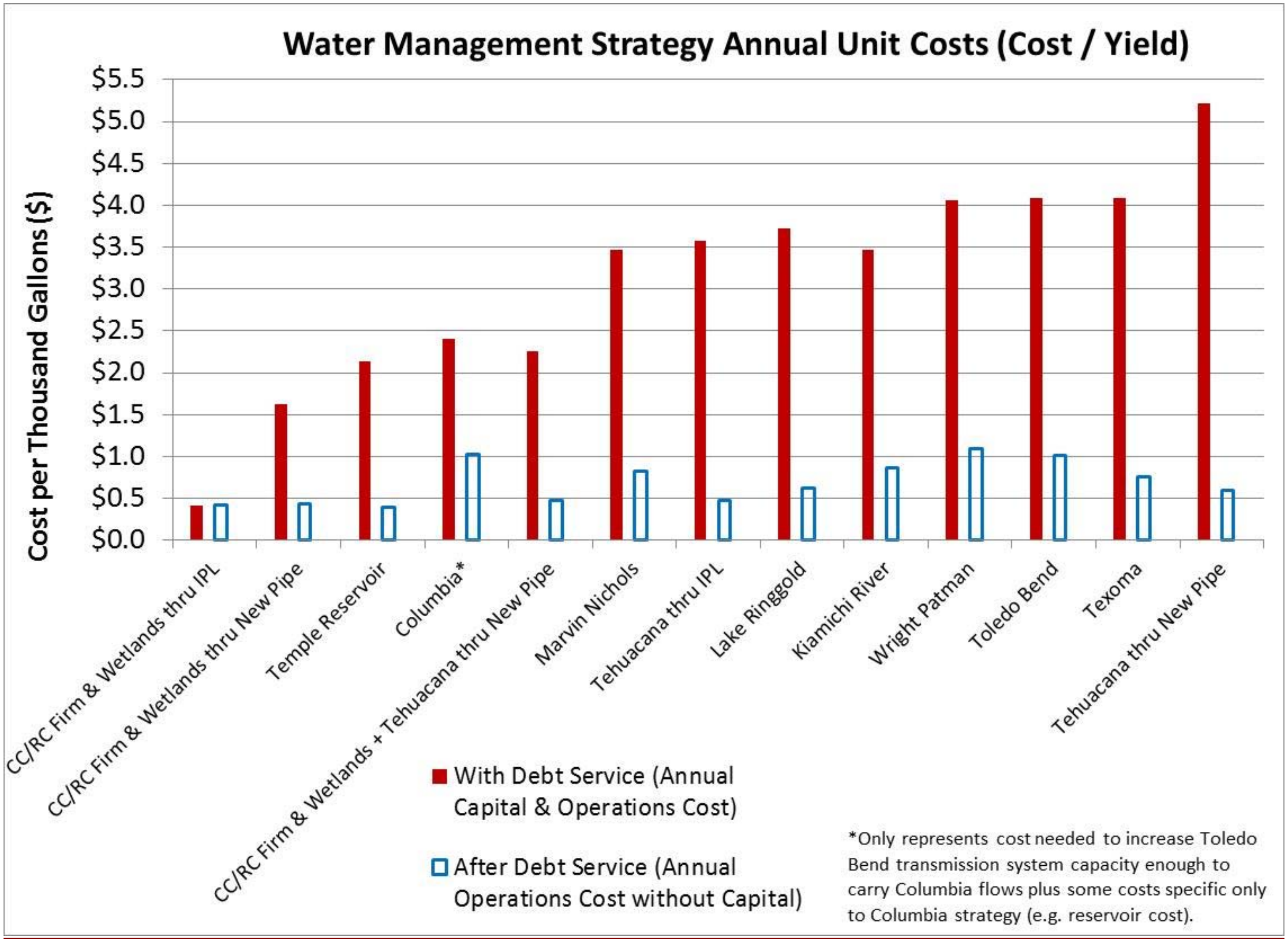

Regulatory / Environmental Risk
Minor Process, Successful
10% Probability
0 yr Schedule Risk
Major Process
90% Probability
Successful, Proceeds as Expected
40% Probability
0 yr Schedule Risk
Successful, but a Process More Difficult than Expected
40% Probability
2-6 yr Schedule Risk
Successful, but a Process with Significant Difficulty
10% Probability
8-12 yr Schedule Risk
Unsuccessful
10% Probability


Capital Cost Variability / Water Quality
As Planned
10% Probability
0 yr Schedule Risk
Significant Change
90% Probability
Decision Unchanged
80% Probability
0-3 yr Schedule Risk
Changes Preferred Sequence of Project, Modify a Portfolio
15% Probability
5-15 yr Schedule Risk
Falls Out of Portfolios
5% Probability
0 yr Schedule Risk

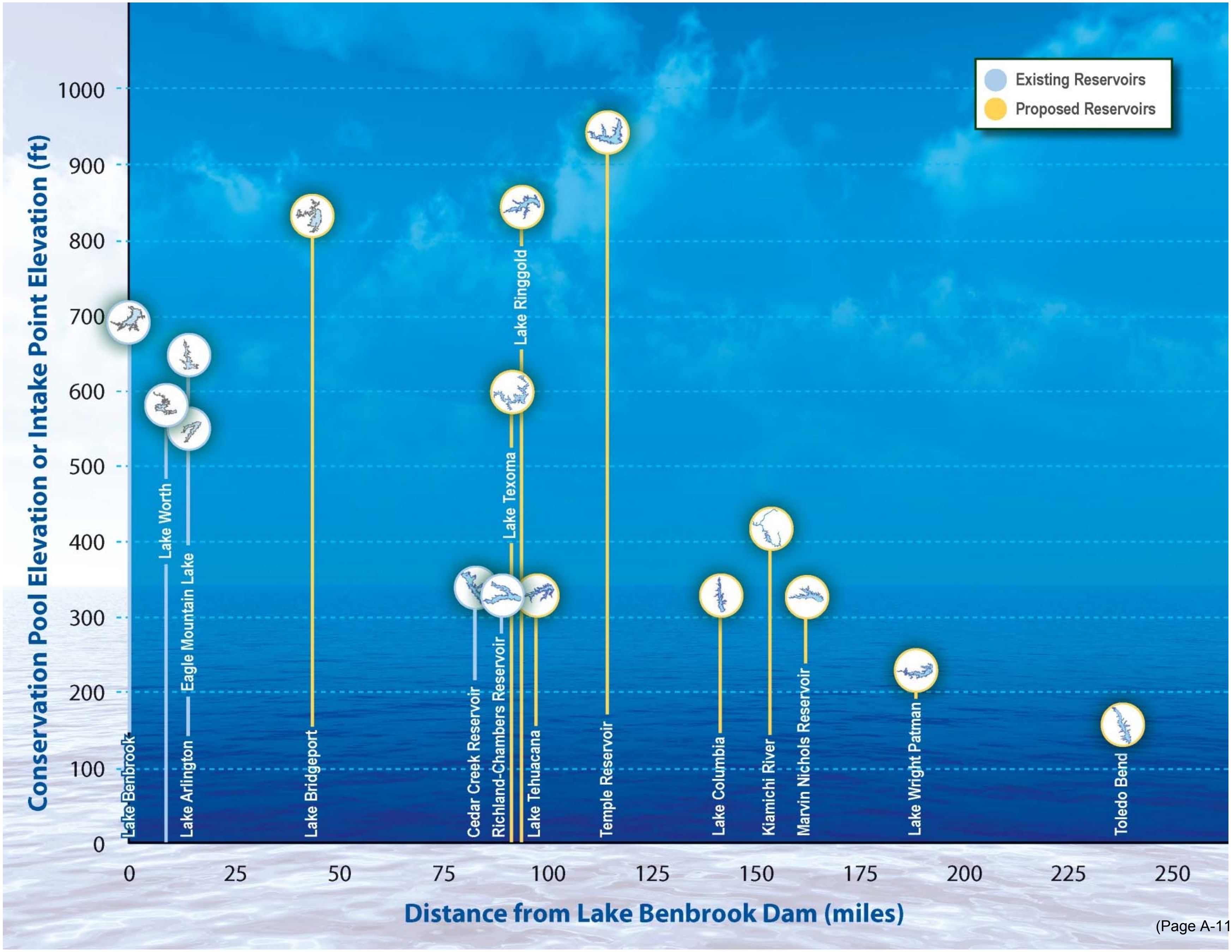
Schedule Impact (Years)	Relative Risk Score				Cache	Ringgold	Texoma (blended)	Kiamichi	Marvin Nichols	Wright Patman	EXFLO	CC/RC Wetlands Permits	CC/RC Firm	Tehuacana	Toledo Bend	Columbia
0	5	**Institutional/ Legal**	No Challenge, Obstruction		0	20	0	0	5	5	80	80	80	30	10	10
			Viable Challenge or Obstruction Worth Disputing		40	70	70	25	70	75	15	15	15	60	70	50
1-4	4			Successful, with Limited Impact	5	60	50	5	30	45	80	80	80	60	30	40
6-10	2			Successful, but with Significant Impact	35	30	40	20	60	50	15	15	15	30	50	40
N/A	0			Unsuccessful	60	10	10	75	10	5	5	5	5	10	20	20
N/A	0		Fatal Flaw, Deal Killer		60	10	30	75	25	20	5	5	5	10	20	40
			Total Level 1		100	100	100	100	100	100	100	100	100	100	100	100
				Total Level 2	100	100	100	100	100	100	100	100	100	100	100	100
0	5	**Regulatory/ Environmental**	Minor Process, Successful		0	0	0	0	0	0	40	40	40	0	0	0
			Major Process		100	100	100	100	100	100	60	60	60	100	100	100
0	5			Successful, Proceeds as Expected	40	50	10	40	10	30	70	70	70	20	60	20
2-6	3			Successful, but a Process More Difficult than Expected	40	30	30	40	20	40	20	20	20	40	30	30
8-12	1			Successful, but a Process with Significant Difficulty	10	15	30	10	60	20	5	5	5	30	5	40
N/A	0			Unsuccessful	10	5	30	10	10	10	5	5	5	10	5	10
			Total Level 1		100	100	100	100	100	100	100	100	100	100	100	100
				Total Level 2	100	100	100	100	100	100	100	100	100	100	100	100
0	5	**Capital Cost Variability/ Water Quality**	As Planned		10	60	40	10	70	30	80	80	80	50	20	70
			Significant Change		90	40	60	90	30	70	20	20	20	50	80	30
0-3	4			Decision Unchanged	80	80	60	40	60	40	90	90	90	60	60	70
5-15	1			Changes Preferred Sequence of Project, Modify a Portfolio	15	15	25	40	20	40	5	5	5	30	20	20
N/A	0			Falls Out of Portfolios	5	5	15	20	20	20	5	5	5	10	20	10
			Total Level 1		100	100	100	100	100	100	100	100	100	100	100	100
				Total Level 2	100	100	100	100	100	100	100	100	100	100	100	100

Cost Comparisons

This Integrated Water Supply Plan also uses capital and annual costs to compare each strategy. A summary comparison of the unit costs (annual cost divided by annual supply) of all strategies is included here.



Costs are strongly tied to distance from demands and elevation of the water supply, both of which are illustrated in this chart.



Implementation Schedule

Each fact sheet is accompanied by an implementation schedule that represents the probable amount of time it will require to develop the project *based on what is currently known.* It does not account for risk factors (e.g. permitting), which have the potential of causing delays above and beyond what is already anticipated.

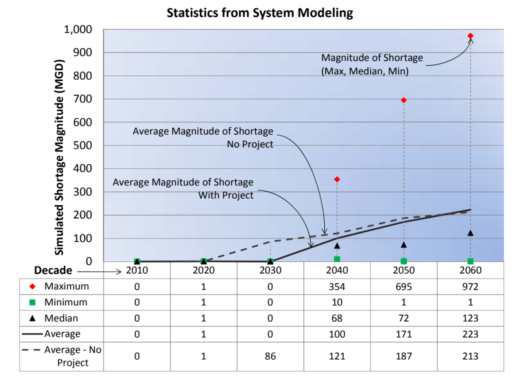
System Reliability

Each fact sheet is also accompanied by graphs that illustrate how each new supply could impact water supply system reliability. A model was developed to simulate TRWD system reliability for every month under an assumed condition of water supply (described by a repeat of the 1941-2008 hydrology) and demand (described by projected demand in a future year, such as 2030). Output from this model was graphed to illustrate how often shortages could occur and how large that shortage could potentially be in any given month. The following graphs are provided:

- The potential *magnitude* of a simulated shortage based on either 2011 Region C Water Plan demand projections or an alternate demand projection developed by TRWD, based on the last 7 years of actual deliveries. This first graph provides some statistics for each demand scenario. For example, the maximum, median, average and minimum monthly shortage that may occur with or without the new supply strategy.

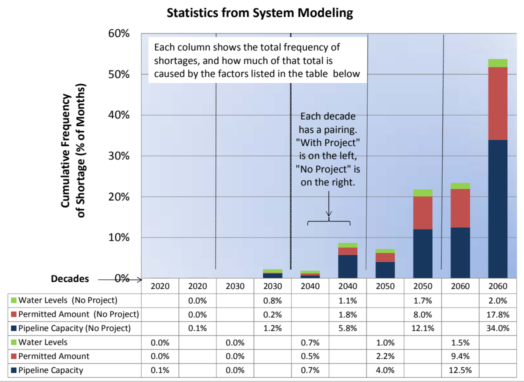
- The potential *frequency* of a simulated shortage (based on the same two demand projections). This second graph illustrates what percentage of months in the 67 year simulation had shortages and compares this result with or without the new supply strategy.

- The average annual shortage (based on the same two demand projections) expressed in



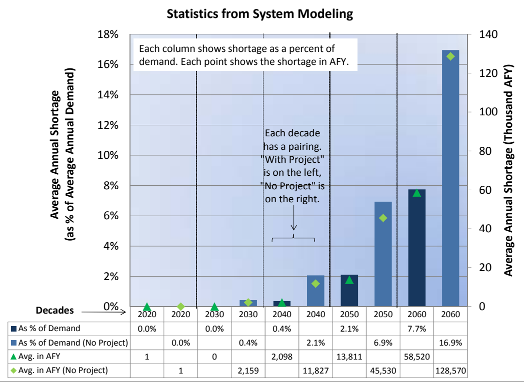
Decade	2010	2020	2030	2040	2050	2060
Maximum	0	1	0	354	695	972
Minimum	0	1	0	10	1	1
Median	0	1	0	68	72	123
Average	0	1	0	100	171	223
Average - No Project	0	1	86	121	187	213

Magnitude



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.8%		1.1%		1.7%		2.0%
Permitted Amount (No Project)		0.0%		0.2%		1.8%		8.0%		17.8%
Pipeline Capacity (No Project)		0.1%		1.2%		5.8%		12.1%		34.0%
Water Levels	0.0%		0.0%		0.7%		1.0%		1.5%	
Permitted Amount	0.0%		0.0%		0.5%		2.2%		9.4%	
Pipeline Capacity	0.1%		0.0%		0.7%		4.0%		12.5%	

Frequency



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
As % of Demand	0.0%		0.0%		0.4%		2.1%		7.7%	
As % of Demand (No Project)		0.0%		0.4%		2.1%		6.9%		16.9%
Avg. in AFY	1		0		2,098		13,811		58,520	
Avg. in AFY (No Project)		1		2,159		11,827		45,530		128,570

Average Annual Shortage

absolute terms (acre-feet) or as a percentage of the demand. This third graph is essentially a product of the statistics shown in the first two graphs.

Shortages occur when projected demand in any given month is greater than the amount of water delivered that month. There are three potential causes of shortage: 1) transmission system capacity is insufficient; 2) permit limits are reached and limit the amount of water that can be delivered; 3) water is physically unavailable, such as when reservoirs run out of water.

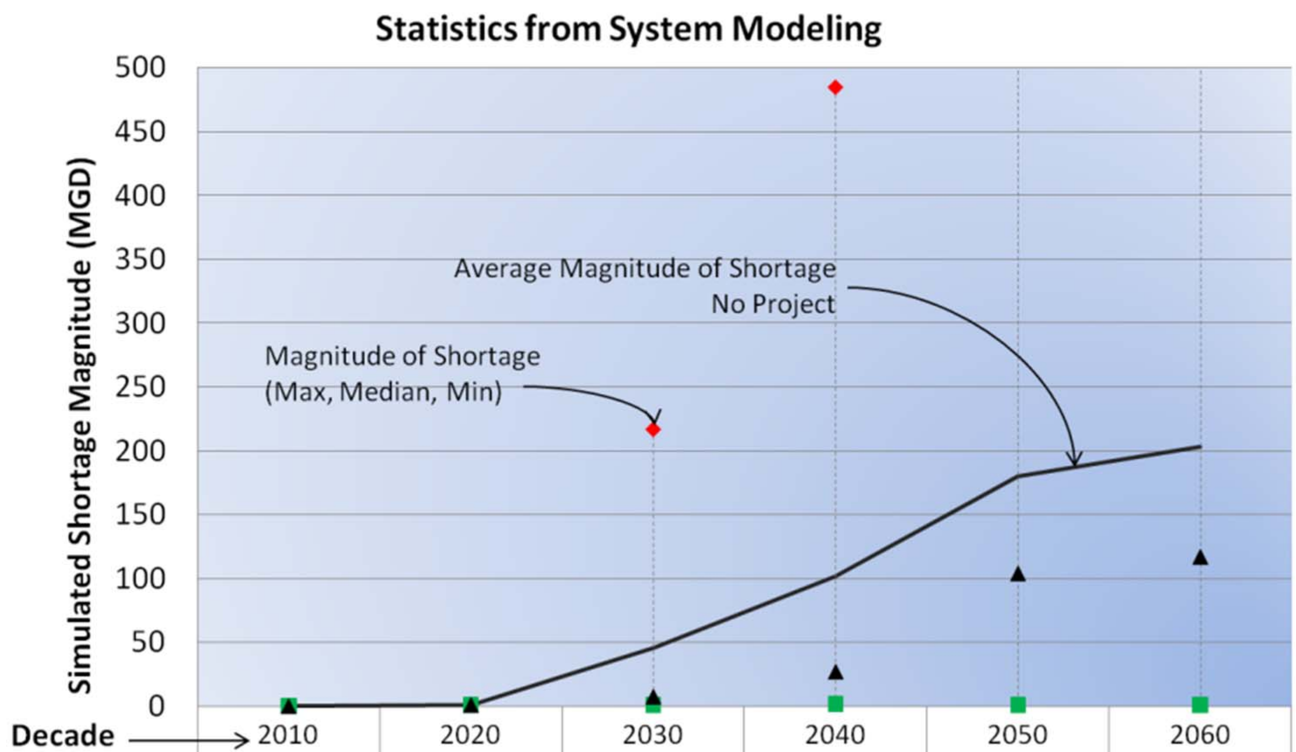
Note that new supply strategies were modeled with the assumption that the Integrated Pipeline, Cedar Creek and Richland-Chambers constructed wetlands, and EXFLO are all operational.

The reader will find that at times, the first two frequency and magnitude graphs described above will provide non-intuitive results. For example, there are times that the frequency of simulated shortages actually increases when a new water supply is included, though intuition would conclude that it should decrease. There are two reasons this sometimes occurs. First, it is because the model is optimized for economic utilization of new sources, not for month-by-month deliveries. As such, results may sometimes indicate reductions in the magnitude of simulated shortages with new water supplies (as compared to the base scenario without new water supplies) even though the deficit frequency sometimes increases marginally.

The second reason the results may not be intuitive is because it is actually the *combination* of frequency and magnitude that governs. When frequency and magnitude statistics are viewed independently, it may be non-intuitive, such as seeing that connecting new sources could increase the frequency of simulated shortages while decreasing their magnitude. But when viewed in combination, it makes sense that the new supply is helping water supply reliability: the number of months that exhibit shortages may have gone up, but the amount of shortage in those months is much smaller, and optimizing operations for reliability will further reduce the number of months in which shortages occur. The third graph described above was created to help decode those sometimes non-intuitive results and to ensure that the average annual shortage is indeed decreasing as new supplies are connected.

Current Supply Status (i.e. "No Project")

Magnitude Chart



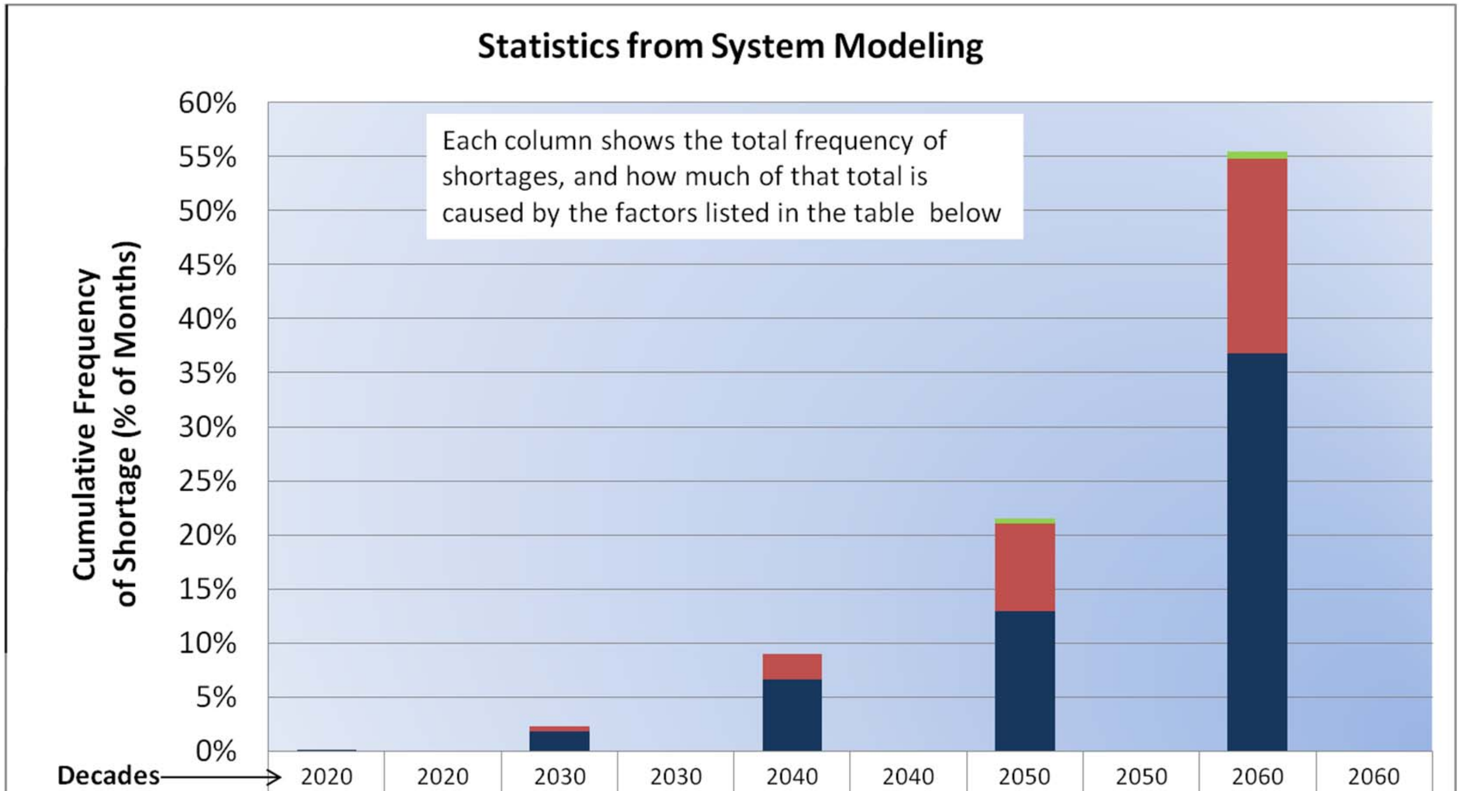
Decade	2010	2020	2030	2040	2050	2060
Maximum	0	1	217	485	767	806
Minimum	0	1	1	2	1	1
Median	0	1	8	27	104	117
Average	0	1	45	101	180	203
– –						

Results Using 2011 Region C Based Demand Projection

*Assumes that the Integrated Pipeline, Cedar Creek Constructed Wetlands, and Richland-Chambers Constructed Wetlands are part of current status.

Current Supply Status (i.e. “No Project”)

Frequency Chart



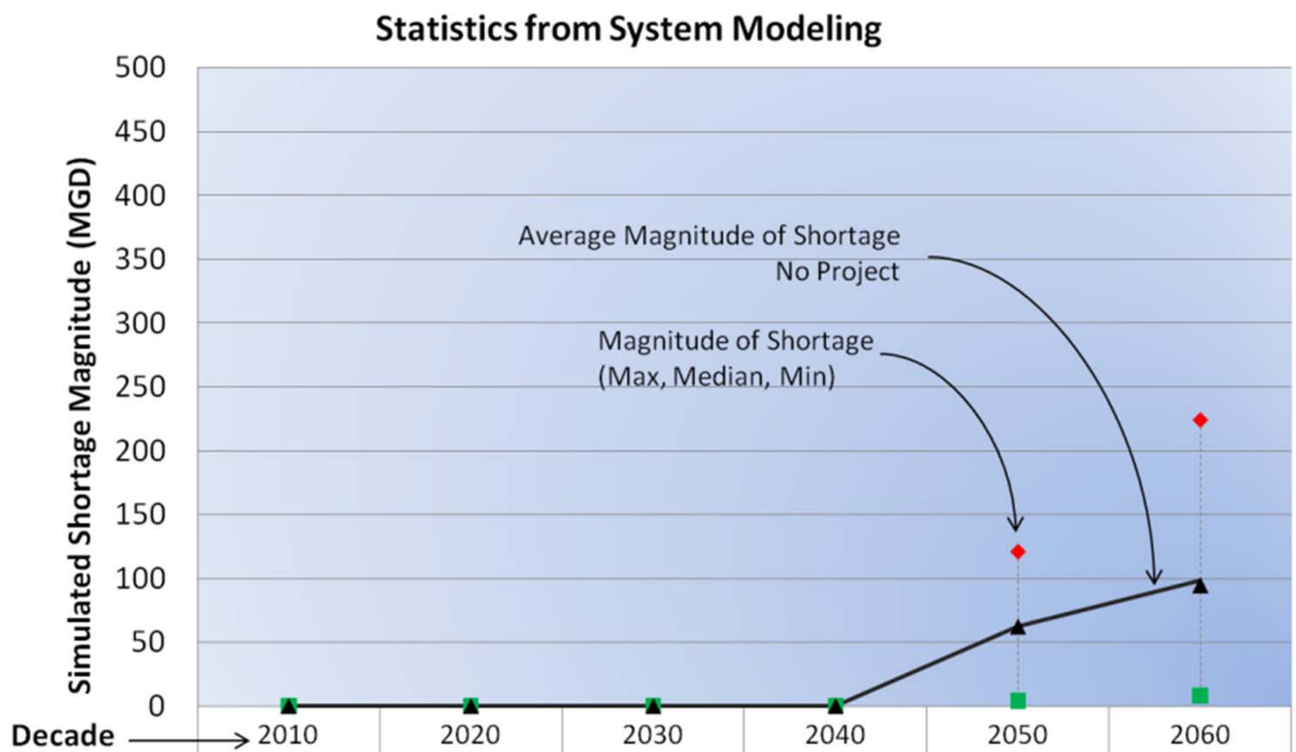
Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels	0.0%		0.0%		0.0%		0.5%		0.7%	
Permitted Amount	0.0%		0.4%		2.4%		8.1%		18.0%	
Pipeline Capacity	0.1%		1.8%		6.6%		12.9%		36.7%	

Results Using 2011 Region C Based Demand Projection

*Assumes that the Integrated Pipeline, Cedar Creek Constructed Wetlands, and Richland-Chambers Constructed Wetlands are part of current status.

Current Supply Status* (i.e. "No Project")

Magnitude Chart



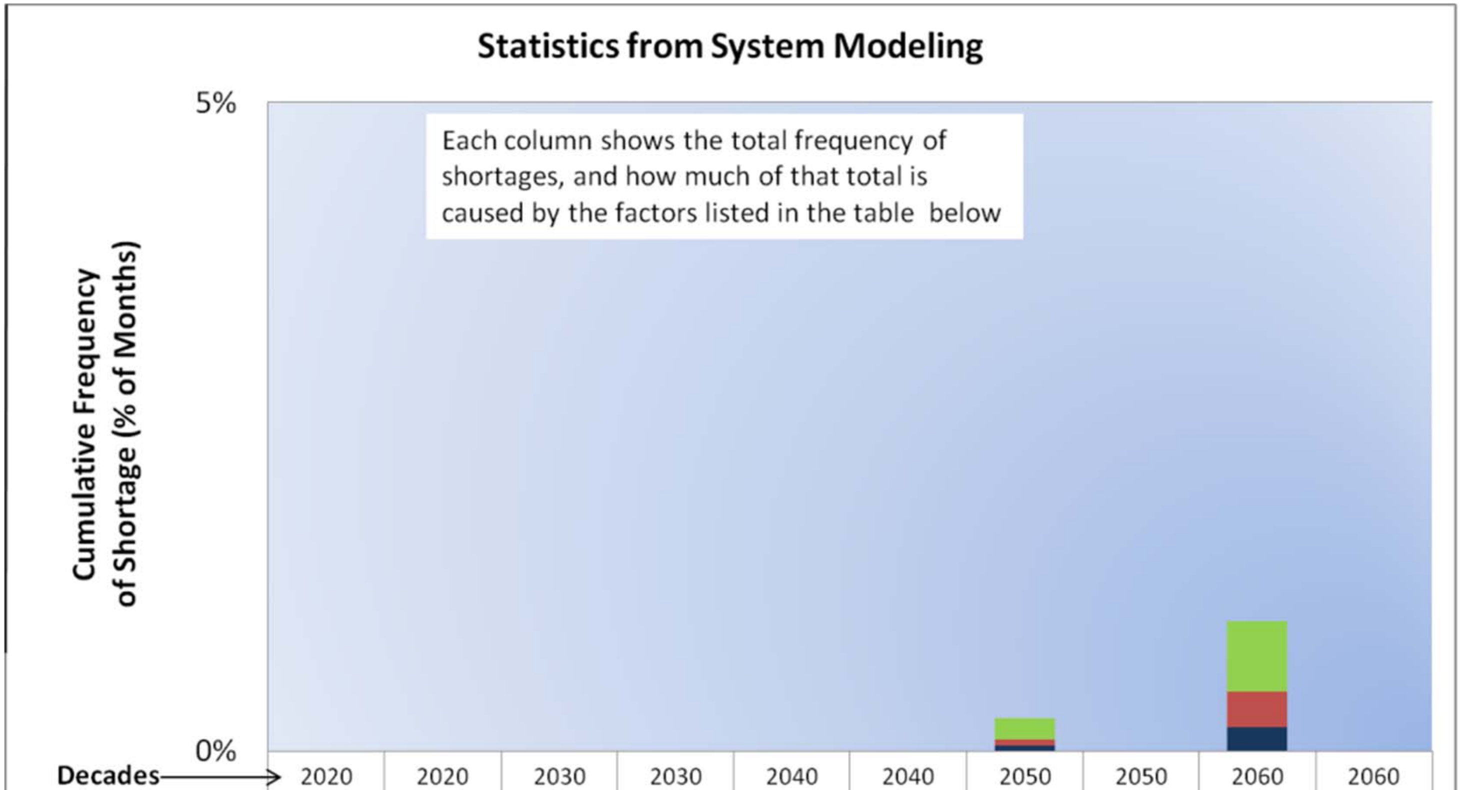
Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	0	121	224
Minimum	0	0	0	0	4	8
Median	0	0	0	0	63	95
Average	0	0	0	0	63	98
– –						

Results Using Recent Trend Extrapolation Demand Projection

*Assumes that the Integrated Pipeline, Cedar Creek Constructed Wetlands, and Richland-Chambers Constructed Wetlands are part of current status.

Current Supply Status (i.e. "No Project")

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
■										
■										
■										
■ Water Levels	0.0%		0.0%		0.0%		0.2%		0.5%	
■ Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.3%	
■ Pipeline Capacity	0.0%		0.0%		0.0%		0.0%		0.2%	

Results Using Recent Trend Extrapolation Demand Projection

*Assumes that the Integrated Pipeline, Cedar Creek Constructed Wetlands, and Richland-Chambers Constructed Wetlands are part of current status.

Water Conservation

Description

In planning and developing new water supplies, water conservation strategies across Texas will play a vital role in meeting the projected water needs throughout the state. The 2012 State Water Plan reports that 12 percent of future water needs in Region C will be met through municipal conservation.[1] From a cost standpoint, water conservation is the most cost-effective alternative for meeting new water demands.

The Texas Water Code defines water conservation as "those practices, techniques, and technologies that will reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling and reuse of water so that a water supply is made available for future or alternative uses" (§11.002 (a) (8) (B)). The end result is lower per capita demands and less pressure on existing water supplies. Meaningful reductions in water loss and water waste, and improvements in water efficiency can help TRWD in many ways. Over time, conserving water on a daily basis:

- extends the life of existing supplies to meet new water demands
- slows the drain on reservoirs making more water available during times of drought
- reduces peak supply requirements, which reduces wear and tear on existing infrastructure
- defers increases in capital and operating cost for existing systems, and
- delays the need for developing new water supplies.

Tarrant Regional Water District recognizes the benefits of using water and energy resources more efficiently. In order to maximize the use of existing water resources, TRWD is pursuing a menu of active water conservation measures, not just in times of drought but year-round. Some of the savings TRWD is observing today are due to passive measures that are occurring naturally, such as the replacement of older fixtures and appliances in existing homes with newer, more efficient models. The water district anticipates that the combination of active and passive conservation measures will lead to long-term, permanent reductions in per capita demand. Lower per capita demands is a trend being observed across the country. A national study found that residential water use over the last 30 years has declined at an average rate of 0.44 percent annually.[2]

TRWD is committed to water conservation and has established a program that is generating an annual savings that can be measured in billions of gallons. Water conservation will continue to play a vital role in the district's long-term water supply strategy.

Strategic Water Conservation Plan

TRWD's Strategic Water Conservation Plan[3] ("Strategic Plan") is designed to serve as a roadmap for developing and implementing water conservation strategies and to provide a way to evaluate their success. The goals of TRWD's water conservation program include reducing per capita use, reducing seasonal peak demands, and reducing water loss and water waste. The target for improving water efficiency is a one percent per year reduction in average water use over a five-year planning period.

The Strategic Plan evaluated the cost and effectiveness of twenty water conservation measures. These particular strategies were screened and selected because of their water savings potential, customer feedback, and their applicability to the majority of customers in the water district's service area. The top six measures projected to generate the highest per capita savings included a combination of active and passive measures[4]:

- Twice per week irrigation limits 6.20 gpcd
- Water use reductions due to price increases 4.74 gpcd
- Natural toilet replacement 1.07 gpcd
- Clothes washer natural replacement 0.96 gpcd
- Model water conservation ordinance 0.62 gpcd
- Wholesale customer water loss reduction 0.42 gpcd

By 2017, the Plan estimates the total per capita savings generated by these measures will be 14.01 gallons per day. These six measures represent 89.8 percent of all the water savings outlined in the Plan.

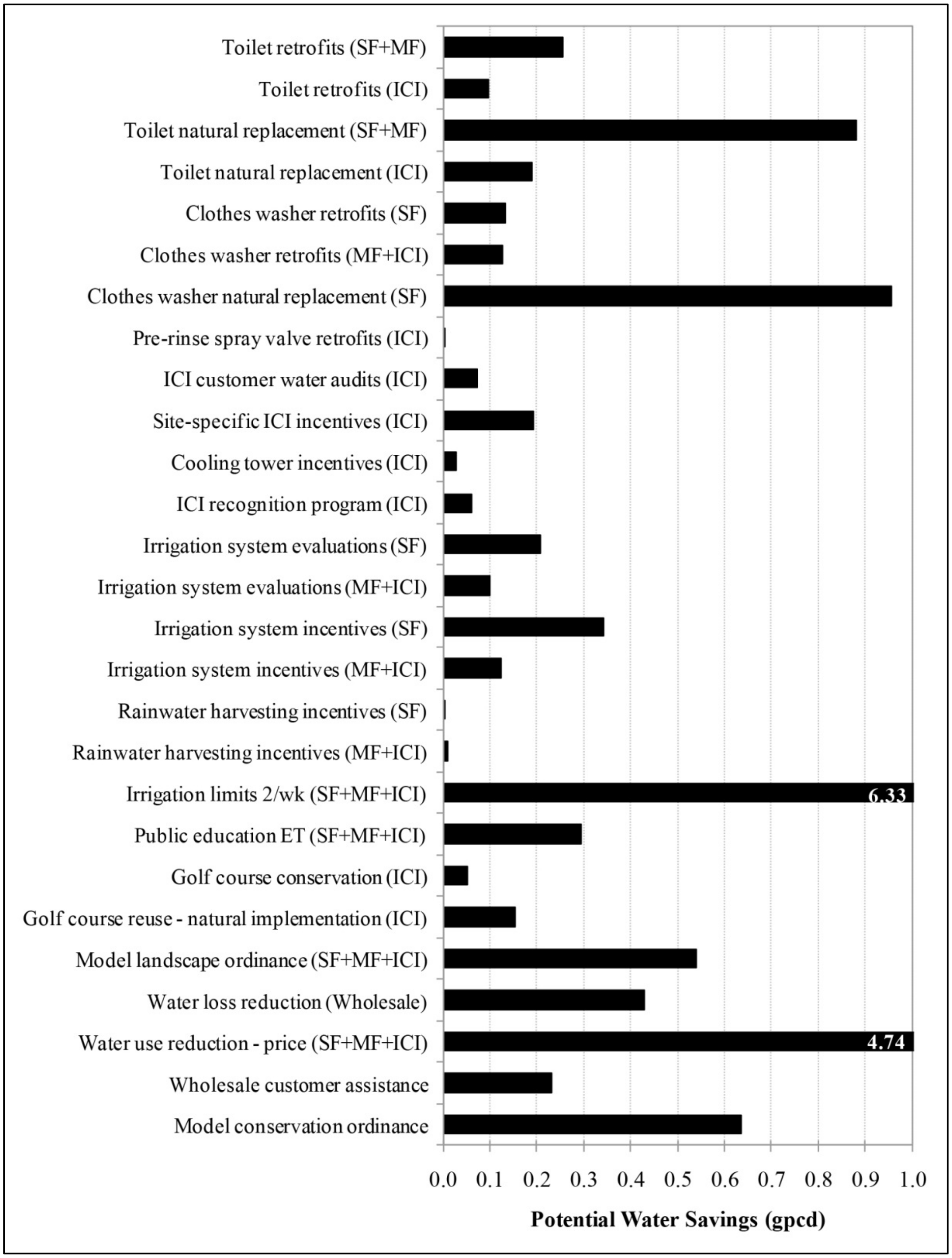


Figure 1: Potential Per Capita Water Savings in Year 5 of the Strategic Plan

Each measure was evaluated by separate categories. SF represents single family residences; MF represents multi-family dwellings, such as apartment complexes; and ICI covers industrial, commercial, and institutional establishments.

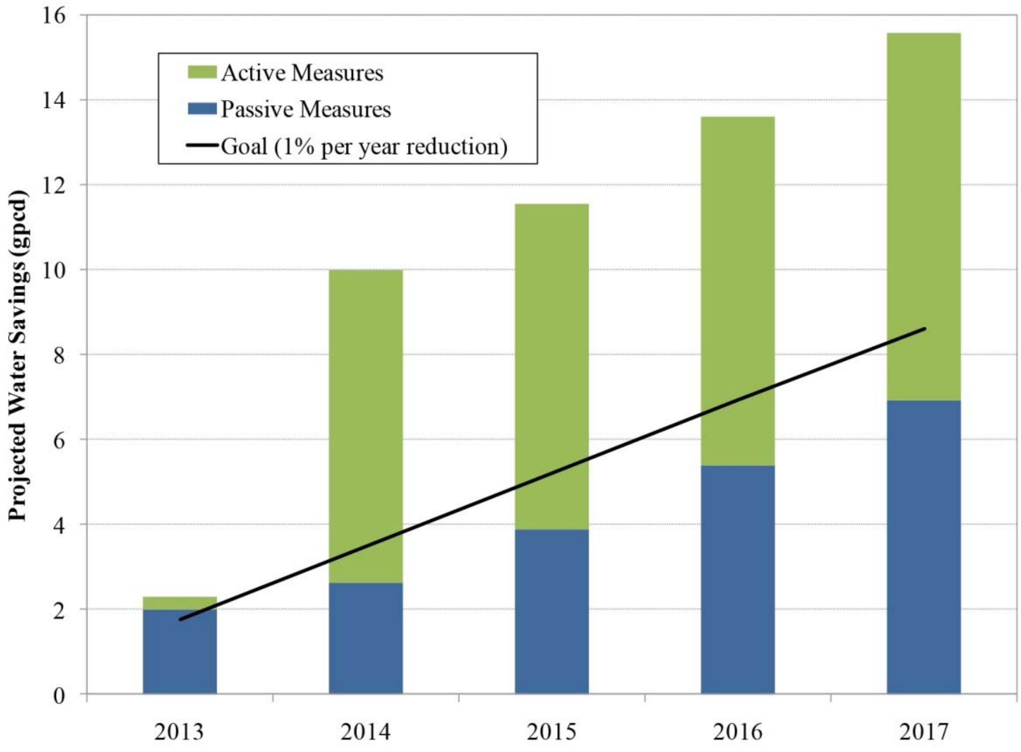


Figure 2: Projected Per Capita Water Savings

Water Conservation Savings

The Strategic Plan includes a model of TRWD annual demands. The model was calibrated using water demands among the district's primary customers from 1997 to 2004, before water conservation measures were put in place. The model is used to predict TRWD annual demands without conservation and allows for a comparison with actual demands. The difference between the model's projected demands and actual consumption is assumed to be savings.

Here are some highlights of the savings achieved from ongoing conservation efforts from 2007 through 2012:

- A cumulative savings of 72.29 billion gallons or 221,859 acre-feet.
- Annual savings ranging from 8.0 to 21.9 billion gallons, with savings on an annual basis averaging 12.0 billion gallons.
- An average savings of 33.0 mgd. At the 2012 rolling average consumption rate (180 gpcd), 33.0 mgd could supply an additional 183,300 people.
- An average savings of 36,977 acre-feet per year, which is 70 percent of the firm yield of the proposed Cedar Creek indirect reuse project.

Savings among the district's primary customers in 2012 alone was nearly 22 billion gallons – about 20 percent of the predicted demands without conservation. A chart illustrating the projected water demands versus actual demands and a table of the estimated annual savings is included below.

Table 1: Estimated Annual Savings Due to Ongoing Water Conservation Efforts and Drought Contingency Measures, 2007-2012

Year	Billion Gallons	Acre-Feet
2007	8.97	27,534
2008	7.95	24,395
2009	9.44	28,979
2010	9.65	29,612
2011	14.43	44,269
2012	21.86	67,070
Total Savings	**72.29**	**221,859**

Note: Some savings in 2011 and 2012 can be attributed to the implementation of Stage 1 drought contingency measures, which were in effect from August 29, 2011 through May 3, 2012. The Strategic Plan estimates Stage 1 drought measures lowered demands by an additional 5.76 billion gallons during that timeframe.

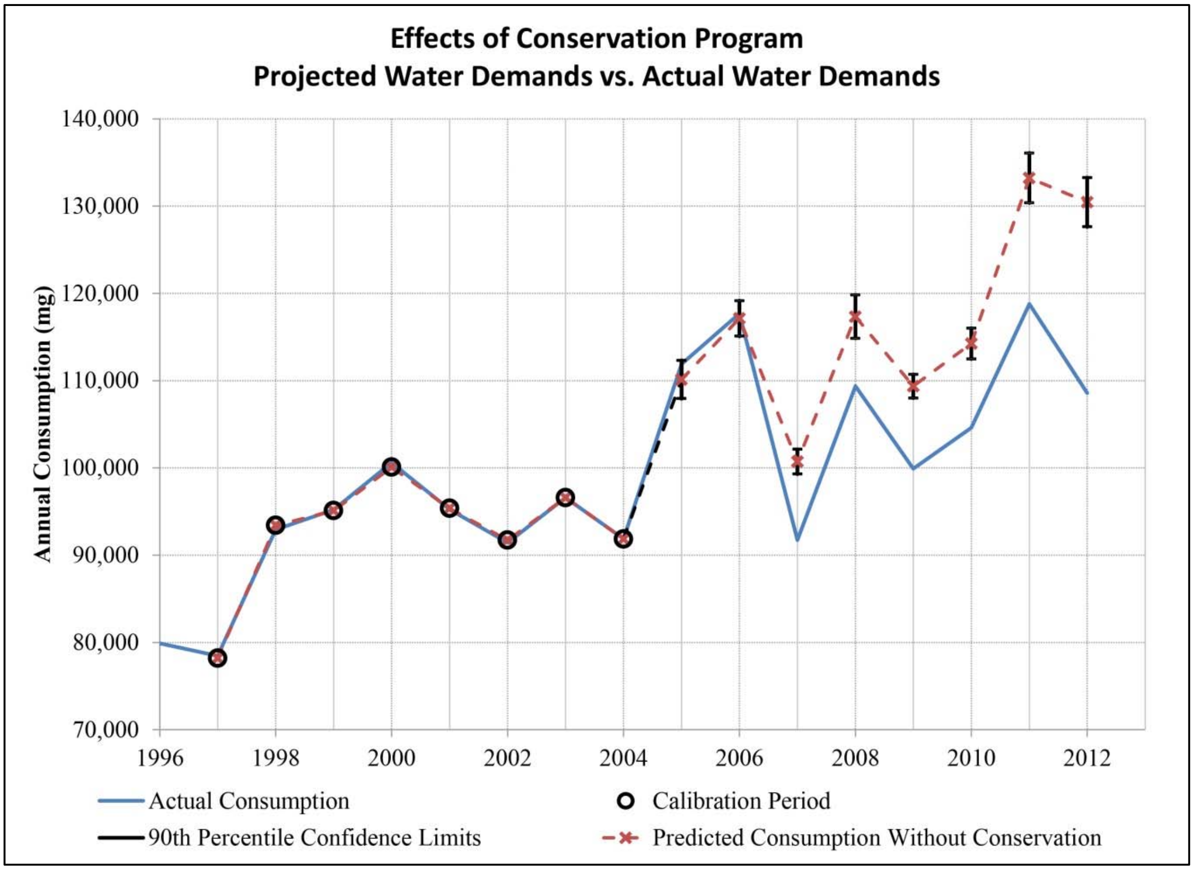


Figure 3: Estimated Consumption of TRWD's primary customers without Conservation Versus Actual Consumption

Projected Water Savings, Benefits, and Costs

Implementing all of the water conservation strategies over the next five years would nearly double the water savings achieved so far. The combined savings would amount to more than 63 mgd when compared to 2006 water use. By 2017, implementing the recommendations described above would produce the following water savings, benefits, and costs:[5]

- Annual water savings of 30.1 mgd, which is 56 percent greater than the conservation savings projected in the 2011 Region C Water Plan.
- Annual per capita water savings of 15.6 gpcd, putting TRWD on course to surpass its 2018 total water use goal of 166 gpcd.
- Cumulative present value benefits of about $30.9 million.
- Cumulative present value costs to utilities of about $14.4 million

Full implementation of all measures in the Plan would increase TRWD's water conservation budget from its current level of $1.89 million to $5.0 million annually by 2017. The projected annual water savings would be 33,700 acre-feet, enough to serve the needs of an additional 180,000 people using existing supplies. The potential water savings through 2060 would be more than 2.84 million acre-feet. [6]

Saving water comes with economic benefits, as well. The potential economic benefit from all the evaluated water conservation measures has a present value of $8.0 to 10.0 million, and today's funding of water conservation measures will provide a substantial long-term return on the investment. The net present value of the potential long-term benefits from all evaluated measures through 2060 is projected to be $987.6 million.[7]

The other advantages of supporting a successful water conservation program include:[8]

- Extending the life of existing supplies and delaying the need for new water supplies.
- Reducing peak supply requirements and extending the life of existing infrastructure. Since water system infrastructure is sized to meet peak demands, reducing the peaks also delays the need to expand facilities.
- Positioning TRWD to obtain future water rights. To secure authorization of an interbasin transfer, the applicant must have "developed and implemented a water conservation plan that results in the highest practicable levels of water conservation…"[9]
- Positive environmental effects, improved customer good will, continued growth and economic development, and a reduction in TRWD's carbon footprint.

TRWD and Dallas Outreach Campaign

Since 2007, the water district has stepped up its commitment to water conservation and budgeted $9.49 million (through FY 2013) for its programs and staff support. Approximately $6.24 million or 66 percent of those funds were used to develop and promote a joint public outreach campaign with Dallas Water Utilities. The combined contribution from both entities for media outreach and production costs amounts to more than $2.0 million annually. By coordinating regional outreach to promote water conservation, TRWD doubles its advertising for the money spent.

The biggest focus of the water district's conservation efforts has been on reducing excessive outdoor water use. On an annual basis the four primary customers use 31 percent to 50 percent of their water for seasonal uses depending on climatic conditions.[10] In most years, outdoor water consumption exceeds 40 percent of total water demands. And studies have shown that overall homeowners over-water as much as 2-3 times the amount needed by plants, based on climate conditions. Changing outdoor irrigation habits and reducing excessive outdoor water use offers an opportunity to save tremendous amounts of water.

The investment in water conservation outreach and other programs is paying off. A simple comparison of the water savings and the water conservation budget from 2007 to 2012 indicates the unit cost of the savings to be $0.11 per thousand gallons.

Water Conservation as a Supply Strategy

Water supplies are not endless resources. The number of people living in our region is expected to nearly double in the next 50 years. That means the demand for water will rise – and meeting that demand in a sustainable way will be a challenge.

Conservation is a viable water supply strategy. It maximizes the use of current supplies to help meet the water needs of growing communities. And there are signs the water district's conservation efforts are increasing the efficient use of its water resources:

- In 2011, water consumption during the one-year drought of record among its primary customers increased less than 4,000 acre-feet compared to 2006, despite an increase in population of about 100,000 residents.
- In 2012, TRWD's primary customers used 67,000 acre-feet less than predicted based on climate conditions and a model of water use before water conservation measures were put in place.
- The savings in 2012 alone was slightly more than the firm yield of the Richland-Chambers indirect reuse project, which is 63,000 acre-feet.
- TRWD estimates the average water savings between 2007 through 2012 was 33.0 mgd. At today's consumption rate, 33.0 mgd could supply an additional 183,300 people with existing supplies.

When people use less water, it frees up more water (and energy) for us to accommodate the needs of more people. And the overall reduction in demands and lower peaking requirements should allow the water district to extend the horizon for developing new supplies.

The water district anticipates the savings to continue in the coming years. Since 2002, TRWD's average per capita water use has decreased more than eight percent. The declining trends in water consumption are not an accident. They are a combination of numerous influences, including the availability of more water efficient fixtures and appliances, pricing structures at the retail level, water utility leak detection and water loss programs, and an ongoing public education and outreach campaign.

The Tarrant Regional Water District embraces, and will continue to invest in, water conservation as a supply strategy. It's one of the most economical ways for TRWD to meet the needs of its customers. Using the water we have available today more efficiently means we will have more water to share with new residents, new businesses, and for future economic growth.

References

[1] Texas Water Development Board. 2011. Water for Texas: Summary of the 2011 Regional Water Plans. Retrieved August 1, 2013 from: http://www.twdb.state.tx.us/waterplanning/rwp/regions/doc/2011RWPLegislativeSummary.pdf

[2] Coomes, Paul, Tom Rockaway, Josh Rivard, Barry Kornstein, 2010. North America Residential Water Use Trends Since 1992, Water Research Foundation. Retrieved August 1, 2013 from: http://www.waterrf.org/PublicReportLibrary/4031.pdf.

[3] McDonald, Brian, Mike Mocek, 2013, January 16. Tarrant Regional Water District Strategic Water Conservation Plan, Alan Plummer Associates, Inc., Available from http://www.savetarrantwater.com/Pages/0307_043_01_final_report_v29%20trwd%20strategic%20plan.pdf.

[4] Ibid. p. 134

[5] Ibid. p. 133

[6] Ibid. p. 98

[7] Ibid. p. 103

[8] Ibid. p. 102

[9] Freese and Nichols, Inc. Alan Plummer Associates, Inc., CP&Y, Inc. and Cooksey Communications, Inc., 2011 Region C Water Plan: prepared for the Region C Water Planning Group, Fort Worth, October 2010.

[10] McDonald, Brian, Mike Mocek, 2013, January 16. Tarrant Regional Water District Strategic Water Conservation Plan, Alan Plummer Associates, Inc., Available from http://www.savetarrantwater.com/Pages/0307_043_01_final_report_v29%20trwd%20strategic%20plan.pdf. p. 41

Unpermitted Firm Yield in Cedar Creek and Richland-Chambers Reservoirs

Description

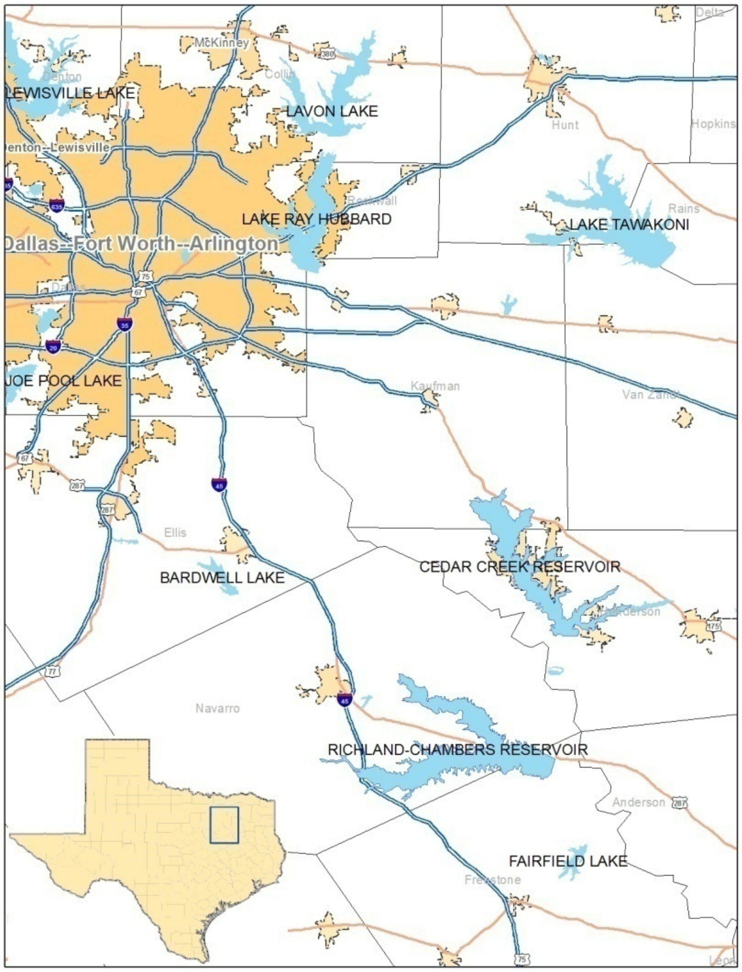
The original water right permits for Cedar Creek Reservoir and Richland-Chambers Reservoir authorized annual diversions that are less than the actual firm yield of the reservoirs. This strategy is to obtain a permit for the difference between the current water rights and the firm yields.

Facilities Required

Two configurations were analyzed:

1. Deliver additional Cedar Creek and Richland-Chambers supplies through the Integrated Pipeline (IPL) to Benbrook Lake. Because the Integrated Pipeline will not be operated at full capacity in the near term, unpermitted firm yield from Cedar Creek and Richland-Chambers reservoirs could initially be delivered through the IPL. In the future, the IPL will become fully utilized by current supply sources it has been designed to deliver.

2. Deliver additional Cedar Creek and Richland-Chambers supplies through a new pipeline constructed parallel to the IPL to carry this additional supply, possible additional supply from Cedar Creek and Richland Chambers wetlands (a separate strategy), and water from Lake Tehuacana (a separate supply strategy).



Vicinity Map

Yield

The amount of supply calculated to be available in Cedar Creek and Richland-Chambers depends on the model inputs (such as historic hydrology or water right priorities). Based on the models considered most accurate by TRWD, an unpermitted yield of 46,831 ac-ft/yr for Cedar Creek and 17,201 ac-ft/yr for Richland-Chambers were considered for this strategy. These models predict that 19,679 acre-feet/year will be available from Richland-Chambers in 2010, decreasing to roughly 7,223 acre-feet/year in 2060 because of sedimentation in the reservoir; 48,928 acre-feet/year will be available from Cedar Creek in 2010, decreasing to 38,444 acre-feet/year in 2060 because of sedimentation.

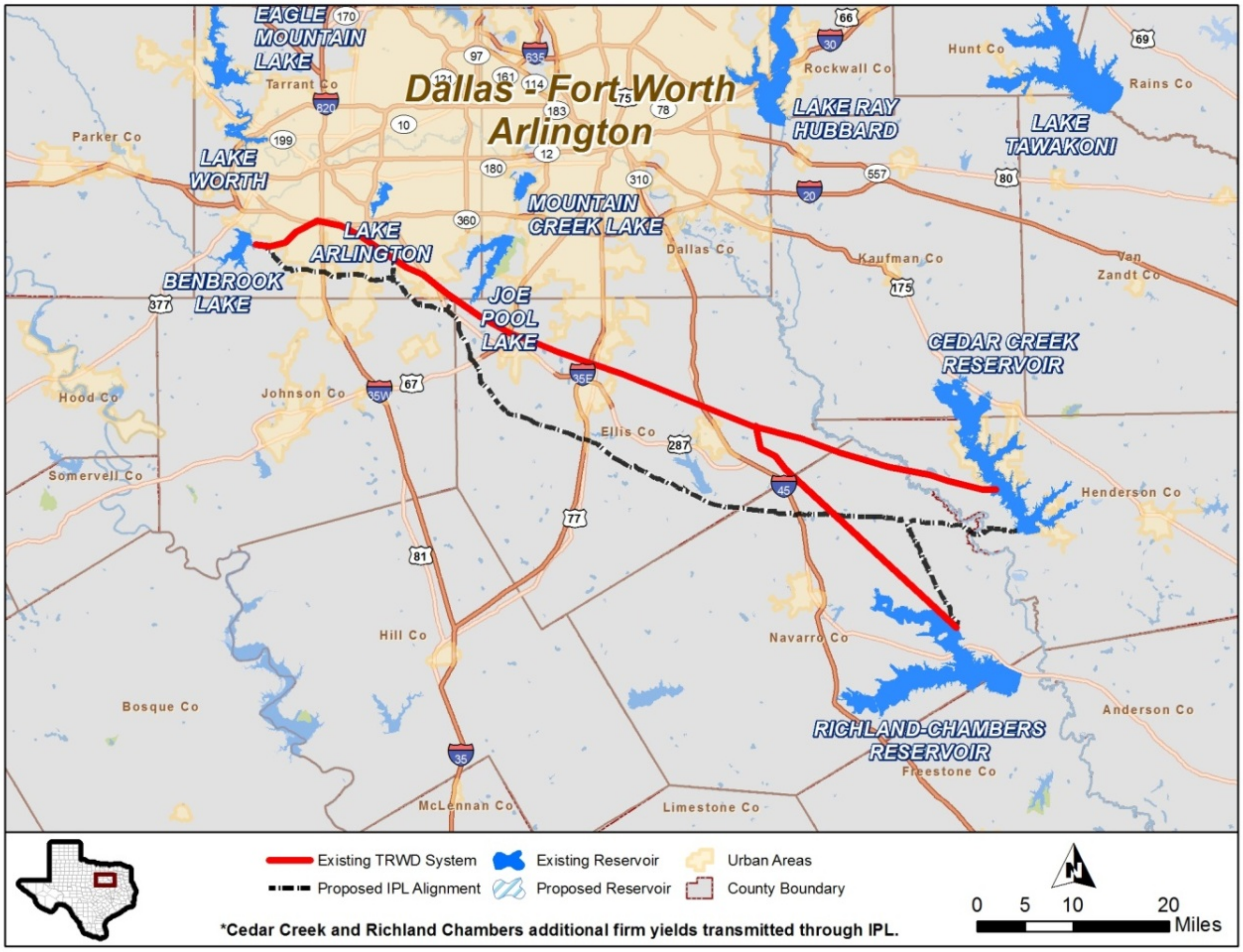
It was reported in the Region C 2011 Water Plan that Cedar Creek could have 36,900 acre-feet/year available for 2000 sedimentation conditions and 30,200 acre-feet/year available using 2060 sedimentation conditions. Richland-Chambers could yield up to 18,300 acre-feet/year for 2000 sedimentation conditions and 800 acre-feet/year using 2060 conditions. When TRWD applies for permits, the version of the Texas Water Availability Model current at that time will control and TRWD will request the largest amount of water available. However, during long-term planning, new supply from Cedar Creek and Richland-Chambers will be calculated using the models considered most accurate by TRWD.

Both of these yields are subject to change because environmental flow requirements are currently being developed. And both of these yields are *in addition to* the existing permitted yields. See the table below.

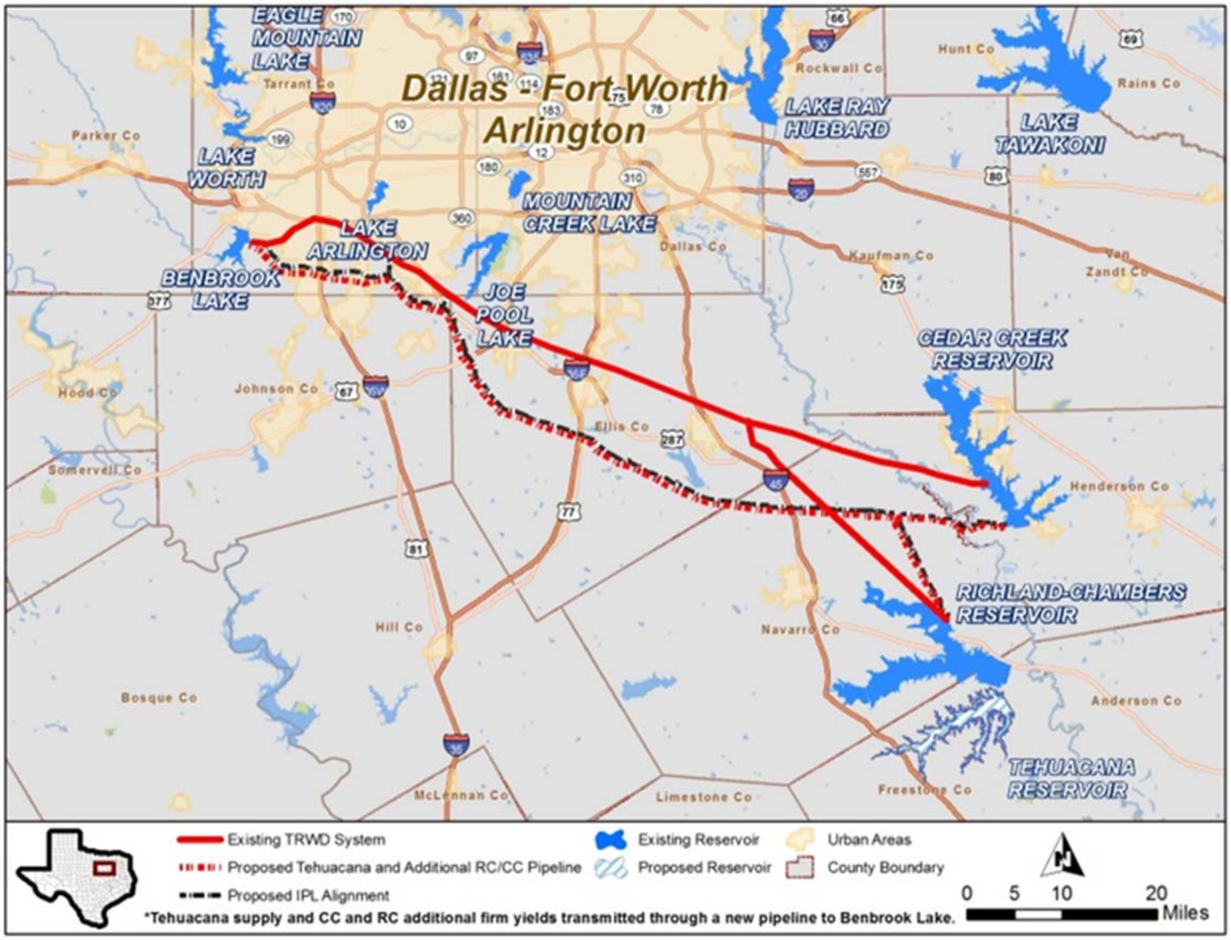
Table 1: Cedar Creek and Richland-Chambers Unpermitted Reservoir Firm Yield Estimates

Reservoir	Existing Permit (ac-ft/yr)	Proposed New Supply (ac-ft/yr) by Decade					
		2010	2020	2030	2040	2050	2060
Richland-Chambers	210,000	19,679	17,201	14,715	12,221	9,724	7,223
Cedar Creek	175,000	48,928	46,831	44,734	42,637	40,540	38,444

*Note: Existing permits for yield from the Cedar Creek (63,000 ac-ft/year) and Richland-Chambers (52,500 ac-ft/yr) Constructed Wetlands are not included in these numbers (though they are accounted for in the appropriate places of the TRWD Integrated Water Supply Plan)



Pipeline Route to Lake Benbrook (Transmitted through IPL)



Pipeline Route to Lake Benbrook (Tehuacana and Additional Richland-Chambers & Cedar Creek in a new Pipeline Parallel to IPL)

Cost (in 2012 dollars if delivered through IPL)

Capital

- Capital expenditure needed for new facilities is part of the Integrated Pipeline project, and therefore not attributable to this strategy.

Annual

- Annual unit cost of water (electrity costs only) based on 64,032 acft/yr firm yield ($/1000 gal) – $0.42

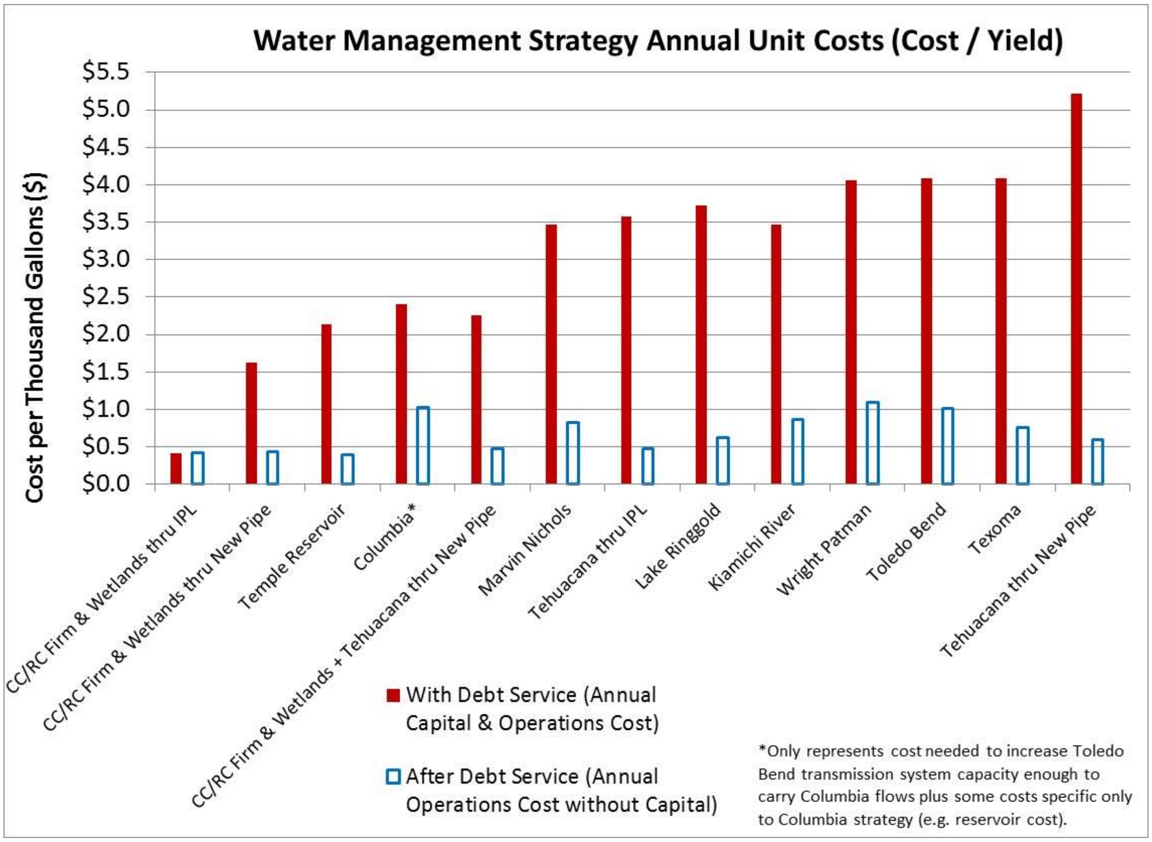
*These costs do not include debt service on a new pipeline that will eventually be needed to convey flows from Richland-Chambers and Cedar Creek. It is most probable that the new pipeline would be built to carry unpermitted Cedar Creek and Richland-Chambers firm yield supplies and another supply (such as Tehuacana and Cedar Creek and Richland-Chambers wetlands).

Cost (in 2012 dollars if delivered through new pipeline)

The additional supply from the unpermitted firm yield could be delivered through the Integrated Pipeline until it is fully utilized by the supply sources it is designed to carry. At that point, a new pipeline will be needed. It is not now known with full certainty what other supplies will be available when the new pipeline is needed, but it is highly probably that the new line will be sized to jointly deliver additional supply from the unpermitted firm yield and both/either supply from the Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits and/or Lake Tehuacana. Therefore, costs for all combinations of the three strategies are provided in Table 2 below.

Table 2: Cost Estimates for Strategies delivered through New Pipeline

Supply Option	TRWD Share of Supply (AFY)	Capital Cost		Annual Cost		With Debt Service (DS) Unit Cost (per 1,000 gal)		Without Debt Service Unit Cost (per 1,000 gal)	
		Total	TRWD Share	TRWD	TRWD w/out DS	Total	TRWD Share	Total	TRWD Share
Unpermitted RC & CC Firm yield (FY) through new pipeline	64,032	$415,460,000	$415,460,000	$40,329,000	$10,146,000	$1.93	$1.93	$0.49	$0.49
Unpermitted RC & CC wetlands through new pipeline	73,024	$465,373,000	$465,373,000	$44,840,000	$11,031,000	$1.88	$1.88	$0.46	$0.46
Tehuacana through new pipeline	41,900	$868,331,000	$868,331,000	$71,308,000	$8,225,000	$5.22	$5.22	$0.60	$0.60
Unpermitted RC & CC FY + Tehuacana though new pipeline	105,932	$1,152,482,000	$1,152,482,000	$101,039,000	$17,312,000	$2.93	$2.93	$0.50	$0.50
Unpermitted RC & CC wetlands + Tehuacana though new pipeline	114,924	$1,217,707,000	$1,217,707,000	$106,410,000	$17,945,000	$2.84	$2.84	$0.48	$0.48
Unpermitted RC & CC wetlands + FY though new pipeline	137,056	$725,528,000	$725,528,000	$72,470,000	$19,761,000	$1.62	$1.62	$0.44	$0.44
Unpermitted RC & CC wetlands + FY + Tehuacana though new pipeline	178,956	$1,440,491,000	$1,440,491,000	$131,799,000	$27,149,000	$2.26	$2.26	$0.47	$0.47
Unpermitted RC & CC wetlands + FY though IPL	137,056	$0	$0	$28,832,000	$28,832,000	$0.65	$0.65	$0.65	$0.65
Unpermitted RC & CC FY through IPL	64,032	$0	$0	$8,841,000	$8,841,000	$0.42	$0.42	$0.42	$0.42
Unpermitted RC & CC wetlands through IPL	73,024	$0	$0	$10,700,000	$10,700,000	$0.45	$0.45	$0.45	$0.45
Tehuacana through IPL	41,900	$580,790,000	$580,790,000	$48,781,000	$6,587,000	$3.57	$3.57	$0.48	$0.48

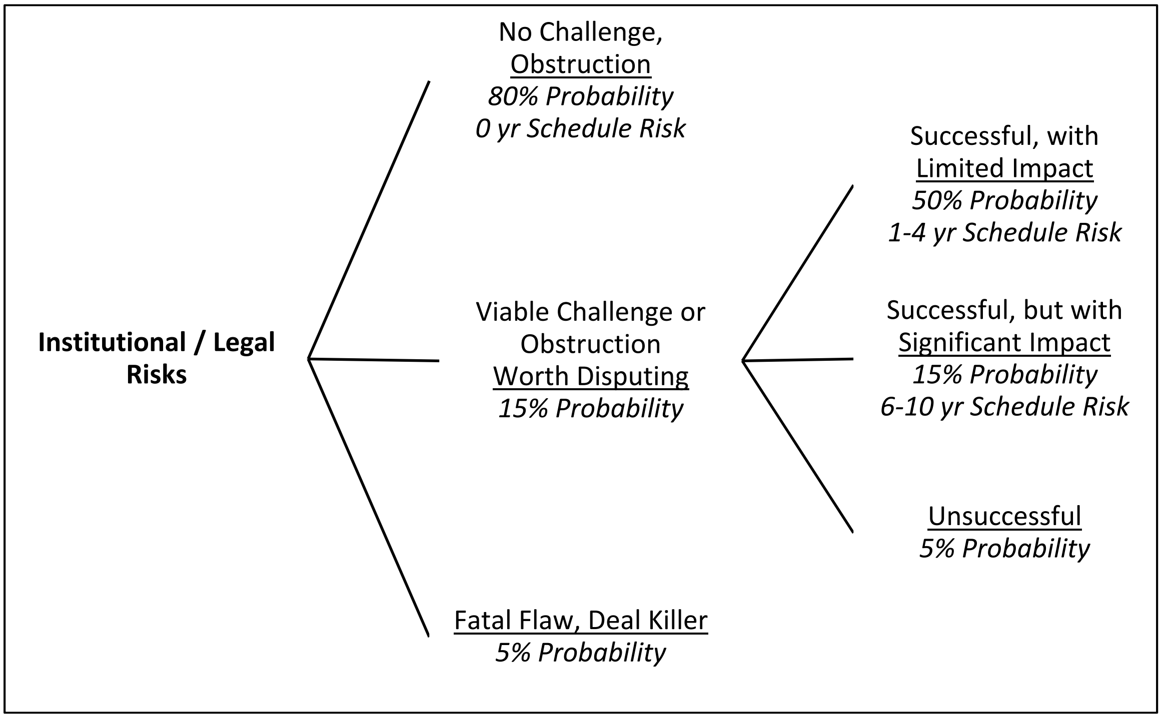


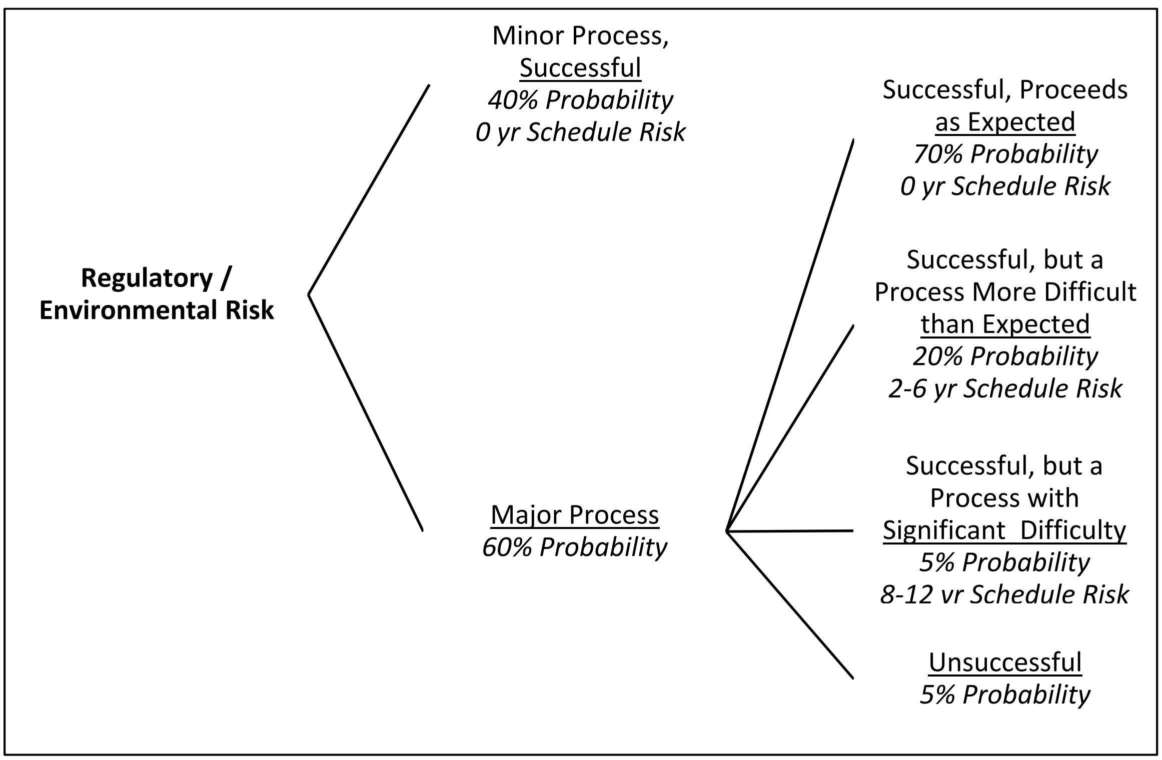
Comparison to Other Strategies

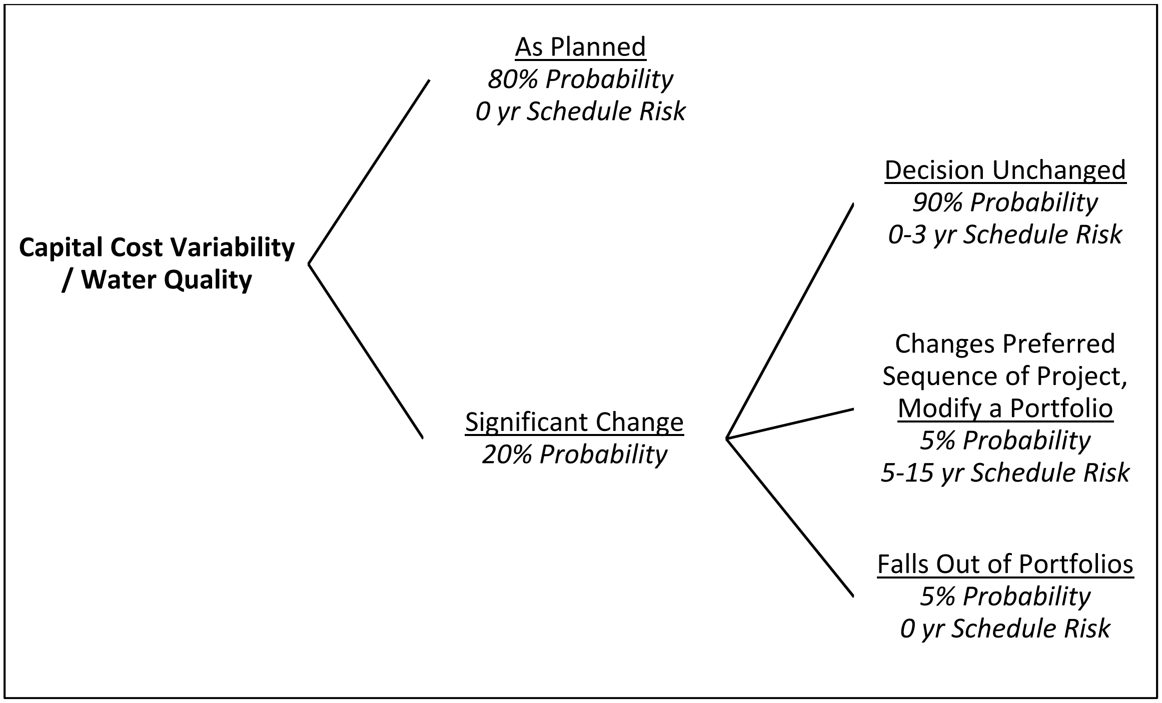
Key Assumptions

- Firm yields used for this water supply strategy were developed using TRWD's RiverWare hydrology. Yields calculated using Texas WAM modeling are significantly different (higher) and are therefore not used for long-range water supply planning.

Risk Assessment



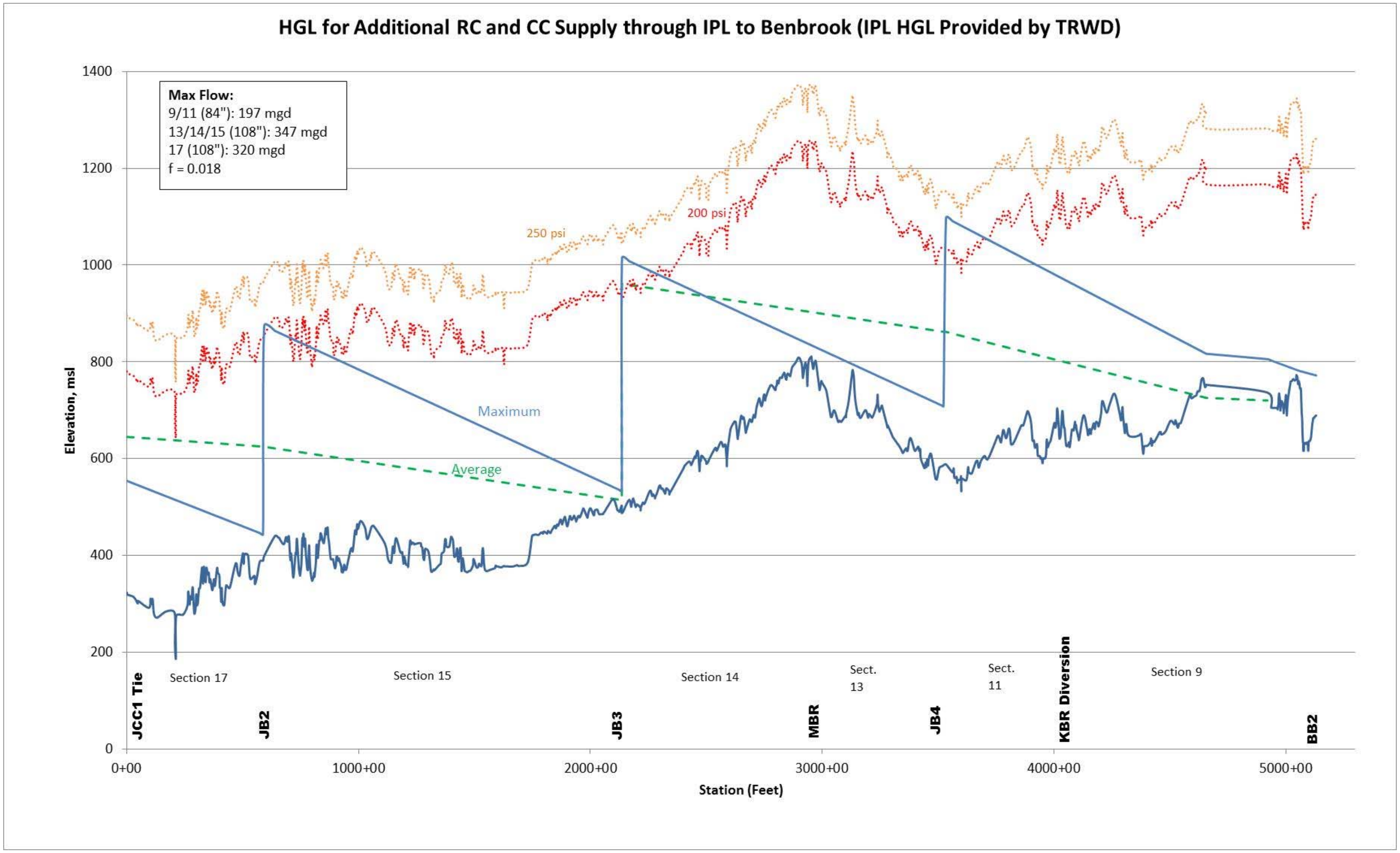




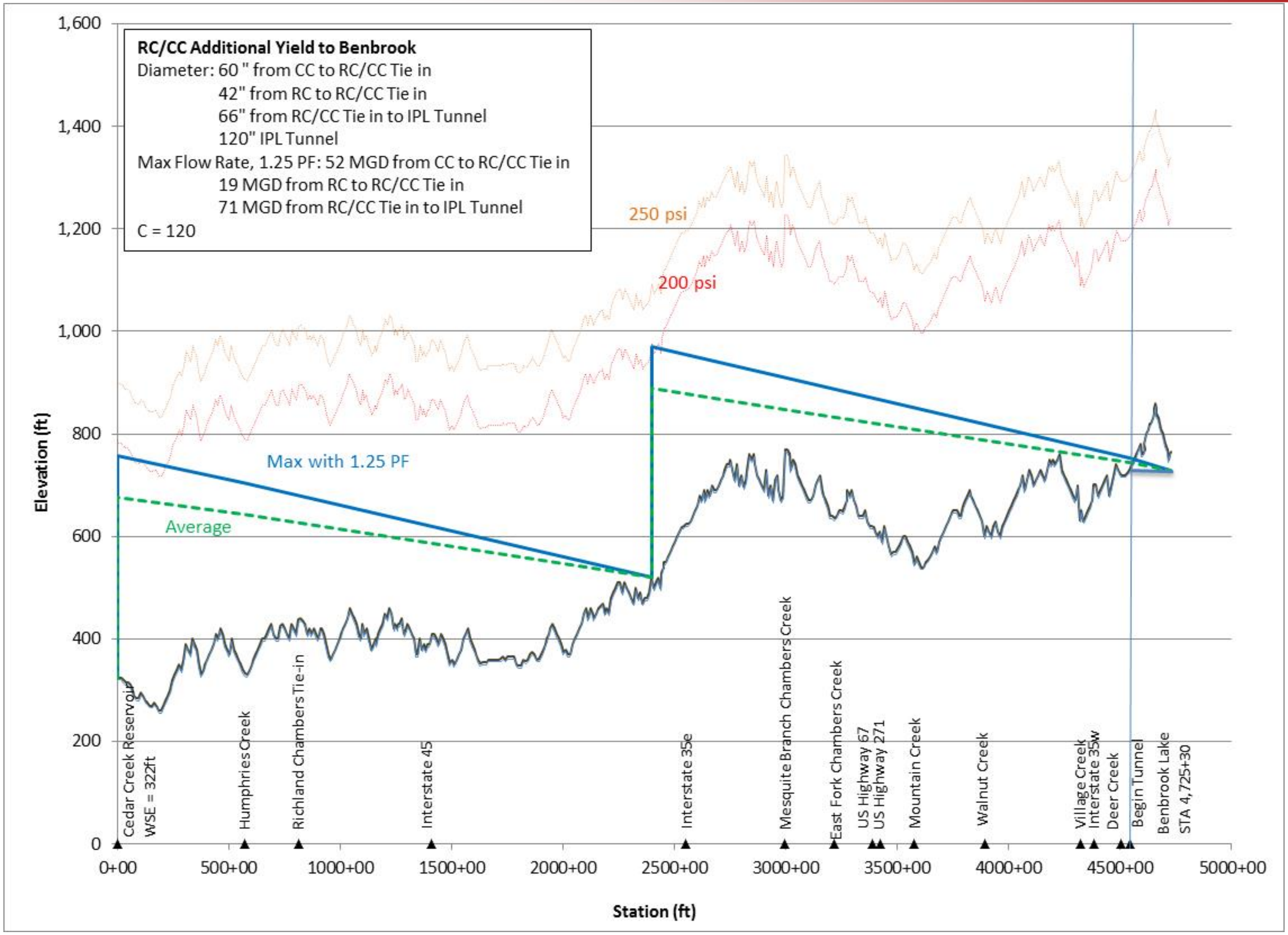
Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
No partnering. Possible challenge by downstream parties	New water right with possible challenge by downstream parties. Environmental flow requirements may have significant impact on yield	Unit cost dependent on degree to which environmental flow requirements reduce yield.

References

Yield values are based on Tarrant Regional Water District modeling, which was provided to the IWSP consulting team.



Hydraulic Grade Line –Richland Chambers and Cedar Creek Unpermitted Firm Yields through IPL



Hydraulic Grade Line –Richland Chambers and Cedar Creek Unpermitted Firm Yield through New Pipeline

Note: This hydraulic grade line illustrates the option of delivering this strategy's supply through a new pipeline sized only for this supply. Table 2 above provides several other options of pipelines sized for joint delivery of multiple supplies.

Cedar Creek and Richland-Chambers Firm Yield Permits Implementation Schedule for TRWD IWSP:

Assumptions

- New water rights permits would be needed
- Because there are no new facilities to be constructed, not subject to regulation under the Clean Water Act (no 404 permit or 401 certification required)

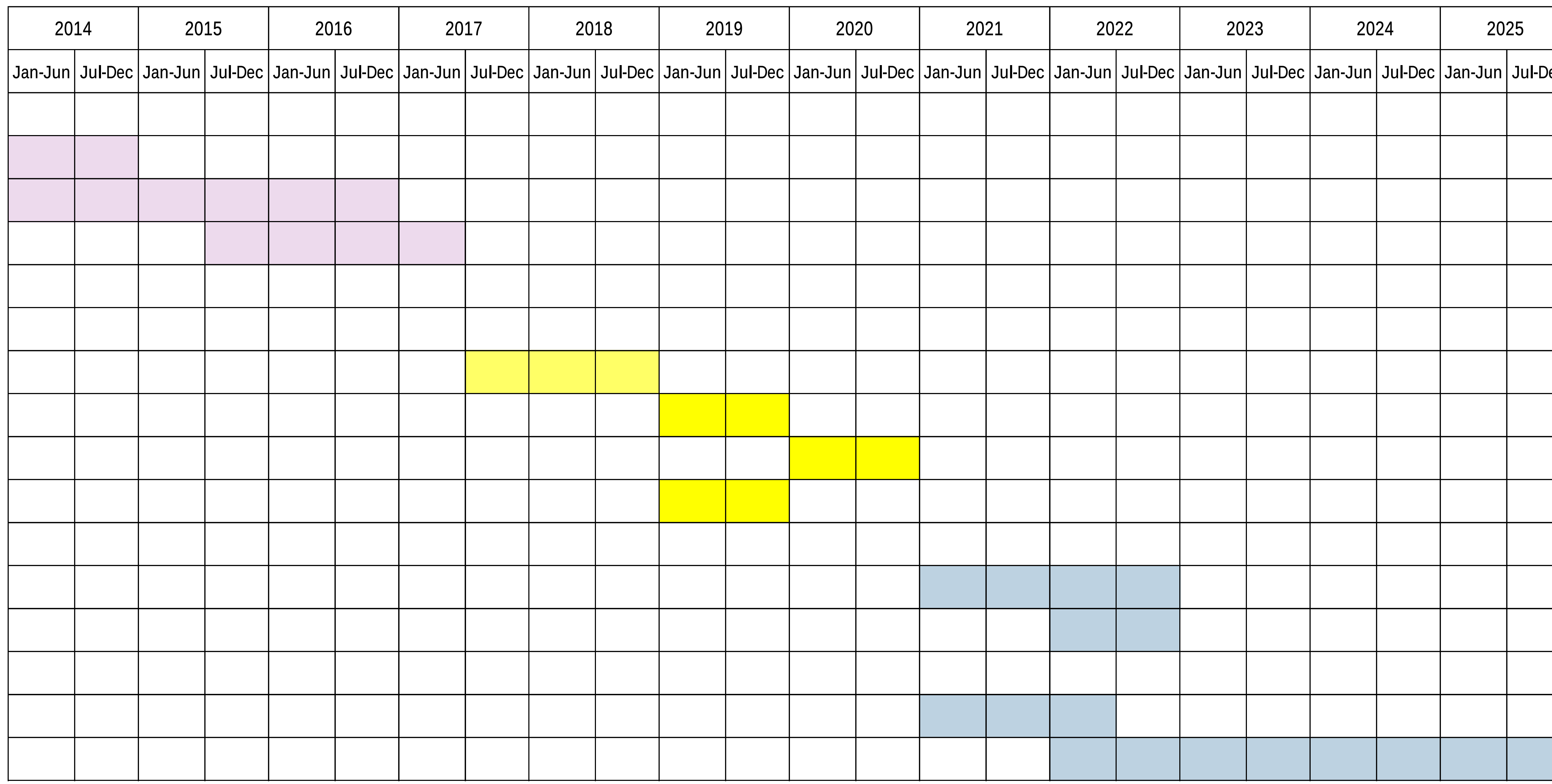
TASKS	START DATE	DURATION	2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun	2015 Jul-Dec	2016 Jan-Jun	2016 Jul-Dec
PLANNING TASKS								
Conceptual Design and Planning	January 2014	1 Year						
Water Rights Application	January 2014	3 Years						

Cedar Creek and Richland-Chambers Firm Yield Permits with a New Pipeline Implementation Schedule for TRWD IWSP:

Assumptions

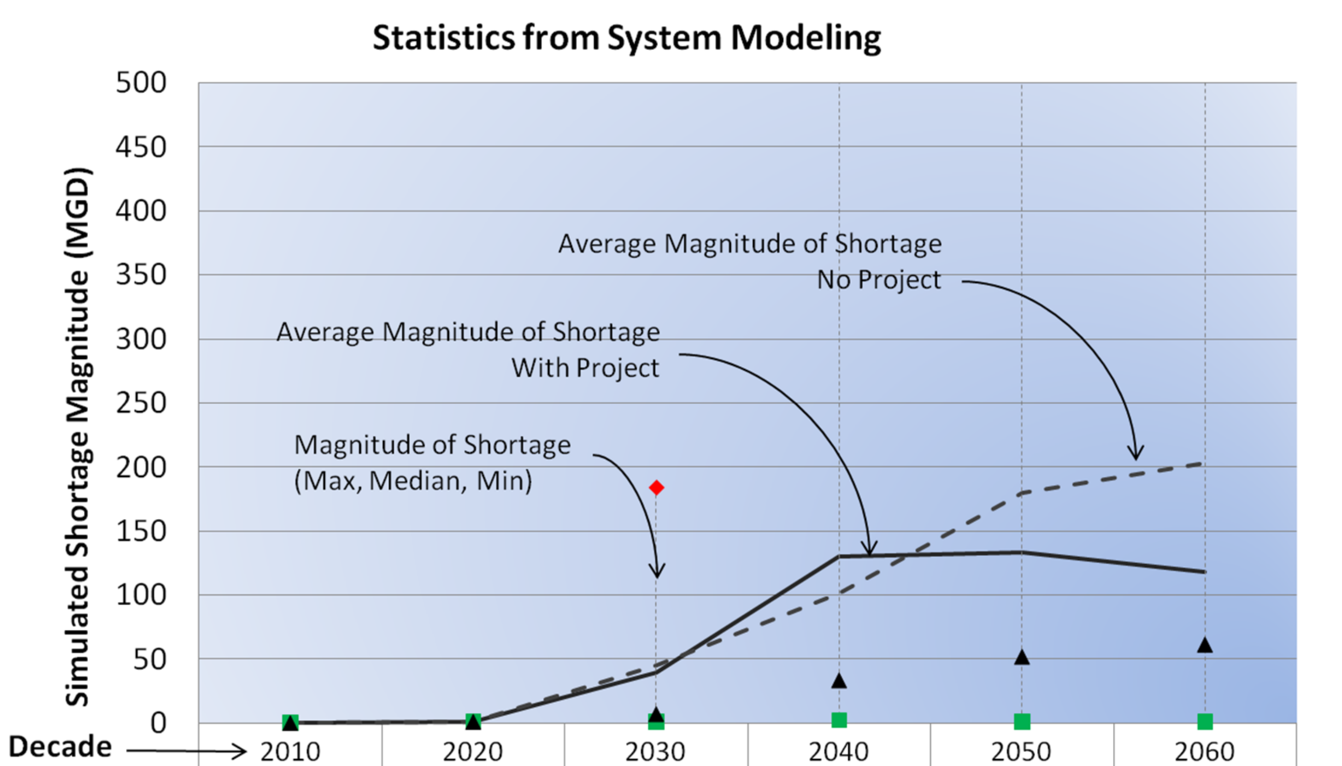
- New water rights permits would be needed
- The pipeline would require a Federal 404 permit
- Water right permits and 404 permit process would run concurrently
- A portion of the eventual new pipeline capacity would be constructed in the IPL right-of-way and no additional real estate will be required
- Conceptual design and planning includes preliminary pipeline route selection for permitting purposes

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	1 Year
Water Rights Application	January 2014	3 Years
404 Permit Application / Approval (pipeline)	January 2020	2 Years
DESIGN TASKS		
Transmission Facilities	July 2016	3.5 Years
Route Selection	July 2017	1.5 Years
Survey and Preliminary Design	January 2019	1 Year
Final Design	January 2020	1 Year
Design Mitigation Features (if needed)	January 2019	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition for Pump Stations	January 2021	2 Years
Implement Mitigation (if needed)	January 2022	1 Year
Transmission Facilities	January 2021	5 Years
Easement Acquisition	January 2021	1.5 Years
Bid and Construction Phase	January 2022	4 Years



CC&RC Unpermitted Yield

Magnitude Chart

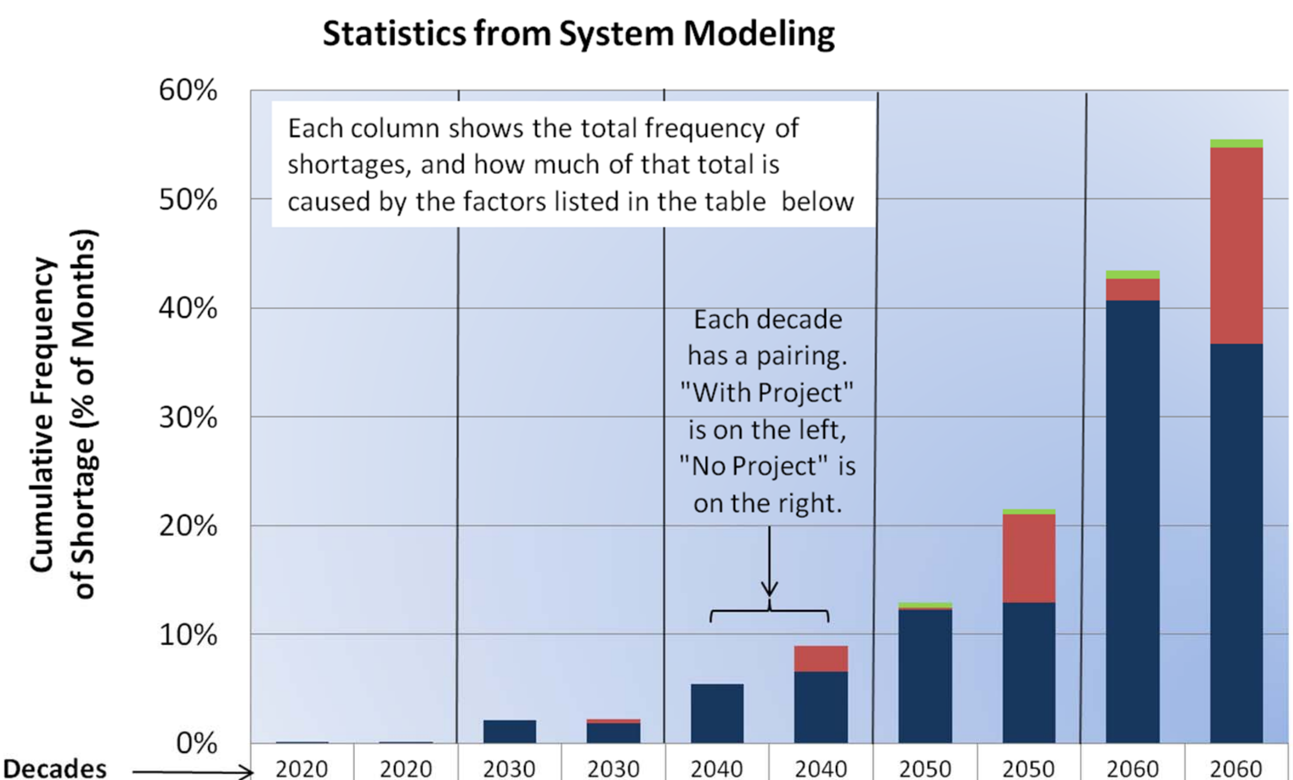


Decade	2010	2020	2030	2040	2050	2060
◆ Maximum	0	1	184	733	909	990
■ Minimum	0	1	1	2	1	1
▲ Median	0	1	7	34	52	62
—— Average	0	1	39	130	133	118
- - Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

CC&RC Unpermitted Yield

Frequency Chart

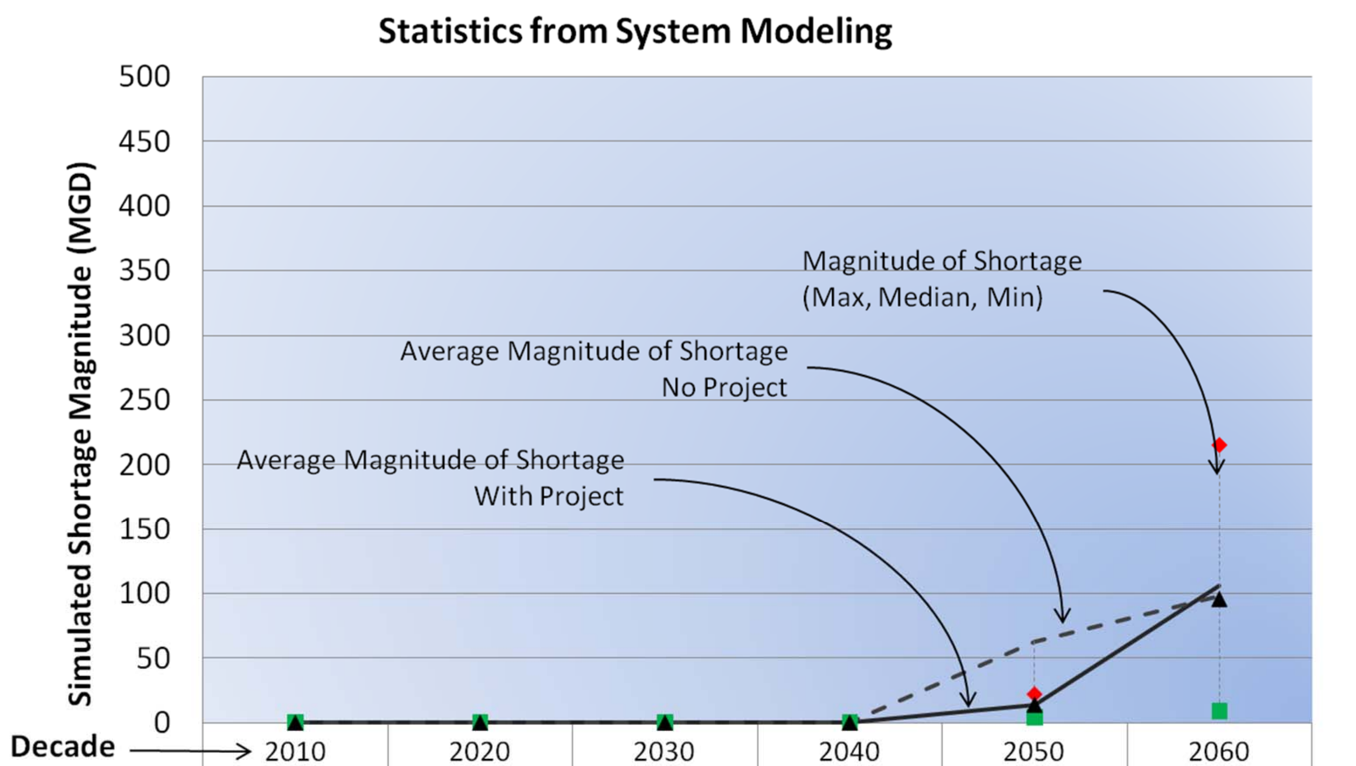


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.5%		0.7%	
Permitted Amount	0.0%		0.0%		0.0%		0.1%		2.0%	
Pipeline Capacity	0.1%		2.1%		5.5%		12.3%		40.7%	

Results Using 2011 Region C Based Demand Projection

CC&RC Unpermitted Yield

Magnitude Chart

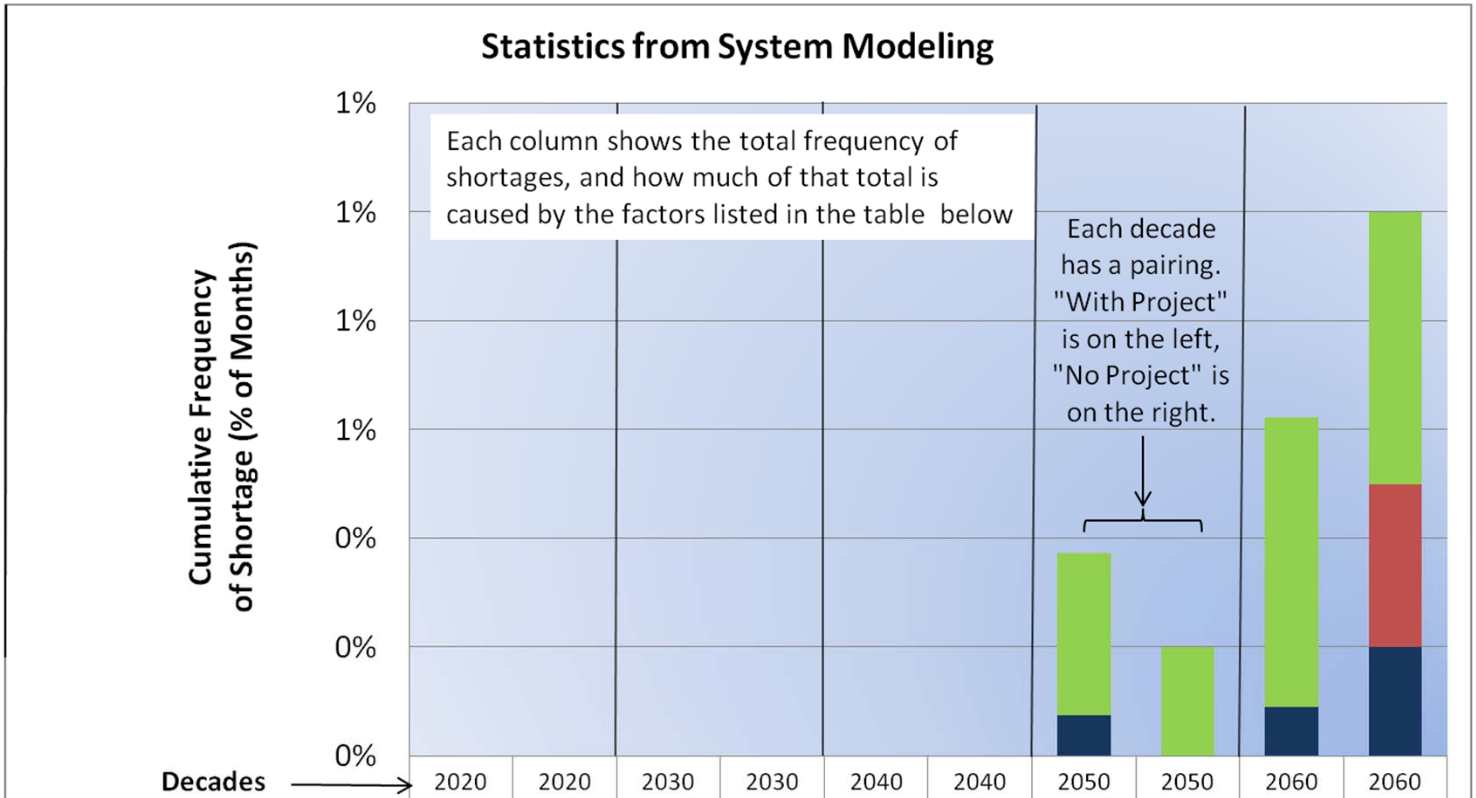


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	0	22	215
Minimum	0	0	0	0	4	9
Median	0	0	0	0	14	96
Average	0	0	0	0	13	106
Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

CC&RC Unpermitted Yield

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.3%		0.5%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.0%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.1%		0.1%	

Results Using Recent Trend Extrapolation Demand Projection

Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits

Description

TRWD has constructed wetlands adjacent to Richland-Chambers Reservoir and is planning to construct wetlands adjacent to Cedar Creek Reservoir. Water from the Trinity River is pumped into these constructed wetland systems where it is treated naturally in a series of sedimentation ponds and wetland cells and then put back into the reservoir for use as a water supply. TRWD has permits from the Texas Commission on Environmental Quality (TCEQ) to divert water from the Trinity River into constructed wetlands, deliver that water to Cedar Creek and Richland-Chambers Reservoirs, and then deliver to TRWD customers. TRWD customers' wastewater treatment plant discharges are a source of water permitted for delivery to the constructed wetlands.

On February 8, 2005 the TCEQ granted Certificates of Adjudication for the Cedar Creek Wetlands (08-4976C for 52,500 acre-feet/year) and Richland-Chambers Wetlands (05-5035C for 63,000 acre-feet/year). These permitted amounts are not equal to the full volume of water available for delivery to the wetlands or permitted for delivery to the reservoirs (each permitted amount is different in this three step process). The difference exists because it was previously decided that at any point of time, the total volumetric contribution to Cedar Creek and Richland-Chambers Reservoirs from their respective wetlands should not be greater than 30% of the reservoir storage volume. This decision was meant to protect reservoir water quality. The 30% rule was chosen based on engineering judgment, but actual operations of the wetlands system have shown that this rule is not required to maintain acceptable water quality.

This water supply strategy is to secure a permit from the TCEQ to use all water delivered to the reservoirs from the constructed wetlands. The strategy is to pump water out of the reservoirs and to TRWD customers on the same day as it is delivered from the wetlands. This eliminates evaporative losses and will not impact reservoir storage that could be otherwise used (such as to permit the difference between the current water rights in Cedar Creek and Richland-Chambers and their firm yields).

Table 1: Cedar Creek and Richland-Chambers Reservoir and Wetlands Yield Estimates

Reservoir	Permitted Delivery from Trinity River to Wetlands (ac-ft/yr)	Permitted Delivery from Wetlands to Reservoir (ac-ft/yr)	Permitted Supply of Wetland Water from Reservoir to Customers (ac-ft/yr)	**Proposed Additional Supply of Wetland Water from Reservoir to Customers** (ac-ft/yr)
Richland-Chambers	105,019	100,465	63,000	**37,465**
Cedar Creek	90,799	88,059	52,500	**35,559**

Facilities Required

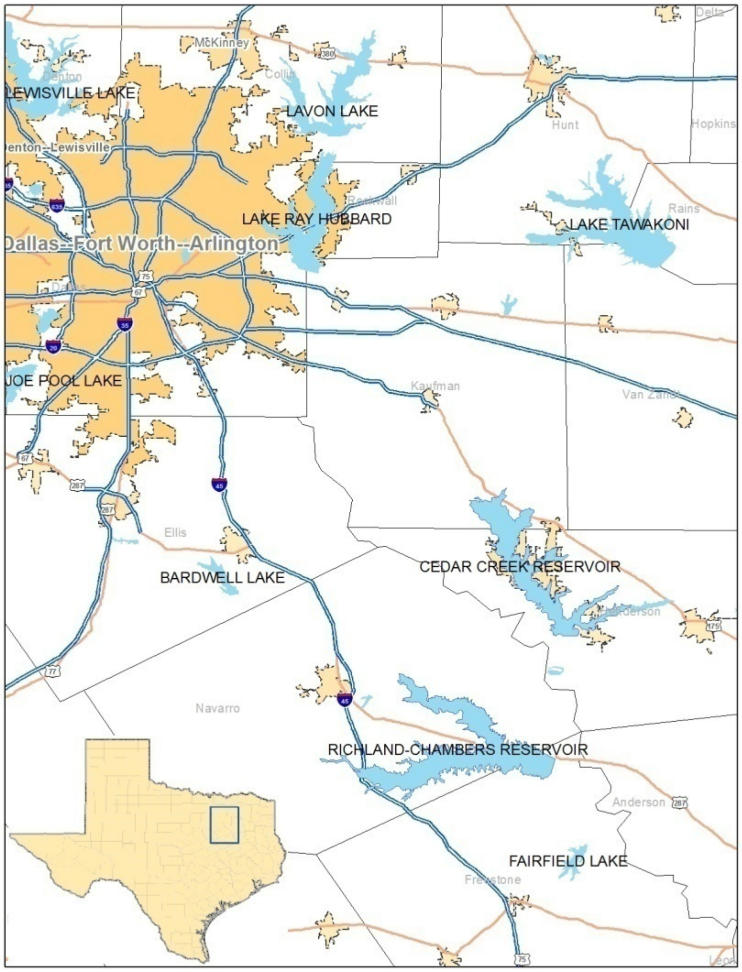
Two configurations were analyzed:

1. Deliver additional Cedar Creek and Richland-Chambers supplies through the Integrated Pipeline (IPL) to Benbrook Lake. Because the Integrated Pipeline will not be operated at full capacity in the near term, wetlands supply could initially be delivered through the IPL. In the future, the IPL will become fully utilized by current supply sources it has been designed to deliver.

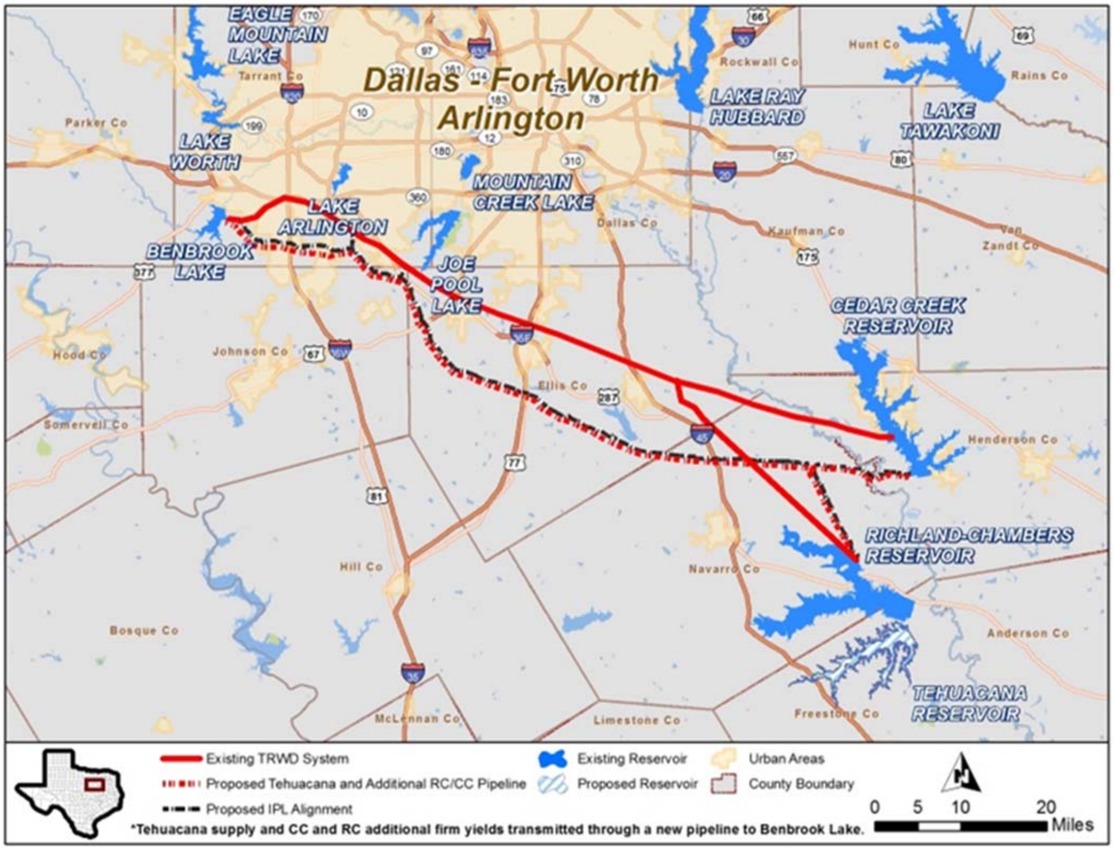
2. Deliver additional Cedar Creek and Richland-Chambers supplies through a new pipeline constructed parallel to the IPL to carry this additional supply, and water from the *Unpermitted Firm Yield in Cedar Creek and Richland-Chambers Reservoirs* strategy (a separate strategy), and water from Lake Tehuacana (a separate supply strategy).

Yield

The strategy is to pump water out of the reservoirs and to the customers on the same day as it is delivered from the wetlands because this will eliminate evaporative losses and will not impact reservoir storage that could be otherwise used. Under these conditions, and assuming that environmental flow requirements are not changed because of these permits, the additional amount that can be permitted from Richland-Chambers Reservoir is 37,465 acre-feet/year; the additional amount that can be permitted from Cedar Creek Reservoir is 35,559 acre-feet/year.



Vicinity Map



Pipeline Route to Lake Benbrook (Tehuacana and Richland-Chambers & Cedar Creek Constructed Wetlands Supply in a New Pipeline Parallel to IPL)

Cost (in 2012 dollars if delivered through IPL)

Capital

- Capital expenditure needed for new facilities is part of the Integrated Pipeline project, and therefore not attributable to this strategy.

Annual

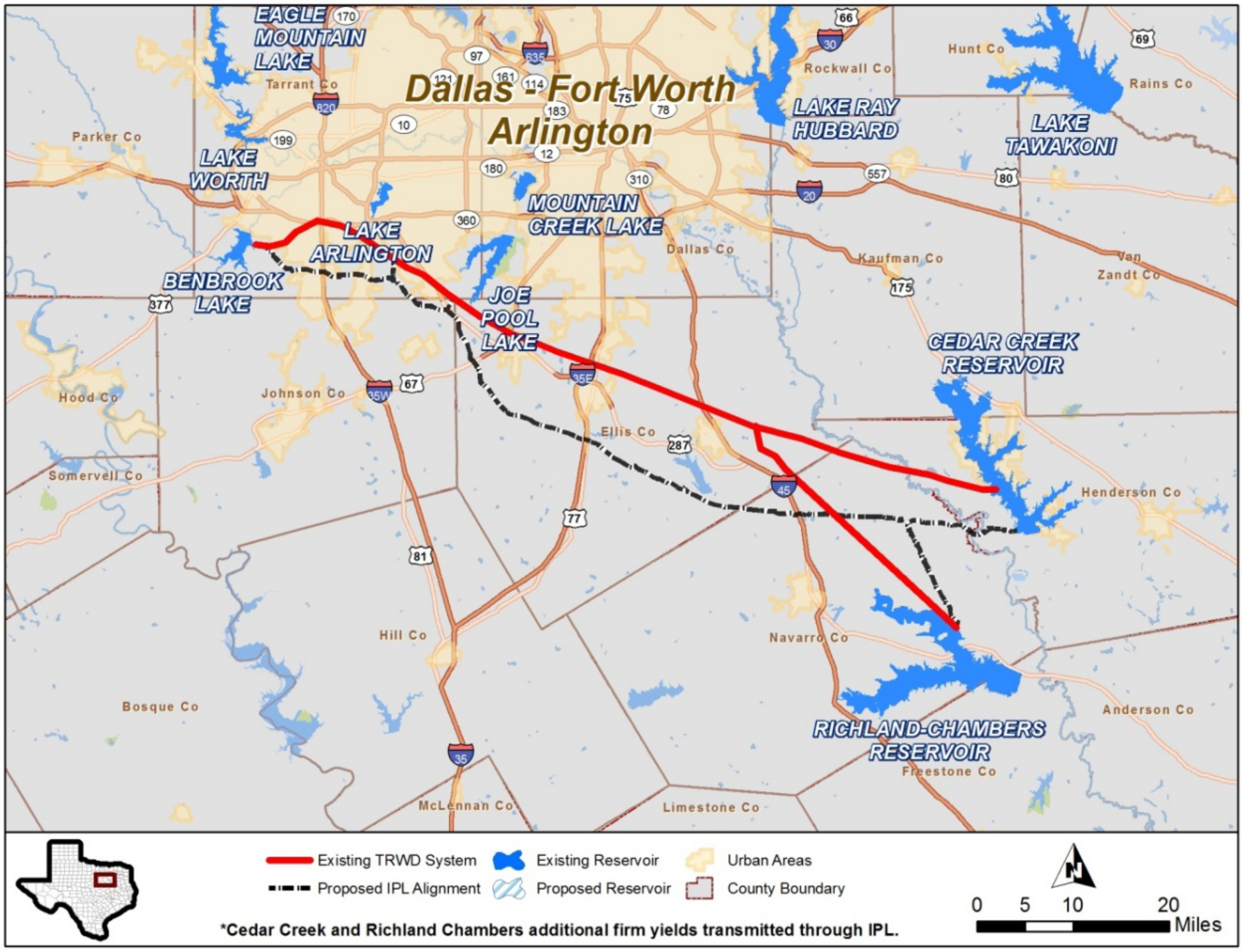
- Annual unit cost of water (electrity costs only) based on 73,024 acft/yr firm yield ($/1000 gal) – $0.45

Cost (in 2012 dollars if delivered through new pipeline)

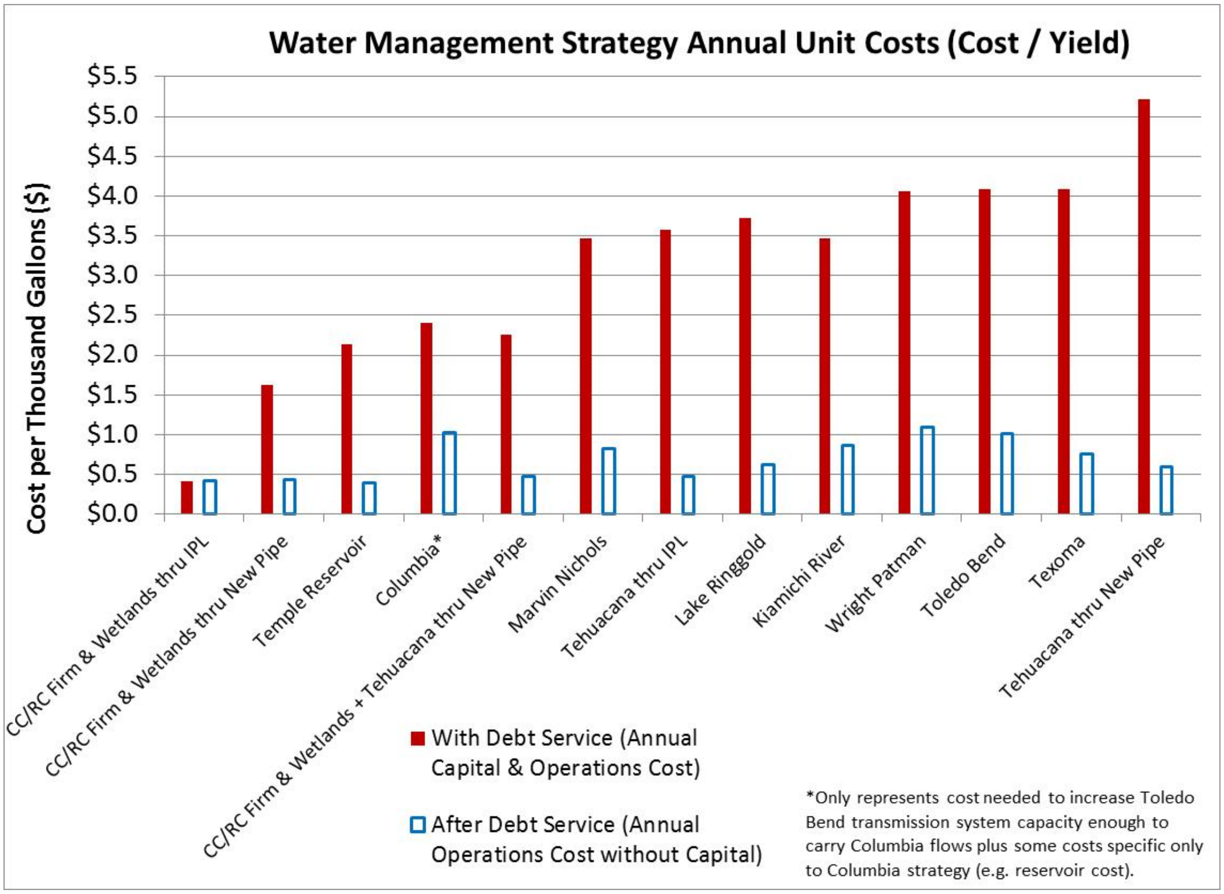
The additional supply from the constructed wetlands could be delivered through the Integrated Pipeline until it is fully utilized by the supply sources it is designed to carry. At that point, a new pipeline will be needed. It is not now known with full certainty what other supplies will be available when the new pipeline is needed, but it is highly probably that the new line will be sized to jointly deliver additional supply from the wetlands and both/either supply from the Unpermitted Firm Yield in Cedar Creek and Richland-Chambers Reservoirs and/or Lake Tehuacana. Therefore, costs for all combinations of the three strategies are provided in Table 2 below.

Table 2 –Cost Estimates

Supply Option	TRWD Share of Supply (AFY)	Capital Cost		Annual Cost		With Debt Service (DS) Unit Cost (per 1,000 gal)		Without Debt Service Unit Cost (per 1,000 gal)	
		Total	TRWD Share	TRWD	TRWD w/out DS	Total	TRWD Share	Total	TRWD Share
Unpermitted RC & CC Firm yield (FY) through new pipeline	64,032	$415,460,000	$415,460,000	$40,329,000	$10,146,000	$1.93	$1.93	$0.49	$0.49
Unpermitted RC & CC wetlands through new pipeline	73,024	$465,373,000	$465,373,000	$44,840,000	$11,031,000	$1.88	$1.88	$0.46	$0.46
Tehuacana through new pipeline	41,900	$868,331,000	$868,331,000	$71,308,000	$8,225,000	$5.22	$5.22	$0.60	$0.60
Unpermitted RC & CC FY + Tehuacana though new pipeline	105,932	$1,152,482,000	$1,152,482,000	$101,039,000	$17,312,000	$2.93	$2.93	$0.50	$0.50
Unpermitted RC & CC wetlands + Tehuacana though new pipeline	114,924	$1,217,707,000	$1,217,707,000	$106,410,000	$17,945,000	$2.84	$2.84	$0.48	$0.48
Unpermitted RC & CC wetlands + FY though new pipeline	137,056	$725,528,000	$725,528,000	$72,470,000	$19,761,000	$1.62	$1.62	$0.44	$0.44
Unpermitted RC & CC wetlands + FY + Tehuacana though new pipeline	178,956	$1,440,491,000	$1,440,491,000	$131,799,000	$27,149,000	$2.26	$2.26	$0.47	$0.47
Unpermitted RC & CC wetlands + FY though IPL	137,056	$0	$0	$28,832,000	$28,832,000	$0.65	$0.65	$0.65	$0.65
Unpermitted RC & CC FY through IPL	64,032	$0	$0	$8,841,000	$8,841,000	$0.42	$0.42	$0.42	$0.42
Unpermitted RC & CC wetlands through IPL	73,024	$0	$0	$10,700,000	$10,700,000	$0.45	$0.45	$0.45	$0.45
Tehuacana through IPL	41,900	$580,790,000	$580,790,000	$48,781,000	$6,587,000	$3.57	$3.57	$0.48	$0.48



Pipeline Route to Lake Benbrook (Transmitted through IPL)

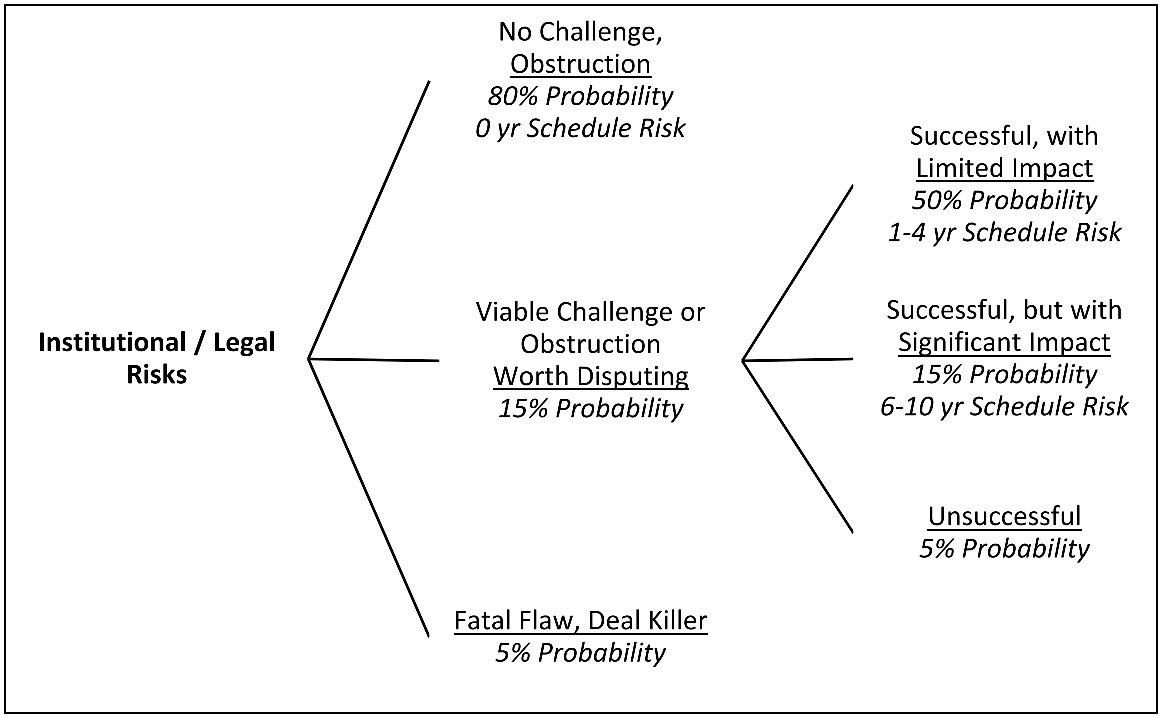


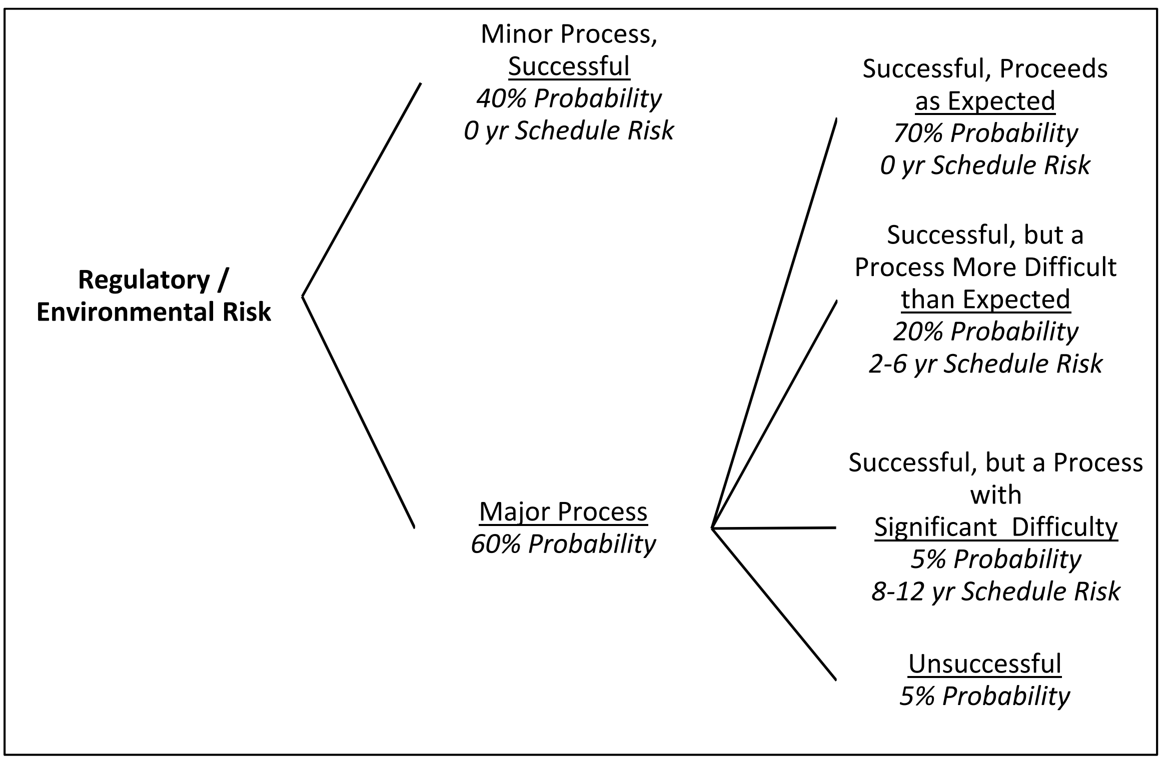
Comparison to Other Strategies

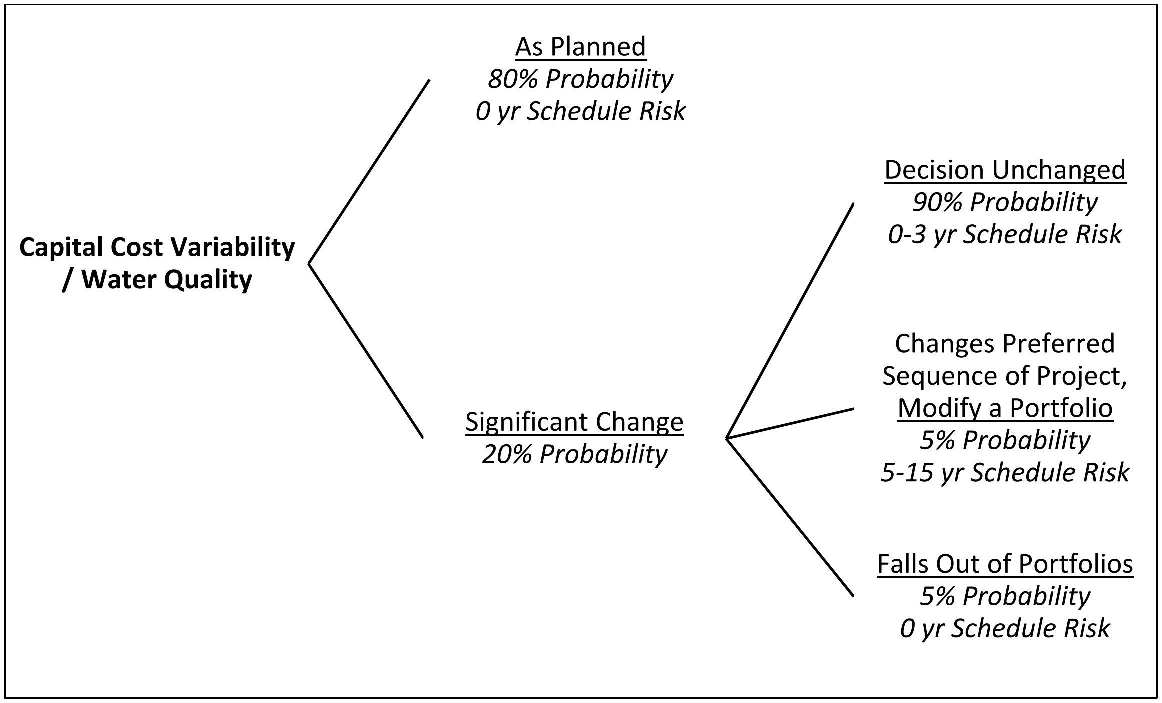
Key Assumptions

- Environmental flow requirements do not have a significant impact on yield.
- TCEQ accepts operating plan and does not require accounting for evaporative losses and use of reservoir storage.

Risk Assessment



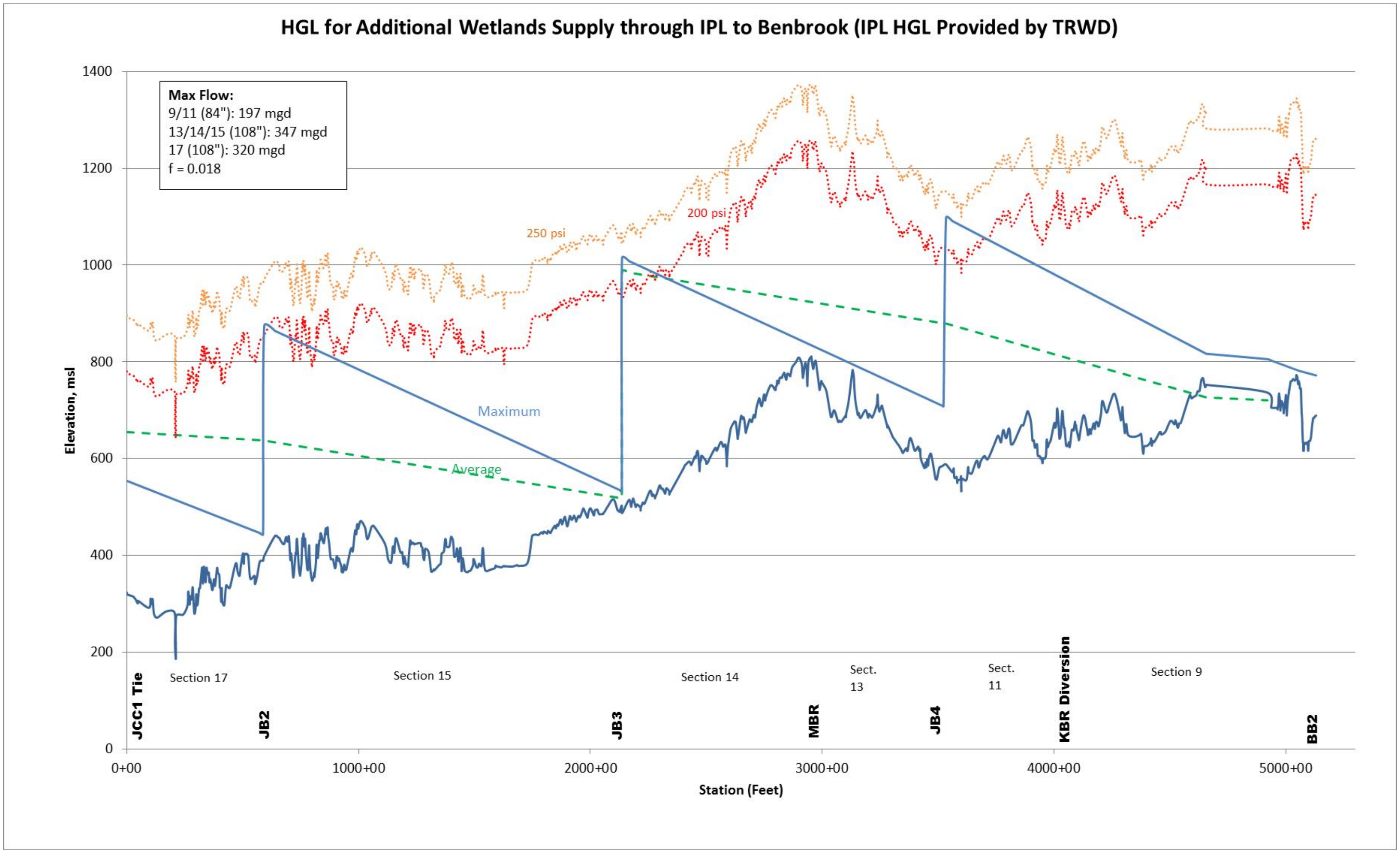




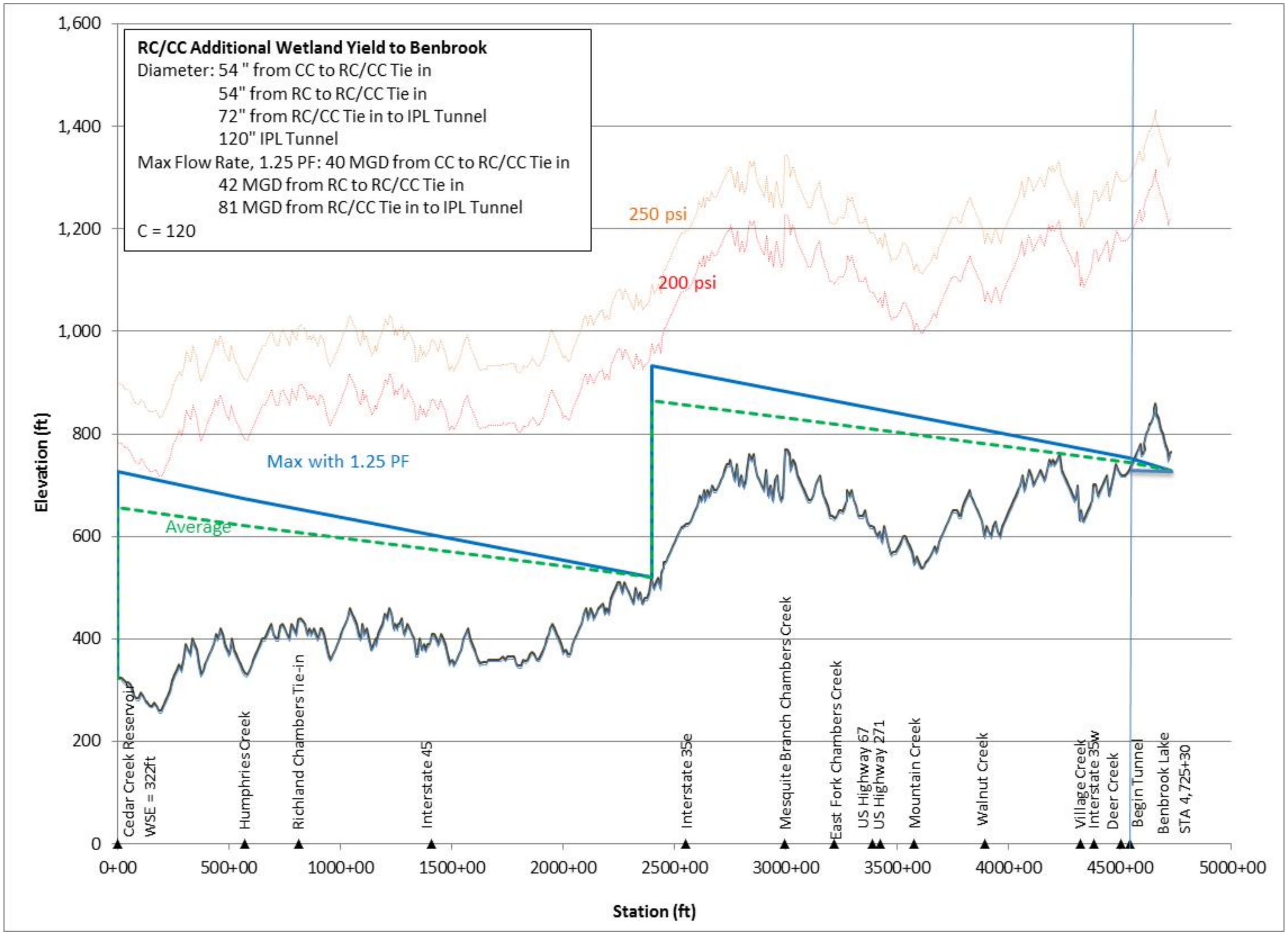
Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
No partnering. Possible challenge by downstream parties	New water right with possible challenge by downstream parties. Environmental flow requirements could be imposed and have significant impact on yield. TCEQ could dispute operating plan and require accounting for evaporative losses and use of reservoir storage.	Unit cost dependent on final yield.

References

(None)



Hydraulic Grade Line – Richland Chambers and Cedar Creek Constructed Wetlands Full Yields through IPL



Hydraulic Grade Line –Richland-Chambers and Cedar Creek Constructed Wetlands Full Yields through New Pipeline

Note: This hydraulic grade line illustrates the option of delivering this strategy's supply through a new pipeline sized only for this supply. Table 2 above provides several other options of pipelines sized for joint delivery of multiple supplies.

Cedar Creek and Richland-Chambers Constructed Wetlands Full Yield Permits Implementation Schedule for TRWD IWSP:

Assumptions

- New water rights permits would be needed
- New facilities will be required for operating the wetlands. These new facilities will be considered as part of the baseline condition and not part of this strategy. Because there are no new facilities to be constructed as part of this strategy, it is not subject to regulation under the Clean Water Act (No 404 permit or 401 certification required)

TASKS	START DATE	DURATION	2014		2015		2016	
			Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec
PLANNING TASKS								
Conceptual Design and Planning	January 2014	1 Year						
Water Rights Application	January 2014	3 Years						

Cedar Creek and Richland-Chambers Wetland Permits with a New Pipeline Implementation Schedule for TRWD IWSP:

Assumptions

- New water rights permits would be needed
- The pipeline would require a Federal 404 permit
- Water right permits and 404 permit process would run concurrently
- A portion of the eventual new pipeline capacity would be constructed in the IPL right-of-way and no additional real estate will be required
- Conceptual design and planning includes preliminary pipeline route selection for permitting purposes
- New facilities will be needed to utilize the yield from wetlands. However, these facilities are considered as part of the baseline condition and not a part of this strategy.

			2014		2015		2016		2017		2018		2019		2020		2021		2022		2023		2024		2025	
TASKS	START DATE	DURATION	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec
PLANNING TASKS																										
Conceptual Design and Planning	January 2014	1 Year																								
Water Rights Application	January 2014	3 Years																								
404 Permit Application / Approval (pipeline)	January 2020	2 Years																								
DESIGN TASKS																										
Transmission Facilities	July 2016	3.5 Years																								
Route Selection	July 2017	1.5 Years																								
Survey and Preliminary Design	January 2019	1 Year																								
Final Design	January 2020	1 Year																								
Design Mitigation Features (if needed)	January 2019	1 Year																								
CONSTRUCTION TASKS																										
Real Estate Acquisition for Pump Stations	January 2021	2 Years																								
Implement Mitigation (if needed)	January 2022	1 Year																								
Transmission Facilities	January 2021	5 Years																								
Easement Acquisition	January 2021	1.5 Years																								
Bid and Construction Phase	January 2022	4 Years																								

Lake Columbia

Description

The Angelina and Neches River Authority (ANRA) has a Texas water right for the development of the proposed Lake Columbia on Mud Creek in the Neches River Basin. ANRA is pursuing development of the reservoir and is working toward a Section 404 permit from the Corps of Engineers. Lake Columbia would inundate approximately 10,133 acres.

The Lake Columbia dam could be designed, constructed, and begin filling within six years of 404 permit issuance. Water would be available to meet identified demands once the lake fills, and an interbasin transfer permit is issued.

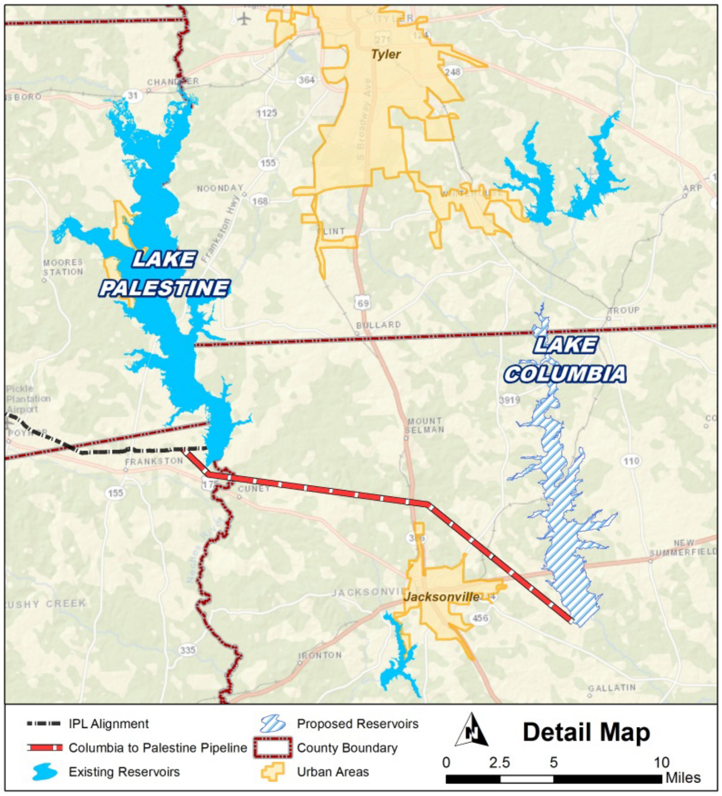
Facilities Required

- Dam/Reservoir - the Lake Columbia dam would be an earthen fill structure approximately 6,800 feet long with a maximum height of 67 feet.
- One intake structure and 4,200 HP pump station located on the west side of Lake Columbia.
- One 2,500 HP booster pump station and a 9 MG open storage tank.

Vicinity Map

- 23-miles of 54-inch diameter pipe from Lake Columbia to the Integrated Pipeline (IPL) on the west side of Lake Palestine (This configuration assumes water will be transported around Lake Palestine.)

- Because the Integrated Pipeline will not be flowing at full capacity initially, Lake Columbia supply could initially be delivered through the Integrated Pipeline (IPL). Once the IPL becomes fully utilized by TRWD and Dallas, delivery of Lake Columbia will require a new pipeline. As configured here, Columbia would flow through a pipeline designed to convey Toledo Bend supply and Columbia supply. A pipeline to convey only Lake Columbia is assumed to be cost prohibitive and is not considered here.



Pipeline Route to Lake Palestine

Yield

Of the permitted yield for Lake Columbia (85,507 acre-feet per year), 47 percent (40,188 acre-feet per year) would be available for use by TRWD or other entities in Region C. There could be more available in the future if local partners do not contract for the full 53% of Columbia's yield that is currently planned for in-basin use.

Cost (in April 2012 dollars)

$250,165,000*

Capital

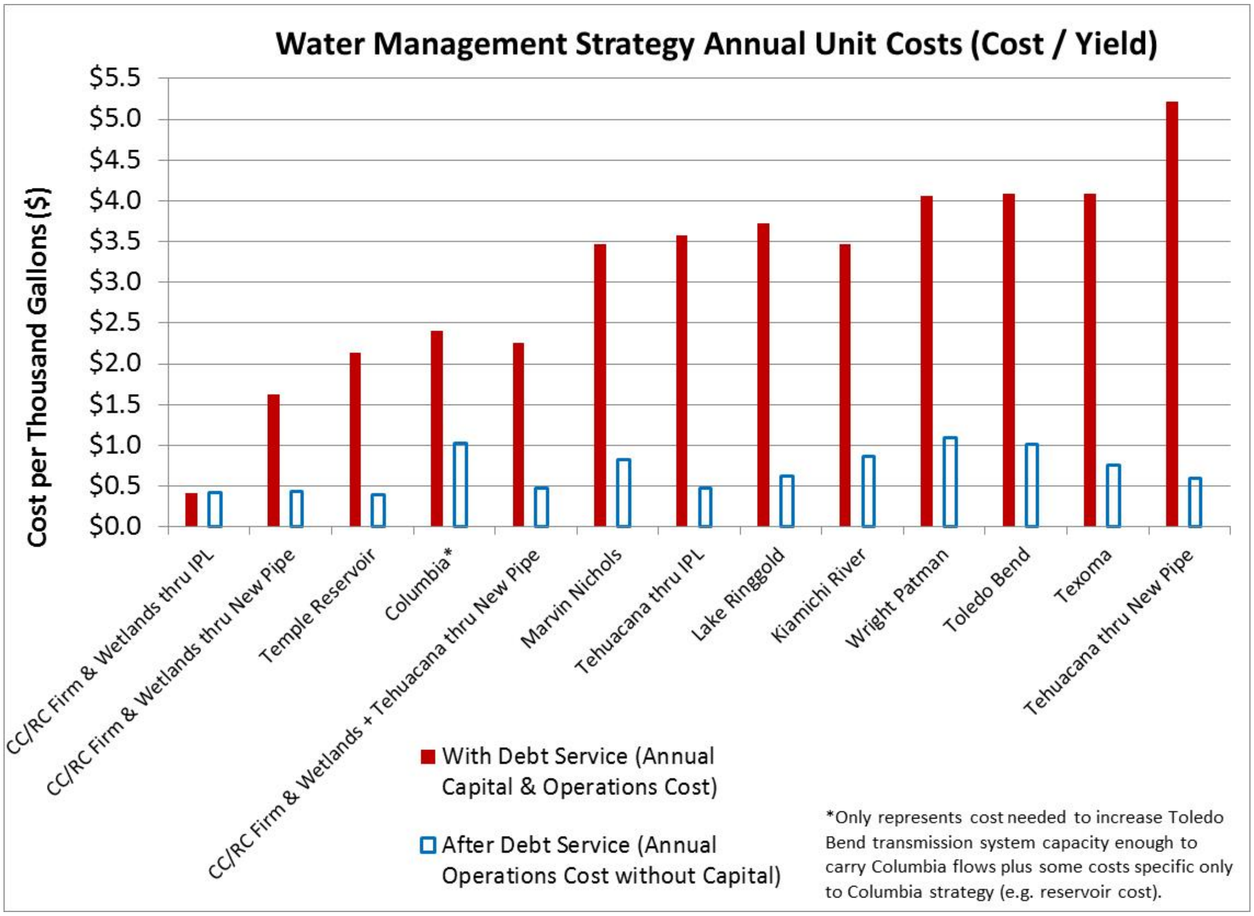
Under this scenario, Lake Columbia would be constructed and operated by ANRA. TRWD would purchase raw water *in situ* from ANRA. TRWD's capital costs would be limited to the pump station and transmission facilities between Lake Columbia and Lake Palestine.

Annual

It is anticipated that *in situ* raw water costs would be based on ANRA's need to retire bonds and/or reimburse private investors for the reservoir's capital costs. Although no negotiations with ANRA as to raw water costs have been initiated, a cost of $0.10 per 1,000 gallons appears to be a reasonable placeholder. The potential that raw water costs could vary significantly from this estimate is addressed through the risk analysis.

- Total annual cost during debt repayment period - $31,505,500*
- Total annual cost after debt is paid - $13,331,500*
- Annual unit cost of water until amortization based on 40,188 acft/yr ($/1000 gal) - $2.41*
- Annual unit cost of water after amortization based on 40,188 acft/yr ($/1000 gal) - $1.02*

**(Assumed Columbia will flow through IPL and Toledo Bend pipeline. Cost attributed to Columbia is the amount needed to increase Toledo Bend transmission system capacity enough to carry Columbia flows plus costs specific to Columbia (reservoir, portion of the pipeline to TRWD). A pipeline to convey only Lake Columbia is assumed to be cost prohibitive and is not considered here.)*



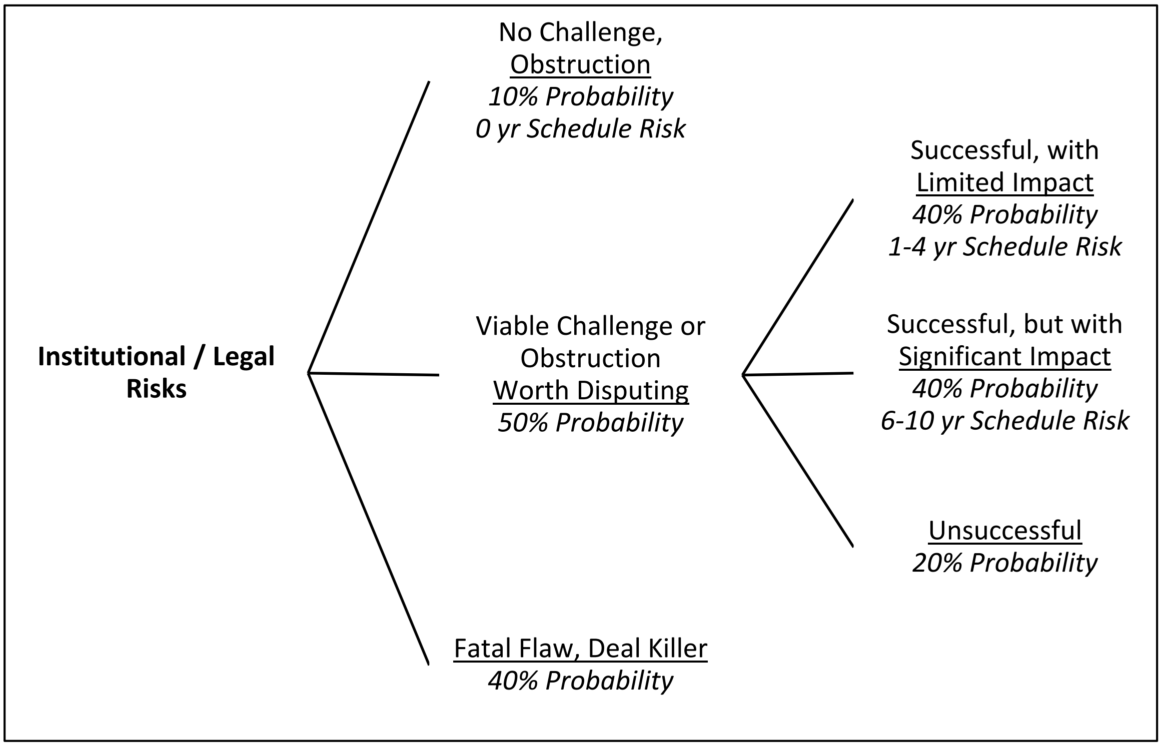
Comparison to Other Strategies

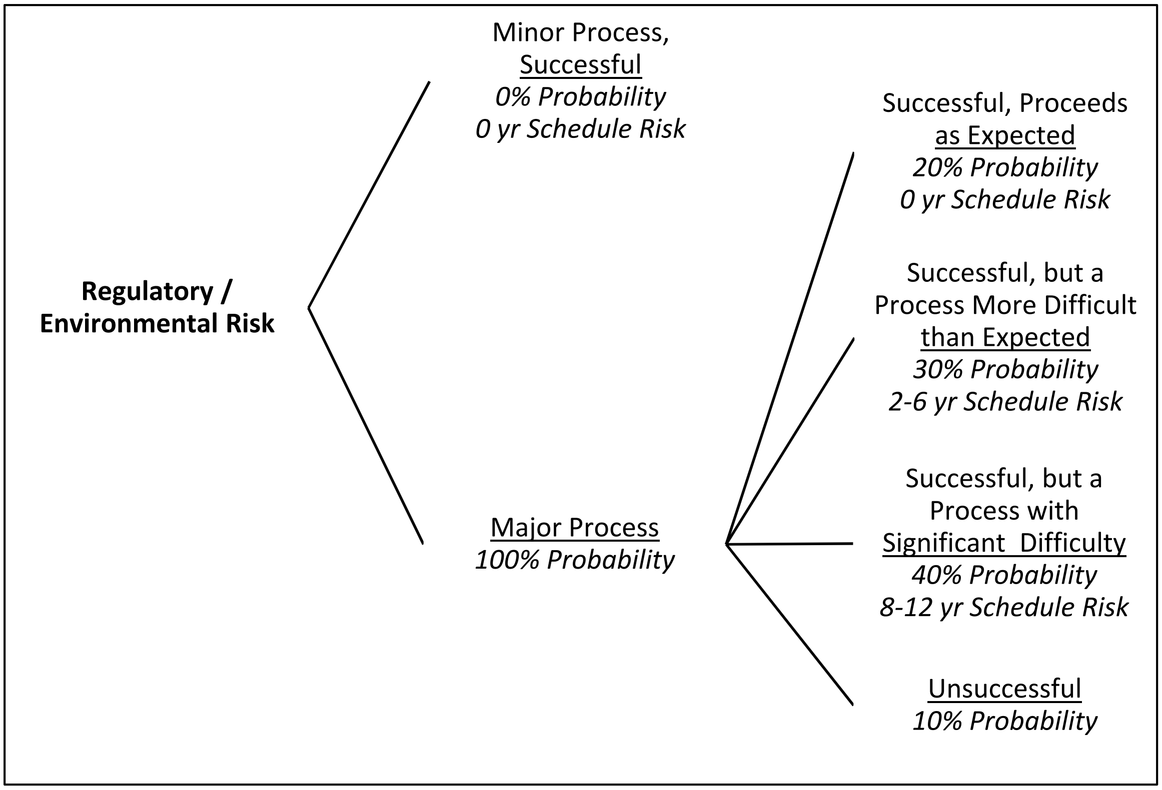
Key Assumptions

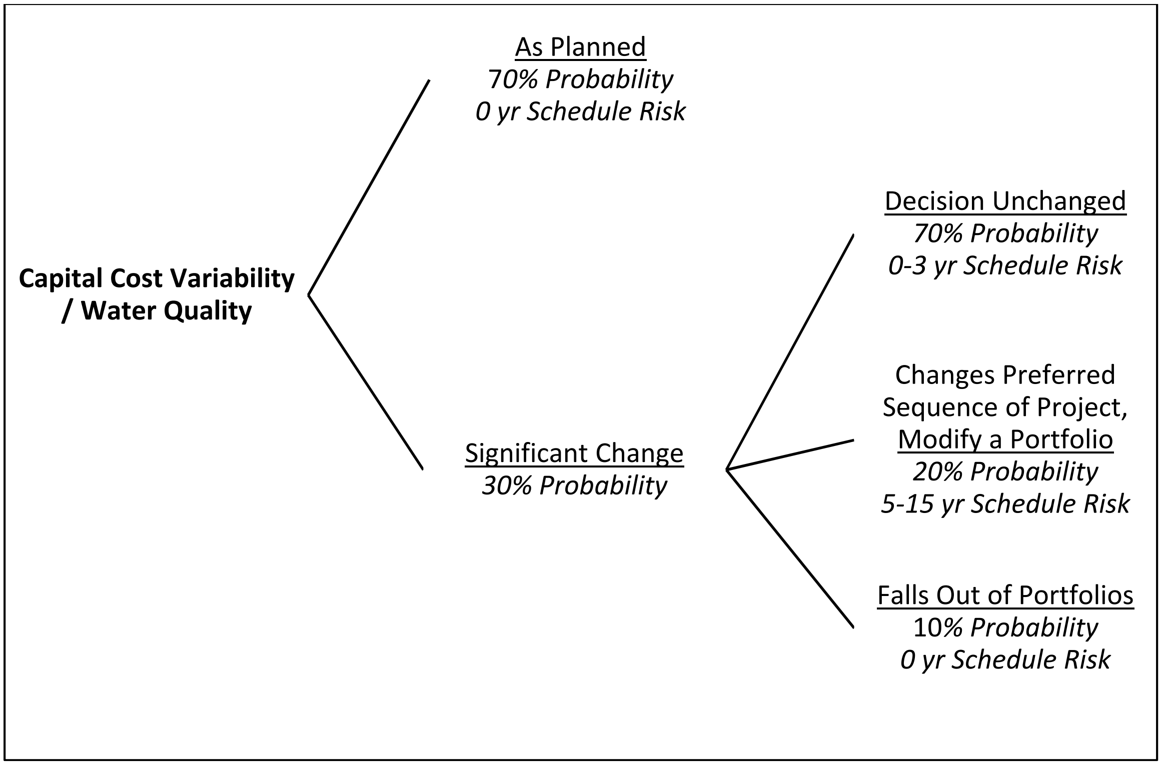
- Neches Basin environmental flow (eFlow) requirements would not be applied to Lake Columbia yields, as the water rights permit has already been issued without environmental flow requirements. However, an application for an interbasin transfer will be subject to an environmental assessment and may re-open the permit for environmental flows.

- An agreement with Dallas to use the Integrated Pipeline (IPL) from Lake Palestine to Cedar Creek Reservoir can be developed. With the selected configuration, the primary mode of operation will be to transmit Lake Columbia water around Lake Palestine to the IPL. If Lake Columbia water is to be discharged into Lake Palestine, it is assumed that Upper Neches Municipal Water Authority (UNMWA) would permit use of Lake Palestine for transfer/incidental storage of Columbia water, and that no increase in TRWD's costs for the IPL would be incurred as a result of this agreement.
- Reliability: Reliability is high. It is anticipated that the Lake Columbia Participants currently reserving 53% of the yield will not ultimately contract for that amount. After issuance of the 404 permit and prior to construction, water contracts will be offered to the existing Participants for the percentage amounts in their pre-permit contracts. Participants will then have the opportunity to commit to their preconstruction percentage or a smaller amount. Water not claimed by the existing Participants during the post-permit offering will be available to others

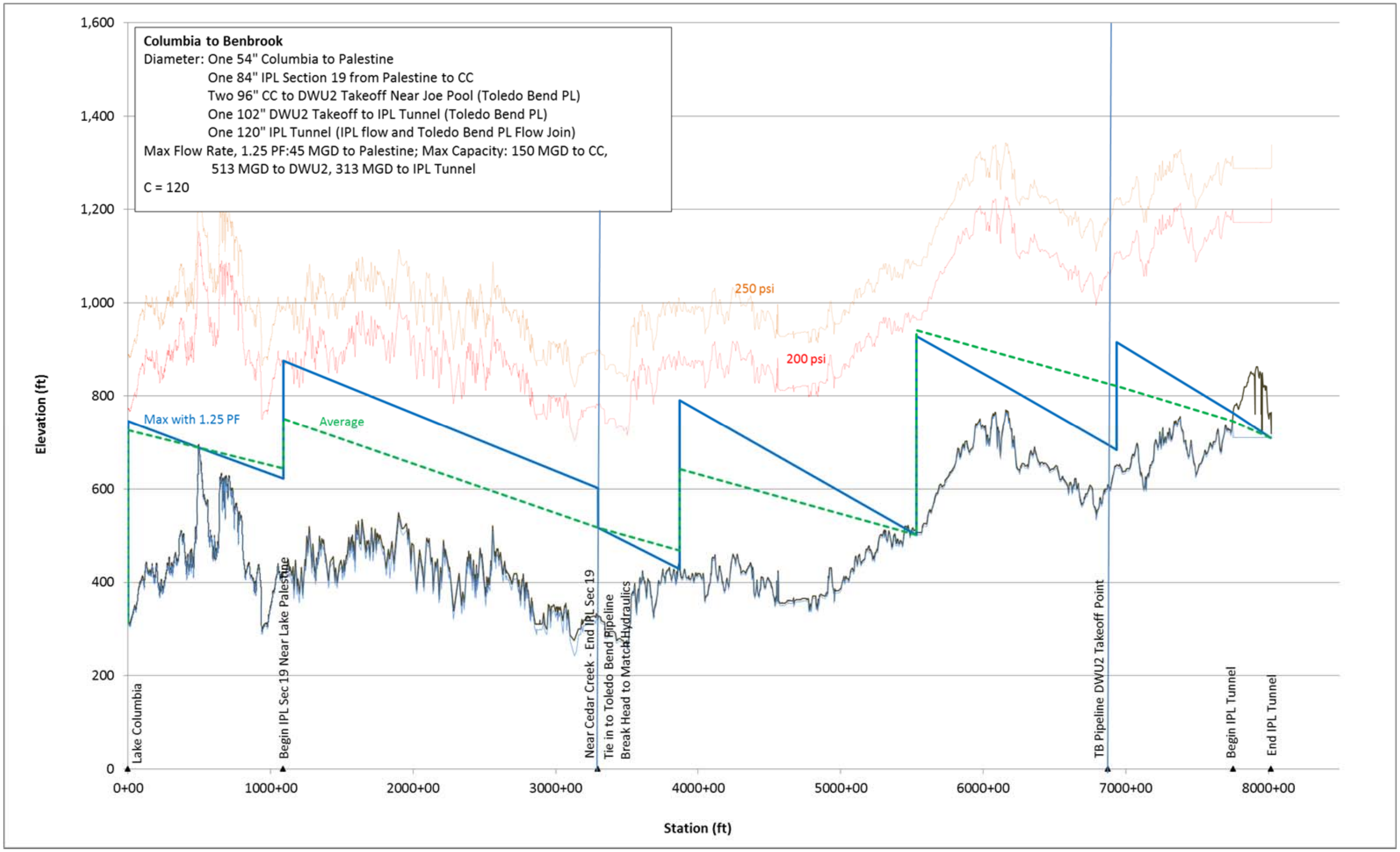
Risk Assessment




Regulatory /
Environmental Risk
Minor Process,
Successful
0% Probability
0 yr Schedule Risk
Major Process
100% Probability
Successful, Proceeds
as Expected
20% Probability
0 yr Schedule Risk
Successful, but a
Process More Difficult
than Expected
30% Probability
2-6 yr Schedule Risk
Successful, but a
Process with
Significant Difficulty
40% Probability
8-12 yr Schedule Risk
Unsuccessful
10% Probability


Capital Cost Variability
/ Water Quality
As Planned
70% Probability
0 yr Schedule Risk
Significant Change
30% Probability
Decision Unchanged
70% Probability
0-3 yr Schedule Risk
Changes Preferred
Sequence of Project,
Modify a Portfolio
20% Probability
5-15 yr Schedule Risk
Falls Out of Portfolios
10% Probability
0 yr Schedule Risk

Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
Requires agreement with Dallas and UNMWA for use of IPL (in the short term) and Lake Palestine. Requires negotiation of acceptable contract terms with ANRA.	Mitigation plan developed by ANRA appears to be acceptable to resource agencies but has not been formally approved through the 404 permit process. Interbasin transfer permit needed and possibility of eFlow requirements being applied.	ANRA is currently seeking both public sector and private sector partners to develop Lake Columbia. Depending on the terms of their ultimate financing as well as the actual amount of water available, per-unit water costs could vary significantly.



Hydraulic Grade Line – Lake Columbia to Lake Palestine

References

Alan Plummer Associates, Inc., Freese and Nichols, Inc., LBG Guyton, and Walker Partners: *2011 Region I Water Plan*, prepared for the East Texas Region Water Planning Group, Fort Worth, September 2010.

US Army Corps of Engineers, Fort Worth District: *Lake Columbia Regional Water Supply Reservoir Project Draft Environmental Impact Statement*, Fort Worth, January 2010.

Columbia Implementation Schedule for TRWD IWSP:

Assumptions

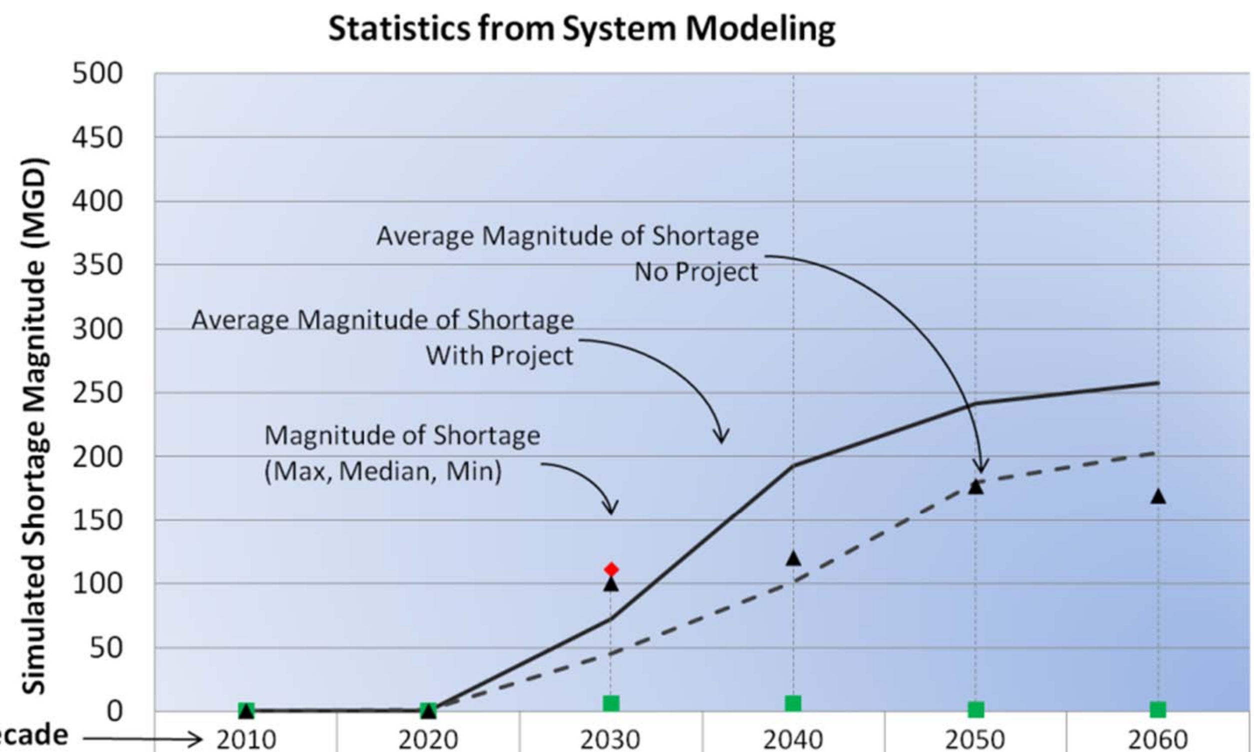
- Columbia would require an IBT permit
- Columbia would require a Federal 404 permit, which is in-progress and estimated to be issued by December 2016.
- Mitigation would be through permittee responsible mitigation with an option to purchase some mitigation bank credits.
- The transmission facility design and construction only includes the pipeline segment from Columbia to the IPL
- Water would initially be delivered to the Metroplex via the IPL
- Detailed design (embankment/spillway) could overlap with permitting processes
- Embankment/spillway construction includes two years for reservoir filling

			2014		2015		2016		2017		2018		2019		2020		2021		2022		2023		2024	
TASKS	START DATE	DURATION	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec
PLANNING TASKS																								
404 Permit Application/Approval	January 2014	4 Years*																						
IBT	July 2015	4 Years																						
DESIGN TASKS																								
Embankment/Spillway	January 2018	1.5 Years																						
Relocations	January 2018	2.5 Years																						
Transmission Facilities	January 2019	2.5 Years																						
Route Selection	January 2019	1 Year																						
Survey and Preliminary Design	January 2020	0.5 Year																						
Final Design	July 2020	1 Year																						
Design Mitigation Features	July 2020	1 Year																						
CONSTRUCTION TASKS																								
Real Estate Acquisition	July 2019	3 Years																						
Relocations	July 2019	3 Years																						
Embankment/Spillway	July 2019	5 Years																						
Transmission Facilities	July 2020	3.5 Years																						
Easement Acquisition	July 2020	1 Year																						
Bid and Construction Phase	July 2021	2.5 Years																						
Implement Mitigation	July 2020	1 Year																						

* In Progress

Columbia

Magnitude Chart

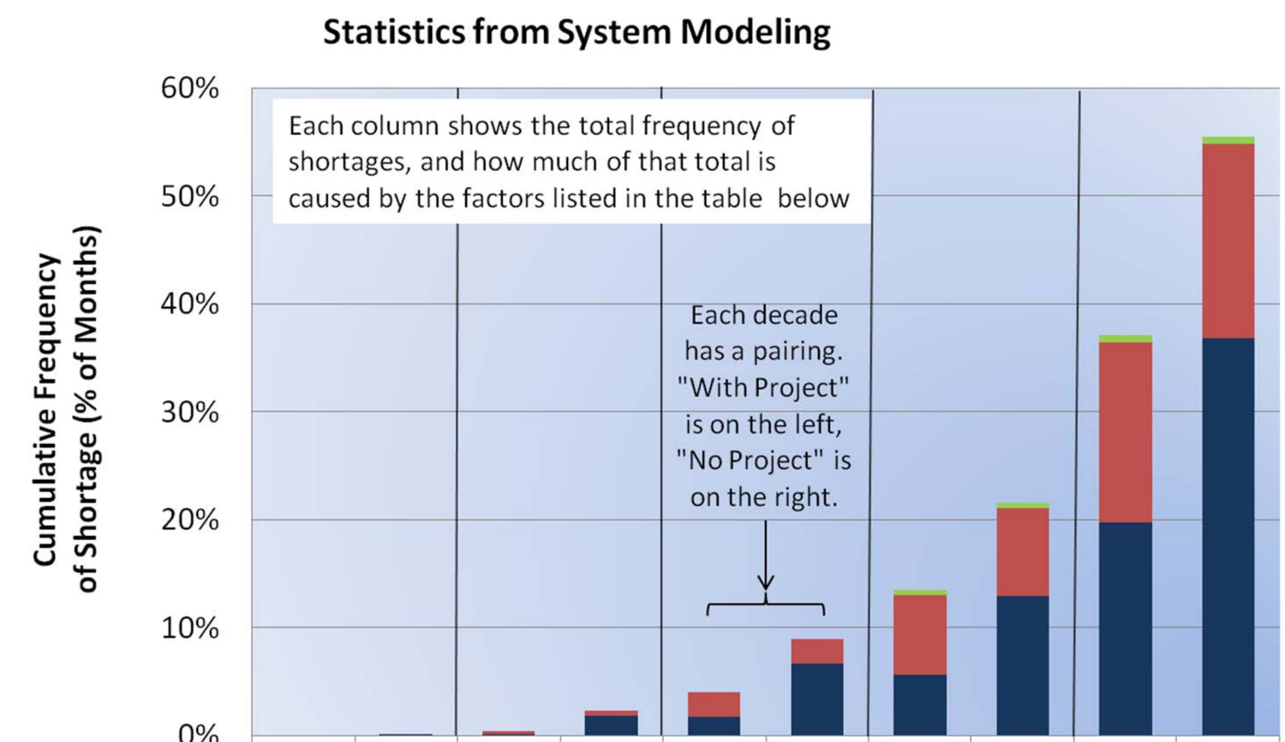


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	111	538	695	806
Minimum	0	0	6	6	1	1
Median	0	0	100	120	177	169
Average	0	0	72	193	242	258
Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Columbia

Frequency Chart

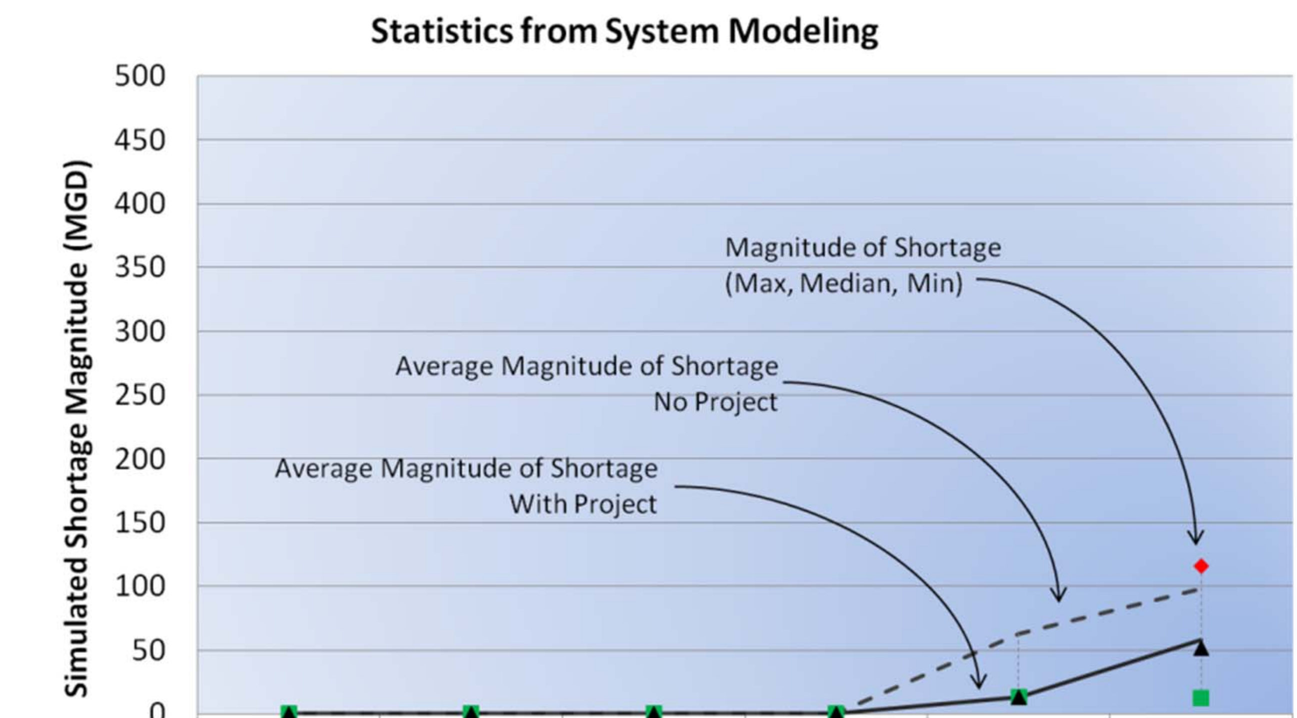


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.5%		0.7%	
Permitted Amount	0.0%		0.2%		2.3%		7.4%		16.6%	
Pipeline Capacity	0.0%		0.1%		1.7%		5.6%		19.7%	

Results Using 2011 Region C Based Demand Projection

Columbia

Magnitude Chart

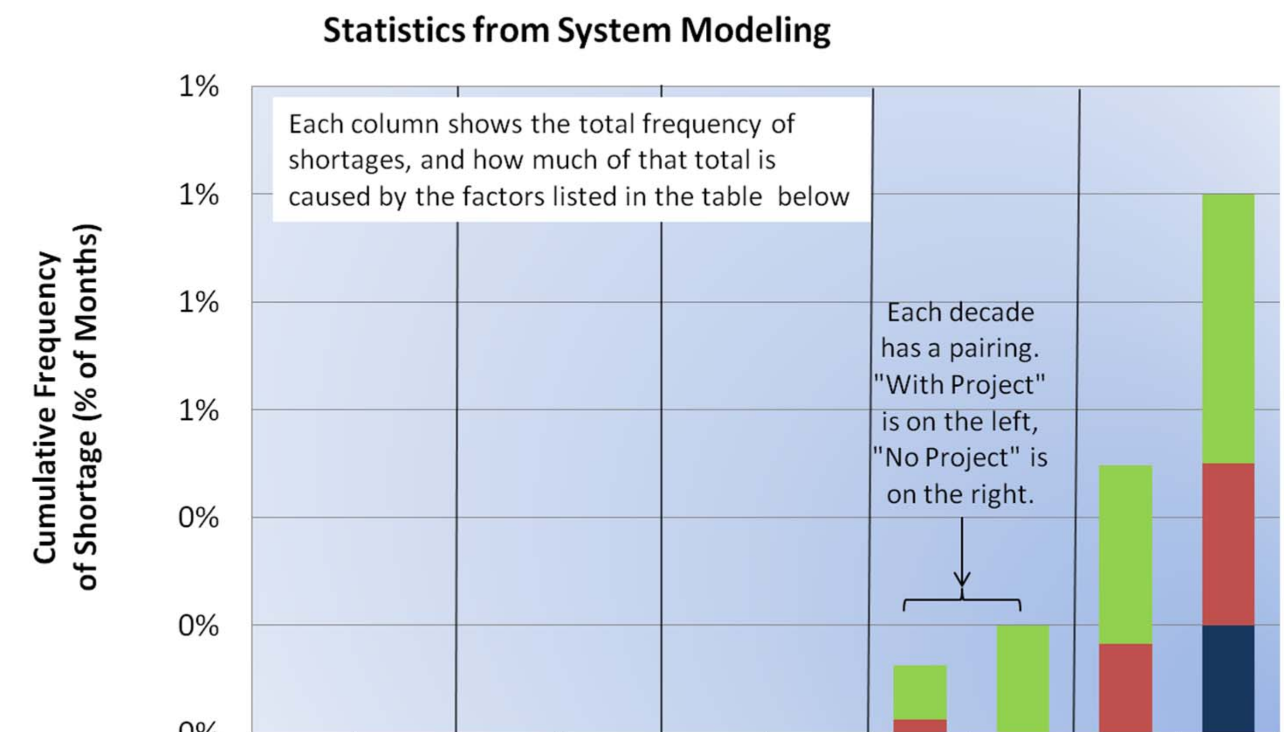


Decade	2010	2020	2030	2040	2050	2060
◆ Maximum	0	0	0	0	13	116
■ Minimum	0	0	0	0	13	12
▲ Median	0	0	0	0	13	52
—— Average	0	0	0	0	13	58
– – Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

Columbia

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.1%		0.3%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.2%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.0%		0.0%	

Results Using Recent Trend Extrapolation Demand Projection

Excess Flow Optimization (EXFLO), Eagle Mountain Lake and Lake Benbrook

Description

"In essence, the District is seeking authorization to divert unappropriated water flowing through [Eagle Mountain Lake and Lake Benbrook] when they are in a defined state of flood stage and to account for these diversions under the authority of the new water rights rather than the existing water rights that authorize these impoundments and their associated diversions. Under certain circumstances, this mode of operation will alleviate the need for the District to pump water from its eastern reservoirs, Richland-Chambers and Cedar Creek, to satisfy the demands of its customers, thereby reducing overall pumping and energy costs. Operation of the EXFLO project will not alter in any way current flood operating procedures for either Eagle Mountain Lake or Lake Benbrook….

"The fundamental purpose of the proposed project will be to provide the District with a supplemental water supply during high-flow periods when excess and unappropriated flows are available at Eagle Mountain Lake and Lake Benbrook. The EXFLO project will allow the District to take advantage of available high flows when they occur, with cost savings realized because of reduced pumping that otherwise would be necessary to delivery water to the District's customers from the District's distant eastern reservoirs, Richland-Chambers and Cedar Creek. A net benefit of this type of operation is that it extends the District's existing sources of supply, effectively making more water available during more extreme drought periods. In the most basic sense, the EXFLO project will be an integral part of the District's overall water supply and delivery system, and it will be operated as such." (*Water Availability Analysis, Excess Flow Optimization Project – EXFLO*, Atkins, 2011)

Vicinity Map

Facilities Required

No new facilities are required to make use of this strategy. Supplies will be delivered through existing infrastructure.

Yield

Lake Benbrook maximum annual diversion is 78,653 acre-feet.

Eagle Mountain Lake maximum annual diversion is 63,899 acre-feet.

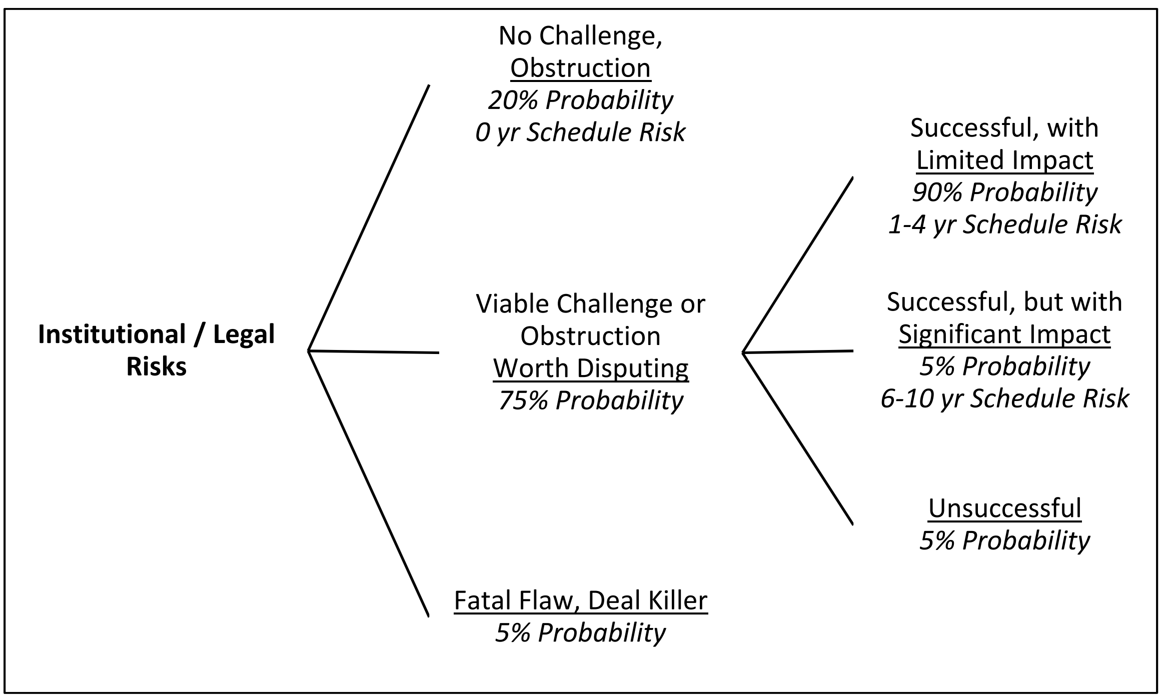
"It should be noted that the proposed EXFLO project is not intended to produce a firm supply of water [i.e. 100% reliable even in drought of record] for the District, nor does it need to with the availability of the District's other existing sources of supply. It is also not expected to be utilized often, since diversions under the EXFLO permits will be limited to only those times when Eagle Mountain Lake and Lake Benbrook are in flood stage." (*Water Availability Analysis, Excess Flow Optimization Project – EXFLO*, Atkins, 2011)

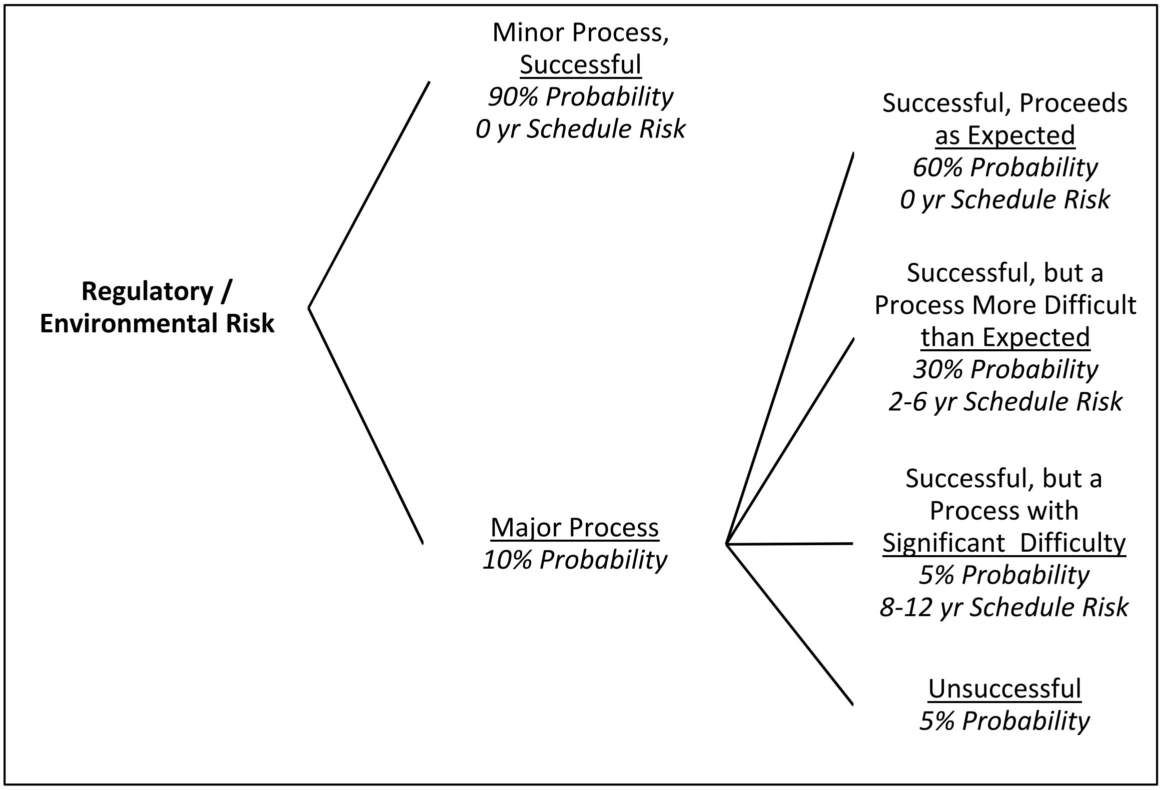
Cost (in April 2012 dollars)

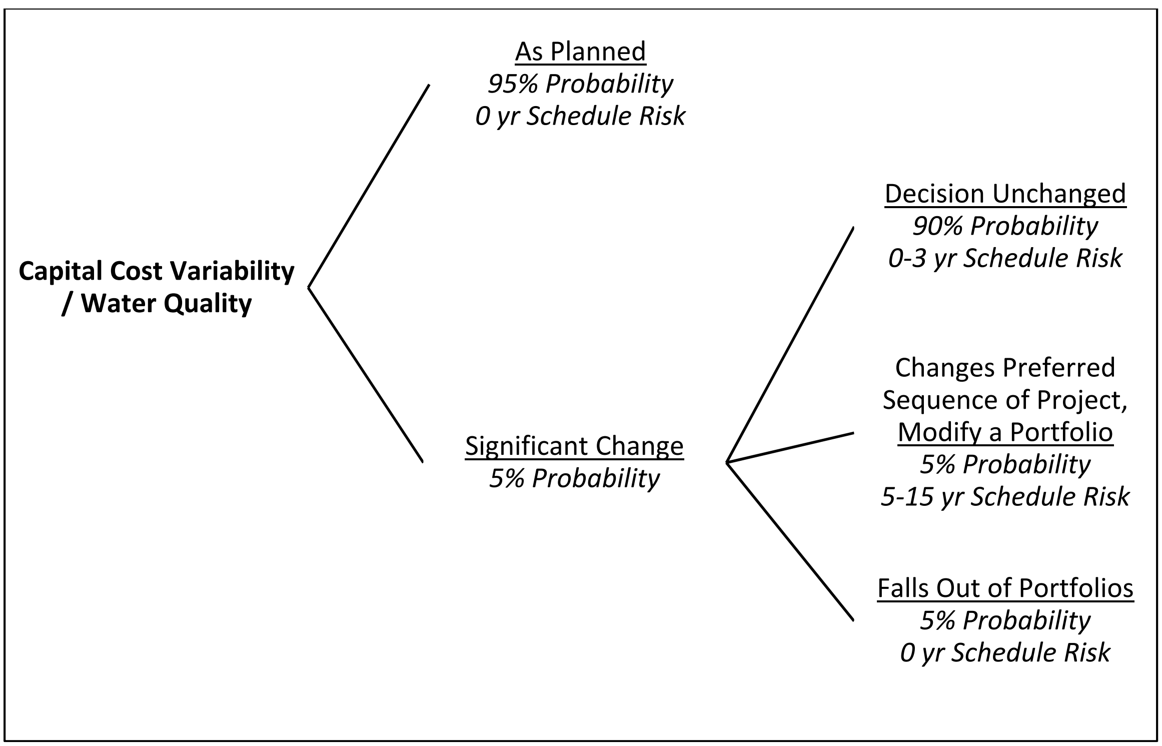
No capital costs for additional infrastructure are required. (Legal, staff and permitting fees will apply but are not significant when compared to the cost for new infrastructure.)

Because annual yields depend on the availability of excess flows in Eagle Mountain Lake and Lake Benbrook, there is no standard annual cost for delivering this water. In general, it will be delivered by gravity flow (with the exception of pumping from Benbrook to Rolling Hills WTP when optimal) and will be the least expensive water available to TRWD.

Risk Assessment




Regulatory / Environmental Risk
Minor Process, Successful
90% Probability
0 yr Schedule Risk
Major Process
10% Probability
Successful, Proceeds as Expected
60% Probability
0 yr Schedule Risk
Successful, but a Process More Difficult than Expected
30% Probability
2-6 yr Schedule Risk
Successful, but a Process with Significant Difficulty
5% Probability
8-12 yr Schedule Risk
Unsuccessful
5% Probability


Capital Cost Variability / Water Quality
As Planned
95% Probability
0 yr Schedule Risk
Significant Change
5% Probability
Decision Unchanged
90% Probability
0-3 yr Schedule Risk
Changes Preferred Sequence of Project, Modify a Portfolio
5% Probability
5-15 yr Schedule Risk
Falls Out of Portfolios
5% Probability
0 yr Schedule Risk

References

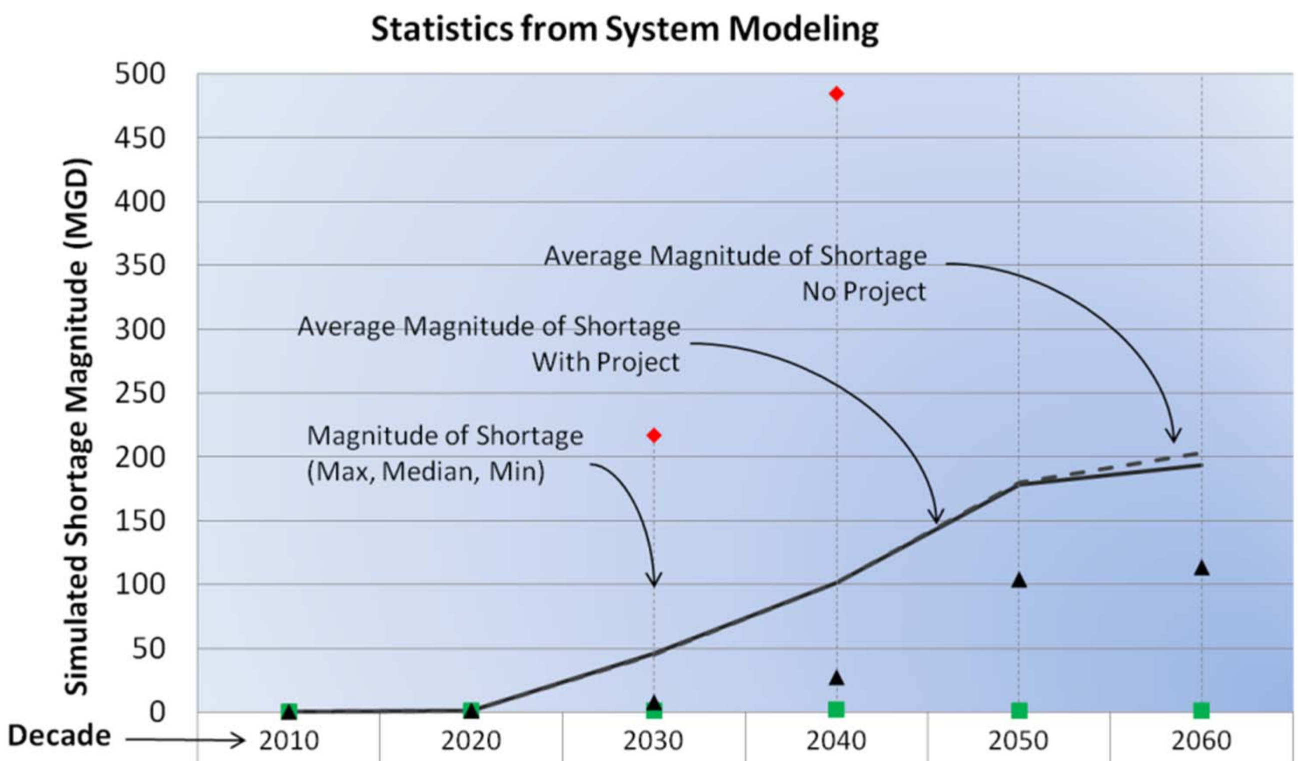
Atkins, *Water Availability Analysis, Excess Flow Optimization Project – EXFLO*, September 2011.

Implementation Schedule

Developing EXFLO supply is essentially a permitting process and does not require construction of new facilities. It is anticipated that the permitting process will take less than five years.

EXFLO

Magnitude Chart

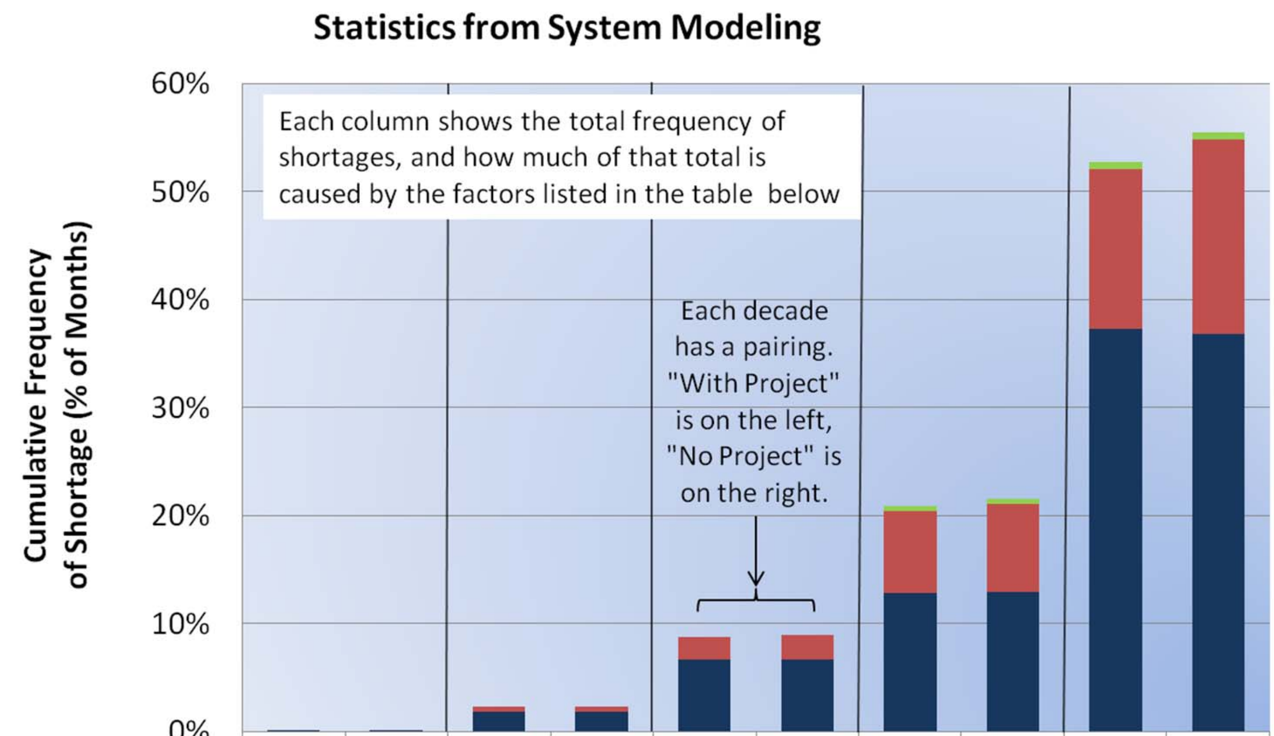


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	1	217	485	701	908
Minimum	0	1	1	2	1	1
Median	0	1	8	27	104	113
Average	0	1	45	101	178	193
Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

EXFLO

Frequency Chart

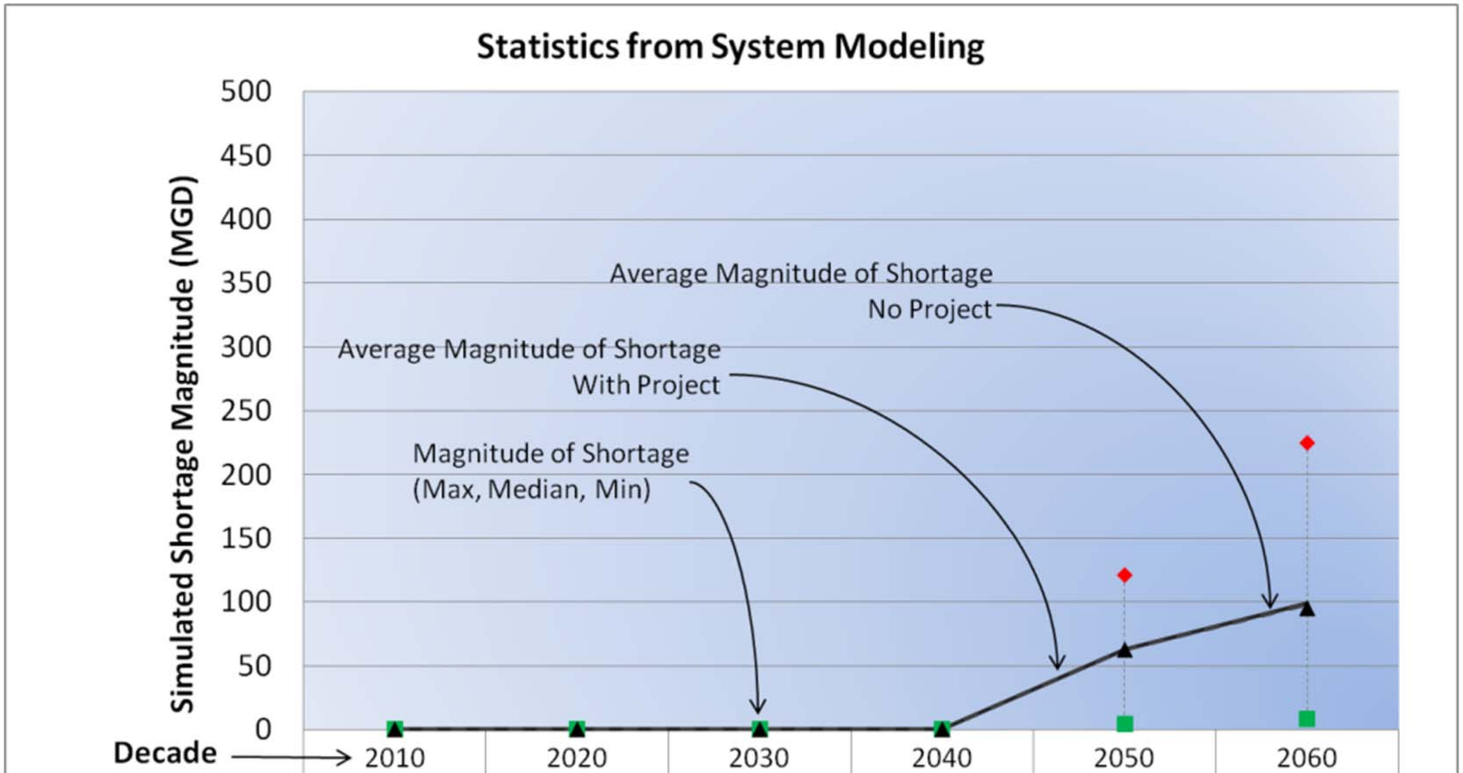


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.5%		0.7%	
Permitted Amount	0.0%		0.4%		2.1%		7.6%		14.7%	
Pipeline Capacity	0.1%		1.8%		6.6%		12.8%		37.3%	

Results Using 2011 Region C Based Demand Projection

EXFLO

Magnitude Chart

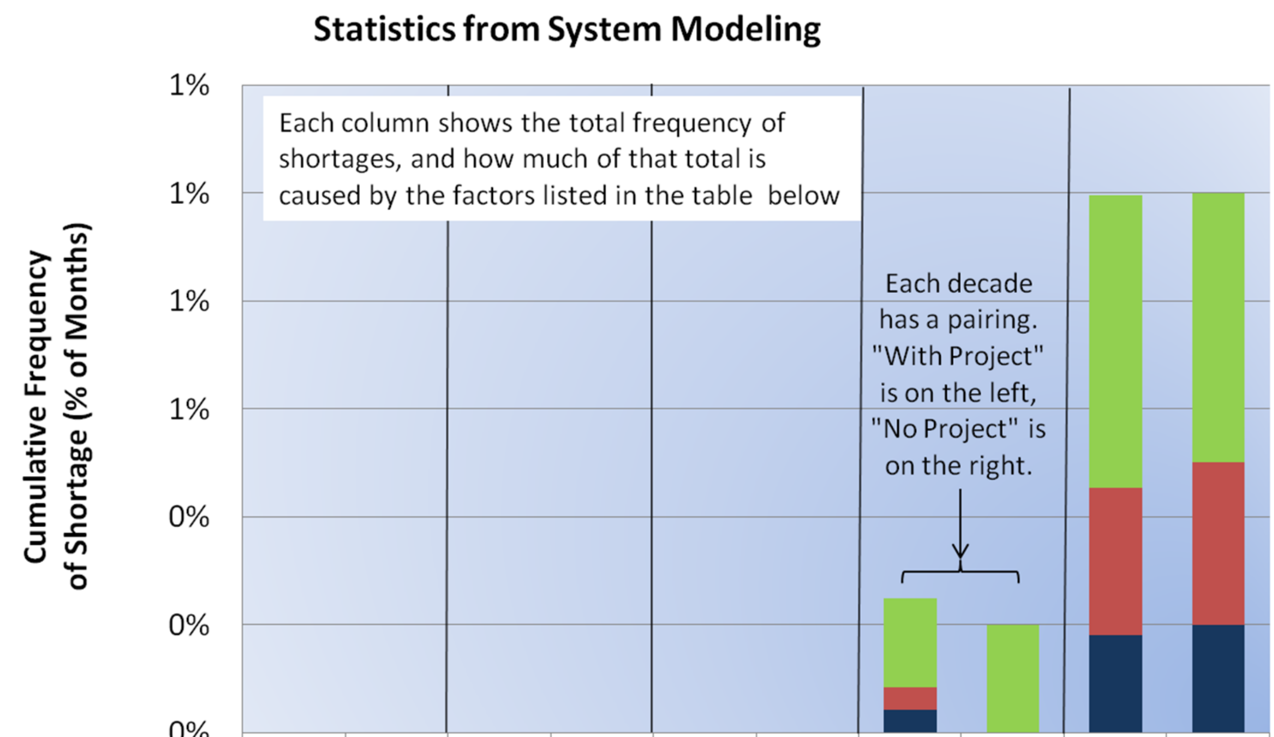


	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	0	121	225
Minimum	0	0	0	0	4	8
Median	0	0	0	0	63	95
Average	0	0	0	0	63	98
Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

EXFLO

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.2%		0.5%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.3%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.0%		0.2%	

Results Using Recent Trend Extrapolation Demand Projection

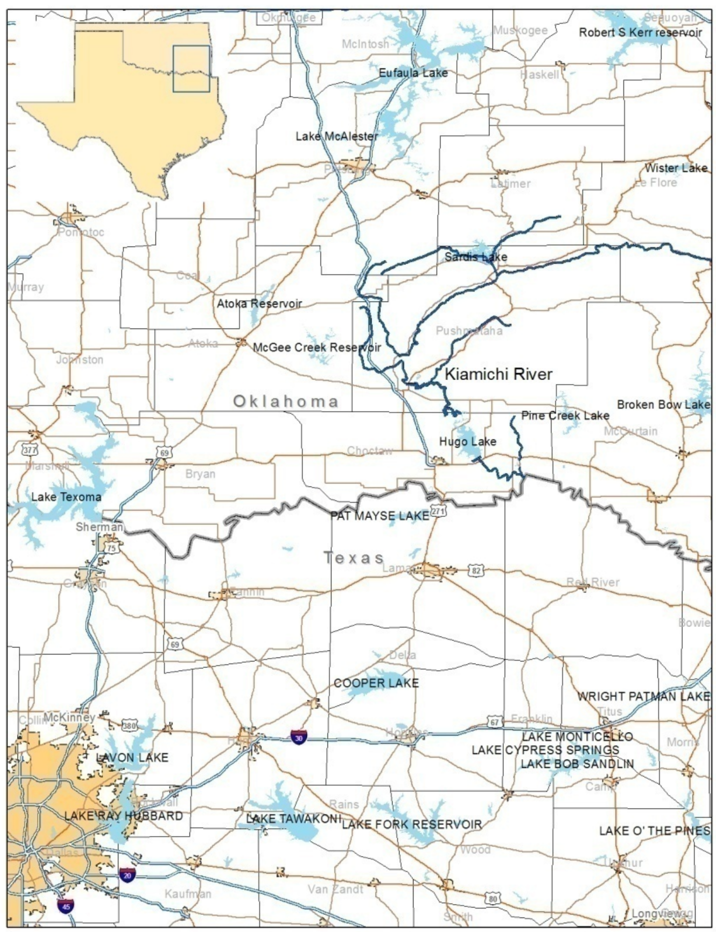
Kiamichi River, Eastern Oklahoma

Description

In 2006 TRWD applied to the Oklahoma Water Resources Board for a 310,000 acre-feet/year water right permit on the Kiamichi River in Southeastern Oklahoma. The permit application was subject to the result of litigation in the federal courts, which has concluded with a decision that supports Oklahoma's refusal to grant the permits. Therefore, water supply from Southeastern Oklahoma is subject to on-going efforts to negotiate a contract for the sale of water to TRWD. A run-of-river supply with an off-channel storage facility (OCSF) is planned close to the Red River confluence. Transmission facilities will deliver water from the Kiamichi River to a nearby OCSF and then on to TRWD and regional partners (in this case NTMWD and Dallas). The breakdown of assumed percent of yield (in acre-feet per year) available to each entity is 50% TRWD, 25% NTMWD, and 25% Dallas.

Facilities Required

- Channel dam and one 46,630 HP run-of-river intake and pump station
- Approximately 2 miles of 144-inch pipe from Kiamichi River to an off-channel storage facility
- One 80,000 acre-foot off-channel storage facility (OCSF)
- One 50,000 HP intake pump station to deliver from OCSF to TRWD and partners
- One 35,000 HP Intake Pump Station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.
- 167 miles of transmission pipeline to Lake Bridgeport if built independently of the



Vicinity Map

Sulphur River transmission system and in a separate route. Approximately 15 additional miles would be required if the Kiamichi pipeline were re-routed to be in the same right of way as the Sulphur River system transmission lines. The pipeline lengths are detailed below.

- Approximately 52 miles of 120-inch pipe, 54 miles of 108-inch pipe, and 61 miles of 90-inch pipe
- Three booster pump stations along the pipeline route: 38,840 HP, 29,200 HP and 25,200 HP
- Three earthen storage reservoirs: 69 MG, 52 MG, and 35 MG
- 207 MGD discharge structure at Lake Bridgeport

Yield

A run-of-river diversion has a variable annual yield because of its dependency on available river flow without storage. The Kiamichi River water right permit application sought 310,000 acre-feet/year; it is assumed that this quantity could be obtained through a negotiated sale. A 1,050 mgd run-of-river diversion with OCSF and 350 mgd delivery pump station could supply 310,000 acre-feet/year with 90% reliability, and could supply a long-term average 300,000 acre-feet/year. Approximately 300,000 could be supplied on an annual average during the North Texas drought of record, which occurred between 1951 and 1957. Based on the period-of-record, the minimum one-year supply could drop as low as 164,000 acre-feet/year.

The 310,000 acre-feet/year total yield would be shared among TRWD and regional partners. In the current configuration under consideration, 50% is delivered to TRWD, 25% to NTMWD, and 25% Dallas.

Preliminary water availability estimates indicate that the same infrastructure (a 1,050 mgd run-of-river diversion with OCSF and 350 mgd delivery pump station) could yield an average of about 350,000 acre-feet/year at 83% reliability if deliveries were only limited by available supply (assuming no permit restrictions), and a maximum of almost 400,000 acre-feet/year.

TRWD's Cost (in 2012 dollars)

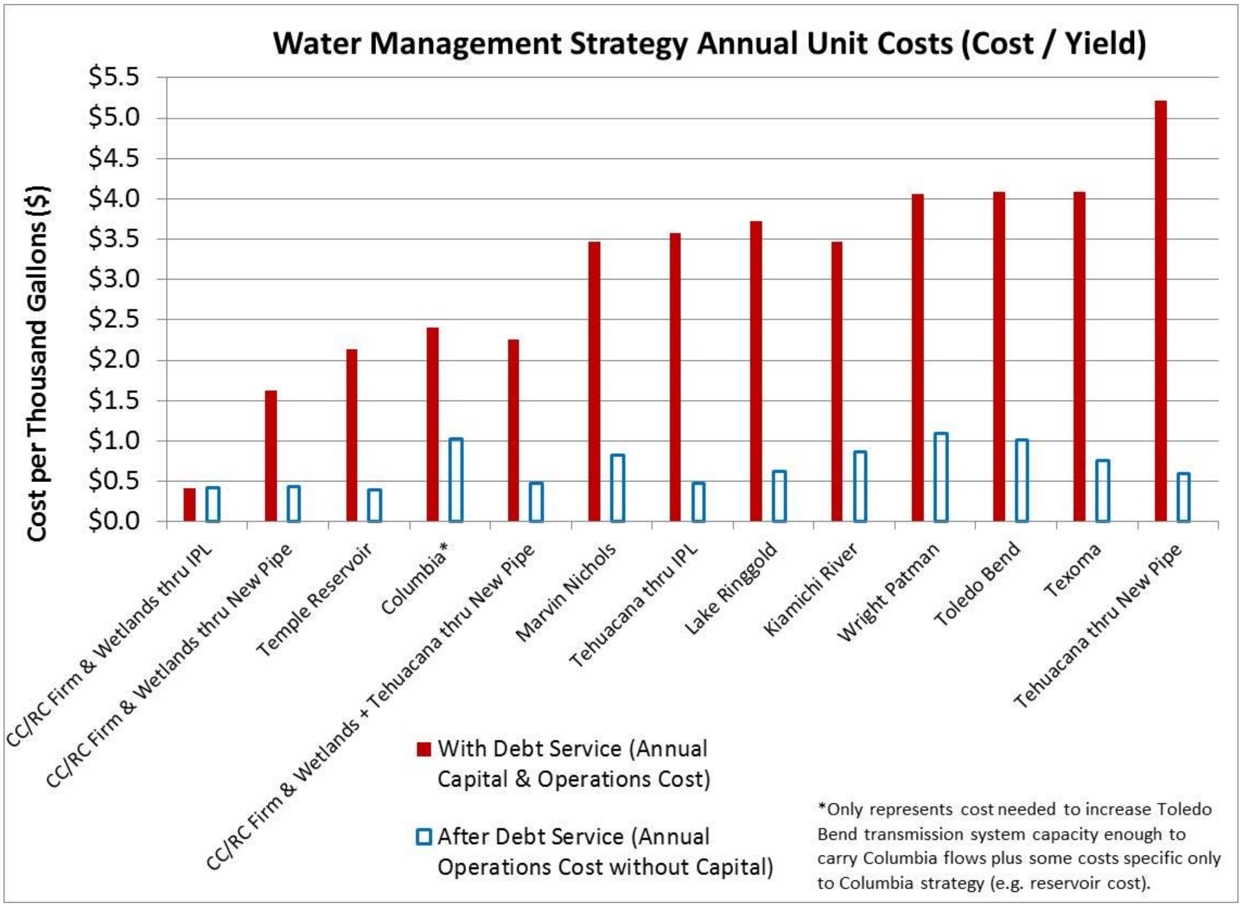
Capital

- $1,810,696,000

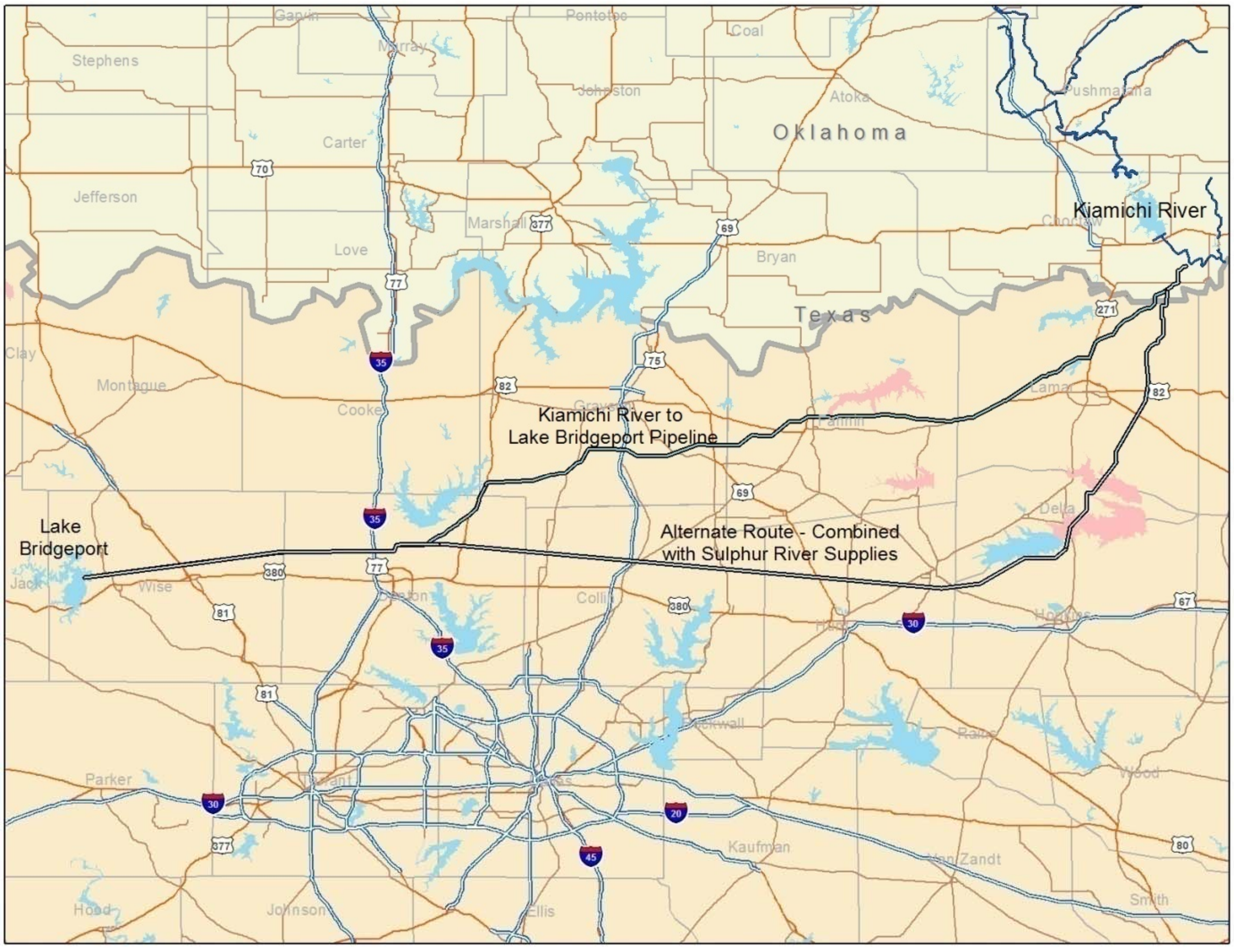
Annual

- Total annual cost during debt repayment period - $175,420,000
- Total annual cost after debt is payed – $43,875,000
- Annual unit cost of water until amortization based on 155,000 acft/yr firm yield ($/1000 gal) - $3.47

- Annual unit cost of water after amortization based on 155,000 acft/yr firm yield ($/1000 gal) - $0.87



Comparison to Other Strategies

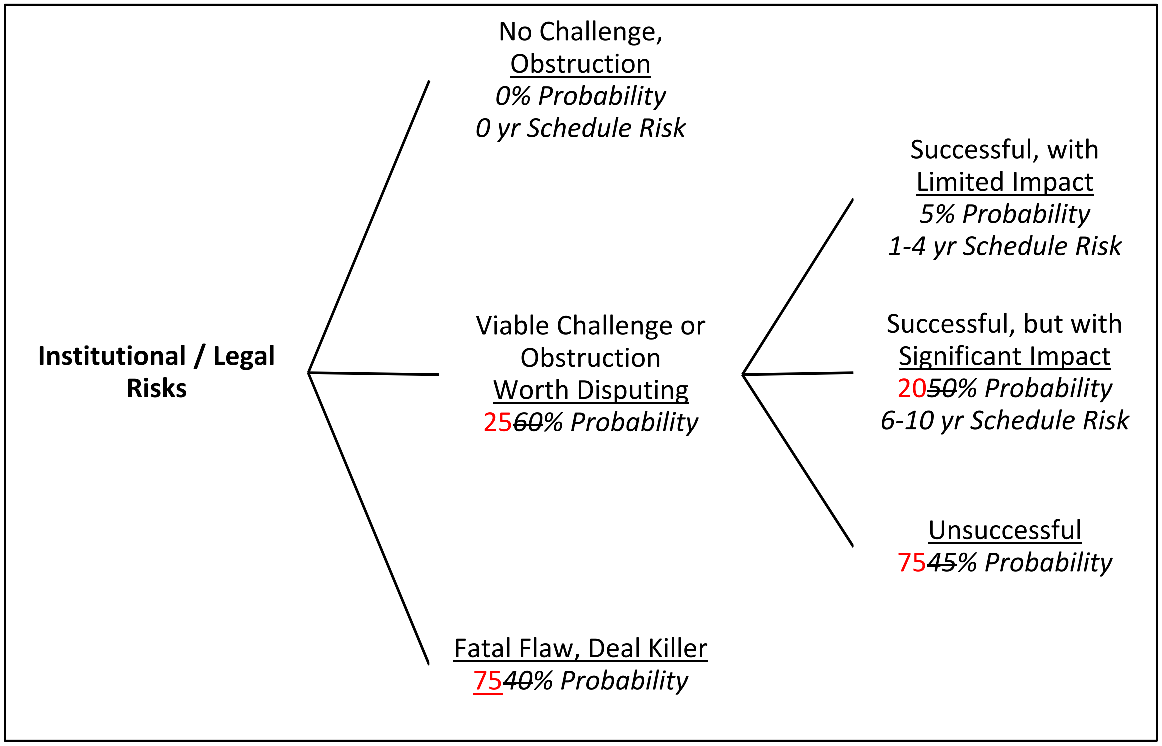


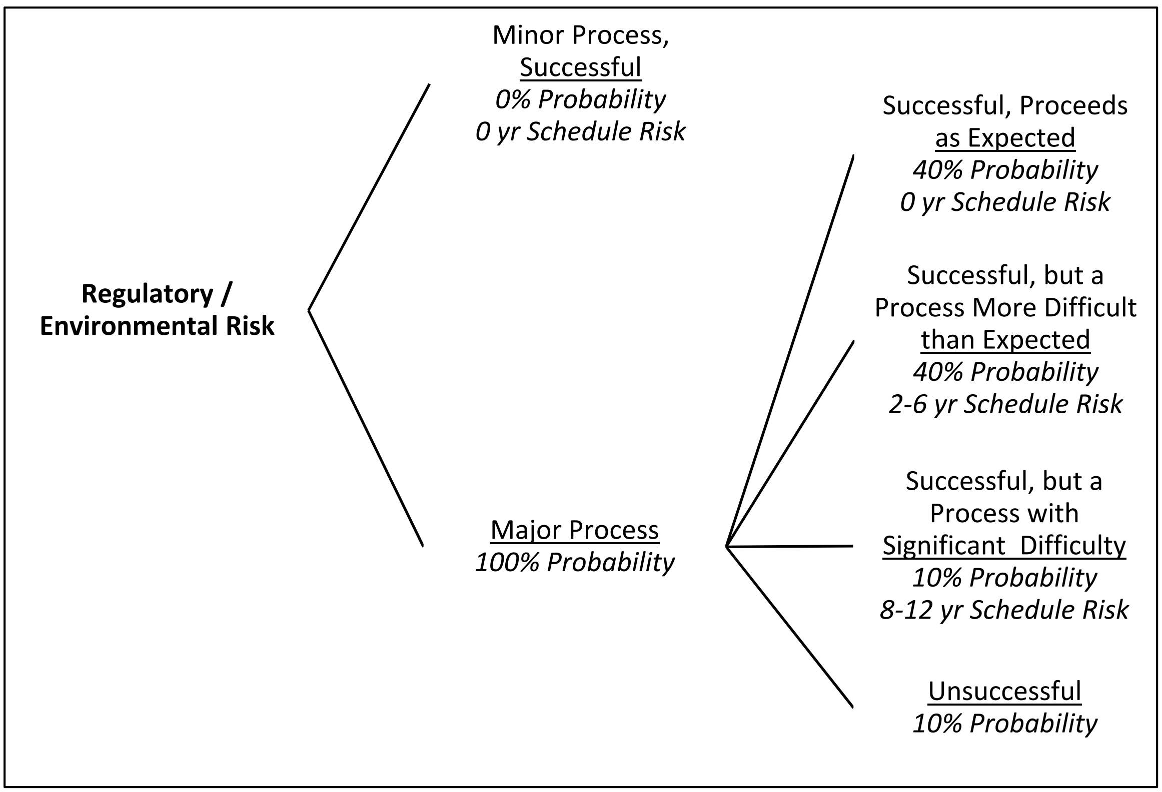
Pipeline Route to Lake Bridgeport

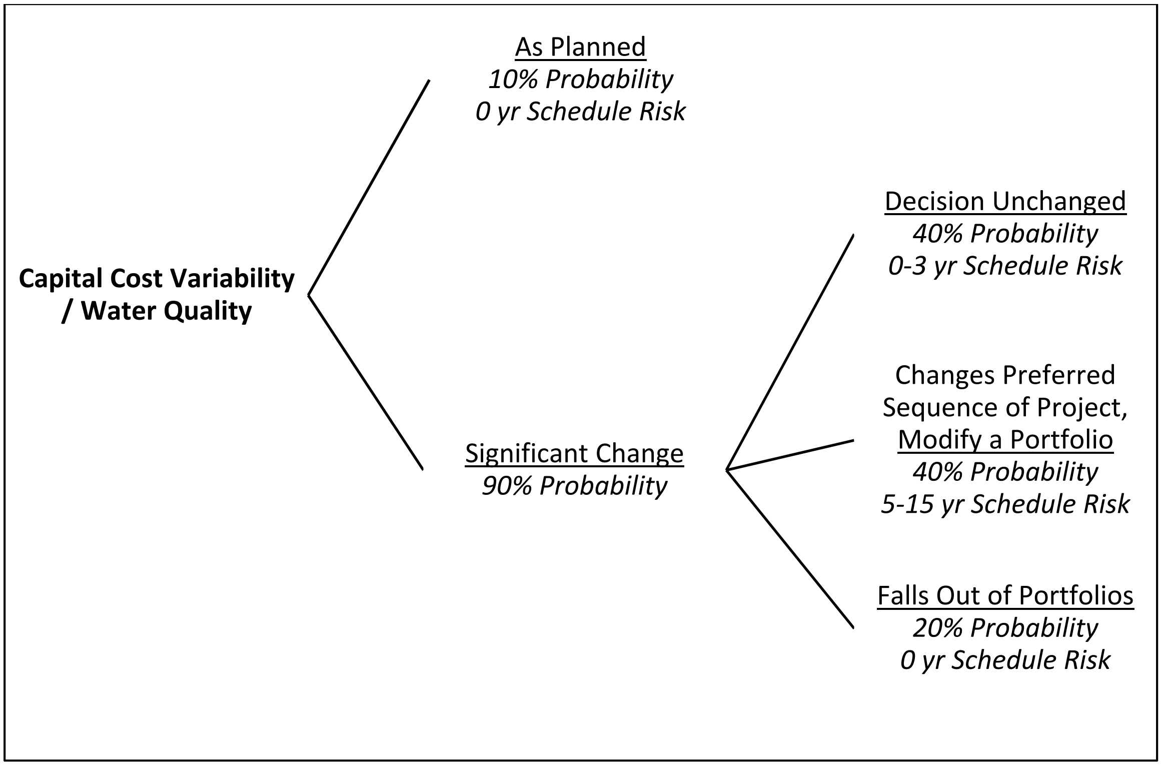
Key Assumptions

- TRWD secures a contract for the sale of water to Texas.
- Yield and annual pumping costs are based on the assumption that delivery to intermediate points (Lakes Chapman, Tawakoni, and Cedar Creek) or terminal points (Lake Benbrook) is not restricted by lake levels or permit conditions.

Risk Assessment



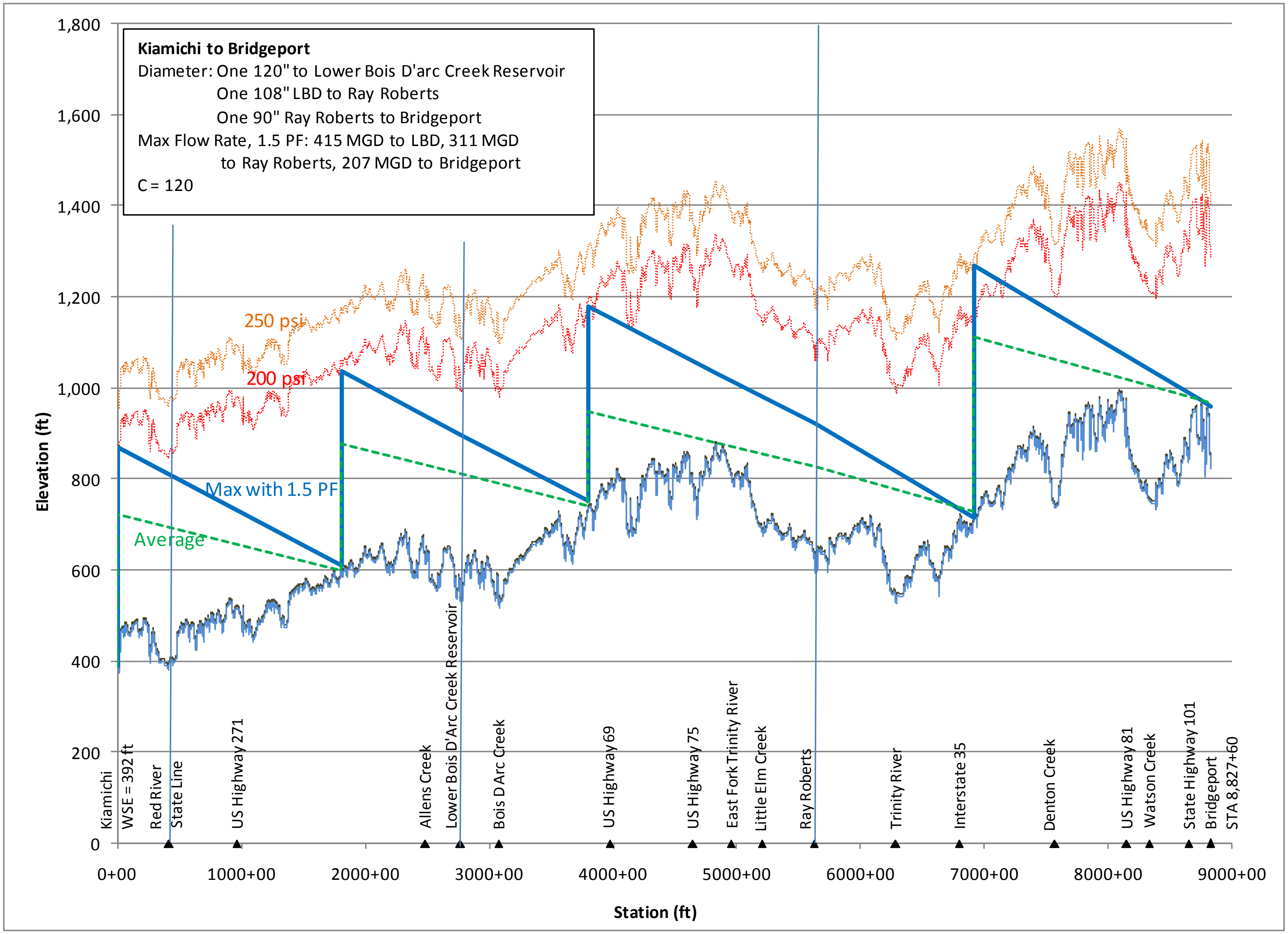




Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
Significant political issues. Negotiated contract will require political support or Tribal quantification of water rights and subsequent sale to TRWD.	Interstate transfer of water. 404 permit required for pipeline. Bed and banks permit required.	Raw water costs uncertain. Project definition very low so cost uncertainty is significant.

References

(None)



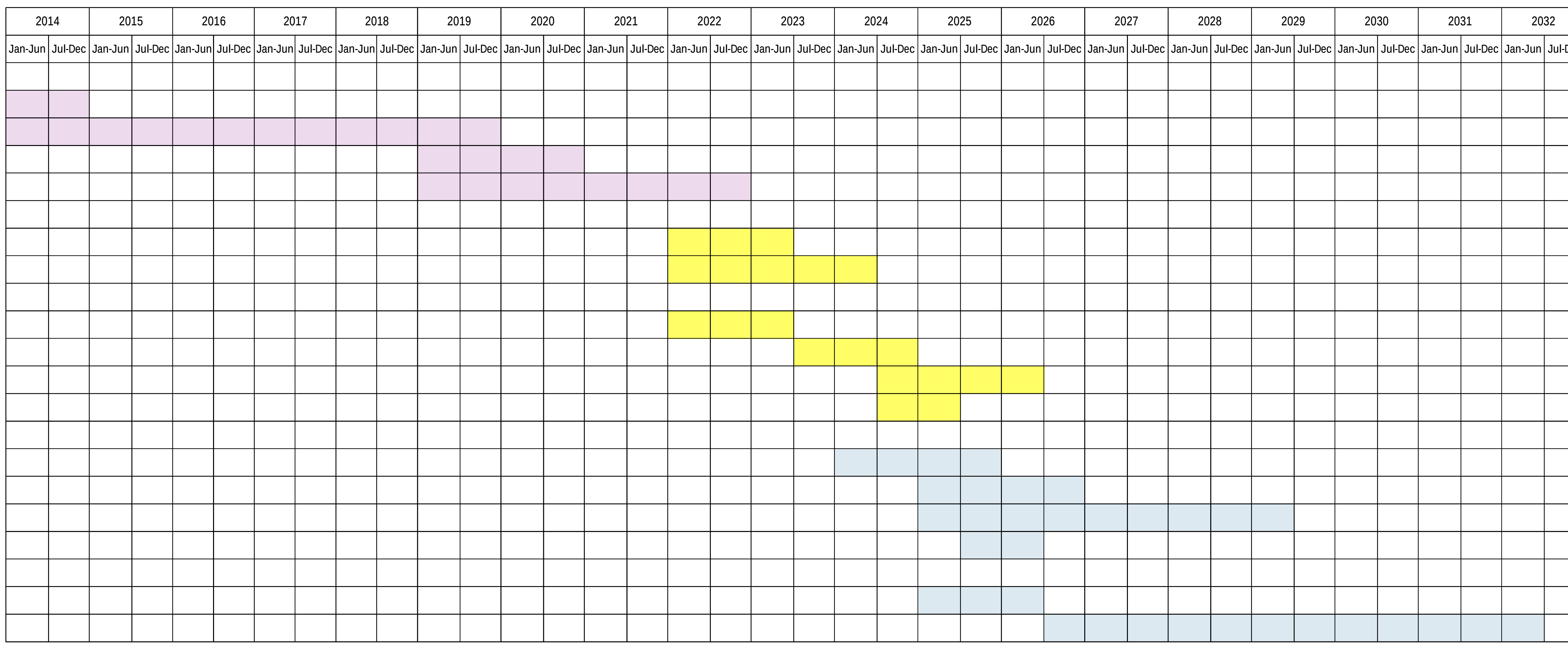
Hydraulic Grade Line – Kiamichi to Lake Bridgeport

Kiamichi River Implementation Schedule for TRWD IWSP:

Assumptions

- Kiamichi River supply would be developed in partnership with NTMWD and/or DWU
- Kiamichi River supply would require a long term contract with an Oklahoma entity
- Kiamichi River supply would require a Federal 404 permit, which would be issued without triggering an EIS
- Mingling of Oklahoma water into Texas reservoirs, as an interim step in the delivery process, would be allowed (invasive species considerations)
- A “bed and banks” permit from TCEQ would be required to store additional water in existing Texas reservoirs
- An accounting plan would be prepared and approved in conjunction with the bed and banks permit
- The conservation pools (normal operating elevation) of none of the storage reservoirs (Bois d’Arc, Ray Roberts, Bridgeport) would be increased as a result of the additional water to be stored therein
- 404 process and the bed and banks permit would not start until contract negotiations are well advanced to almost complete
- Limited design could overlap with permitting processes
- Some construction activities could start before real estate acquisition is complete
- Conceptual design and planning includes preliminary pipeline route selection for permitting purposes
- Embankment\spillway construction includes two years for reservoir filling

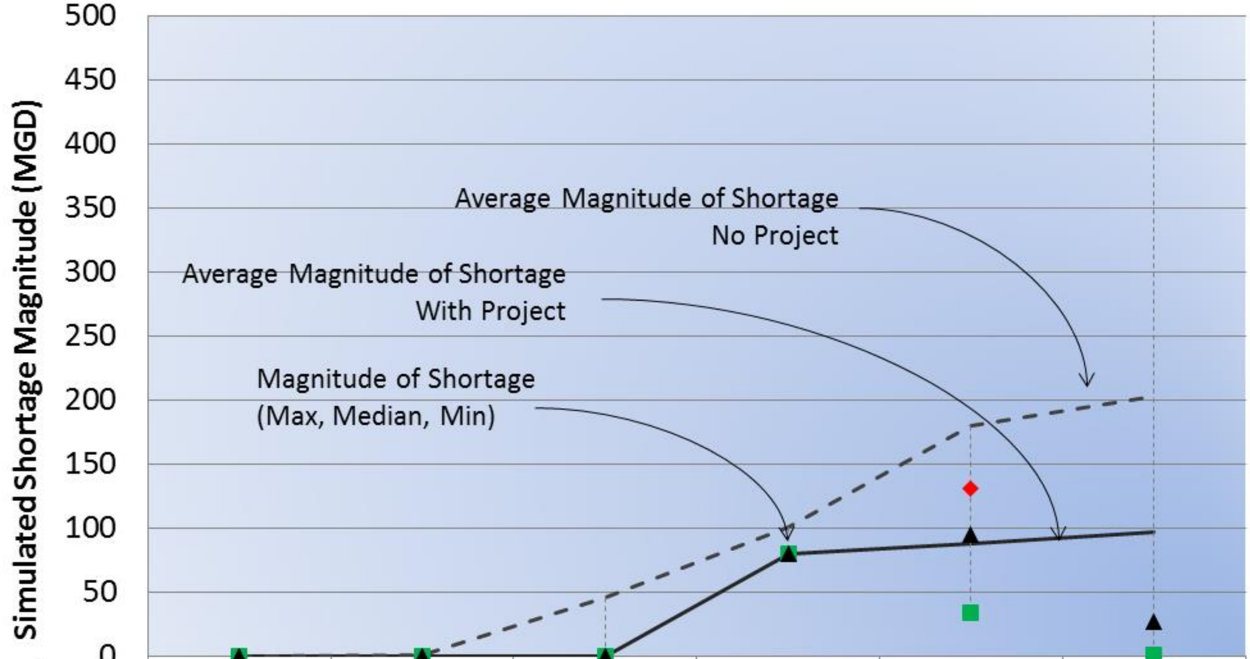
TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	1 Year
Negotiate Contract for Oklahoma Water	January 2014	6 Years
Bed and Banks Permit	January 2016	2 Years
404 Permit Application/Approval	January 2016	4 Years
DESIGN TASKS		
Channel Dam and Off Channel Storage Facility	January 2019	1.5 Years
Relocations	January 2019	2.5 Years
Transmission Facilities	January 2019	4.5 Years
Route Selection	January 2019	1.5 Years
Survey and Preliminary Design	July 2020	1.5 Years
Final Design	July 2021	2 Years
Design Mitigation Features	July 2021	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition	January 2021	2 Years
Relocations	January 2022	2 Years
Embankment/Spillway	January 2022	4.5 Years
Implement Mitigation	July 2022	1 Year
Transmission Facilities	January 2022	7.5 Years
Easement Acquisition	January 2022	1.5 Years
Bid and Construction Phase	July 2023	6 Years



Kiamichi

Magnitude Chart

Statistics from System Modeling

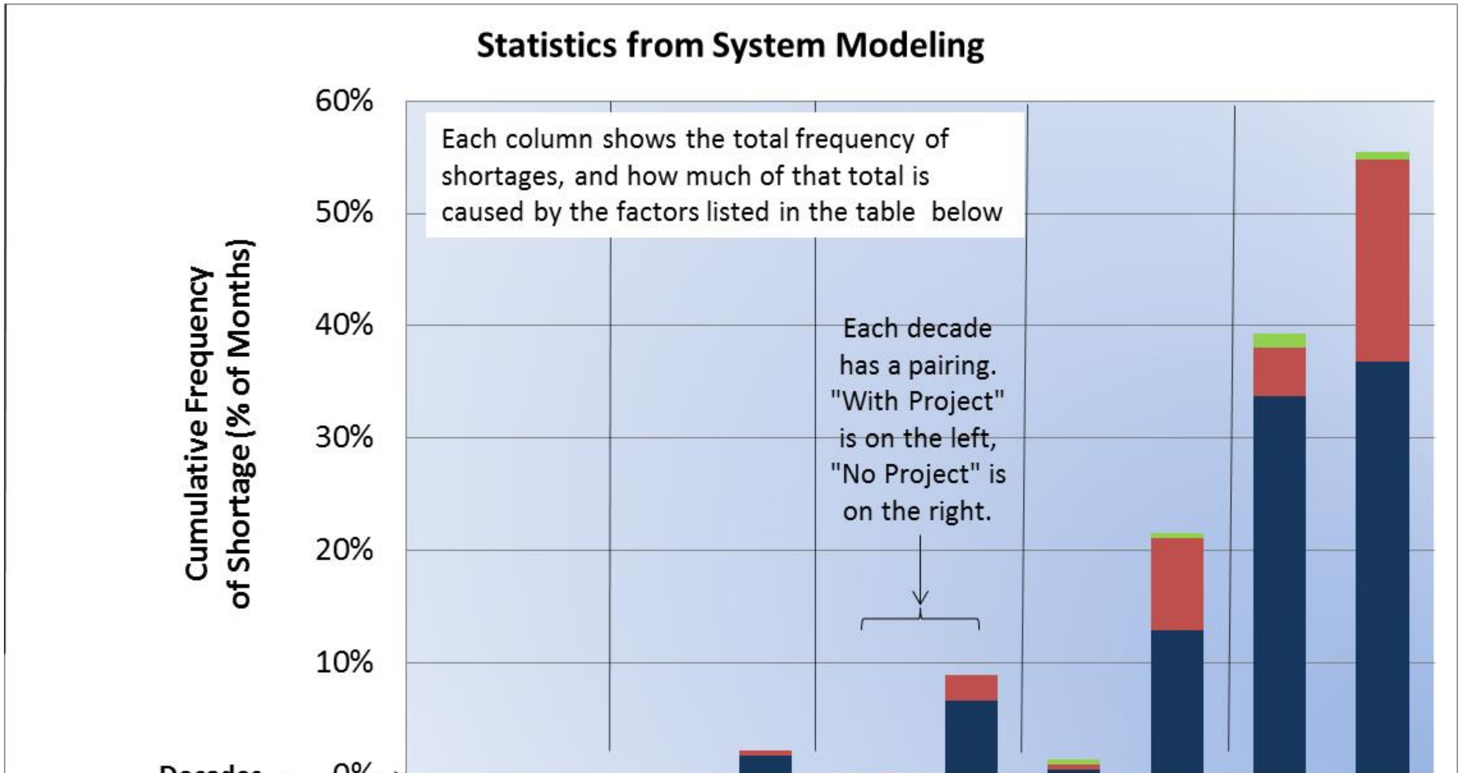


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	80	131	609
Minimum	0	0	0	80	34	1
Median	0	0	0	80	95	27
Average	0	0	0	80	87	97
Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Kiamichi

Frequency Chart

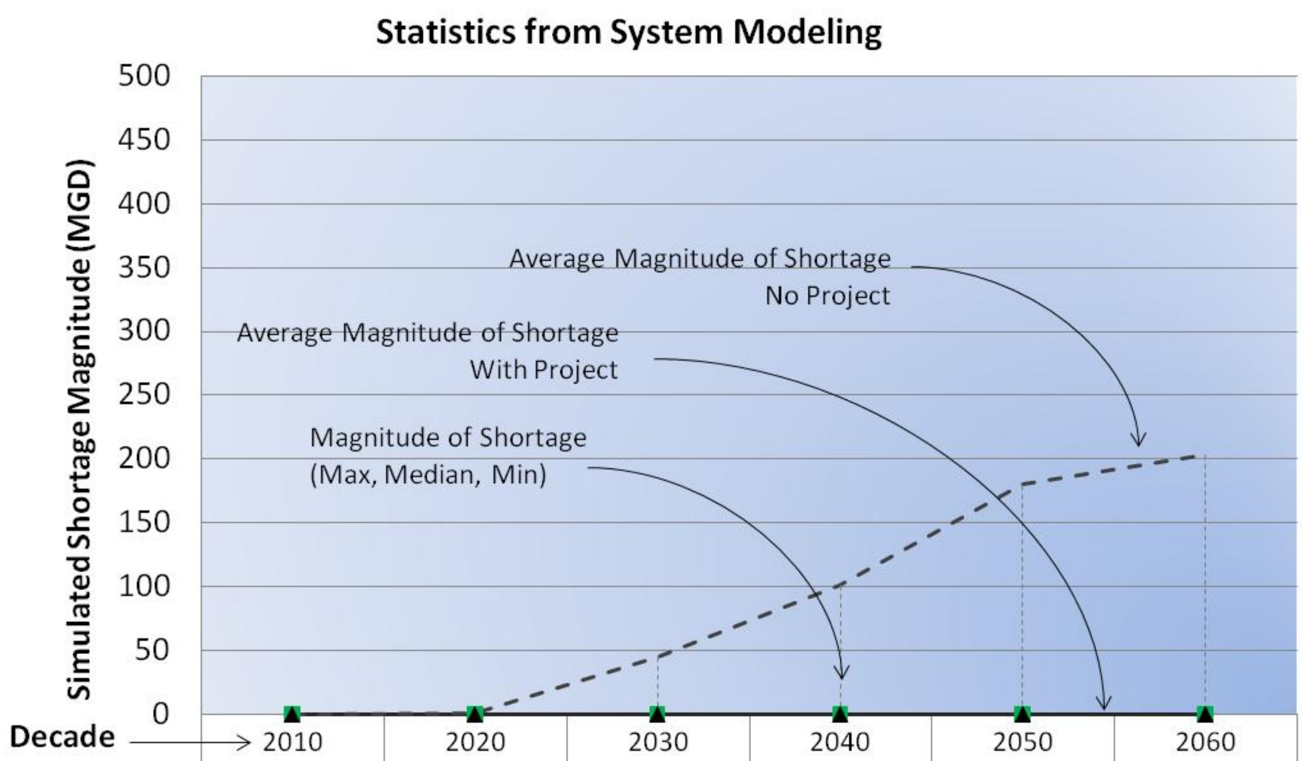


	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.4%		1.2%	
Permitted Amount	0.0%		0.0%		0.1%		0.5%		4.4%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.5%		33.7%	

Results Using 2011 Region C Based Demand Projection

Kiamichi

Magnitude Chart

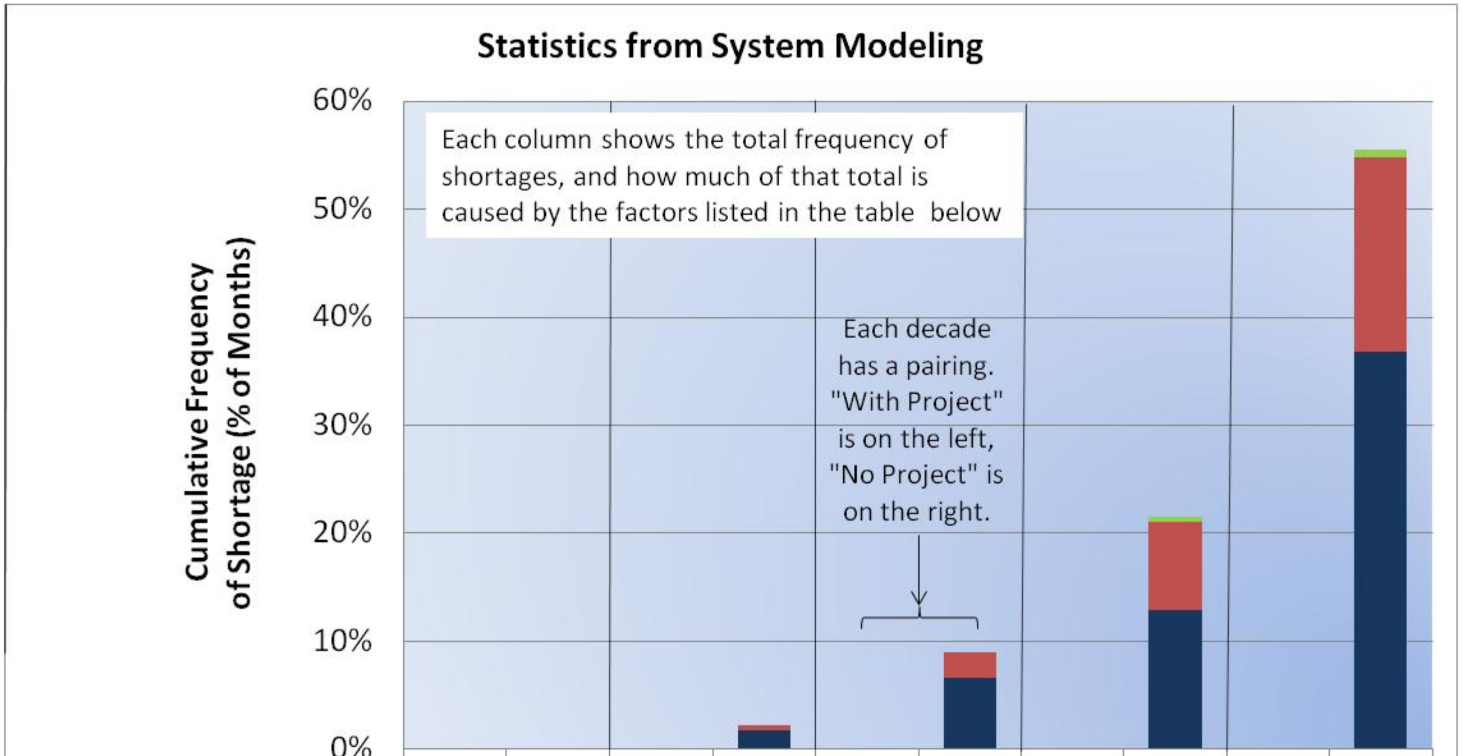


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	0	0	0
Minimum	0	0	0	0	0	0
Median	0	0	0	0	0	0
Average	0	0	0	0	0	0
Average - No Project	0	1	45	101	180	203

Results Using Recent Trend Extrapolation Demand Projection

Kiamichi

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.0%		0.0%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.0%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.0%		0.0%	

Results Using Recent Trend Extrapolation Demand Projection

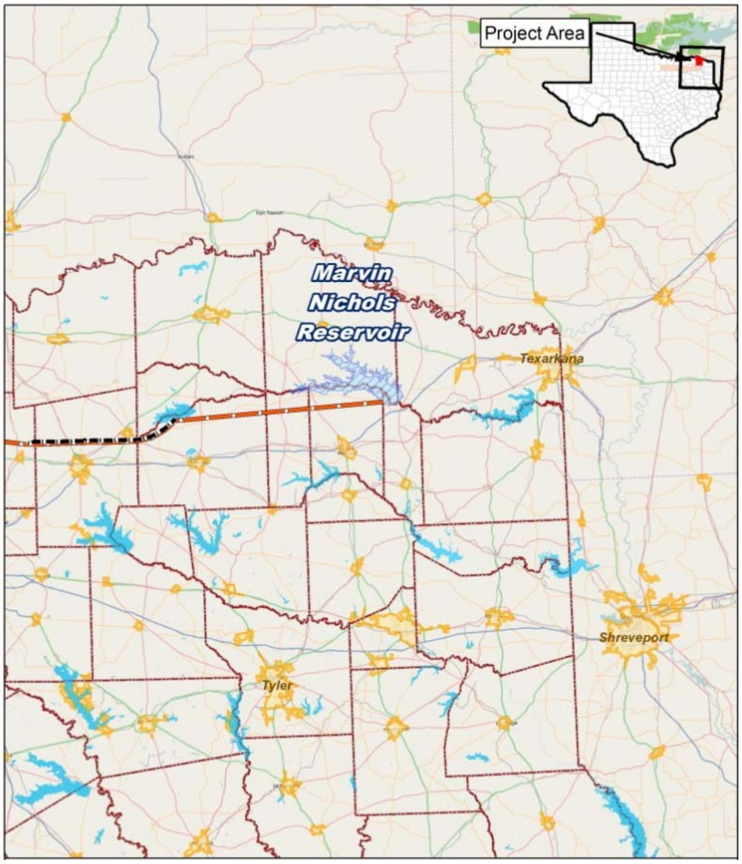
Marvin Nichols Reservoir

Description

The proposed Marvin Nichols Reservoir is located on the Sulphur River in the Sulphur River Basin in Texas' Regional Water Planning Group D ("Region D – North East Texas). The 80th Texas Legislature designated the Marvin Nichols Reservoir site as a site of unique value for reservoir development (Senate Bill 3, Section 4.01).The proposed reservoir would be about 115 miles from the Dallas-Fort Worth Metroplex and would inundate approximately 68,000 acres. This strategy assumes that NTMWD, TRWD, Dallas, Irving, and UTRWD would collaborate to construct Marvin Nichols Reservoir and transmission facilities. Below is a breakdown of the assumed percent of yield (in acre-feet per year) available to each entity.

- NTMWD – 142,850 (29.167%)*
- TRWD – 142,850 (29.166%)*
- DWU – 142,850 (29.167%)*
- Irving – 26,451 (5.4%)*
- UTRWD – 34,779 (7.1%)*
- Local Users – 122,521

*Percentages are based on water going to the Metroplex and do not include the water taken by local users.



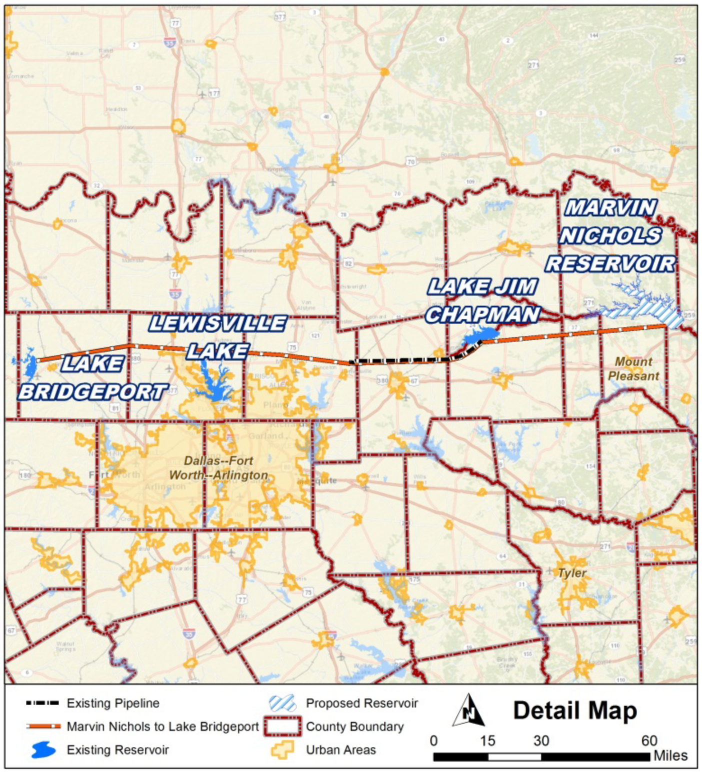
Vicinity Map

Facilities Required

New reservoir:

- Dam height: 82 feet
- Normal Pool Elevation: 328 feet-msl
- Normal Pool Surface Area: 67,392 acres
- Normal Pool Storage: 1,562,669 acre-feet

Transmission Facilities:



Pipeline Route Map

- Approximately 110 miles of two parallel 108-inch pipes,30 miles of two 96-inch pipes, and 60 miles of single 96-inch pipe. The assumed pipeline route runs from Marvin Nichols Reservoir to Lake Bridgeport. Along the route, it passes Jim Chapman Lake, Lake Lavon, and Lewisville Lake
- One 35,000 HP Intake Pump Station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.
- One 58,500 HP Intake Pump Station at Marvin Nichols
- Three booster pump stations along the pipeline route: 68,800 HP, 76,300 HP, and 20,500 HP.
- Two 109 MG earthen storage reservoirs and one 77 MG earthen storage reservoir
- One 191 MGD discharge structure at Lake Bridgeport.

Yield

The yield of Marvin Nichols Reservoir is 602,000 acre-feet/year, assuming stand-alone reservoir operations. The proposed Lake Ralph Hall will likely have a senior water right to Marvin Nichols, and would reduce the firm yield of Marvin Nichols by 17,900 acre-feet/year to 584,100 acre-feet/year (TWDB, 2008). However, if Marvin Nichols Reservoir is operated as a system with Lake Wright Patman, the yield can be increased to 612,300 acre-feet/year, even if Lake Ralph Hall's water rights are senior to Marvin Nichols Reservoir.

The yield used in the *2011 Region C Water Plan* and in this study is 612,300 acre-feet/year. Assuming twenty percent of the supply would go to Local Users in Region D, 489,840 acre-feet per year would be available for use by TRWD and other entities in Region C.

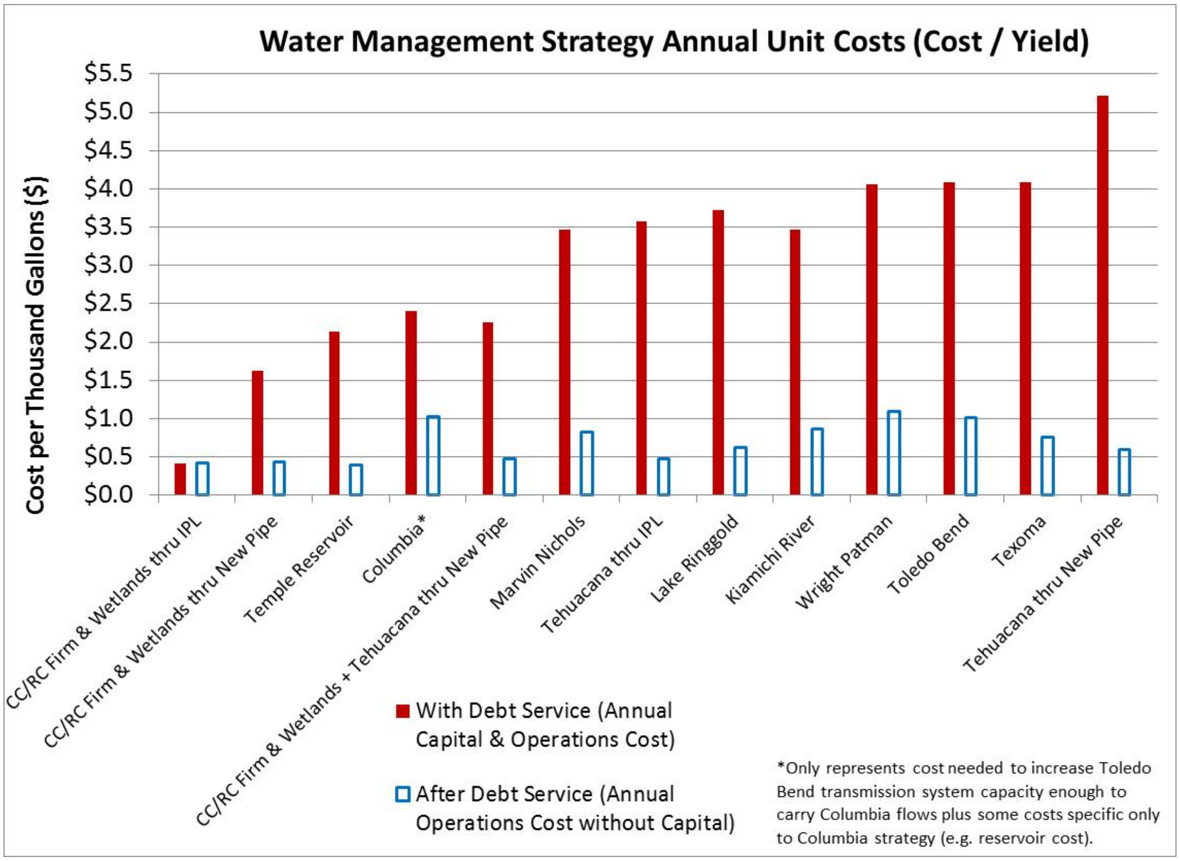
TRWD's Cost (in 2012 dollars)

Capital

$1,695,867,000

Annual

- Total annual cost during debt repayment period - $161,605,000
- Total annual cost after debt is payed – $38,402,000
- Annual unit cost of water until amortization based on 142,850 acft/yr firm yield ($/1000 gal) - $3.47
- Annual unit cost of water after amortization based on 142,850 acft/yr firm yield ($/1000 gal) - $0.82

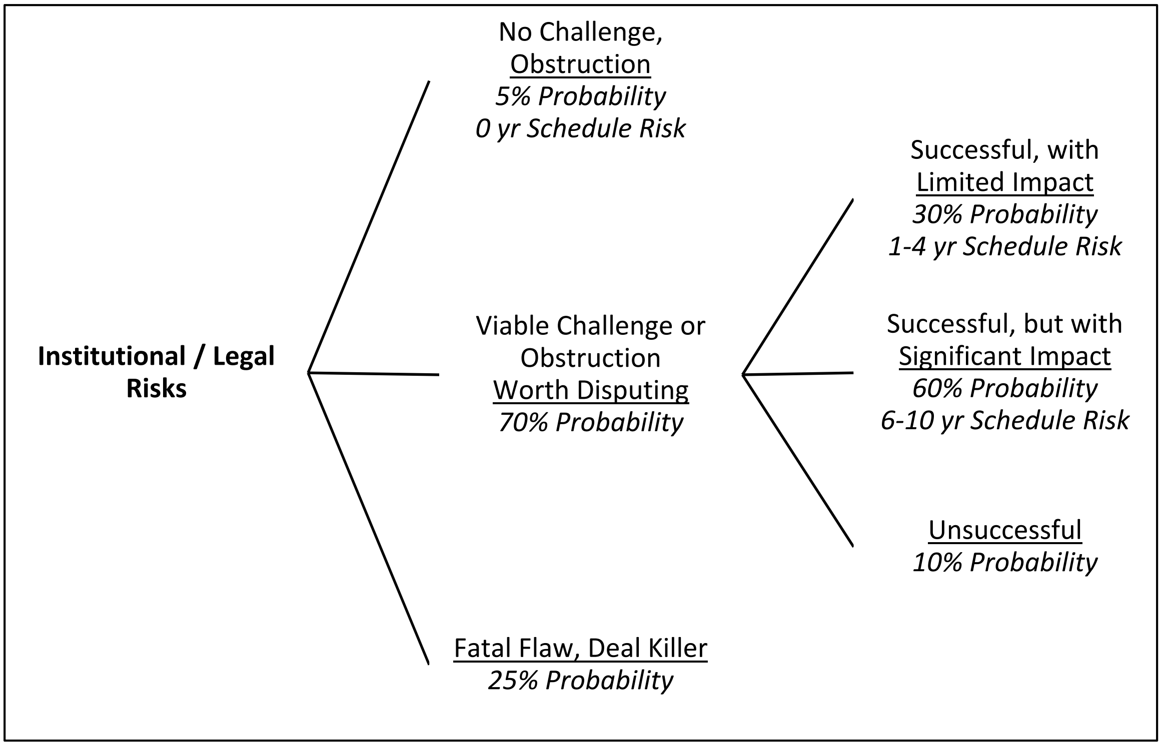


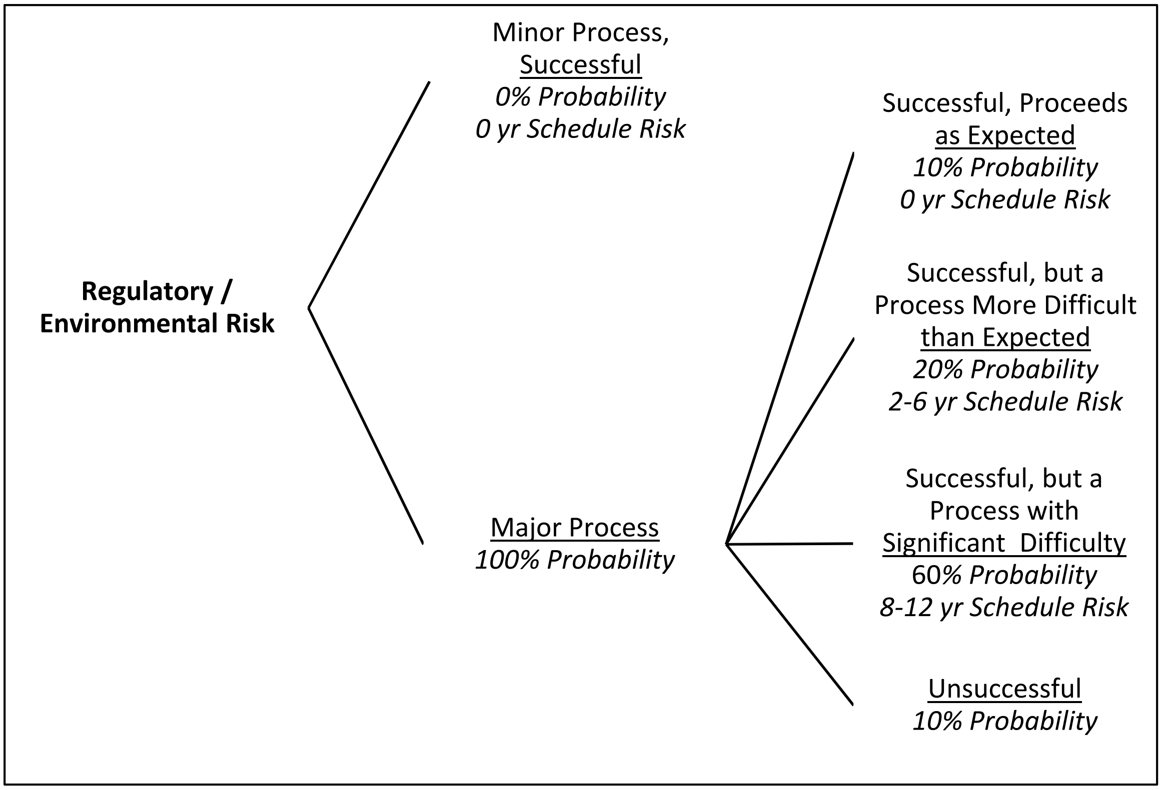
Comparison to Other Strategies

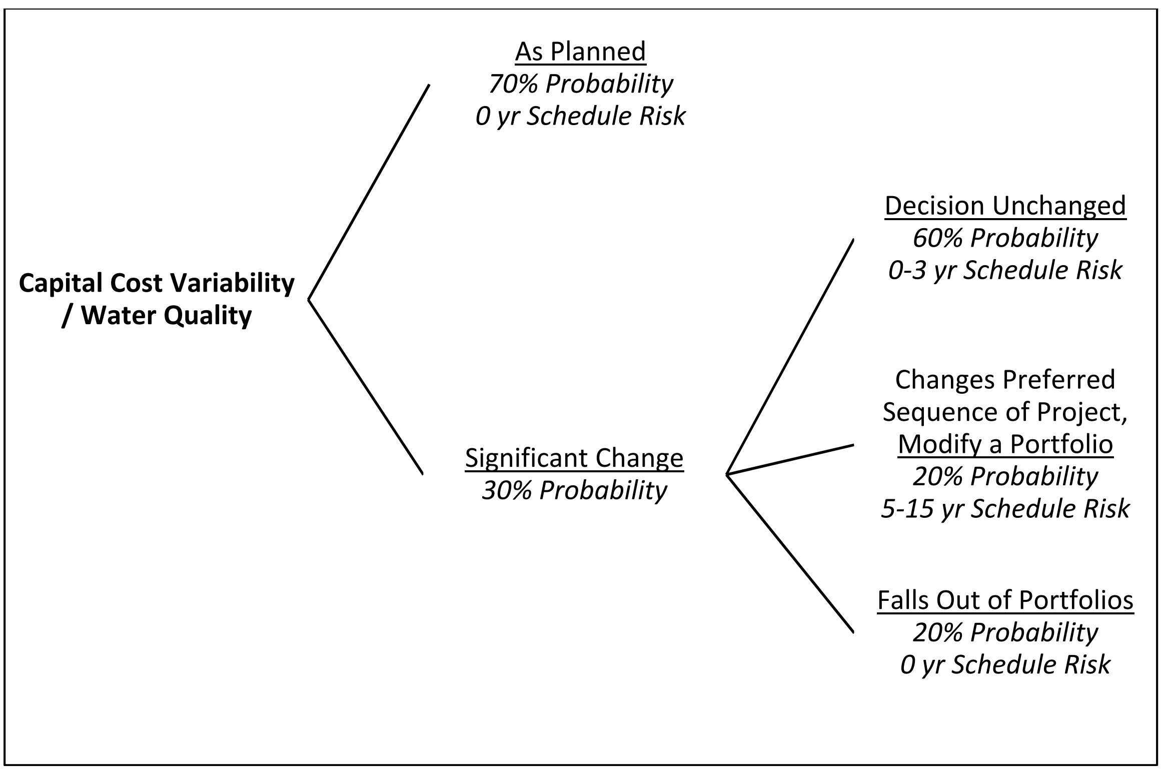
Key Assumptions

- Project agreement involving Metroplex partners and Sulphur River Basin Authority.

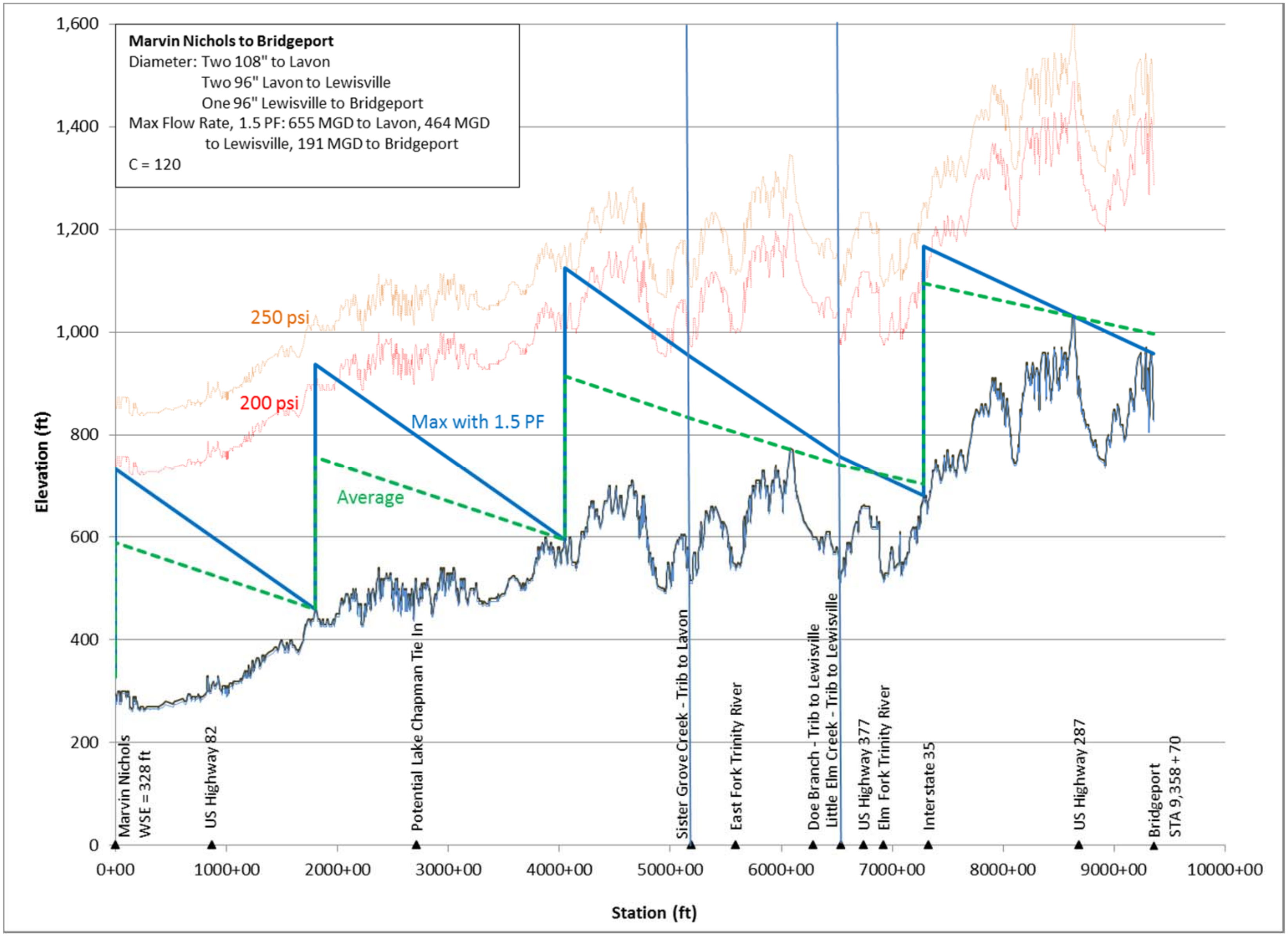
Risk Assessment




Minor Process, Successful
0% Probability
0 yr Schedule Risk
Regulatory / Environmental Risk
Successful, Proceeds as Expected
10% Probability
0 yr Schedule Risk
Successful, but a Process More Difficult than Expected
20% Probability
2-6 yr Schedule Risk
Successful, but a Process with Significant Difficulty
60% Probability
8-12 yr Schedule Risk
Major Process
100% Probability
Unsuccessful
10% Probability


As Planned
70% Probability
0 yr Schedule Risk
Capital Cost Variability / Water Quality
Decision Unchanged
60% Probability
0-3 yr Schedule Risk
Changes Preferred Sequence of Project, Modify a Portfolio
20% Probability
5-15 yr Schedule Risk
Significant Change
30% Probability
Falls Out of Portfolios
20% Probability
0 yr Schedule Risk

Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability/ Water Quality Risk
Not included in the Region D plan. Opposed by the Region D planning group. Need to partner with Metroplex water providers as well as SRBA results in complex decision-making, financial, and administrative processes System operation with Wright Patman will require agreements/negotiations with Texarkana, International Paper, and the USACE.	The 1984 U.S. Fish and Wildlife Service *Bottomland Hardwood Preservation Program* classified some of the land that would be flooded by Marvin Nichols Reservoir as Priority 1 bottomland hardwood site, which is "excellent quality bottomlands of high value to key waterfowl species." This will result in significant opposition from environmental groups. Effect of reservoir footprint and required mitigation on timber production in the Sulphur River Watershed is of major concern to in-basin interests. 404 Permit, new water right, and interbasin transfer permit required.	Significant uncertainty as to real estate costs, particularly related to extent and location of mitigation lands in addition to reservoir footprint. Uncertainty in costs associated with permitting and mitigation.



Hydraulic Grade Line – Marvin Nichols Reservoir to Lake Bridgeport

References

Freese and Nichols, Inc., Alan Plummer Associates, Inc., CP&Y, Inc., and Cooksey Communications Inc.: *2011 Region C Water Plan*, prepared for the Region C water Planning Group, Fort Worth, October 2010.

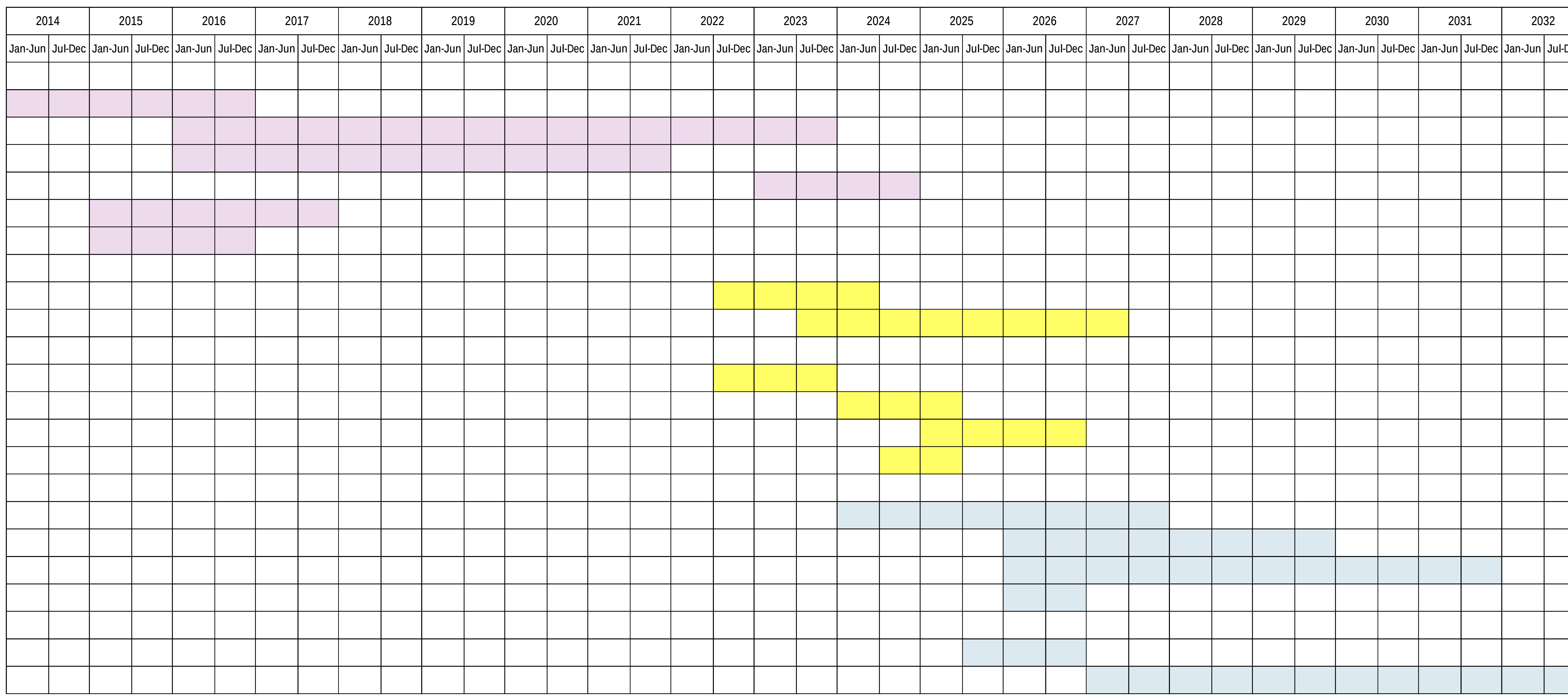
Texas Water Development Board Report 370, *Reservoir Site Protection Study*, July 2008.

Marvin Nichols Implementation Schedule for TRWD IWSP:

Assumptions

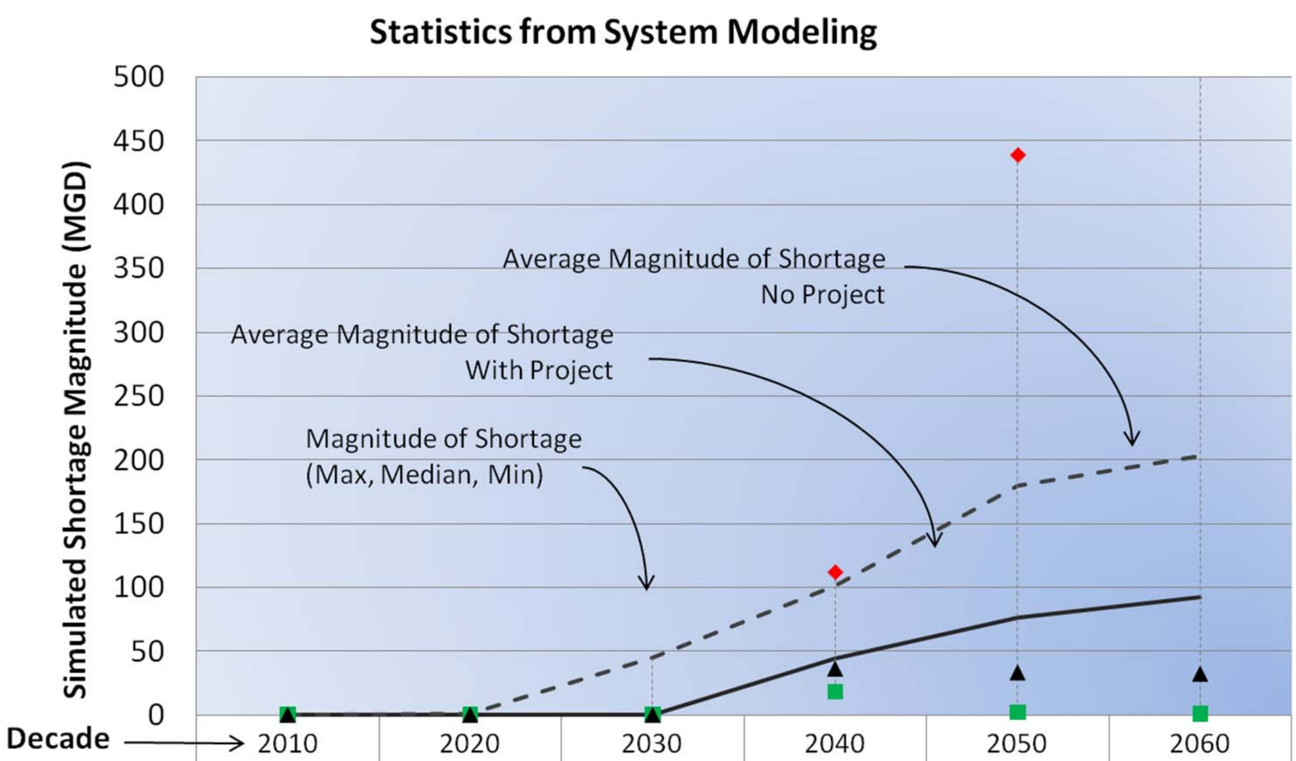
- MN will be developed through the JCPD and SRBA
- Lake Ralph Hall would be in place and would have a senior water right
- MN would require a new water right and IBT permit
- MN would require a Federal 404 permit with an EIS
- The “systems operation” with Wright Patman would require:
    - Negotiation with Texarkana regarding their water right and the in-basin uses from Marvin Nichols
    - Revisions to the Wright Patman Water Control Manual (with NEPA document)
    - Possible review under Corps’ Dam Safety Action Classification
- Water Right application and 404 permit process would run concurrently
- Detailed design (embankment/spillway) could overlap with permitting processes
- Update to the Wright Patman water control manual would proceed concurrently with Marvin Nichols design
- Some construction activities can start before real estate acquisition is complete
- Conceptual design and planning includes preliminary pipeline route selection for permitting purposes
- Embankment/spillway construction includes two years for reservoir filling

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	3 Years
Water Rights / IBT Permit	January 2016	8 Years
404 Permit Application / Approval	January 2016	6 Years
Update to Wright Patman Water Control Manual	January 2023	2 Years
Revision to Wright Patman dam Safety Action Classification	January 2015	3 Years
Negotiations with Texarkana re: Systems Operation	January 2015	2 Years
DESIGN TASKS		
Embankment / Spillway	July 2022	2 Years
Relocations	July 2023	4 Years
Transmission Facilities	July 2022	4.5 Years
Route Selection	July 2022	1.5 Years
Survey and Preliminary Design	January 2024	1.5 Years
Final Design	January 2025	2 Years
Design Mitigation Features	July 2024	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition	January 2024	4 Years
Relocations	January 2026	4 Years
Embankment / Spillway	January 2026	6 Years
Implement Mitigation	January 2026	1 Year
Transmission Facilities	July 2025	7.5 Years
Easement Acquisition	July 2025	1.5 Years
Bid and Construction Phase	January 2027	6 Years



Marvin Nichols

Magnitude Chart

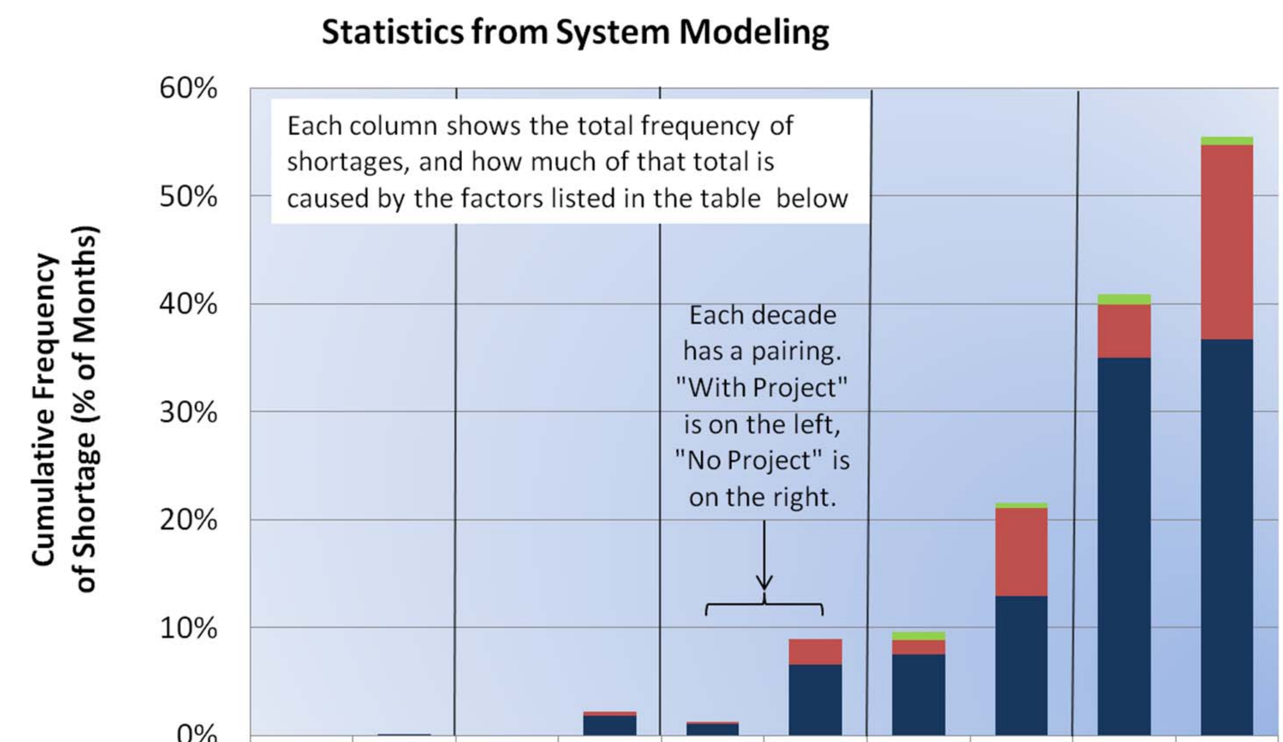


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	112	439	786
Minimum	0	0	0	18	2	1
Median	0	0	0	36	33	32
Average	0	0	0	44	77	92
Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Marvin Nichols

Frequency Chart

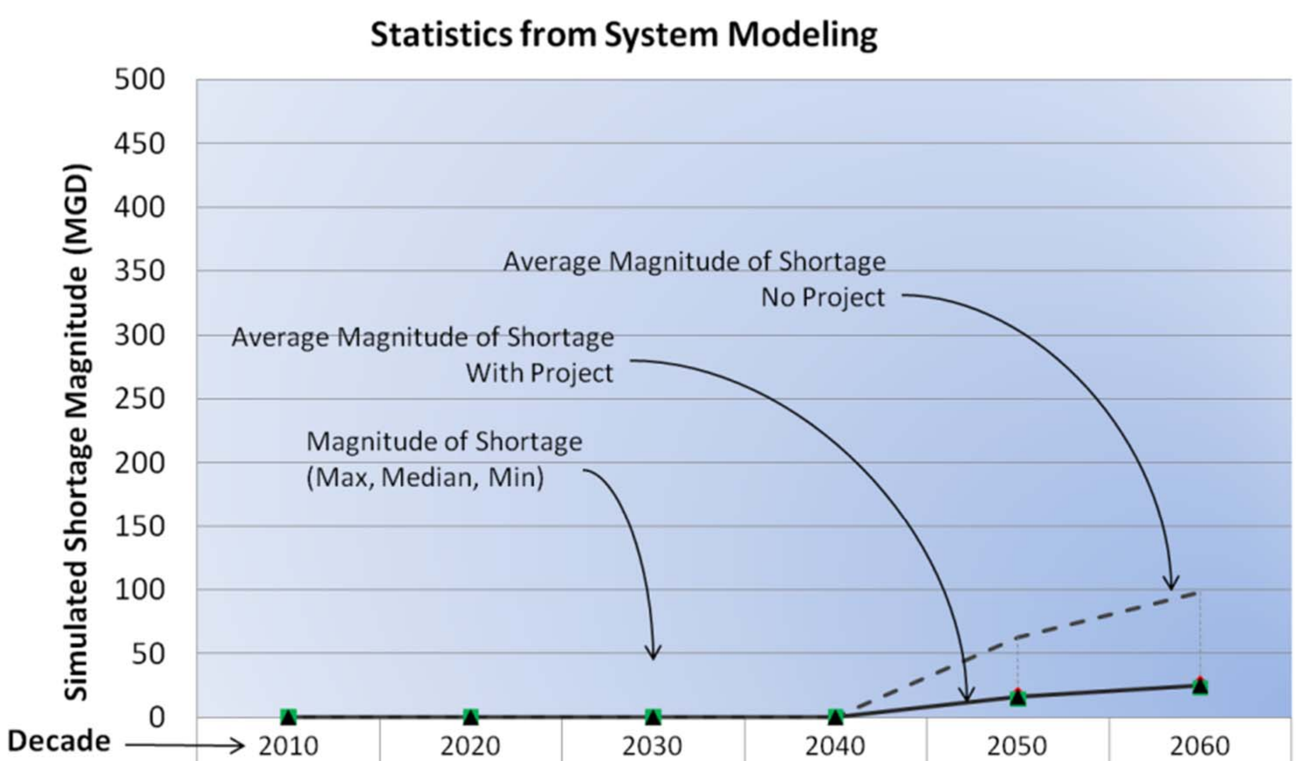


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.8%		1.0%	
Permitted Amount	0.0%		0.0%		0.2%		1.3%		4.9%	
Pipeline Capacity	0.0%		0.0%		1.1%		7.5%		35.0%	

Results Using 2011 Region C Based Demand Projection

Marvin Nichols

Magnitude Chart

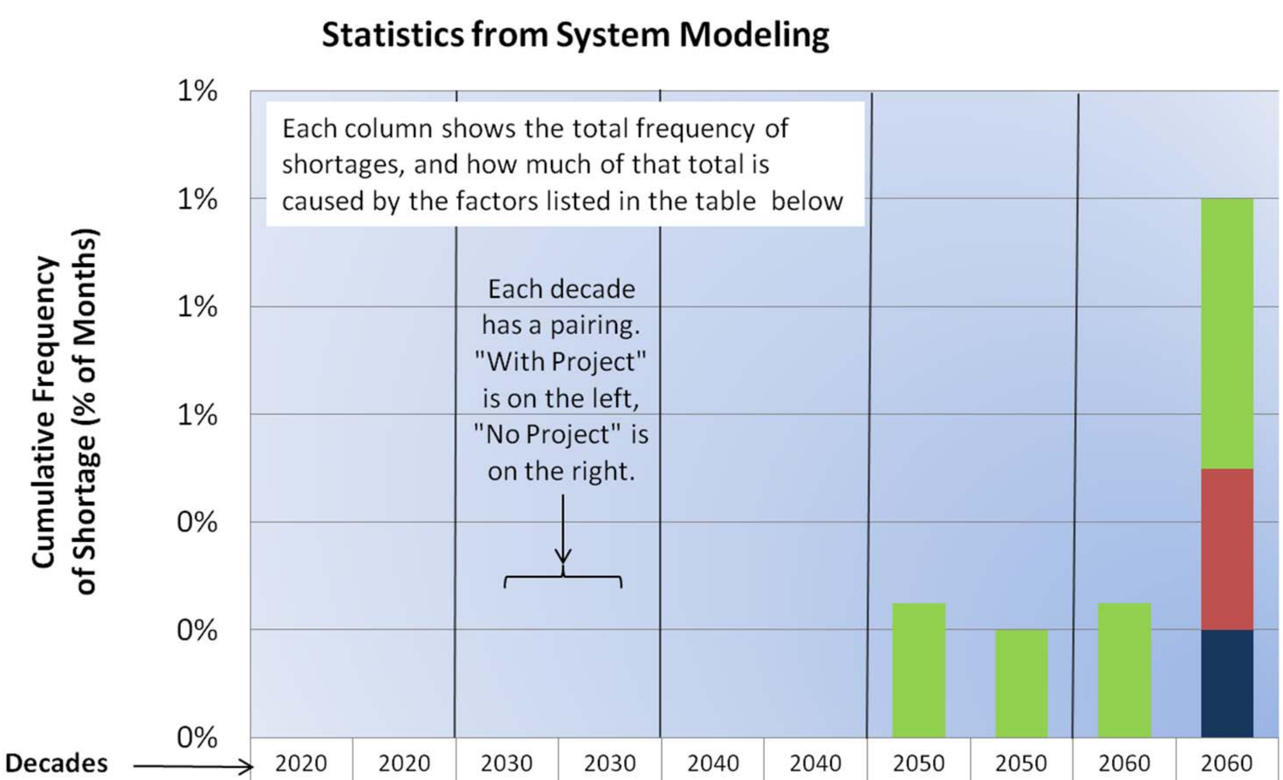


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	0	18	27
Minimum	0	0	0	0	14	23
Median	0	0	0	0	16	25
Average	0	0	0	0	16	25
Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

Marvin Nichols

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.2%		0.2%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.0%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.0%		0.0%	

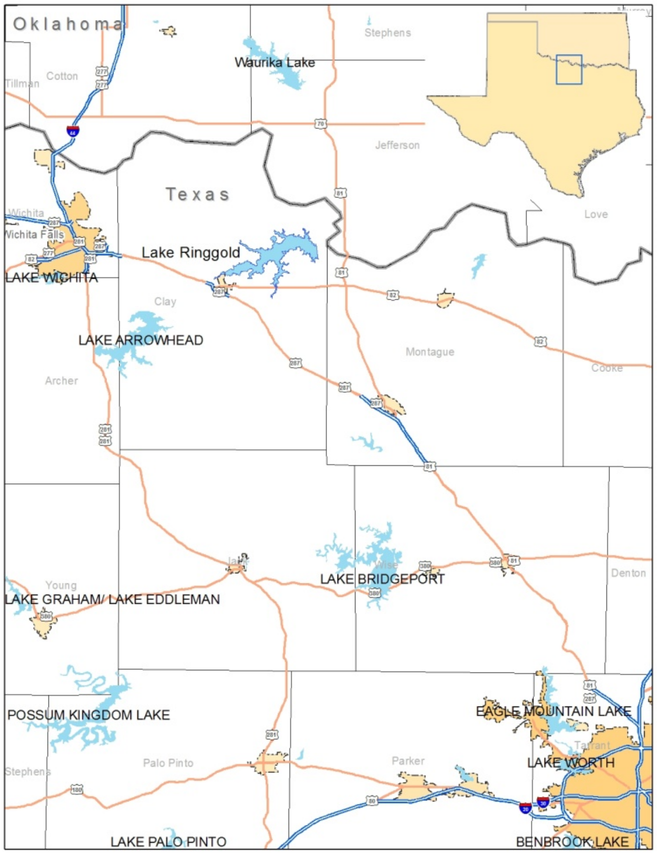
Results Using Recent Trend Extrapolation Demand Projection

Lake Ringgold

Description

The 80th Texas Legislature designated the Lake Ringgold site as a site of unique value for reservoir development (Senate Bill 3, Section 4.01). It is located on the Little Wichita River just upstream of the confluence with the Red River in Clay County and is a water supply strategy for the City of Wichita Falls. Wichita Falls needs an additional 4,200 to 4,900 acre-feet of annual supply to be fully reliable on a safe yield basis in 2060. Their current plan is to meet this gap by constructing Lake Ringgold. Wichita Falls also lists wastewater reuse as an alternative supply that could provide approximately 11,000 acre-feet/year. TRWD and Wichita Falls have agreed to study the feasibility of jointly developing Lake Ringgold.

This strategy is to build Lake Ringgold for two purposes: 1) water supply to TRWD and Wichita Falls; and 2) to integrate with the Southwestern Oklahoma water supply system.



Vicinity Map

Facilities Required

- Dam – 9,350' long zoned earthen embankment at 871' elevation with gated spillway. 844' elevation conservation pool; 271,600 acre-feet capacity; 14,980 acres inundated at top of conservation pool.
- One 3,400 HP intake pump station at Ringgold
- Approximately 42 miles of single 48-inch pipe
- 32 mgd discharge structure at Lake Bridgeport
- One 35,000 HP intake pump station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.

Yield

The Red River Water Availability Model – the Texas Commission on Environmental Quality's (TCEQ) Water Rights Analysis Package (WRAP) – estimates the firm yield at 33,000 acre-feet/year. However, previous studies estimated a lower firm yield. To be conservatively low, the Texas Regional Water Planning Group B 2011 Water Plan used these older yield estimates; 27,000 acre-feet/year was used as the reservoir firm yield and 24,000 was used as the safe yield (reserves a one-year supply of water at all times).

This study uses 28,600 acre-feet/year as the stand-alone Lake Ringgold firm yield. However, the yield can be increased if operated jointly with Southwestern Oklahoma water, and the Ringgold flows can similarly increase Lake Bridgeport yield. These joint operations have not yet been simulated.

This strategy assumes primary use of Ringgold yield by TRWD within the timeframe of this study (50 years). Therefore, all capital and annual costs are attributed to TRWD.

Pipeline Route to Lake Bridgeport

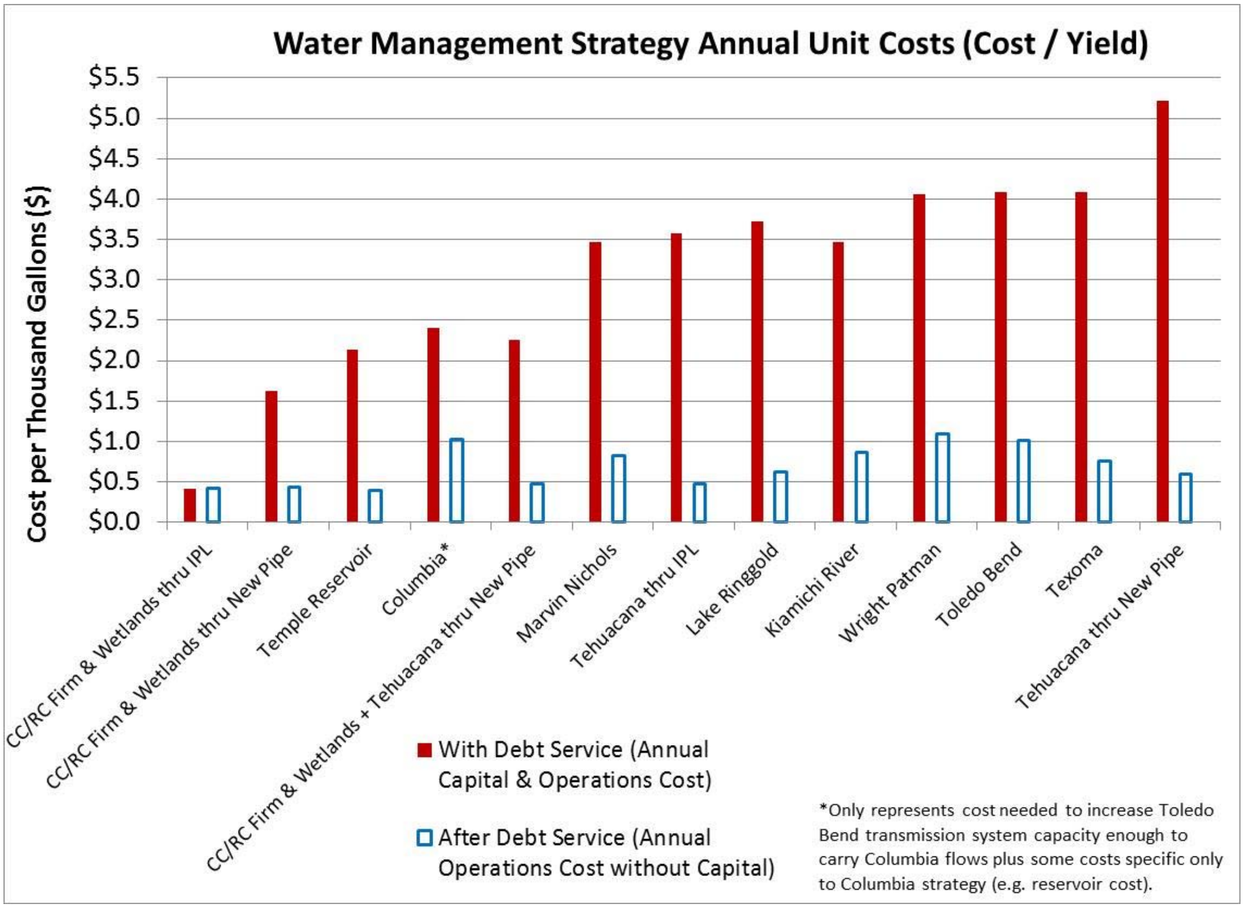
Cost (in 2012 dollars)

Capital

$397,735,000

Annual

- Total annual cost during debt repayment period - $34,682,000
- Total annual cost after debt is payed – $5,787,000
- Annual unit cost of water until amortization based on 28,600 acft/yr firm yield ($/1000 gal) - $3.72
- Annual unit cost of water after amortization based on 28,600 acft/yr firm yield ($/1000 gal) - $0.62

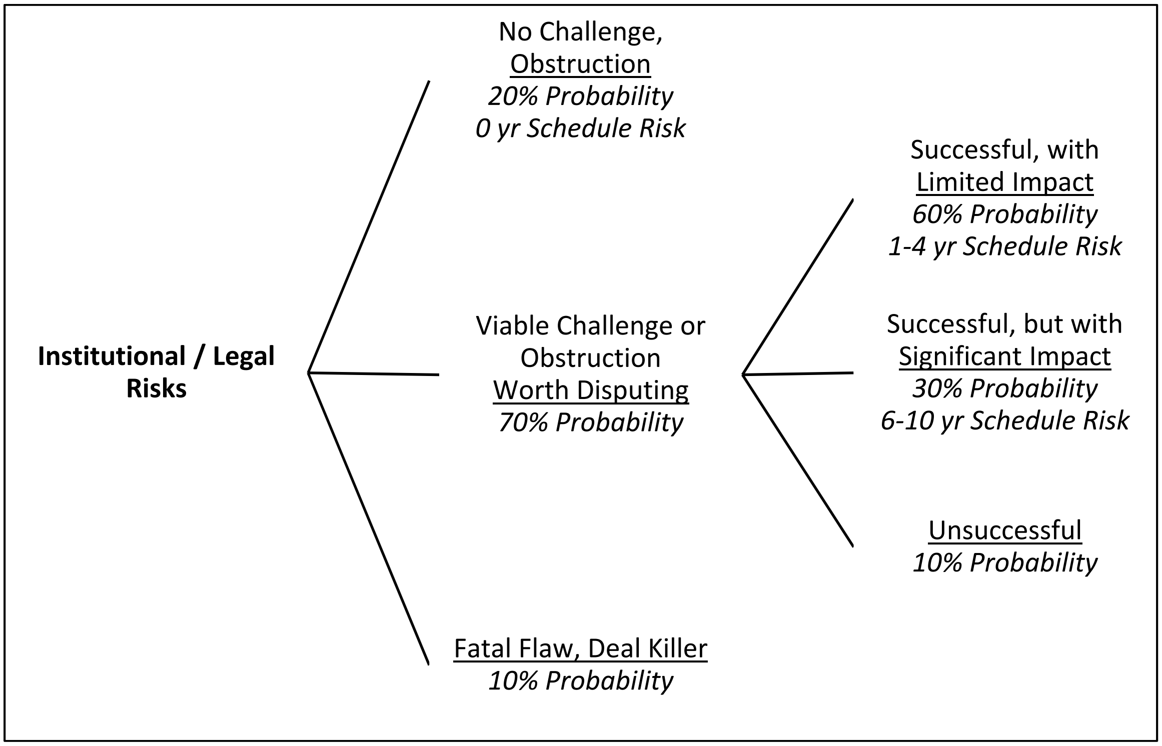


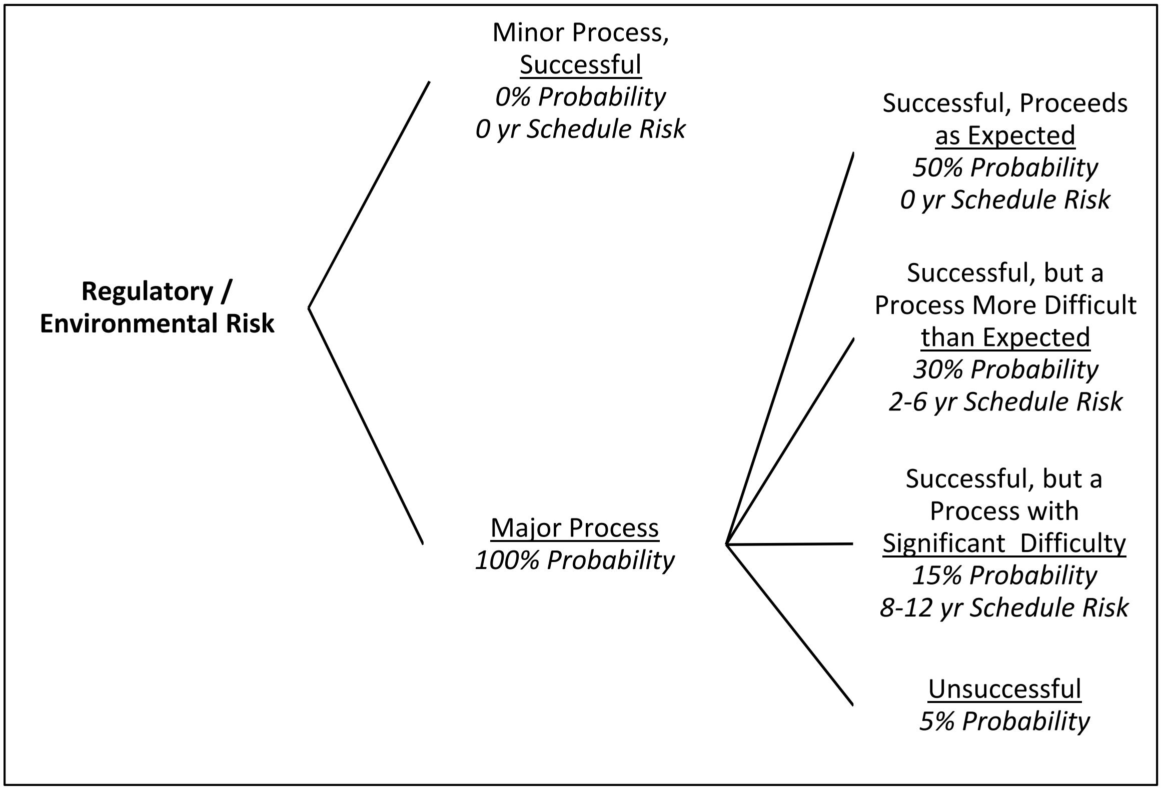
Comparison to Other Strategies

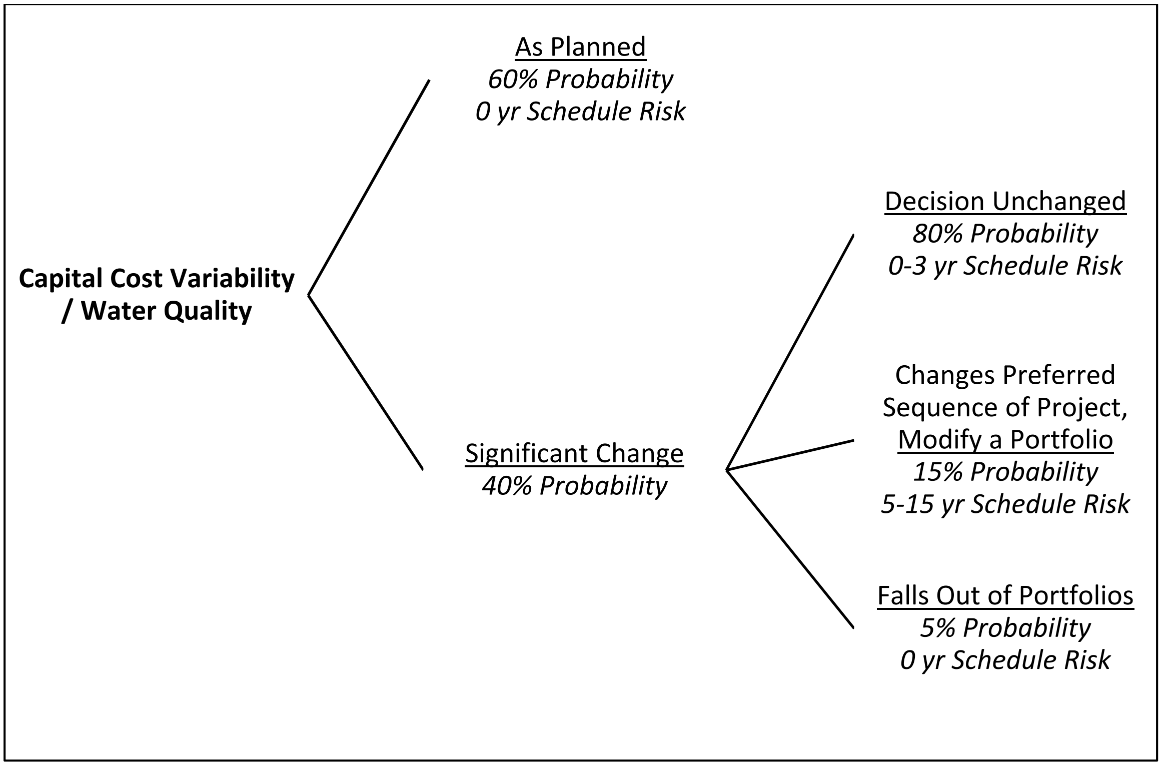
Key Assumptions

- Although not included in this configuration, there is the potential for augmenting Lake Ringgold yield through a combination of other sources, such as reuse water from Wichita Falls (who intends to use all of their reuse water to meet their future demands), groundwater, or blending with brackish surface water.
- Wichita Falls own approximately 40% of the 17,000 acres of land located at the reservoir site.
- Transmission infrastructure is sized to deliver only Ringgold supply to Lake Bridgeport.

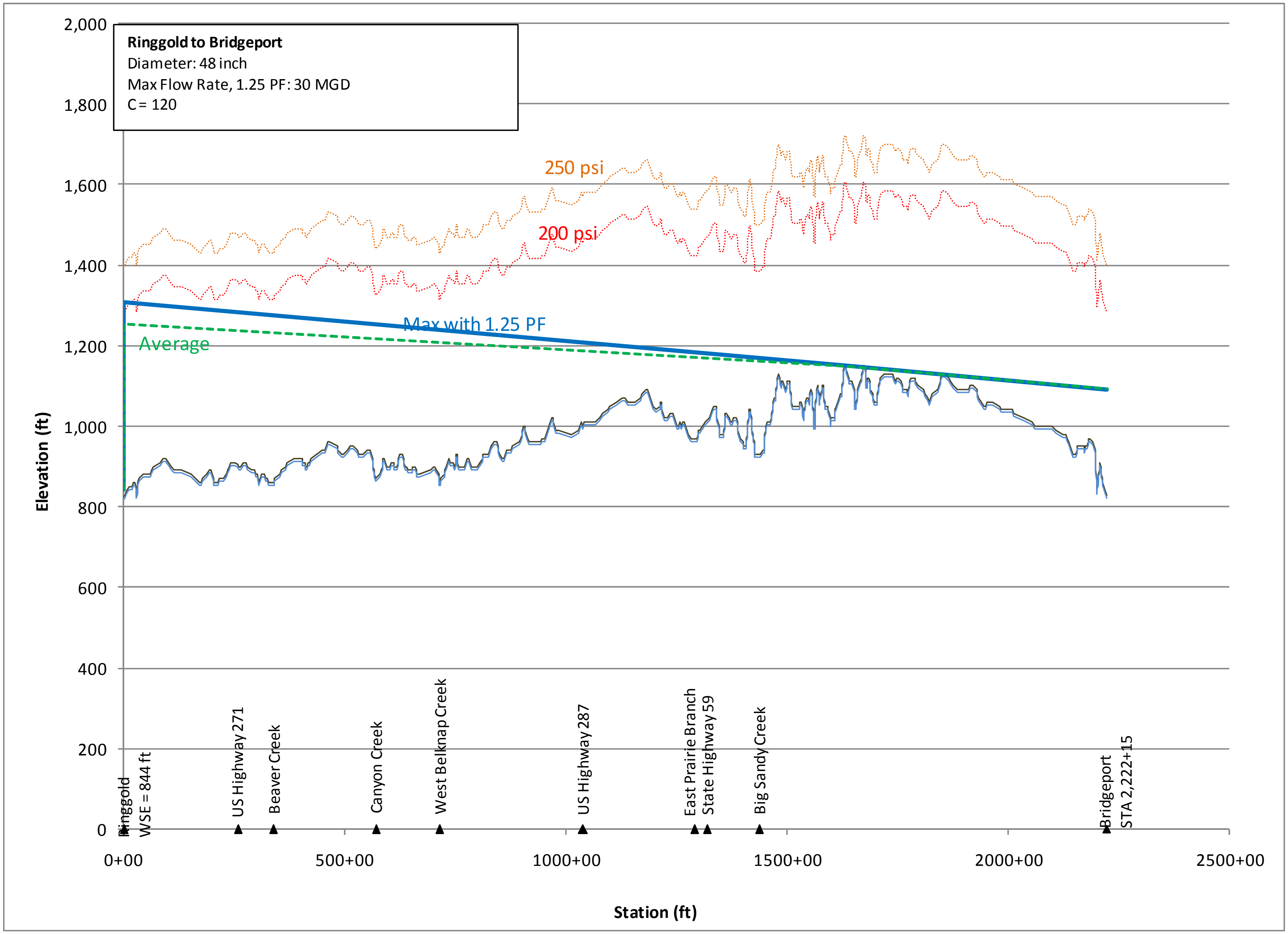
Risk Assessment







Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
Partnership with Wichita Falls may present institutional challenges.	404 permit, water right, and interbasin transfer permit required.	Water Quality: The area that contributes to the water to be impounded by Lake Ringgold includes a stream segment identified on the Section 303(d) list as not attaining the stream standard for dissolved oxygen. (Region B, p. 4-35). This implies a potential water quality risk that will need to be evaluated in further study.



Hydraulic Grade Line – Lake Ringgold to Lake Bridgeport

References

Texas Water Development Board Report 370, *Reservoir Site Protection Study*, July 2008.

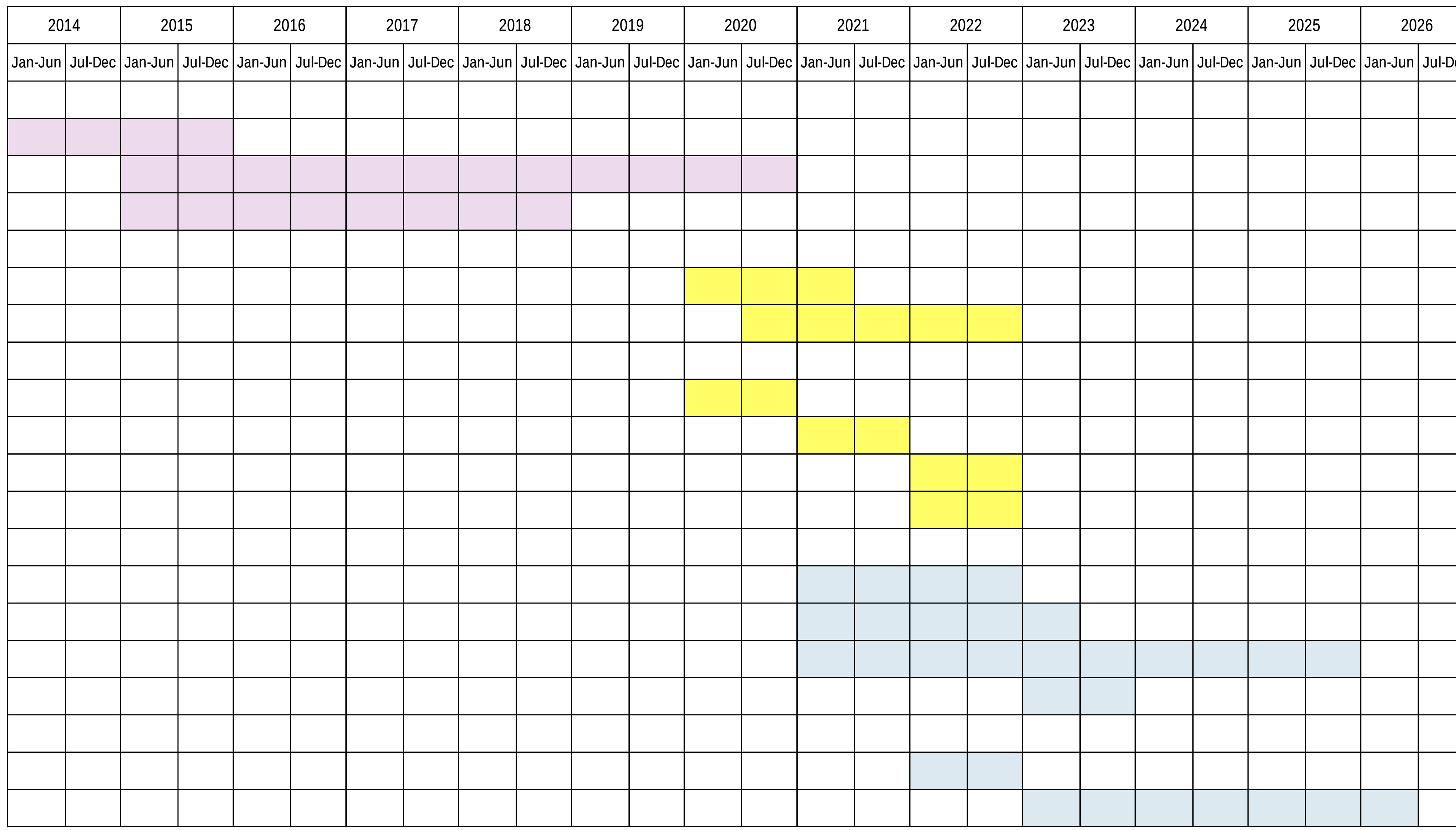
Region B Water Planning Group, *2011 Region B Regional Water Plan*, pp. 4-31 to 4-34.

Lake Ringgold Implementation Schedule for TRWD IWSP:

Assumptions

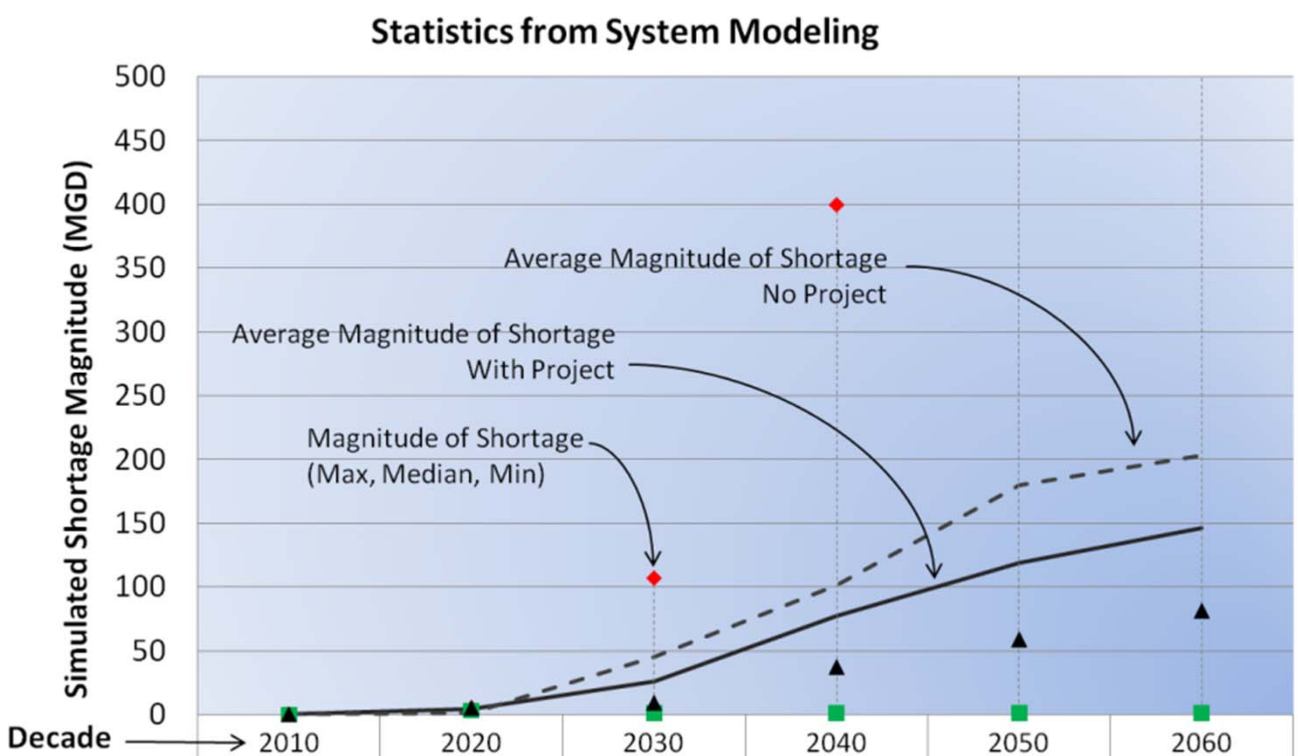
- Lake Ringgold would be developed in partnership with the City of Wichita Falls
- Lake Ringgold would require a new water right and IBT permit
- Lake Ringgold would require a Federal 404 permit with an Environmental Impact Statement
- Lake Ringgold is developed independently of a project in Western Oklahoma (Temple reservoir) and is not dependent on it for justification or needed permits
- Water Right application and 404 permit process would run concurrently
- Detailed design (embankment/spillway) could overlap with permitting processes
- City of Wichita Falls owns a significant portion of the real estate footprint and a considerable amount of construction activities could start as soon as design is complete (after 404 and water right permits are issued)
- Conceptual design and planning includes preliminary pipeline route selection for permitting purposes
- Embankment/spillway construction includes two years for reservoir filling

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	2 Years
Water Rights / IBT Permit	January 2015	6 Years
404 Permit Application / Approval	January 2015	4 Years
DESIGN TASKS		
Embankment / Spillway	January 2020	1.5 Years
Relocations	July 2020	2.5 Years
Transmission Facilities	January 2020	3 Years
Route Selection	January 2020	1 Year
Survey and Preliminary Design	January 2021	1 Year
Final Design	January 2022	1 Year
Design Mitigation Facilities	January 2022	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition	January 2021	2 Years
Relocations	January 2021	2.5 Years
Embankment / Spillway	January 2021	5 Years
Implement Mitigation	January 2023	1 Year
Transmission Facilities	January 2022	4.5 Years
Easement Acquisition	January 2022	1 Year
Bid and Construction Phase	January 2023	3.5 Years



Ringgold

Magnitude Chart

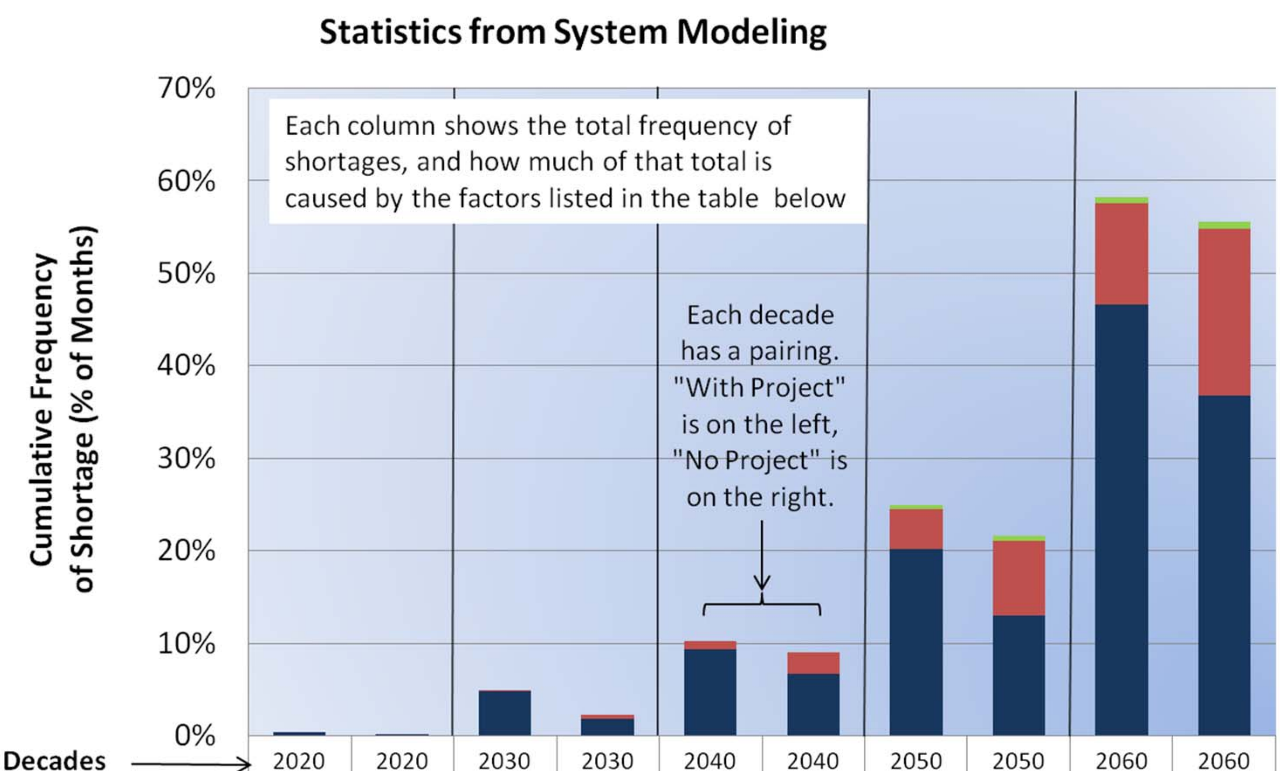


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	5	107	400	680	893
Minimum	0	3	1	1	1	1
Median	0	5	9	37	59	81
Average	0	4	26	77	119	146
Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Ringgold

Frequency Chart

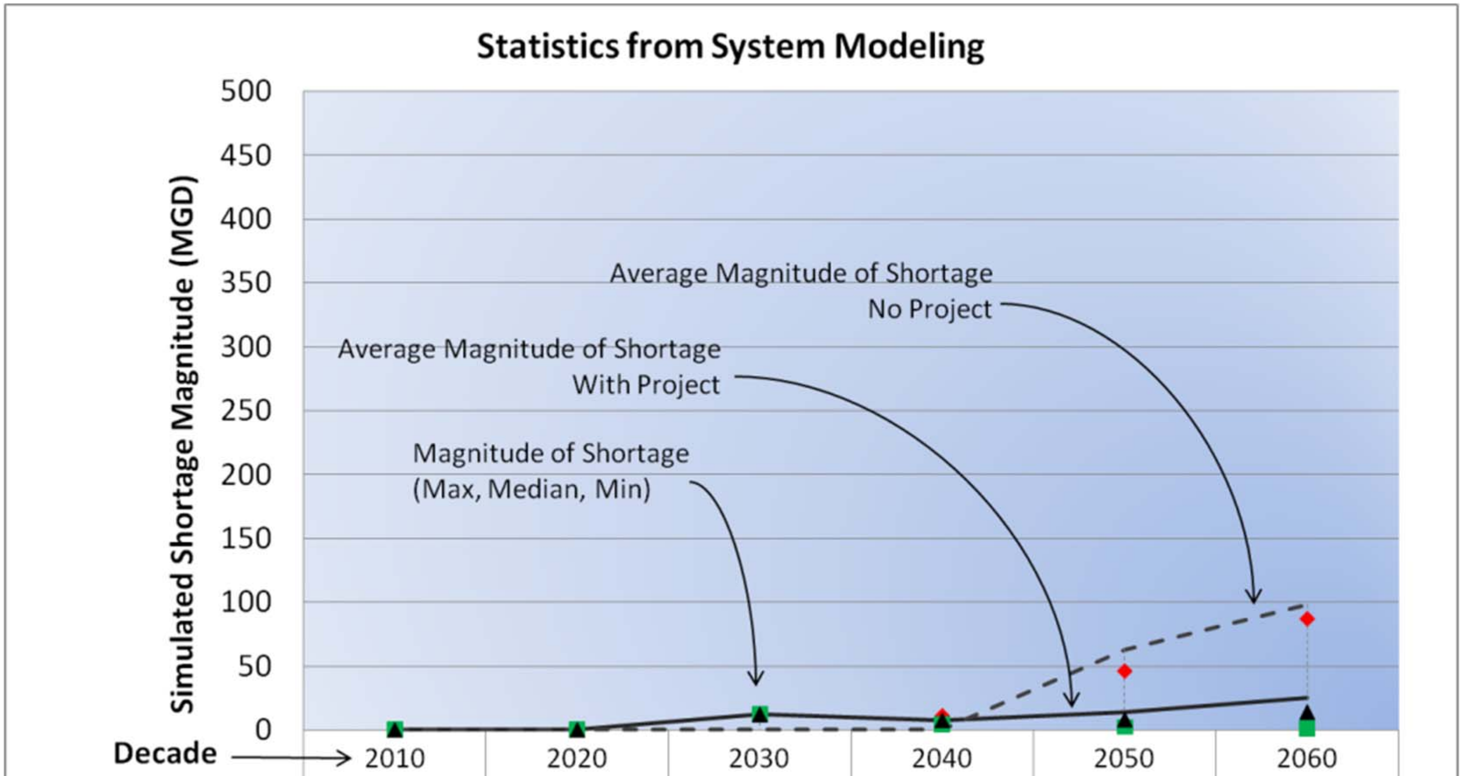


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.5%		0.7%	
Permitted Amount	0.0%		0.1%		0.9%		4.2%		10.9%	
Pipeline Capacity	0.4%		4.7%		9.3%		20.1%		46.6%	

Results Using 2011 Region C Based Demand Projection

Ringgold

Magnitude Chart

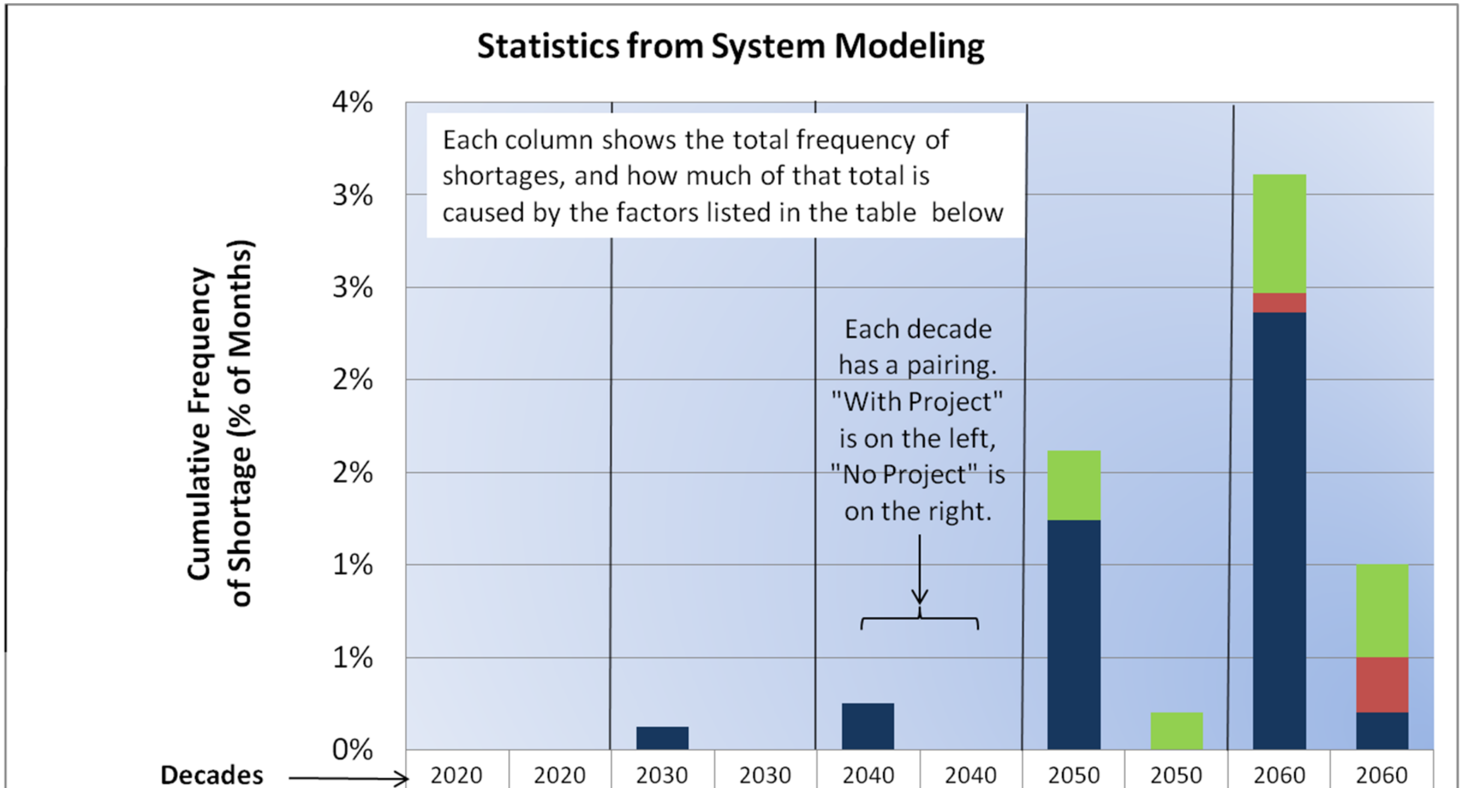


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	12	11	46	87
Minimum	0	0	12	4	2	1
Median	0	0	12	8	8	14
Average	0	0	12	8	14	25
Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

Ringgold

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.4%		0.6%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.1%	
Pipeline Capacity	0.0%		0.1%		0.2%		1.2%		2.4%	

Results Using Recent Trend Extrapolation Demand Projection

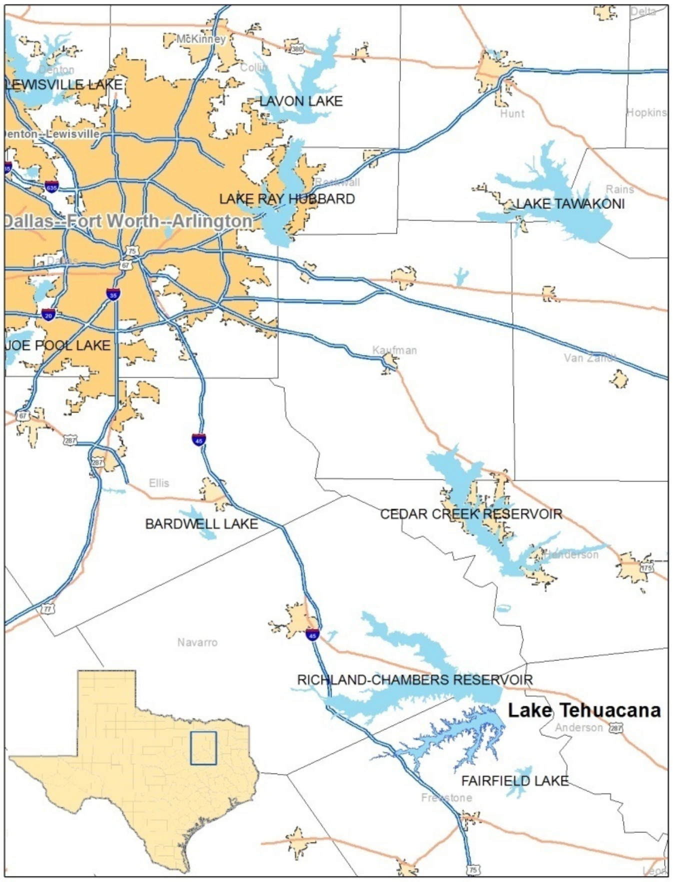
Tehuacana Reservoir

Description

Tehuacana Reservoir is a proposed reservoir on Tehuacana Creek in Freestone County, a tributary to the Trinity River, immediately south and adjacent to Richland-Chambers Reservoir. Tehuacana Reservoir would inundate approximately 15,000 acres adjacent to Richland-Chambers Reservoir and the two would be hydraulically connected with a small channel. Water from Tehuacana would be transported from Richland-Chambers Reservoir into TRWD transmission facilities.

Tehuacana Reservoir has been part of the TRWD water supply portfolio since the 1950's, but mineral issues in the reservoir footprint have made the project expensive to develop.

The existing spillway for Richland-Chambers Reservoir has capacity to handle Probable Maximum Flood flows from the additional storage created by Tehuacana Reservoir. The Tehuacana Reservoir dam can be constructed without an additional spillway and can function as an extension of Richland-Chambers Reservoir.



Vicinity Map

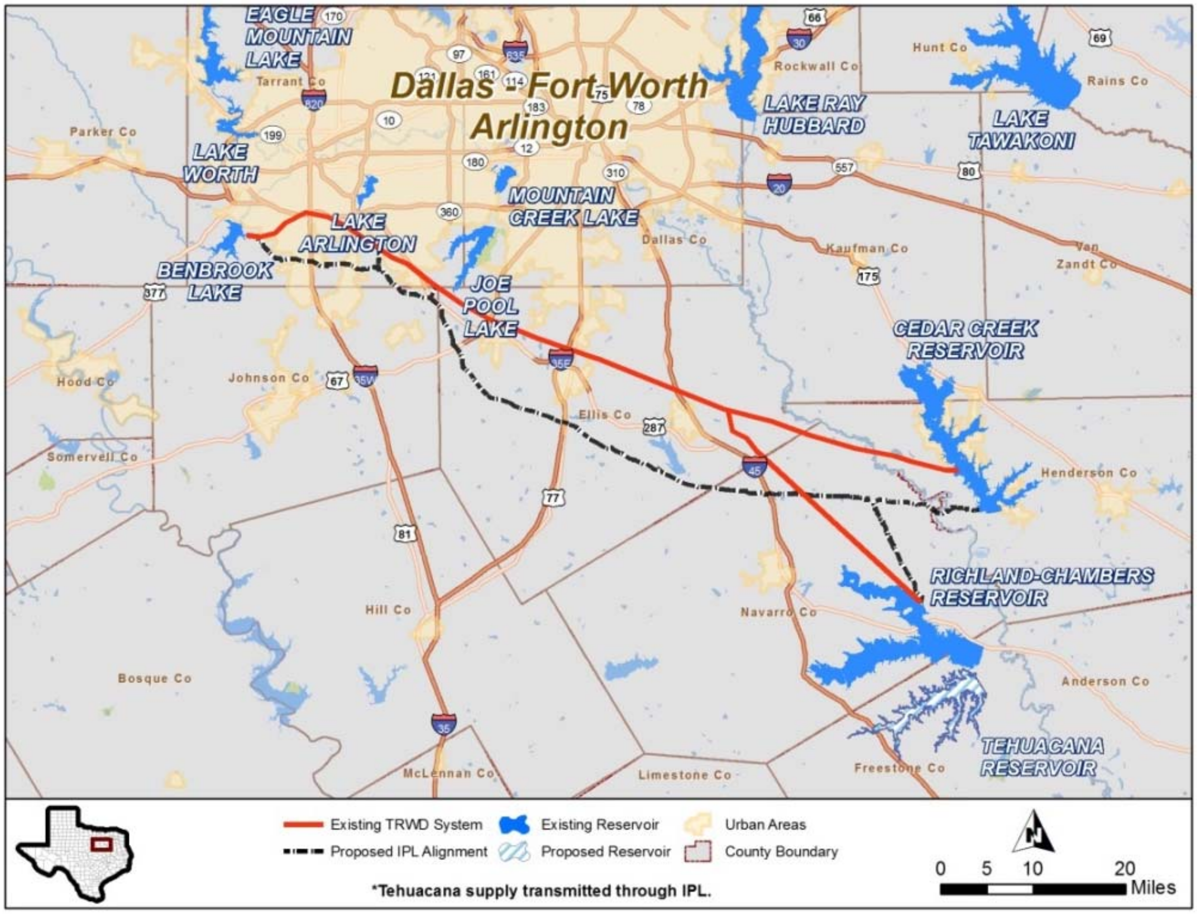
Facilities Required

- Zoned earthen embankment with a maximum height of 81 feet.
- 9,000' channel at elevation 290' connecting to Richland-Chambers Reservoir and a 60 HP booster pump station*[1] to access the full yield of Tehuacana down to elevation 270'.
- Because the Integrated Pipeline will not be operated at full capacity in the near term, Tehuacana supply will

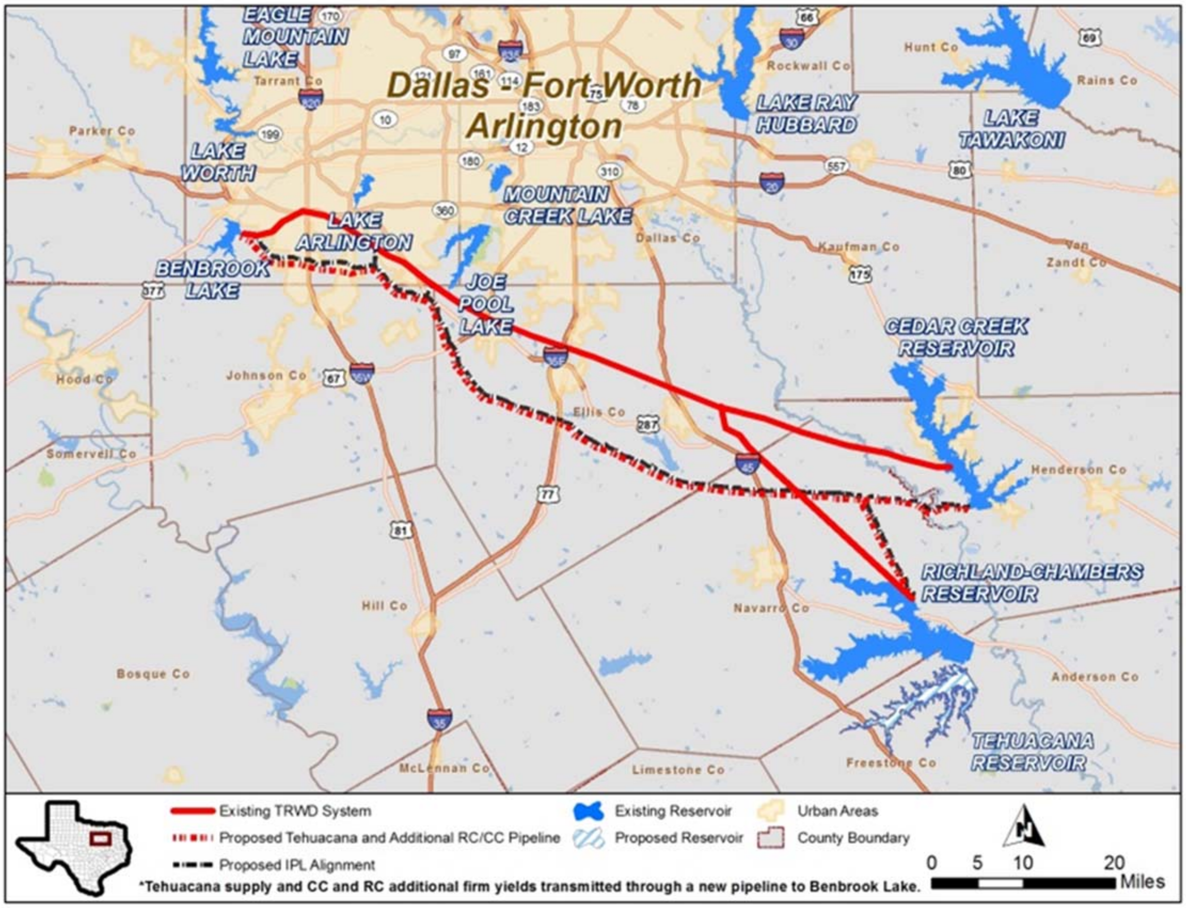
[1] Sized based on July 11, 2013 conversation with Woody Frossard of TRWD based on on-going work to quantify Lake Tehuacana yield.

initially be delivered through the IPL. In the future, the IPL will become fully utilized by current supply sources it has been designed to deliver. At that point it will not have unused capacity and a new pipeline will be needed to deliver Lake Tehuacana flows. This new pipeline will be built within the IPL right of way and will be designed to also carry other supply sources from Southeast of Dallas/Fort Worth. Two configurations were analyzed:

1. Deliver Lake Tehuacana supplies through the Integrated Pipeline (IPL) to Benbrook Lake.
2. Deliver Lake Tehuacana supply through a new pipeline constructed parallel to the IPL to carry this additional supply, and water from the *Unpermitted Firm Yield in Cedar Creek and Richland-Chambers Reservoirs* strategy (a separate strategy), and water from the *Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits* strategy (a separate supply strategy).



Pipeline Route to Lake Benbrook (Tehuacana supply transmitted through IPL)



Pipeline Route to Lake Benbrook (Tehuacana Supply and Additional Richland-Chambers & Cedar Creek Unpermitted Supplies in a new Pipeline)

Yield

The yield from Lake Tehuacana is 41,900 acre-feet/year.

Cost (in 2012 dollars if delivered through IPL)*

Capital

- Capital expenditure needed for new transmission facilities is part of the Integrated Pipeline project, and therefore not attributable to this strategy.
- Reservoir and Pump Station at Tehuacana, and channel to connect Tehuacana and Richland-Chambers Reservoir - $580,790,000

Annual

- Total annual cost during debt repayment period - $48,781,000
- Total annual cost after debt is payed - $6,587,000

- Annual unit cost of water until amortization based on 41,900 acft/yr firm yield ($/1000 gal) - $3.57
- Annual unit cost of water after amortization based on 41,900 acft/yr firm yield ($/1000 gal) - $0.48

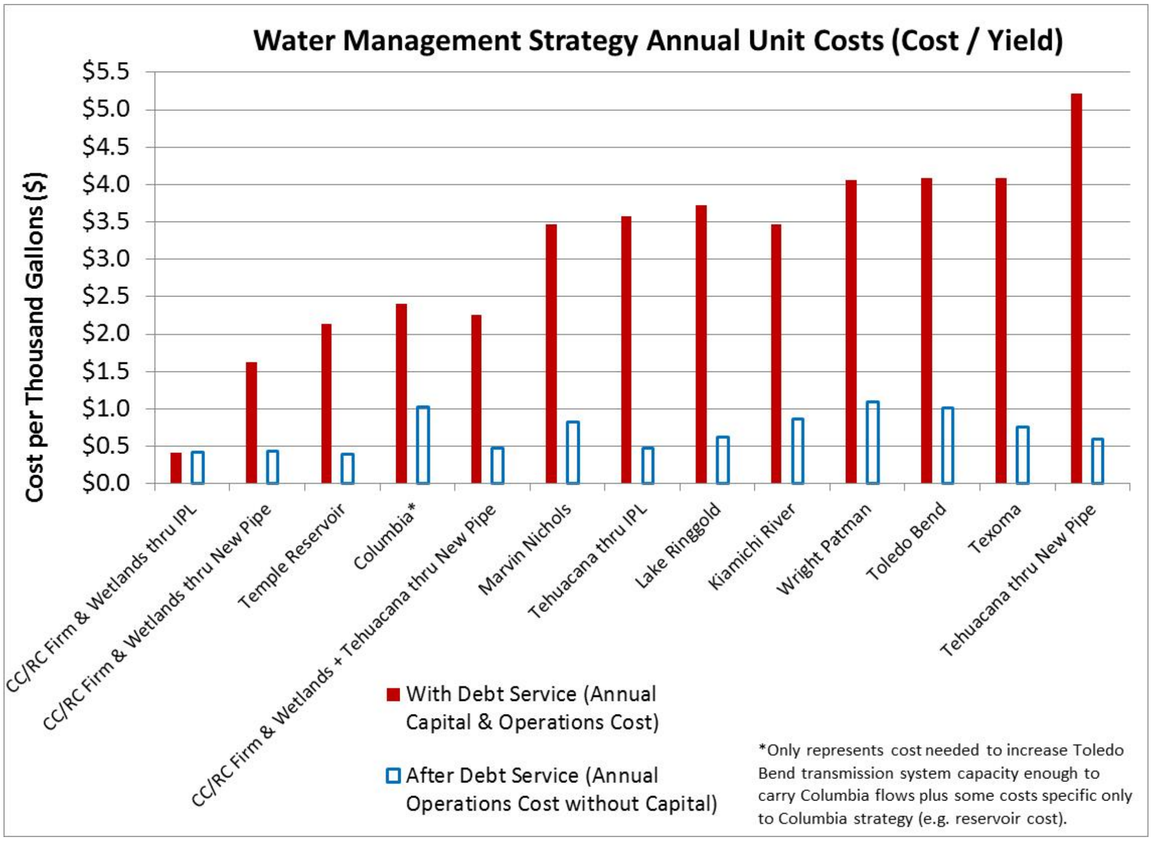
**These costs do not include debt service on a new pipeline that will eventually be needed to convey flows from Lake Tehuacana. It is most probable that the new pipeline would be built to carry Tehuacana and another supply (such as Unpermitted Cedar Creek and Richland-Chambers Firm Yield supplies and Cedar Creek and Richland-Chambers wetlands).*

Cost (in 2012 dollars if delivered through new joint pipeline)

The additional supply from Lake Tehuacana could be delivered through the Integrated Pipeline until it is fully utilized by the supply sources it is designed to carry. At that point, a new pipeline will be needed. It is not now known with full certainty what other supplies will be available when the new pipeline is needed, but it is highly probably that the new line will be sized to jointly deliver additional supply from Lake Tehuacana and both/either supply from the Unpermitted Firm Yield in Cedar Creek and Richland-Chambers Reservoirs and/or Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits. Therefore, costs for all combinations of the three strategies are provided in Table 1 below.

Table 1 –Cost Estimates

Supply Option	TRWD Share of Supply (AFY)	Capital Cost		Annual Cost		With Debt Service (DS) Unit Cost (per 1,000 gal)		Without Debt Service Unit Cost (per 1,000 gal)	
		Total	TRWD Share	TRWD	TRWD w/out DS	Total	TRWD Share	Total	TRWD Share
Unpermitted RC & CC Firm yield (FY) through new pipeline	64,032	$415,460,000	$415,460,000	$40,329,000	$10,146,000	$1.93	$1.93	$0.49	$0.49
Unpermitted RC & CC wetlands through new pipeline	73,024	$465,373,000	$465,373,000	$44,840,000	$11,031,000	$1.88	$1.88	$0.46	$0.46
Tehuacana through new pipeline	41,900	$868,331,000	$868,331,000	$71,308,000	$8,225,000	$5.22	$5.22	$0.60	$0.60
Unpermitted RC & CC FY + Tehuacana though new pipeline	105,932	$1,152,482,000	$1,152,482,000	$101,039,000	$17,312,000	$2.93	$2.93	$0.50	$0.50
Unpermitted RC & CC wetlands + Tehuacana though new pipeline	114,924	$1,217,707,000	$1,217,707,000	$106,410,000	$17,945,000	$2.84	$2.84	$0.48	$0.48
Unpermitted RC & CC wetlands + FY though new pipeline	137,056	$725,528,000	$725,528,000	$72,470,000	$19,761,000	$1.62	$1.62	$0.44	$0.44
Unpermitted RC & CC wetlands + FY + Tehuacana though new pipeline	178,956	$1,440,491,000	$1,440,491,000	$131,799,000	$27,149,000	$2.26	$2.26	$0.47	$0.47
Unpermitted RC & CC wetlands + FY though IPL	137,056	$0	$0	$28,832,000	$28,832,000	$0.65	$0.65	$0.65	$0.65
Unpermitted RC & CC FY through IPL	64,032	$0	$0	$8,841,000	$8,841,000	$0.42	$0.42	$0.42	$0.42
Unpermitted RC & CC wetlands through IPL	73,024	$0	$0	$10,700,000	$10,700,000	$0.45	$0.45	$0.45	$0.45
Tehuacana through IPL	41,900	$580,790,000	$580,790,000	$48,781,000	$6,587,000	$3.57	$3.57	$0.48	$0.48

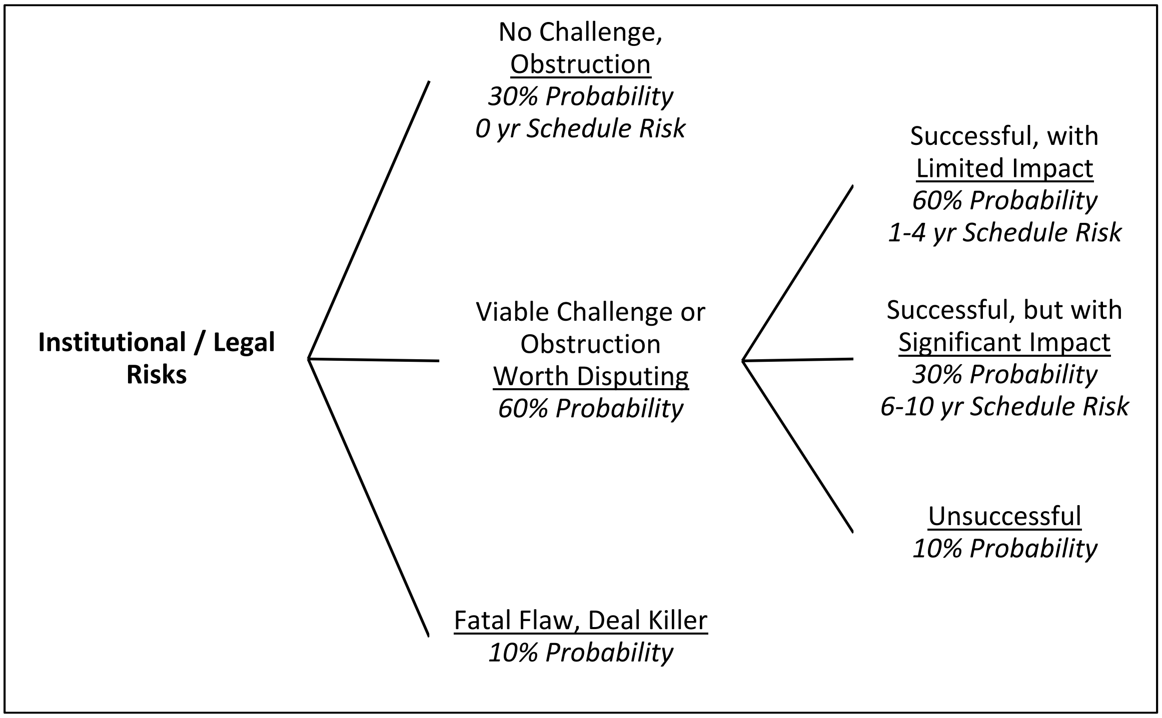


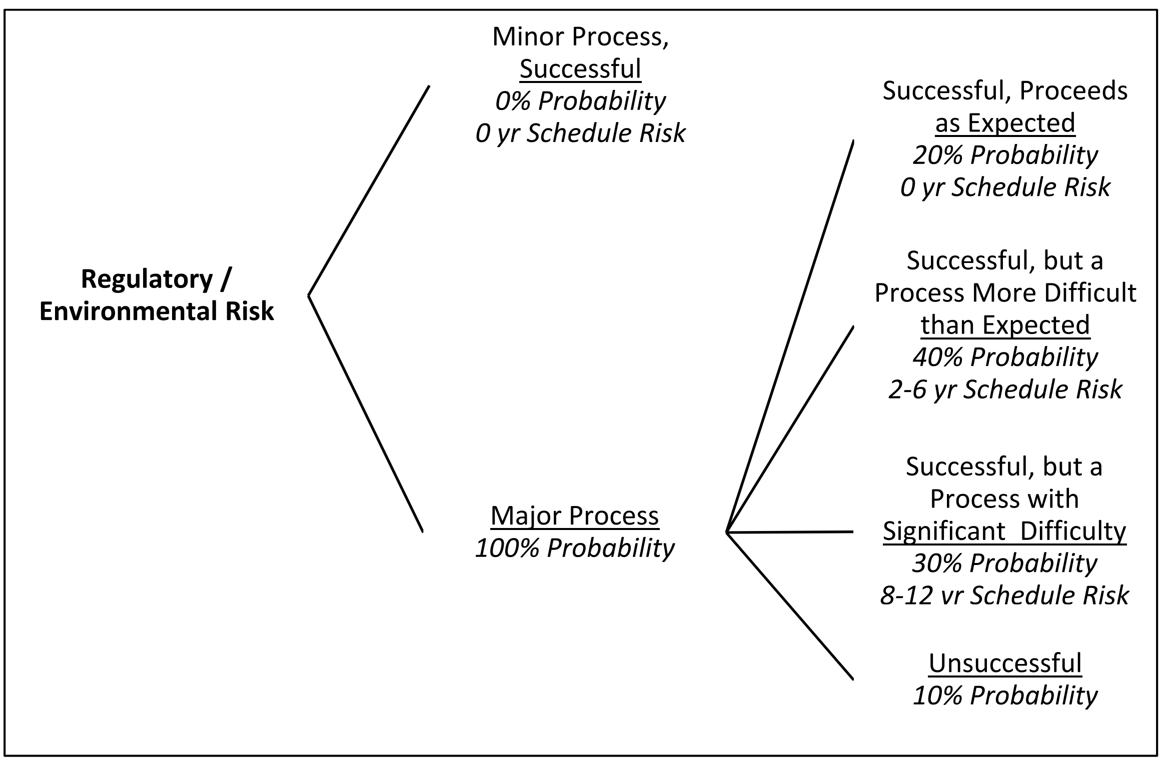
Comparison to Other Strategies

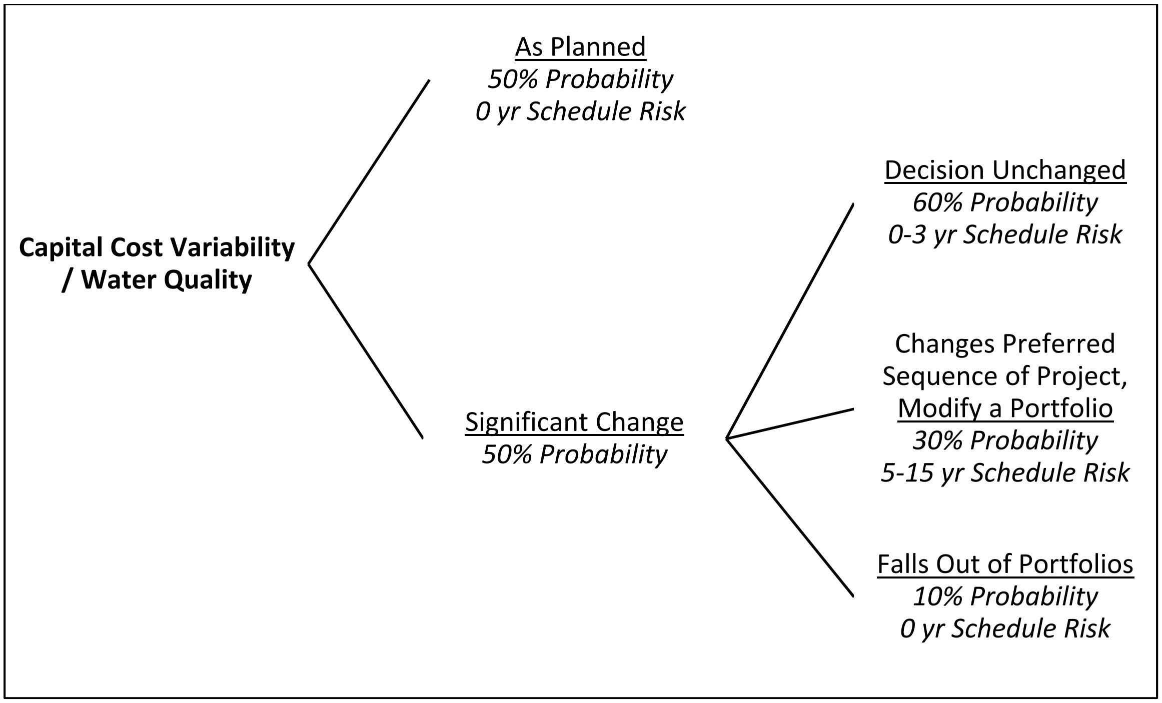
Key Assumptions

- The existing spillway for Richland- Chambers Reservoir was designed to provide enough discharge capacity to accommodate the increased flood flows from Tehuacana Reservoir for the probable maximum flood event. Therefore, the dam for Tehuacana Reservoir can be constructed without a spillway and can function as merely an extension of Richland-Chambers Reservoir (TWDB Report 370, p. 153).
- “As stated in Certificate of Adjudication No. 4248, Lake Livingston, even though it is senior in priority, will be subordinate to Tehuacana Reservoir when and if the reservoir is issued a water right permit by the Texas Commission on Environmental Quality.” (TWDB Report 370, page 155)
- It is assumed that the lignite coal deposits under Tehuacana Reservoir do not need to be purchased by TRWD and do not impact the reservoir cost.

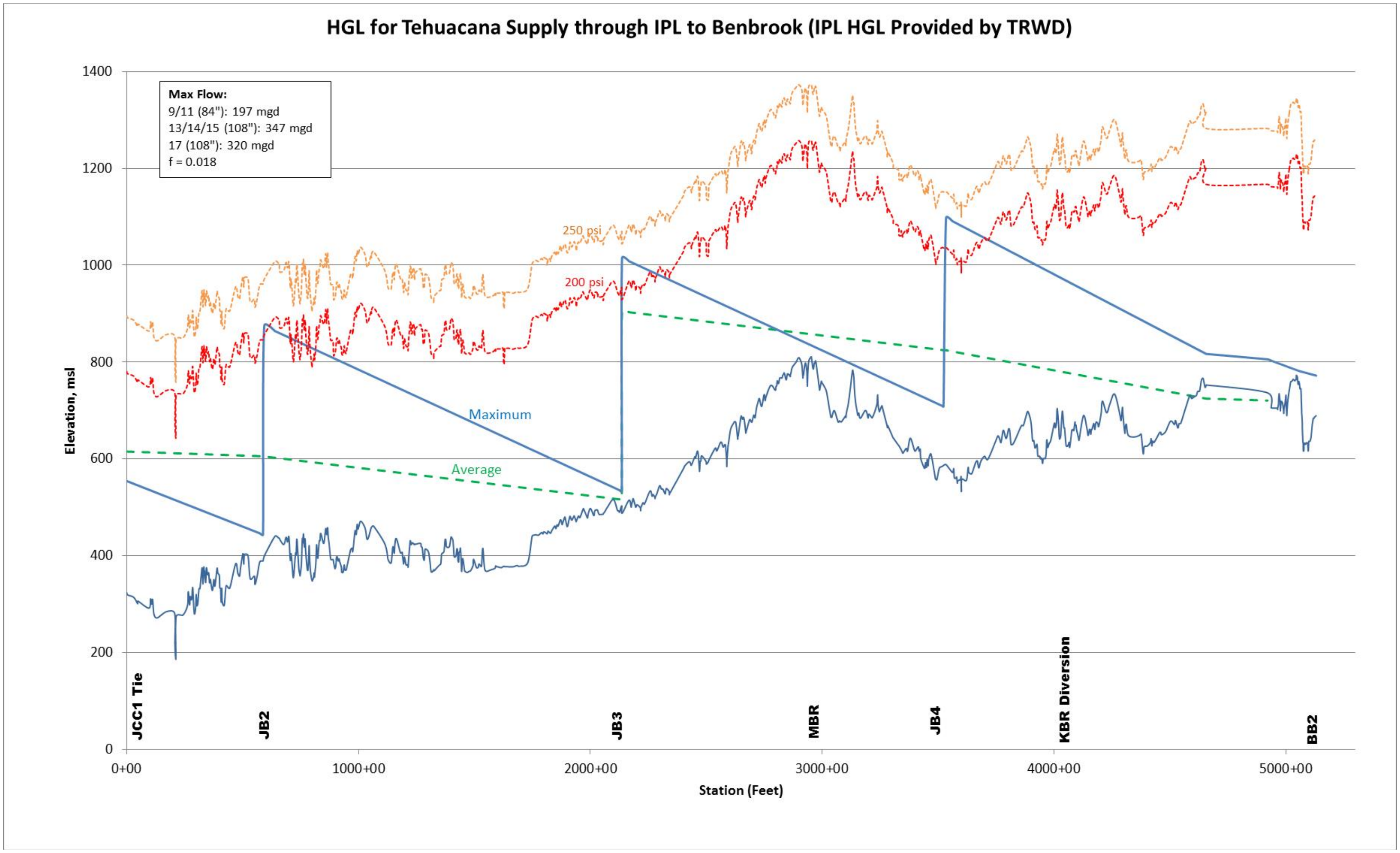
Risk Assessment



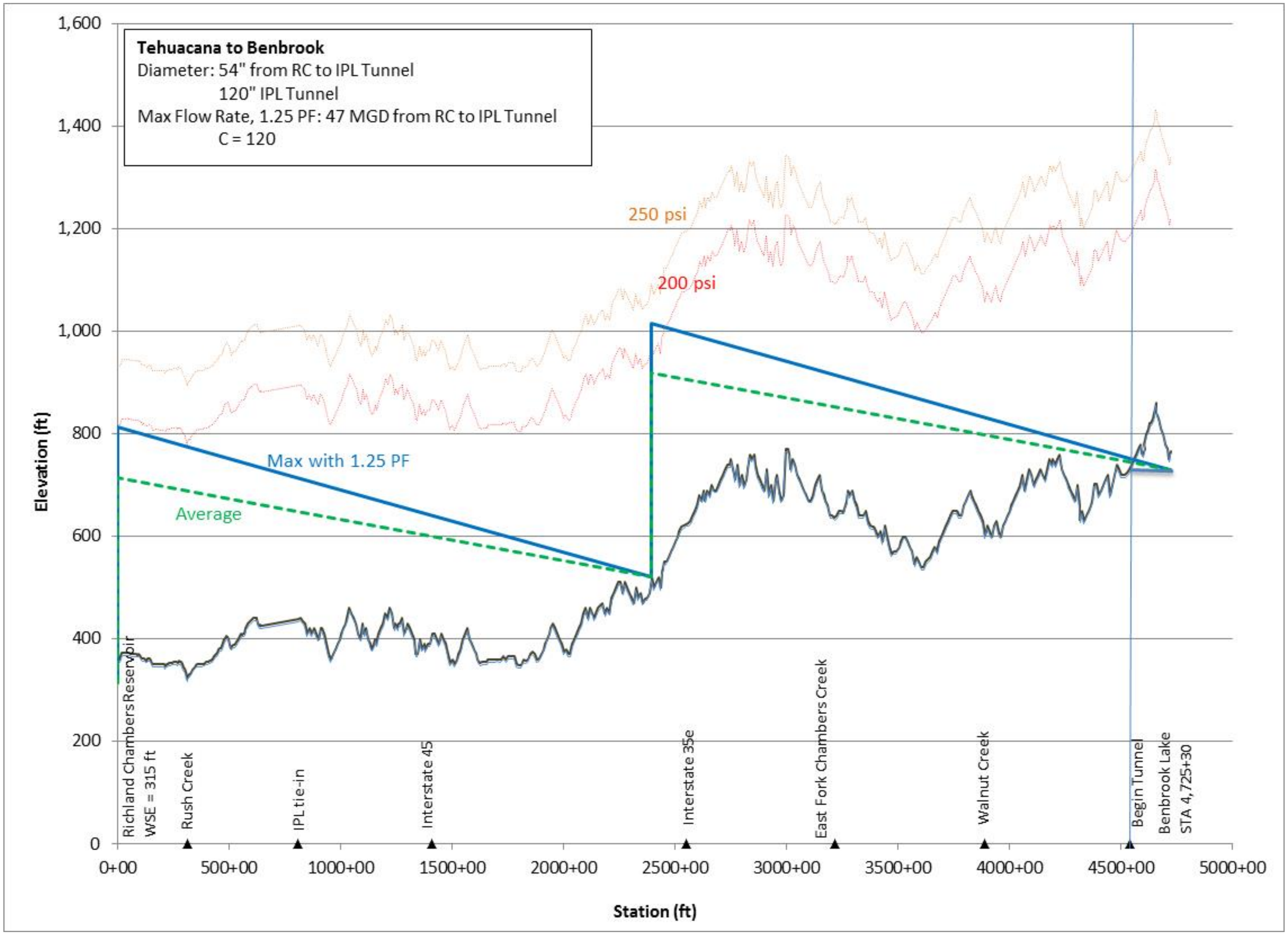




Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
Possible challenge from downstream stakeholders or water right holders	404 permit, water right, and interbasin transfer permit required Environmental flow requirements may have significant impact on yield	Cost uncertainty is fairly significant due to potential future development of lignite resources in reservoir footprint



Hydraulic Grade Line – Tehuacana through the IPL to Lake Benbrook



Hydraulic Grade Line – Lake Tehuacana Supply through New Pipeline

Note: This hydraulic grade line illustrates the option of delivering this strategy's supply through a new pipeline sized only for this supply. Table 1 above provides several other options of pipelines sized for joint delivery of multiple supplies.

References

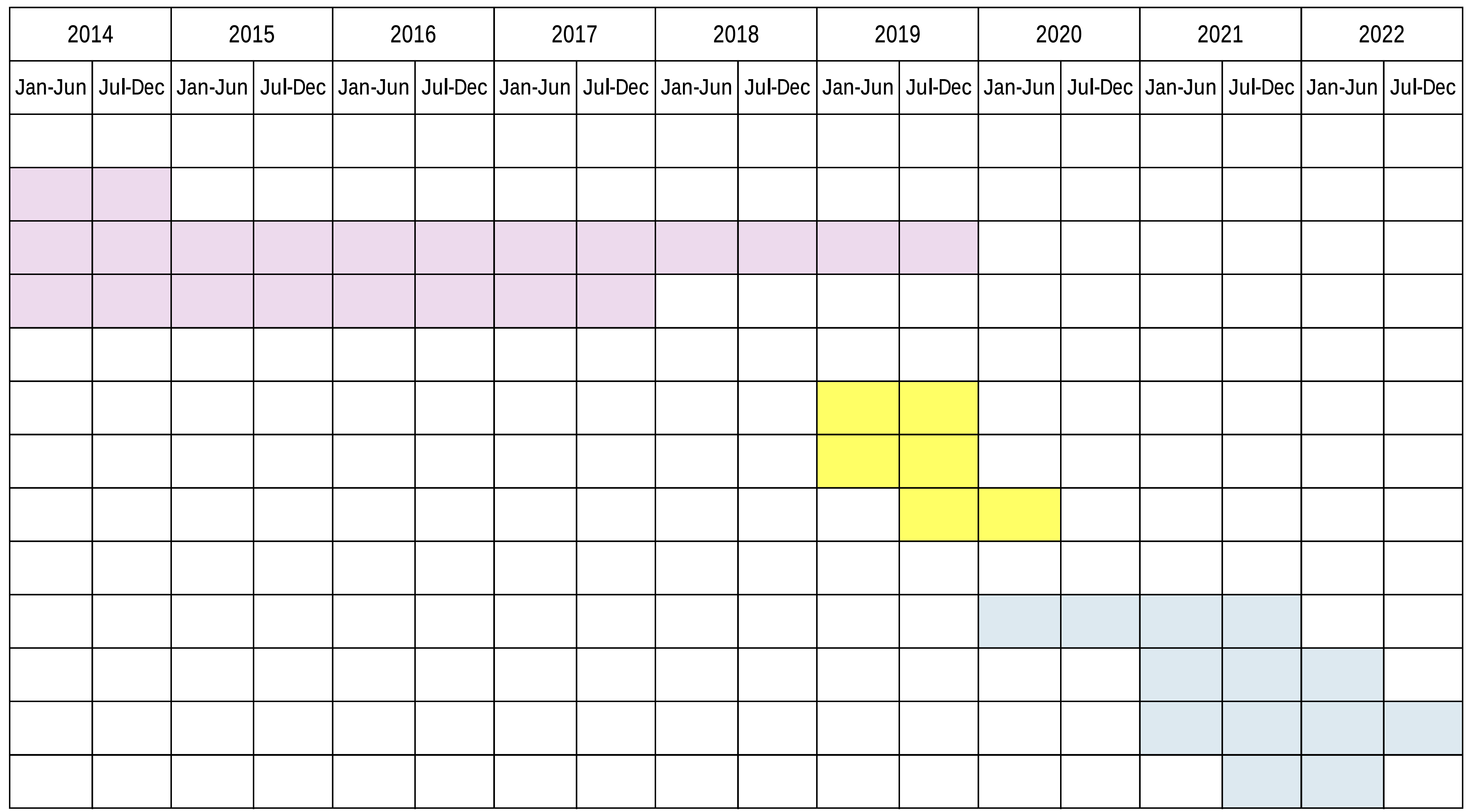
Texas Water Development Board Report 370, *Reservoir Site Protection Study*, July 2008.

Tehuacana Reservoir Implementation Schedule for TRWD IWSP:

Assumptions

- Tehuacana Reservoir would require a new water right
- The Richland-Chambers spillway is adequate to pass the increased flood flows resulting from the hydraulic connection to Tehuacana; an additional spillway is not needed
- Tehuacana Reservoir would require a Federal 404 permit with an Environmental Impact Statement (EIS)
- Water Right application and 404 permit process would run concurrently
- Detailed design (embankment) could overlap with permitting processes
- Some construction activities can start before real estate acquisition is complete
- Yield will initially be transported to the TRWD service area via the IPL (new pipeline not initially required)
- A new pipeline is not included in this schedule
- Eventually, a new pipeline will be constructed in the IPL right-of-way and no additional real estate will be required

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	1 Year
Water Rights	January 2014	6 Years
404 Permit Application/Approval	January 2014	4 Years
DESIGN TASKS		
Embankment	January 2019	1 Year
Relocations	January 2019	1 Year
Design Mitigation Features	July 2019	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition	January 2020	2 Years
Relocations	January 2021	1.5 Years
Embankment	January 2021	2 Years
Implement Mitigation	July 2021	1 Year

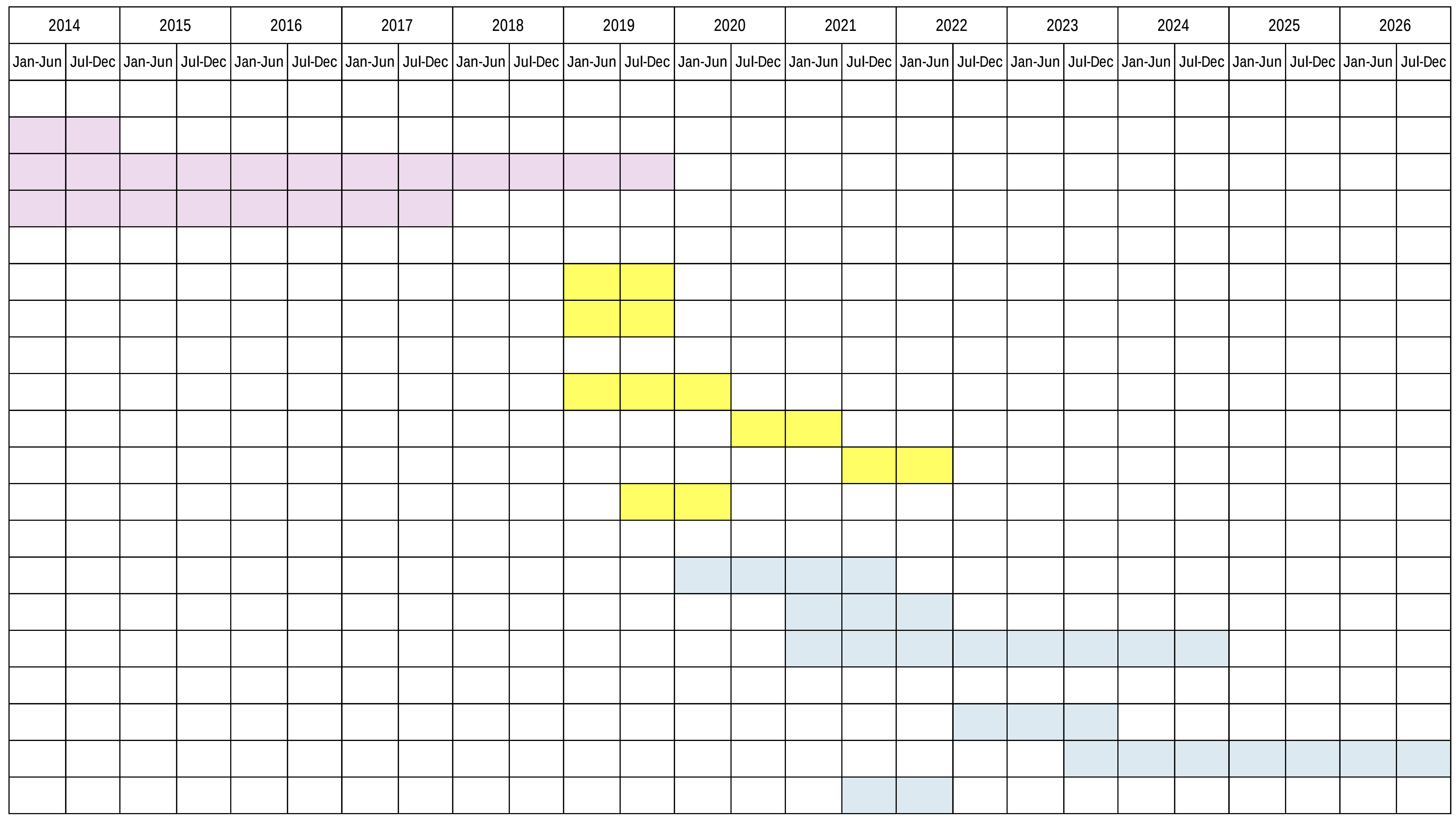


Tehuacana Reservoir with New Pipeline Implementation Schedule for TRWD IWSP:

Assumptions

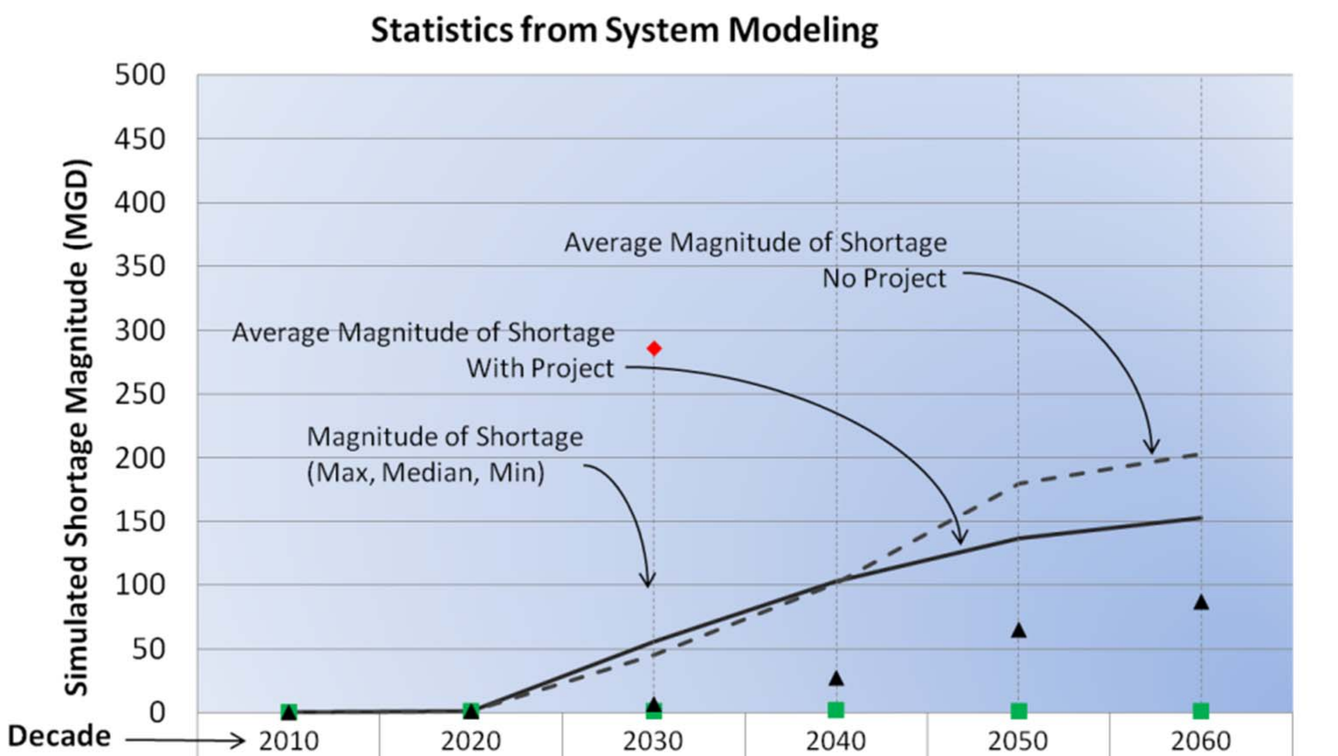
- Tehuacana Reservoir would require a new water right
- The Richland-Chambers spillway is adequate to pass the increased flood flows resulting from the hydraulic connection to Tehuacana; an additional spillway is not needed
- Tehuacana Reservoir and pipeline would require a Federal 404 permit with an Environmental Impact Statement (EIS)
- Water Right application and 404 permit process would run concurrently
- Detailed design (embankment) could overlap with permitting processes
- Some construction activities can start before real estate acquisition is complete
- Yield will initially be transported to the TRWD service area via the IPL (new pipeline not initially required)
- A portion of the eventual new pipeline capacity would be constructed in the IPL right-of-way and no additional real estate will be required
- Conceptual design and planning includes preliminary pipeline route selection for permitting purposes

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	1 Year
Water Rights	January 2014	6 Years
404 Permit Application/Approval	January 2014	4 Years
DESIGN TASKS		
Embankment	January 2019	1 Year
Relocations	January 2019	1 Year
Transmission Facilities	January 2019	3.5 Years
Route Selection	January 2019	1.5 Years
Survey and Preliminary Design	July 2020	1 Year
Final Design	July 2021	1 Year
Design Mitigation Features	July 2019	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition	January 2020	2 Years
Relocations	January 2021	1.5 Years
Embankment	January 2021	4 Years
Transmission Facilities	July 2022	5 Years
Easement Acquisition	July 2022	1.5 Years
Bid and Construction Phase	July 2023	4 Years
Implement Mitigation	July 2021	1 Year



Tehuacana

Magnitude Chart

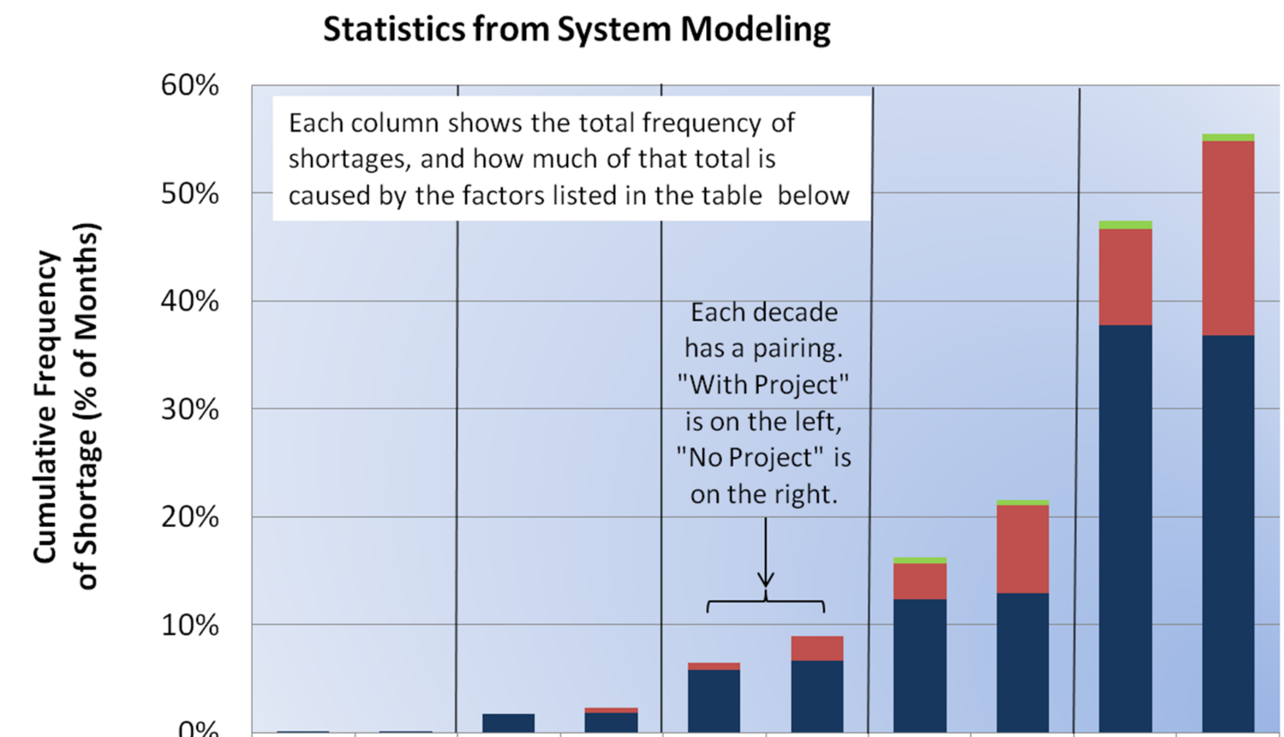


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	1	286	611	782	919
Minimum	0	1	1	2	1	1
Median	0	1	7	27	65	87
Average	0	1	55	103	137	153
Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Tehuacana

Frequency Chart

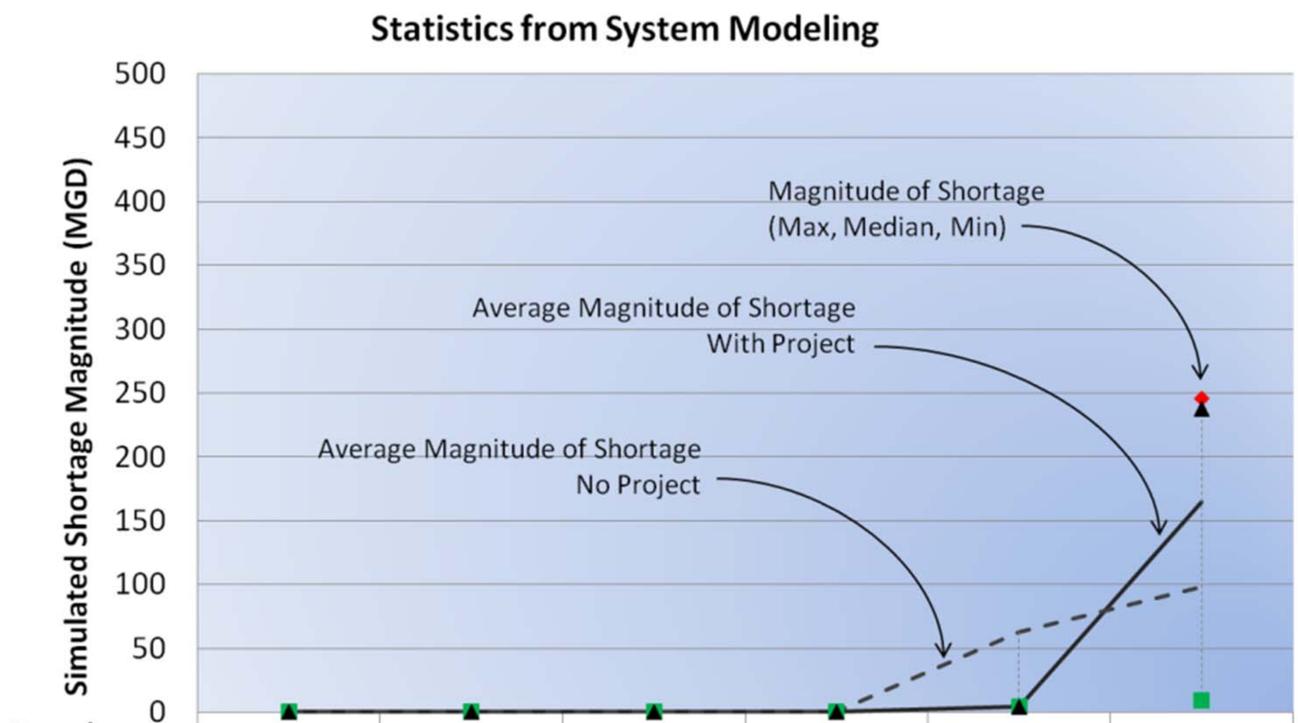


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.5%		0.7%	
Permitted Amount	0.0%		0.0%		0.7%		3.4%		9.0%	
Pipeline Capacity	0.1%		1.7%		5.8%		12.3%		37.7%	

Results Using 2011 Region C Based Demand Projection

Tehuacana

Magnitude Chart

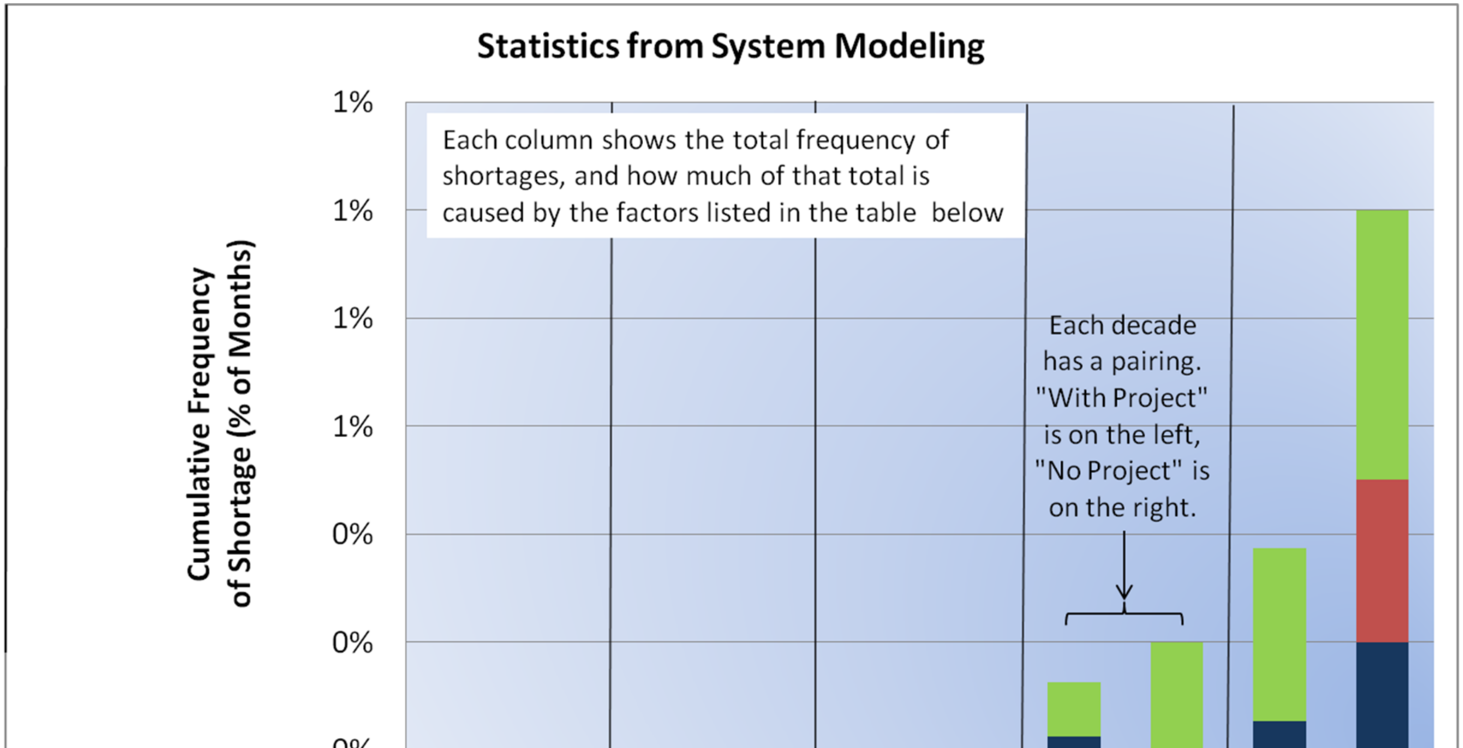


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	0	4	246
Minimum	0	0	0	0	4	9
Median	0	0	0	0	4	238
Average	0	0	0	0	4	164
Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

Tehuacana

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.1%		0.3%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.0%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.0%		0.1%	

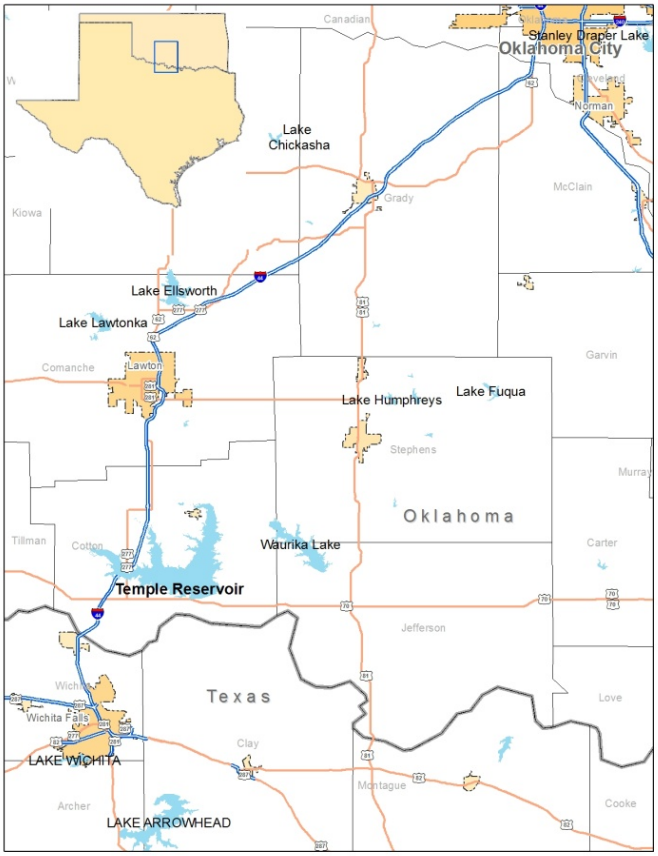
Results Using Recent Trend Extrapolation Demand Projection

Temple Reservoir, Southwestern Oklahoma

Description

In 2006 TRWD applied to the Oklahoma Water Resources Board (OWRB) for water right permits on stream systems in Southwestern Oklahoma: 125,000 acre-feet/year on Cache Creek and 25,000 acre-feet/year on Beaver Creek. The permit applications were subject to the result of litigation in the federal courts, which has concluded with a decision that supports Oklahoma's refusal to grant the permits. Therefore, water supply from Southwestern Oklahoma is subject to on-going efforts to negotiate a contract for the sale of water to TRWD. Several supply configurations from these sources have been evaluated (run-of-river diversion, on-channel reservoir, off-channel storage facility) and the most reliable is construction of a reservoir on the main stem of Cache Creek close to its confluence with the Red River. In 1966, the OWRB identified a potential reservoir sited in this location – the "Temple Reservoir".

A new reservoir at this site could be constructed to store 383,000 acre-feet of water at an average depth of 20 feet and could supply a firm yield of 125,000 ac-ft/yr. Transmission facilities would be designed to take water from Temple Reservoir to Lake Ringgold and/or to TRWD's Lake Bridgeport on the West Fork Trinity River. Though water supply from Beaver Creek (25,000 acre-feet/year from the stream system that includes Lake Waurika) is not included in this strategy, the transmission system is configured so that Beaver Creek supply could be added later.



Vicinity Map

Facilities Required

- 84' high, 17,300' long earthen dam. 383,000 acre-foot conservation pool.
- 68 mile, 84" transmission pipeline. The assumed configuration does not combine Temple Reservoir with Lake Ringgold. If they are combined, approximately 43 miles of pipeline would be upsized to also carry Ringgold water.
- 8,400 HP intake pump station at Temple Reservoir

- 9,700 HP booster pump station along the pipeline route
- One 28 MG earthen storage reservoir
- 139 mgd discharge structure at Lake Bridgeport
- One 35,000 HP intake pump station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.

Pipeline Route to Lake Bridgeport

Yield

The water right permit applications sought 125,000 acre-feet/year from Cache Creek and 25,000 acre-feet/year from Beaver Creek; it is assumed that these quantities could be obtained through a negotiated sale. The Temple Reservoir strategy only includes the Cache Creek yield but is configured so that Beaver Creek supply could be added in the future.

This configuration of Temple Reservoir is sized for a *firm yield* of 125,000 acre-feet/year. It is possible that a contract for more than the firm yield could be secured through negotiations with Oklahoma. Preliminary water availability estimates indicate that Temple Reservoir could supply an *average* of roughly 320,000 acre-feet/year if the transmission infrastructure were upsized accordingly, but as configured, modeled, and priced here, the infrastructure is sized only for the firm yield of 125,000 acre-feet/year (with a peaking factor of 1.25).

In this configuration, Temple Reservoir supply is not combined with Lake Ringgold supply. The Temple Reservoir supply is delivered directly to Lake Bridgeport.

Cost (in 2012 dollars)

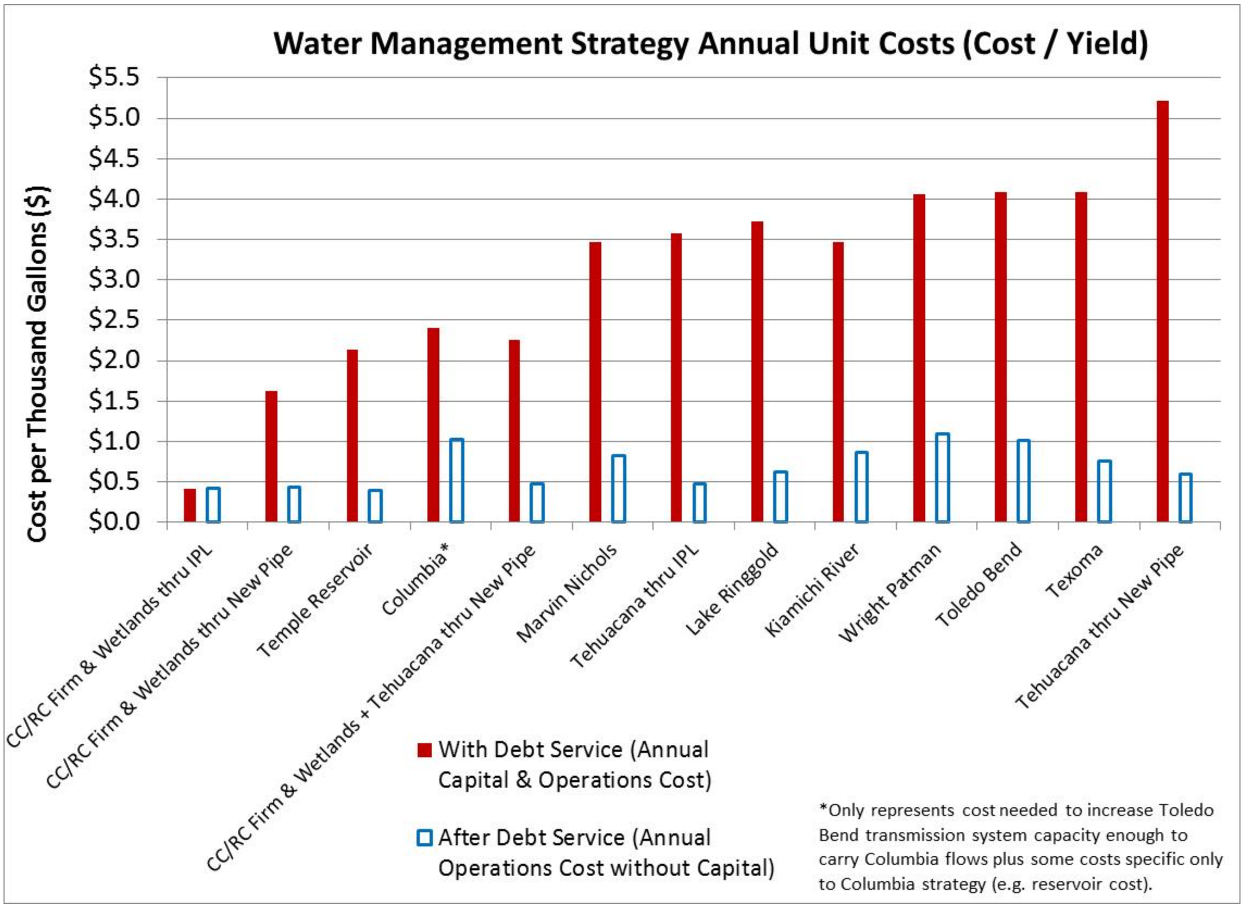
Capital

$972,530,000

Annual

Annual costs presented here do not include raw water costs, which have not yet been determined.

- Total annual cost during debt repayment period - $86,931,000
- Total annual cost after debt is payed – $16,278,000
- Annual unit cost of water until amortization based on 125,000 acft/yr firm yield ($/1000 gal) - $2.13
- Annual unit cost of water after amortization based on 125,000 acft/yr firm yield ($/1000 gal) - $0.40

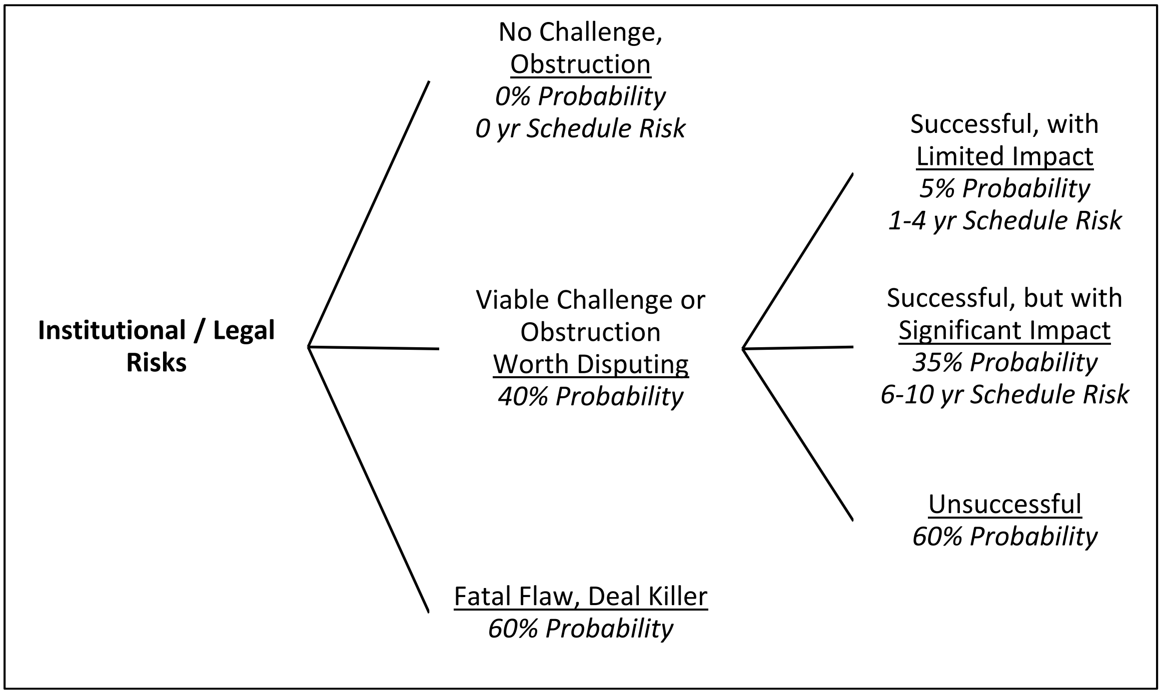


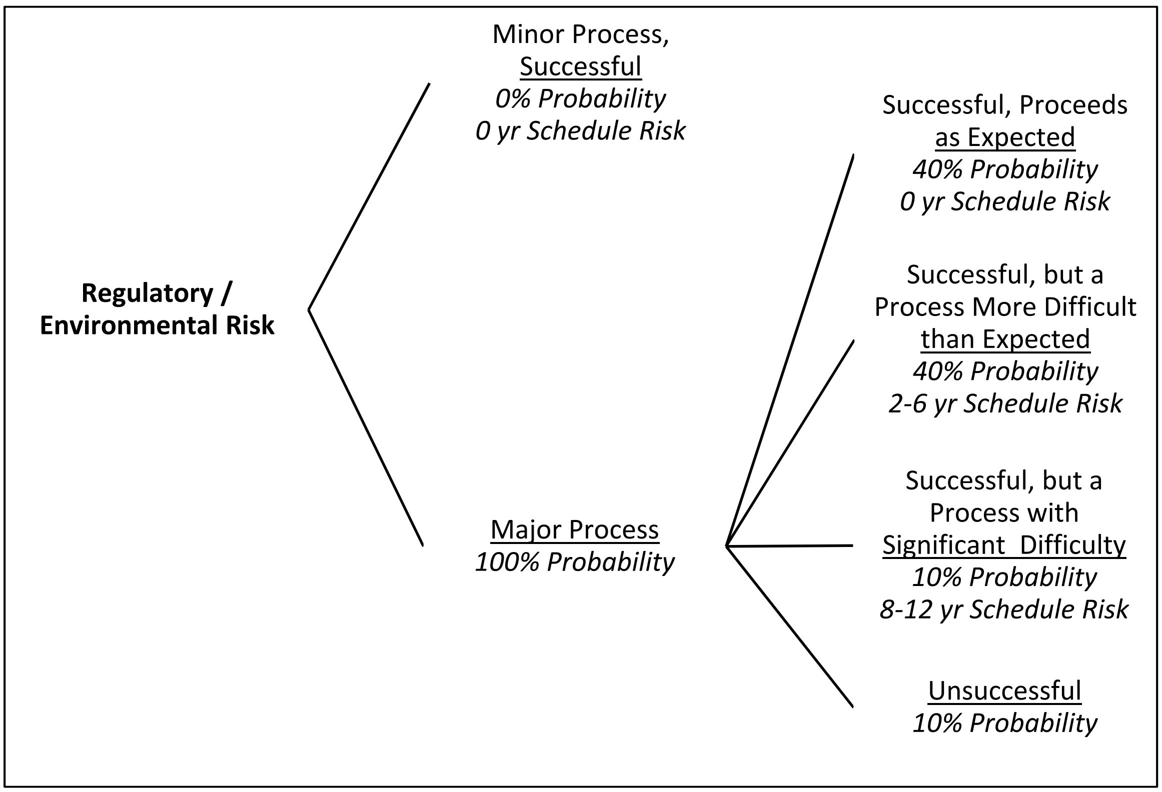
Comparison to Other Strategies

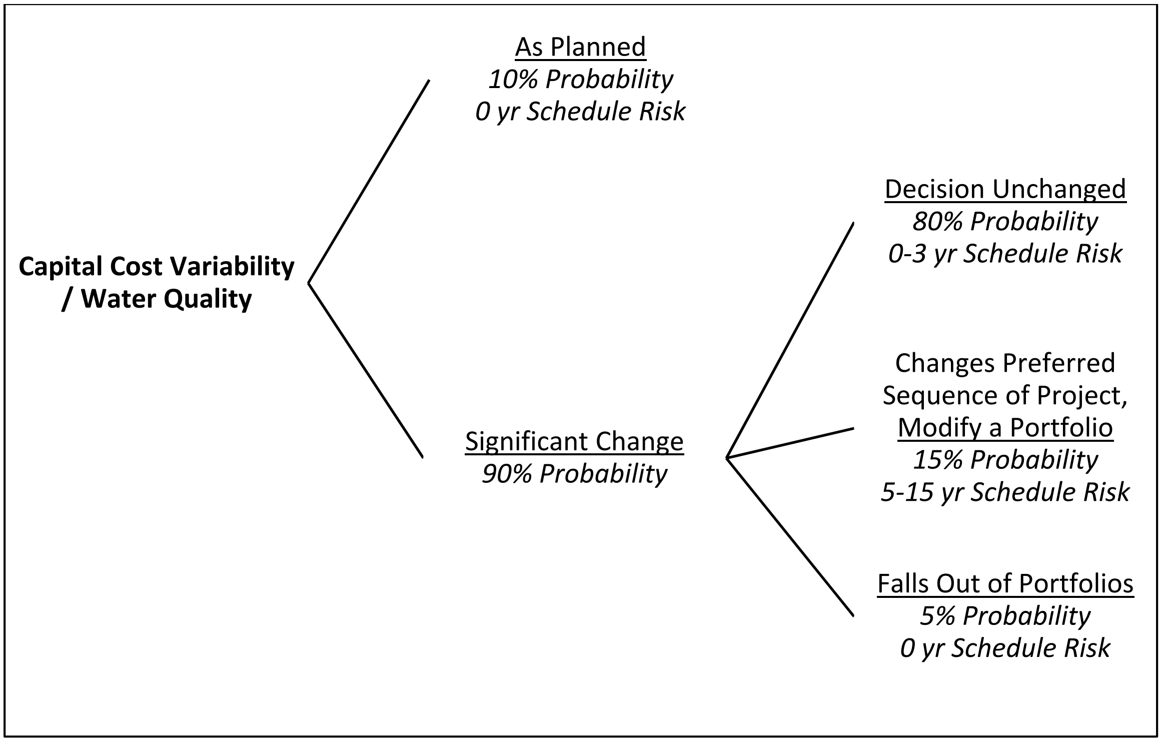
Key Assumptions

- Contract with Oklahoma entity.
- Delivery to Lake Bridgeport and no downstream restrictions to delivery.
- Pipeline route is compatible with a future joint delivery from Beaver Creek in Oklahoma.

Risk Factors



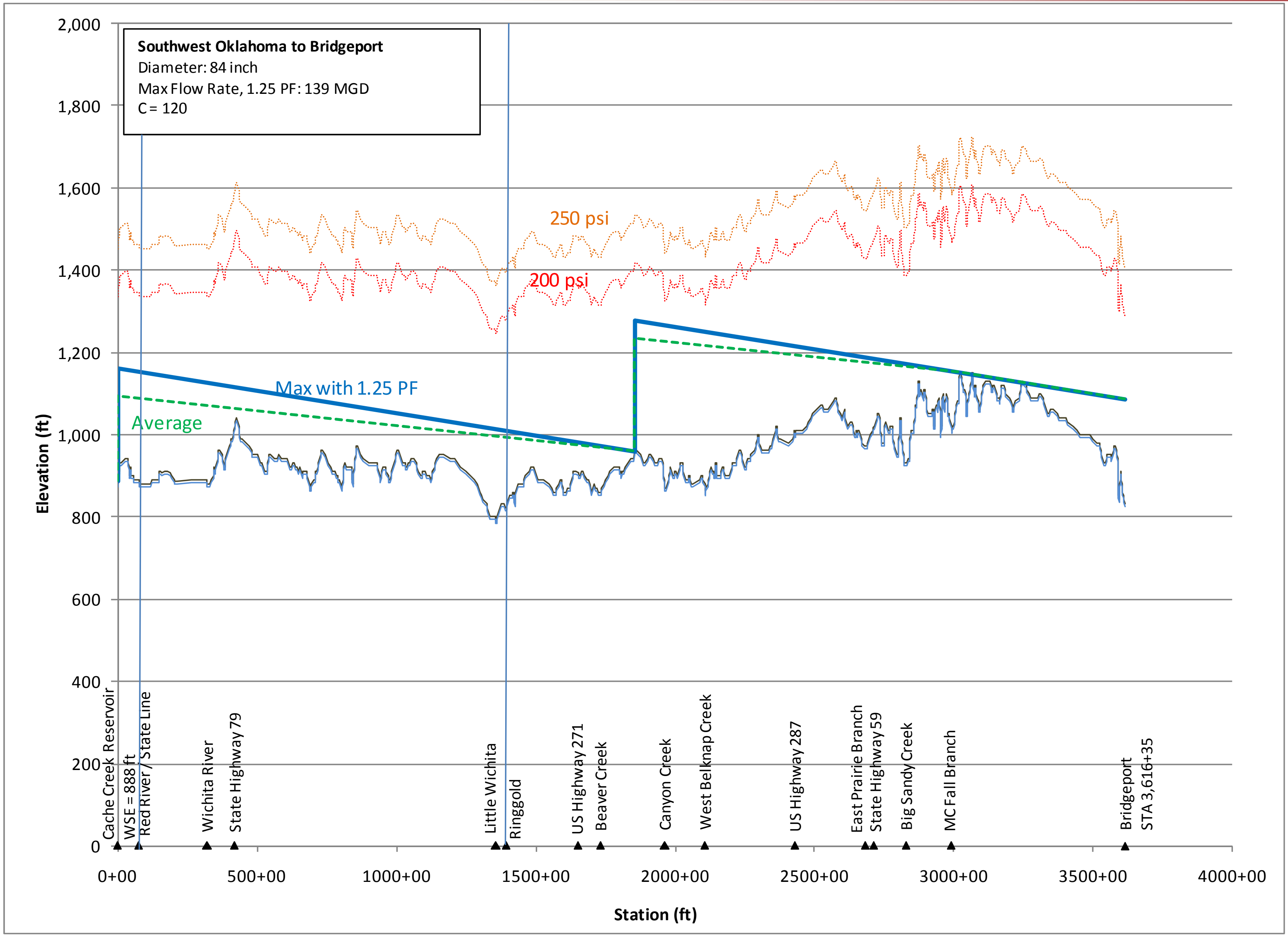




Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
Significant political issues. Negotiated contract will require political support or Tribal quantification of water rights and subsequent sale to TRWD. If negotiated contract is reached, political issues are still significant from opposing parties.	404 permit required. Interstate water transfer. Bed and banks permit required. Expect significant challenges from Oklahoma interests and regulators.	Resolution of lawsuit with Oklahoma may require payment for raw water in addition to reservoir construction costs. Project definition low. Both estimated capital costs and raw water costs highly uncertain.

References

(None)



Hydraulic Grade Line – Temple Reservoir to Lake Bridgeport

Temple Reservoir Implementation Schedule for TRWD IWSP:

Assumptions

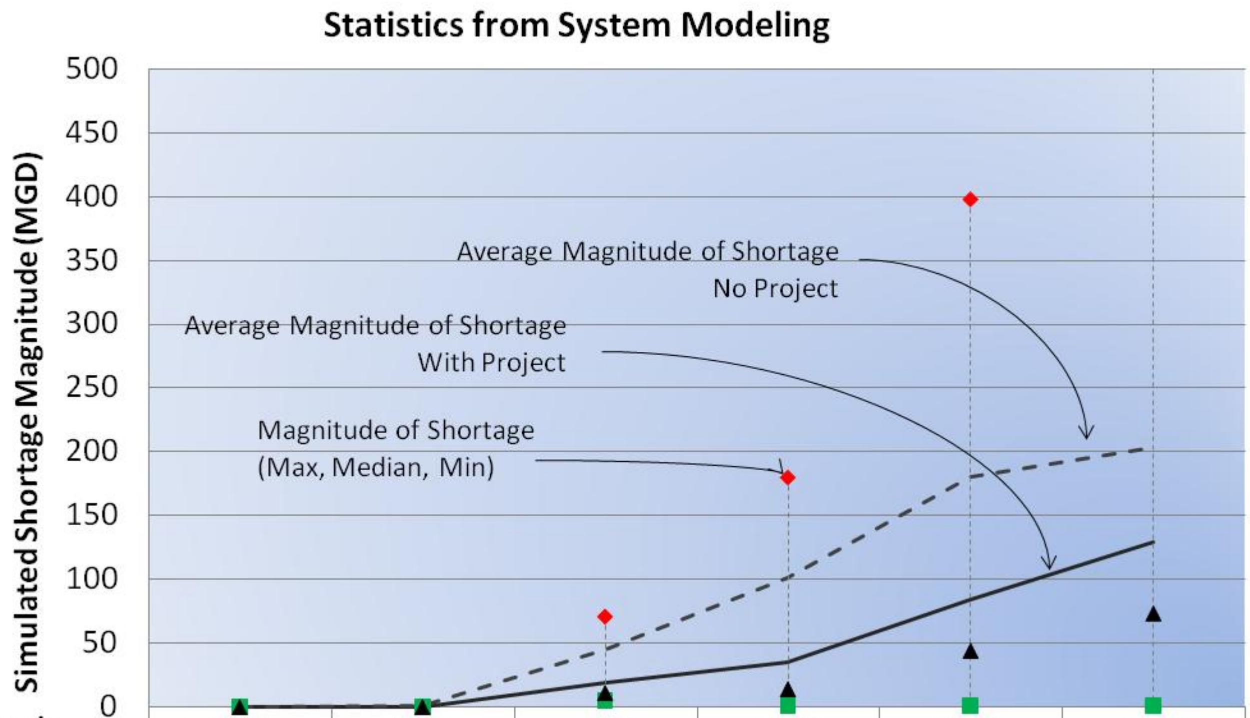
- Temple Reservoir would require a long term contract with an Oklahoma entity
- Temple Reservoir would require a Federal 404 permit and would trigger an EIS
- Mingling of Oklahoma water into Texas reservoirs (Ringgold or Bridgeport), as an interim step in the delivery process, would be allowed (invasive species considerations)
- A “bed and banks” permit from TCEQ would be required to store additional water in existing Texas reservoirs
- An accounting plan would be prepared and approved in conjunction with the bed and banks permit
- The conservation pools (normal operating elevation) of none of the storage reservoirs (Ringgold or Bridgeport) would be increased as a result of the additional water to be stored therein
- 404 process and the bed and banks permit would not start until contract negotiations are well advanced to almost complete
- Limited design (embankment/spillway) could overlap with permitting processes
- Some construction activities could start before real estate acquisition is complete
- Conceptual design and planning includes preliminary pipeline route selection for permitting purposes
- Embankment/spillway construction includes two years for reservoir filling

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	2 Years
Negotiate Contract for Oklahoma Water	January 2014	6 Years
Bed and banks Permit	January 2016	2 Years
404 Permit Application / Approval	January 2016	4 Years
DESIGN TASKS		
Embankment / Spillway	January 2019	3 Years
Relocations	January 2019	3 Years
Transmission Facilities	January 2019	3 Years
Route Selection	January 2019	1 Year
Survey and Preliminary Design	January 2020	1 Year
Final Design	January 2021	1 Year
Design Mitigation Features	January 2021	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition	January 2020	3 Years
Relocations	January 2021	3 Years
Embankment / Spillway	January 2021	5 Years
Implement Mitigation	January 2022	1 Year
Transmission Facilities	January 2021	5 Years
Easement Acquisition	January 2021	1 Year
Bid and Construction Phase	January 2022	4 Years

2014		2015		2016		2017		2018		2019		2020		2021		2022		2023		2024		2025		2026		2027		2028	
Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec

Temple

Magnitude Chart

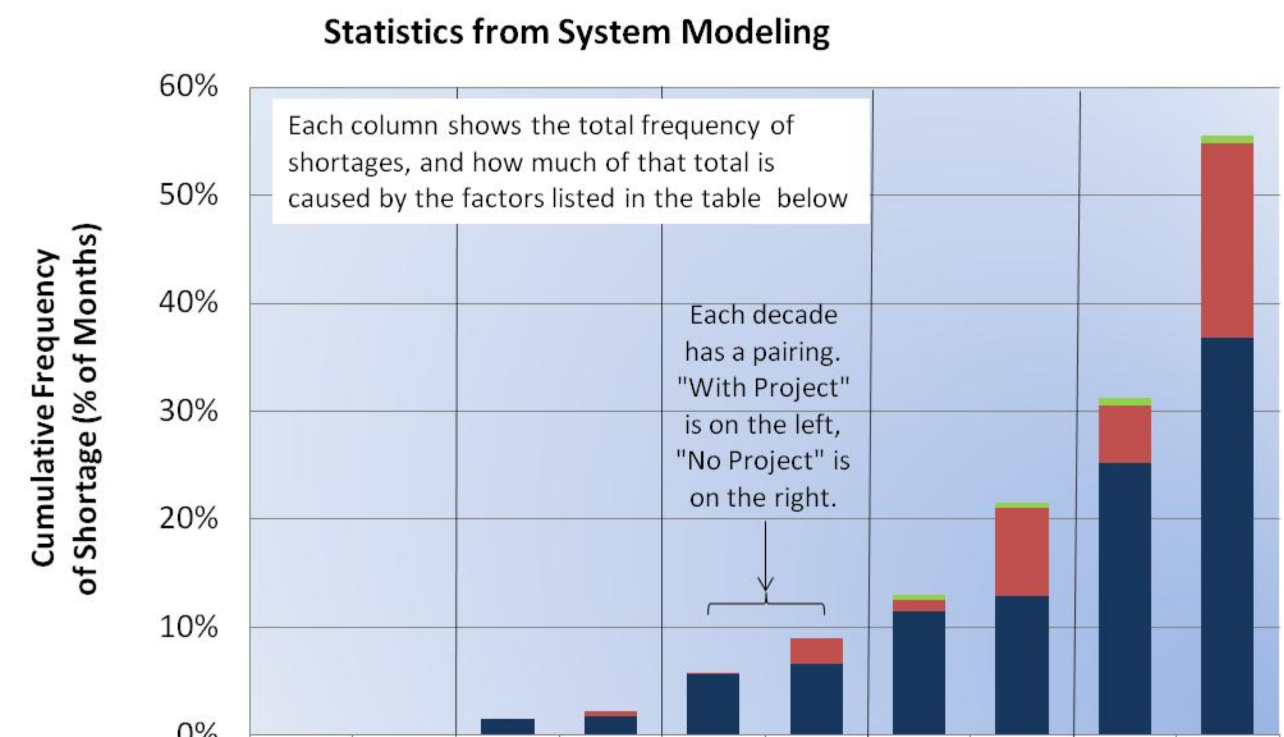


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	71	180	398	711
Minimum	0	0	5	1	1	1
Median	0	0	11	14	44	73
Average	0	0	19	35	85	130
Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Temple

Frequency Chart

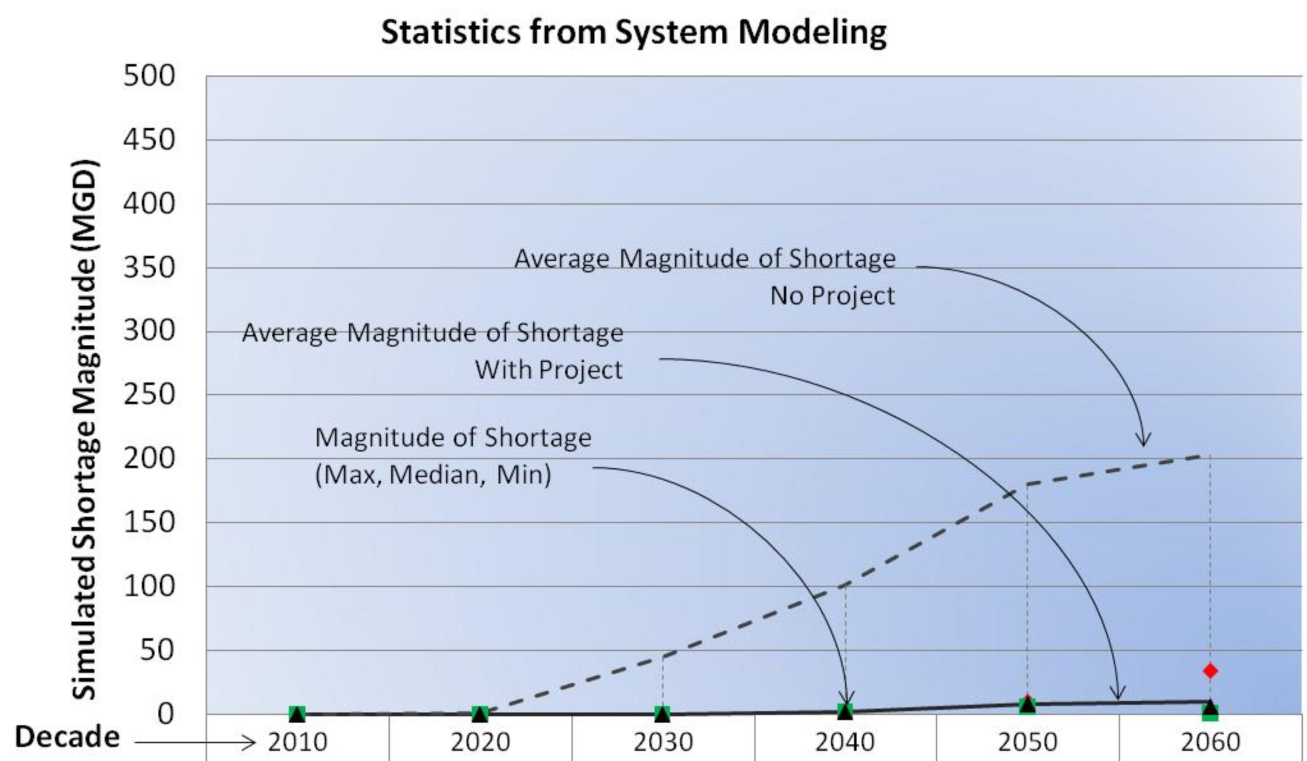


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.5%		0.7%	
Permitted Amount	0.0%		0.0%		0.1%		1.1%		5.2%	
Pipeline Capacity	0.0%		1.5%		5.7%		11.5%		25.2%	

Results Using 2011 Region C Based Demand Projection

Temple

Magnitude Chart

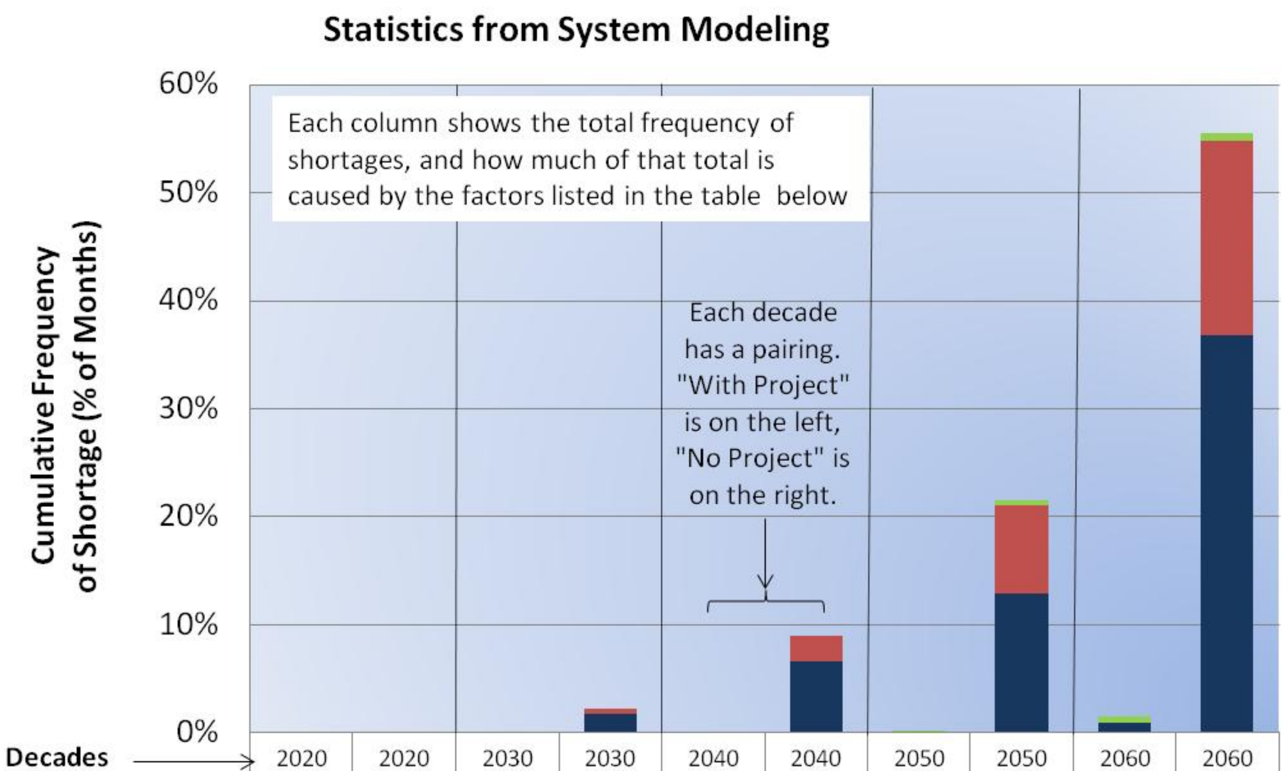


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	0	2	10	34
Minimum	0	0	0	2	6	1
Median	0	0	0	2	8	6
Average	0	0	0	2	8	10
Average - No Project	0	1	45	101	180	203

Results Using Recent Trend Extrapolation Demand Projection

Temple

Frequency Chart



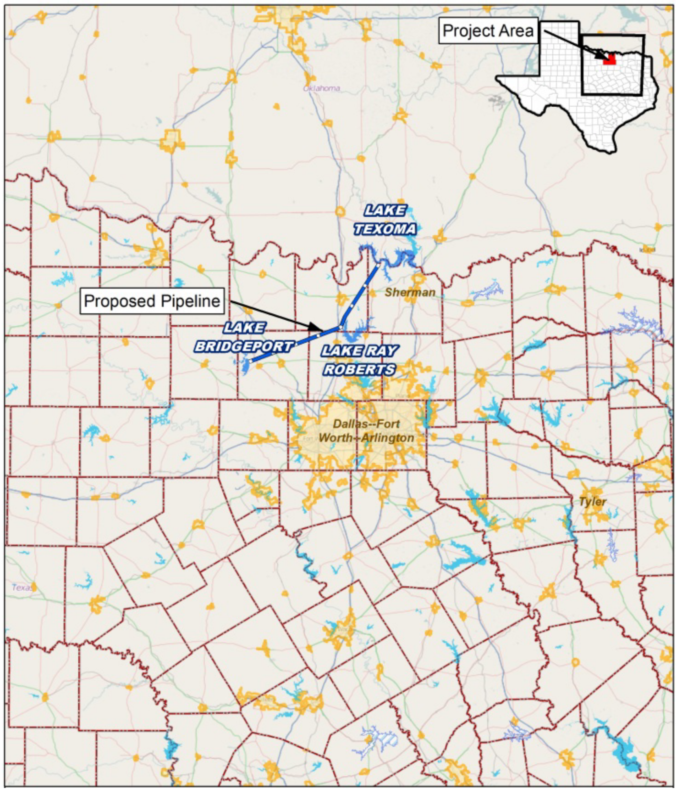
Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.2%		0.5%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.0%	
Pipeline Capacity	0.0%		0.0%		0.1%		0.1%		1.0%	

Results Using Recent Trend Extrapolation Demand Projection

Lake Texoma

Description

Lake Texoma is an existing Corps of Engineers reservoir on the Red River on the border between Texas and Oklahoma, located approximately 50 miles from the Dallas-Fort Worth Metroplex. Under the terms of the Red River Compact, the yield of Lake Texoma is divided equally between Texas and Oklahoma. As stated in the TWDB 2011 Region C Water Plan, the current storage amount available to Texas is 300,000 acre feet. This includes the original 150,000 acre feet that was allocated for municipal supply when Lake Texoma was constructed and the additional 150,000 acre feet that was authorized by Congress in 1986 to be reallocated from hydropower storage. Of the reallocated water, 50,000 acre feet was reserved for the Greater Texoma Utility Authority, and the remaining water was contracted to the North Texas Muncipal Water District. The total permitted yield is 316,550 acre-feet/year. The firm yield of the total storage amount allocated to Texas has already been permitted to the following entities by the TCEQ:

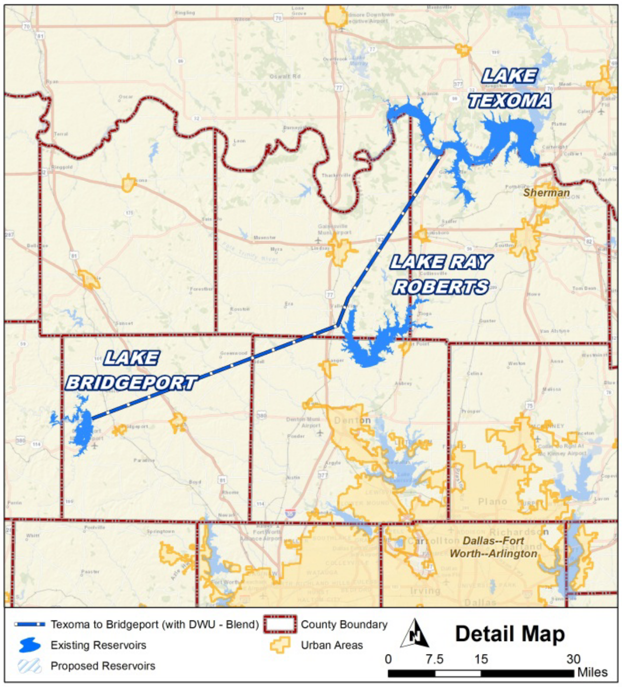


Vicinity Map

- North Texas Municipal Water District (NTMWD): 197,000 acre-feet/year (including their original 84,000 and the additional 113,000 from hydropower reallocation)
- Greater Texoma Utility Authority (GTUA): 83,200 acre-feet/year (including their original 25,000; the additional 56,500 from hydropower reallocation; and 1,700 that was recently added to their permit).
- City of Denison: 24,400 acre-feet/year
- TXU: 16,400 acre-feet/year
- Red River Authority (RRA): 2,250 acre-feet/year

According to the Corps of Engineers and stated in the TWDB 2011 Region C Water Plan, an additional supply of 220,000 acre-feet per year may be available to Texas entities if the U.S. Congress authorizes the reallocation of additional hydropower storage in Lake Texoma to municipal water supply. This is in addition to hydropower storage that has already been reallocated. However, this possible supply is not considered a viable strategy at this time due to the probability that an additional reallocation will not be approved. Texas' entire share of the municipal water supply in Texoma has been permitted and there is therefore no additional water available for TRWD from Texas.

To obtain water supply from Lake Texoma, TRWD would require a contract or permit from Oklahoma. According to the 2011 Oklahoma Comprehensive Water Plan, there is 162,271 acre-feet/year available from Oklahoma's share of Lake Texoma. This does not include the additional 150,000 acre-feet of storage representing Oklahoma's share of the water reallocated from hydropower storage.



Pipeline Route Map

Although Lake Texoma water cannot currently be transmitted directly to other reservoirs across state lines due to the presence of zebra mussels in Lake Texoma, this strategy assumes that conditions change, allowing the transfer of water between reservoirs. The lake has elevated levels of dissolved solids, and the water must be blended with higher quality water or desalinated for municipal use. While desalination is an alternative for Lake Texoma water, this configuration of the Lake Texoma supply strategy focuses on blending Lake Texoma water with other water supplies, allowing conventional treatment. The Lake Texoma water will be delivered to Lake Bridgeport and blended in TRWD's West Fork system.

Facilities Required

Yield from Lake Texoma will be blended with Lake Bridgeport water at a 10:1 ratio, making the annual supply from Texoma highly variable because it depends on the amount of water supply in Bridgeport. A significant modeling effort would be required to determine the optimal monthly delivery rate from Lake Texoma because it depends on the ability to forecast future reservoir levels so that peak flows can be reduced and spread over a period of several months; that modeling will not be done unless Texoma is selected as a preferred strategy and that detail becomes needed to help implement the project. In this study's Lake Texoma strategy configuration, the transmission system is sized such that the unit cost of delivering Lake Texoma water is equivalent to TRWD's most expensive surface water supply strategy: Toledo Bend Reservoir. This assumption helps put an upper limit on Lake Texoma – it tells us the largest transmission system, the one most likely to deliver TRWD's possible supply at a 10:1 ratio, that could be built for Lake Texoma without being more expensive than Toledo

Bend. Facilities for this configuration were therefore sized for a maximum delivery rate of 67 million gallons per day (MGD).

- Pipeline from Lake Texoma to Lake Bridgeport. The pipeline is aligned in anticipation of future delivery to Lake Ray Roberts, assuming TRWD will partner with the City of Dallas to bring part of Texoma supply to Dallas. However, in this configuration the transmission system is sized only for TRWD supply.
- Intake and 6,000 HP Lake Pump Station at Lake Texoma, one 7,800 HP mgd Booster Pump Station, and a 9 MG storage tank.

Supply

According to the 2011 Oklahoma Comprehensive Water Plan, there is 162,271 acre-feet/year available from Oklahoma's share of Lake Texoma. If that water were secured by TRWD and blended in Lake Bridgeport, a 10:1 (Bridgeport to Texoma) blending ratio is required to meet a total dissolved solids (TDS) standard of 625 mg/L, which is a revision from the current standard of 300 mg/L in Lake Bridgeport. Using 2060 demand assumptions, this ratio would result in an average annual yield of 21,050 acre-feet/yr and a maximum annual yield of 72,000 acre-feet/yr from Lake Texoma. (This also leaves a substantial amount of Texoma's 162,271 acre-feet/year to share with Dallas).

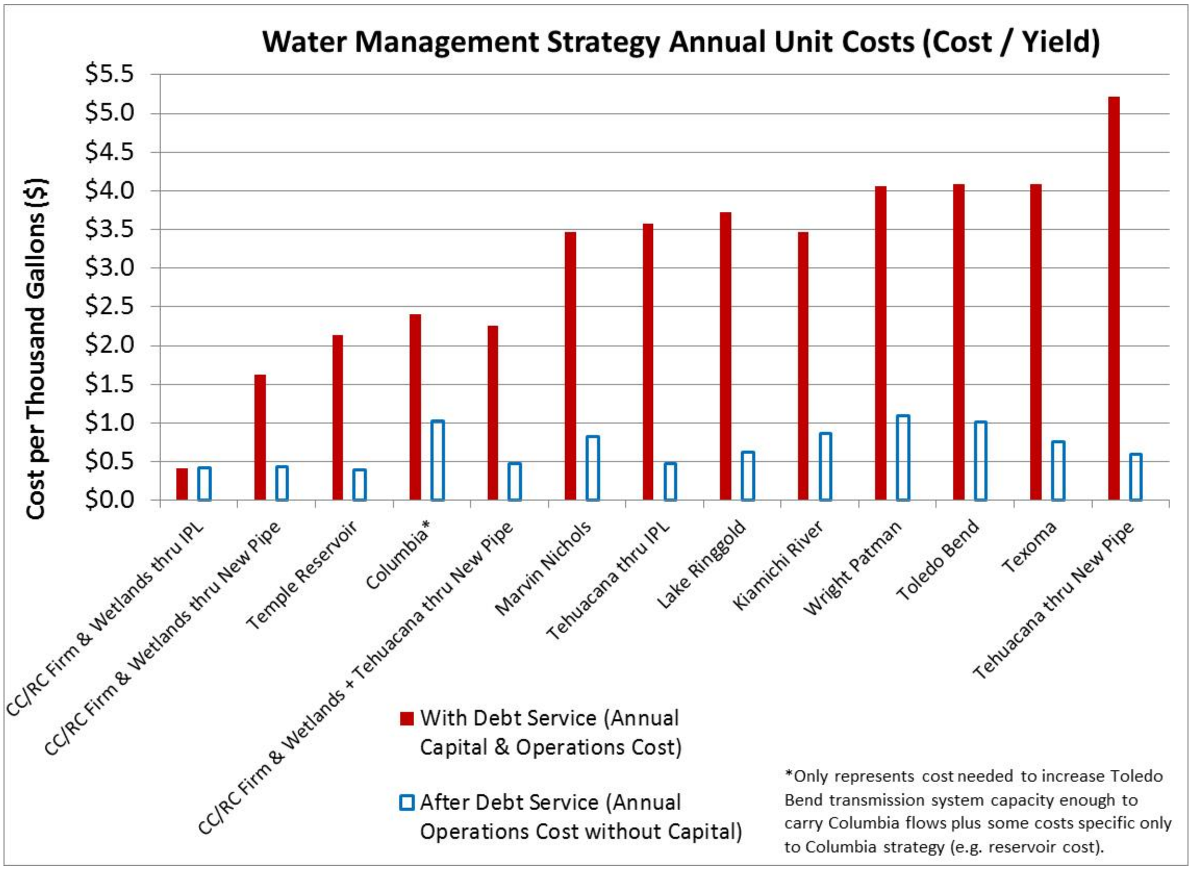
Cost (in 2012 dollars)

Capital

$313,065,000

Annual

- Total annual cost during debt repayment period - $27,970,900
- Total annual cost after debt is payed - $5,226,900
- Annual unit cost of water until amortization based on 21,050 acft/yr yield ($/1000 gal) - $4.08
- Annual unit cost of water after amortization based on 21,050 acft/yr yield ($/1000 gal) - $0.76

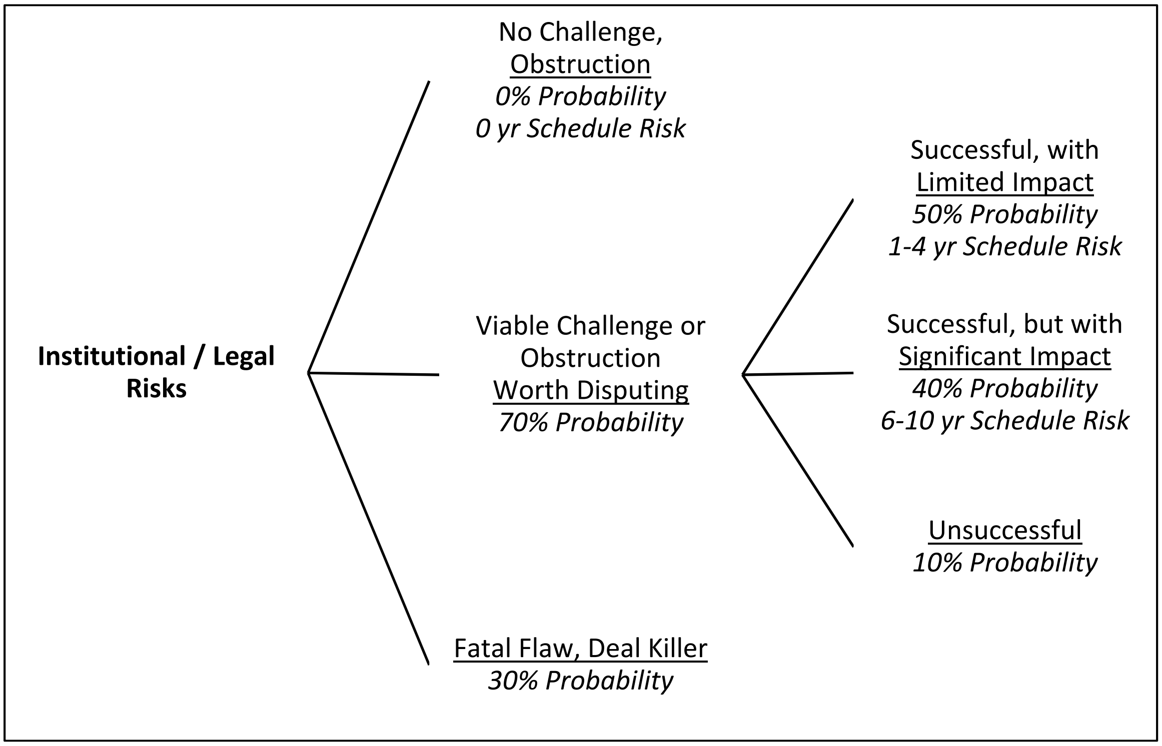


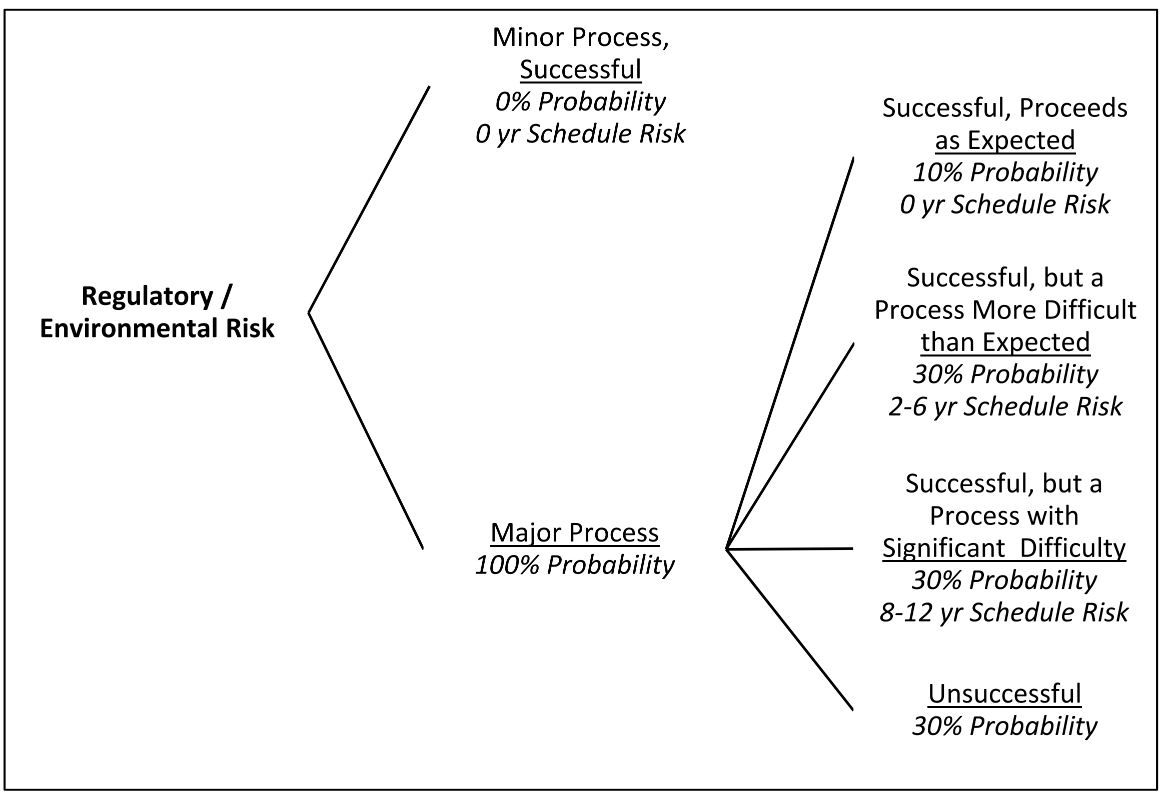
Comparison to Other Strategies

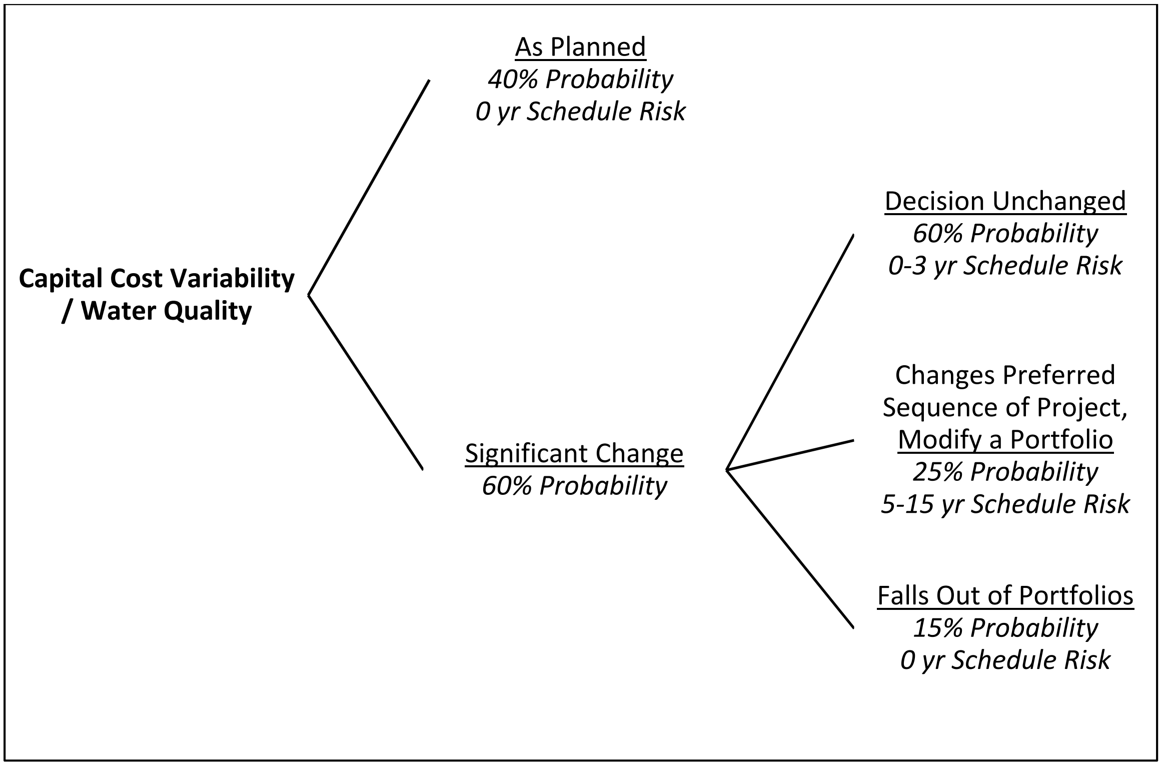
Key Assumptions

- Lake Texoma water can be blended in Lake Bridgeport at a 10:1 ratio (10 Other: 1 Texoma).
- The water quality standard for TDS in Lake Bridgeport can be revised to 675 mg/L.
- For this study, the assumption has been made that zebra mussels will not preclude water transfers from Lake Texoma to other reservoirs. This is currently not the case per Federal law. If zebra mussels do prevent water transfers directly to other reservoirs, this strategy may require advanced treatment of Lake Texoma water or delivering Texoma water directly to the treatment facilities.
- TRWD receives the necessary agreements with Oklahoma and an Inter-Basin transfer permit.

Risk Assessment







Institutional / Legal	Regulatory / Environmental	Capital Cost Variability / Water Quality
Partnering with Dallas or Oklahoma will add significant complexity. Reaction to blending by local users in the West Fork (i.e. entities with WTP's on Bridgeport and/or Eagle Mountain)	Water quality will create a significant process. Downstream water quality impacts to overall Trinity River pose large risk. TCEQ will need to approve the blending plan. Transferring invasive species across state lines is currently prohibited by Federal law; obtaining an exception may not be possible. An interbasin transfer permit is required.	Water quality adds much uncertainty in cost. Potential inability to transport water from Lake Texoma to other reservoirs because of invasive species could require a different configuration and add significant capital and operational costs to this alternative.

Hydraulic Grade Line – Lake Texoma to Lake Bridgeport

References

Freese and Nichols, Inc., Alan Plummer Associates, Inc., CP&Y, Inc., and Cooksey Communications Inc.: *2011 Region C Water Plan*, prepared for the Region C water Planning Group, Fort Worth, October 2010.

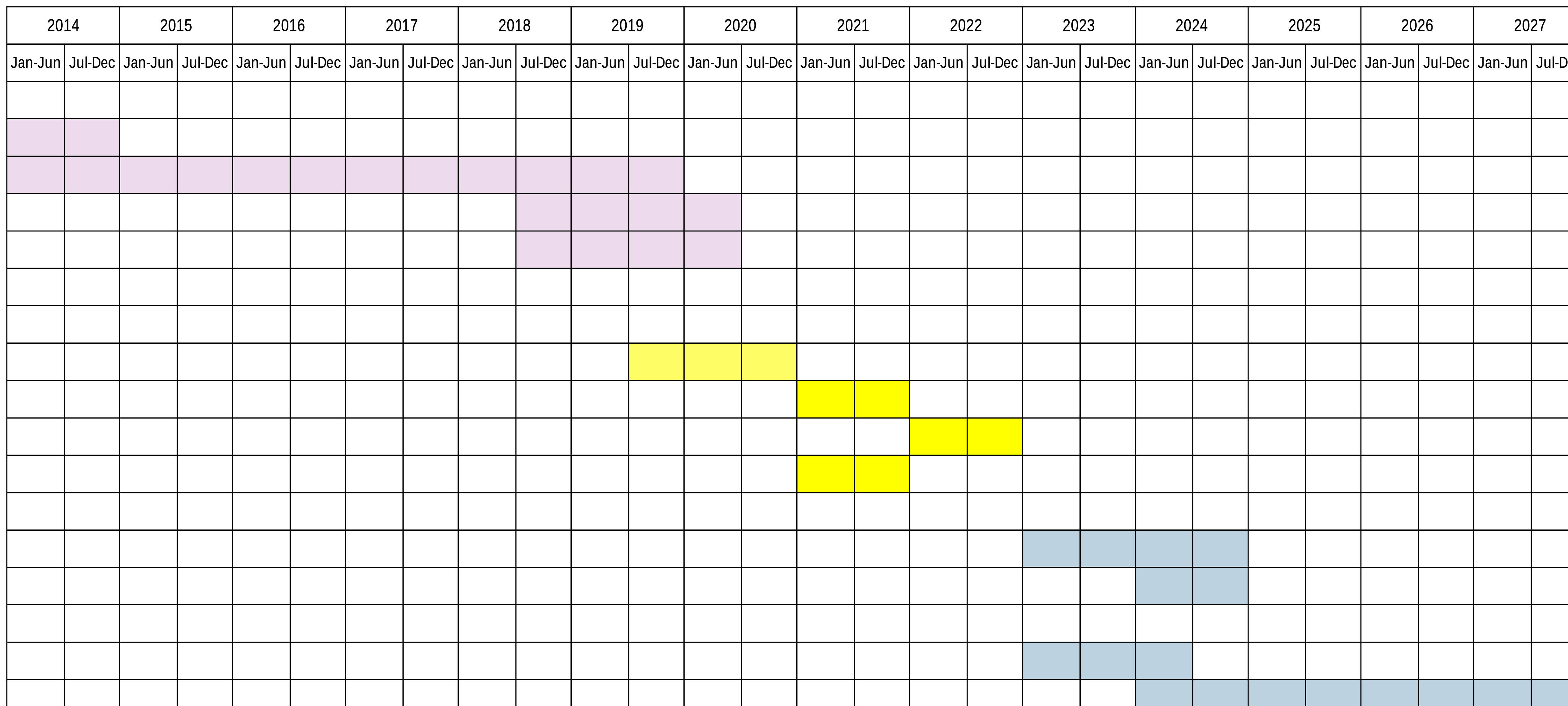
Oklahoma Water Resources Board, *2012 Oklahoma Comprehensive Water Plan, Lower Washita Watershed Planning Region Report, Version 1.1*, http://www.owrb.ok.gov/supply/ocwp/ocwp.php

Lake Texoma Implementation Schedule for TRWD IWSP:

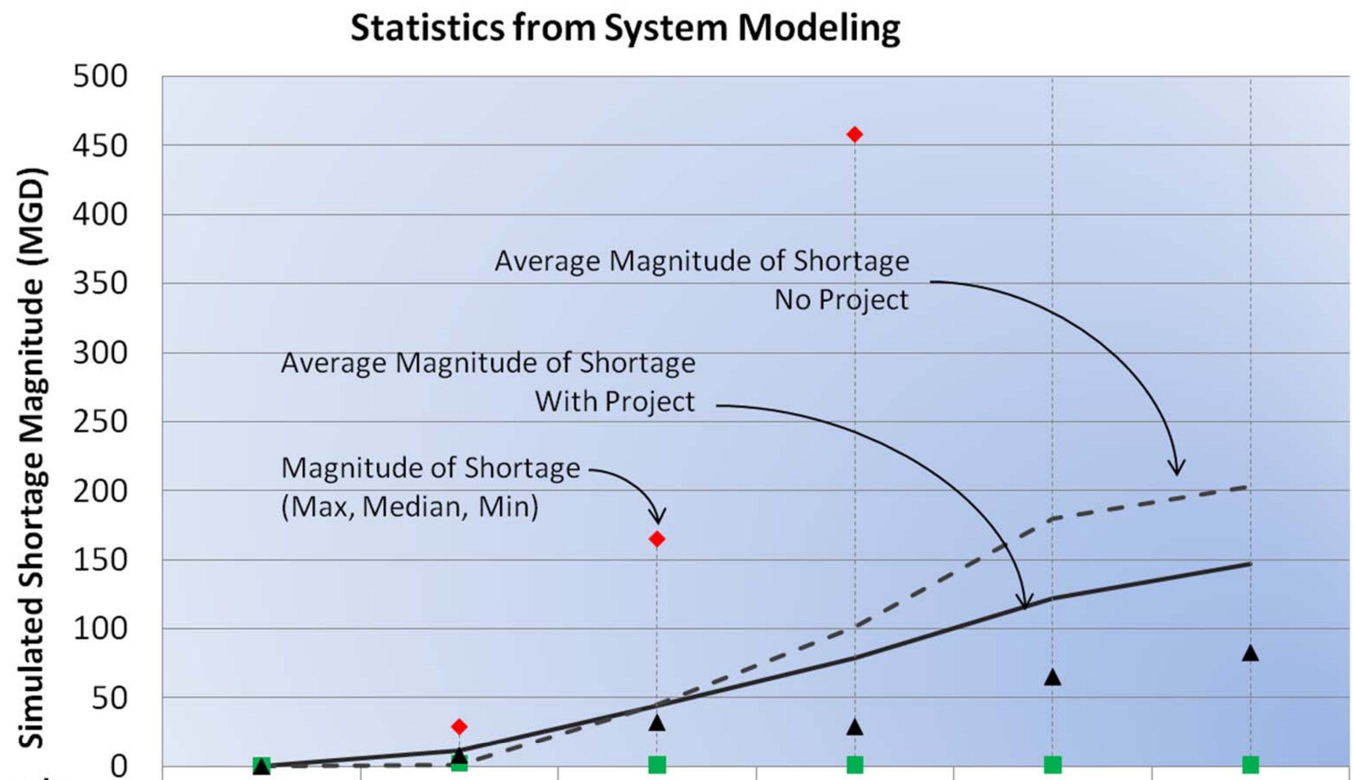
Assumptions:

1. An Oklahoma water right would be required
2. A "bed and banks" permit from TCEQ would be required to store additional water in existing Texas reservoirs
3. An accounting plan would be prepared and approved in conjunction with the bed and banks permit
4. 404 process and the bed and banks permit would not start until water rights or contract negotiations are well advanced to almost complete
5. Mingling of water from a reservoir that straddles an interstate boundary into Texas reservoirs, as an interim step in the delivery process, would be allowed (invasive species considerations)
6. The conservation pool (normal operating elevation) of the storage reservoir (Bridgeport) would not be increased as a result of the additional water to be stored therein
7. Conceptual design and planning includes preliminary pipeline route selection for permitting purposes

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	1 Year
Obtain right to Oklahoma water	January 2014	6 Years
Bed and Banks Permit	January 2018	2 Years
404 Permit Application / Approval (pipeline)	January 2020	2 Years
DESIGN TASKS		
Transmission Facilities	July 2020	3.5 Years
Route Selection	July 2020	1.5 Years
Survey and Preliminary Design	January 2022	1 Year
Final Design	January 2023	1 Year
Design Mitigation Features (if needed)	January 2022	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition for Pump Stations	January 2023	2 Years
Implement Mitigation (if needed)	January 2024	1 Year
Transmission Facilities	January 2023	5 Years
Easement Acquisition	January 2023	1.5 Years
Bid and Construction Phase	January 2024	4 Years



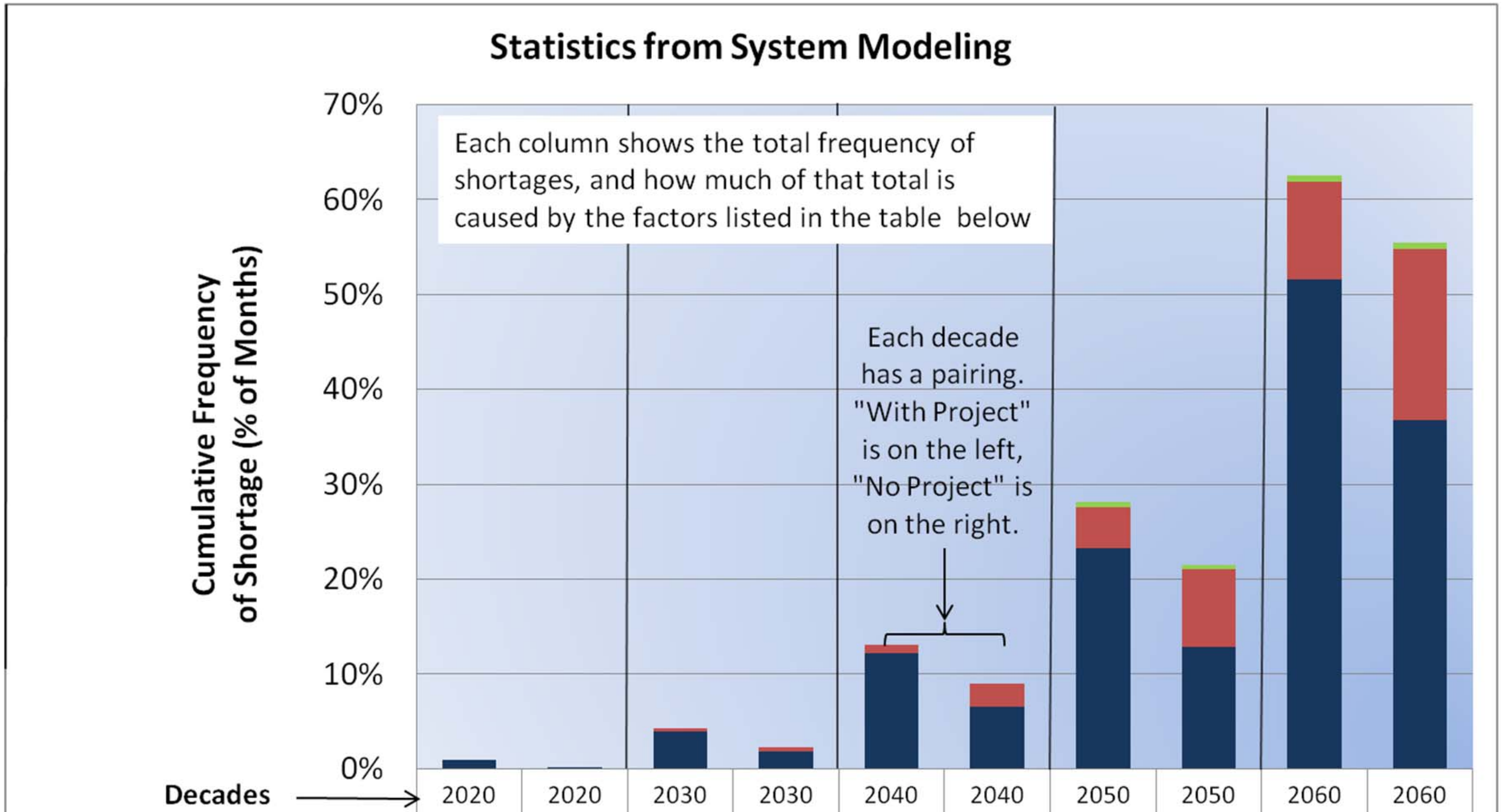
Texoma



Decade	2010	2020	2030	2040	2050	2060
Maximum	0	29	165	458	695	908
Minimum	0	2	1	1	1	1
Median	0	8	32	29	65	83
Average	0	12	45	78	122	147
Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Texoma



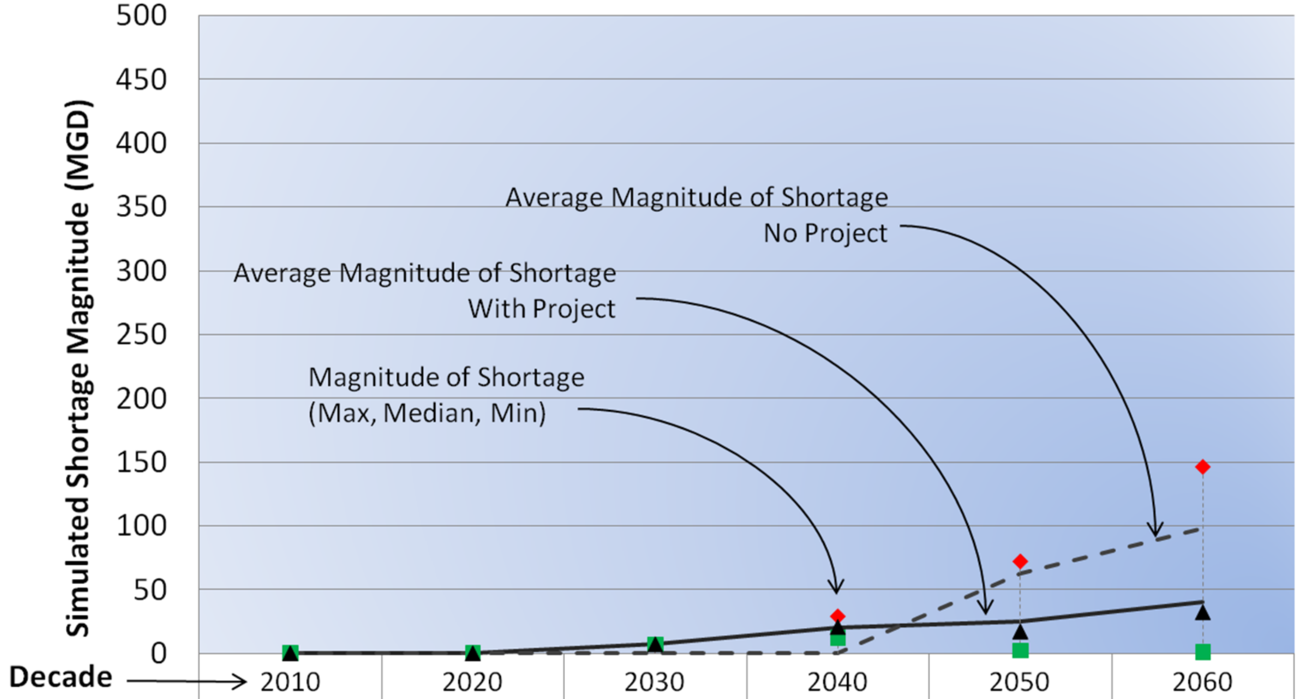
	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.5%		0.7%	
Permitted Amount	0.0%		0.3%		0.9%		4.4%		10.2%	
Pipeline Capacity	0.9%		4.0%		12.2%		23.2%		51.6%	

Results Using 2011 Region C Based Demand Projection

Texoma

Magnitude Chart

Statistics from System Modeling

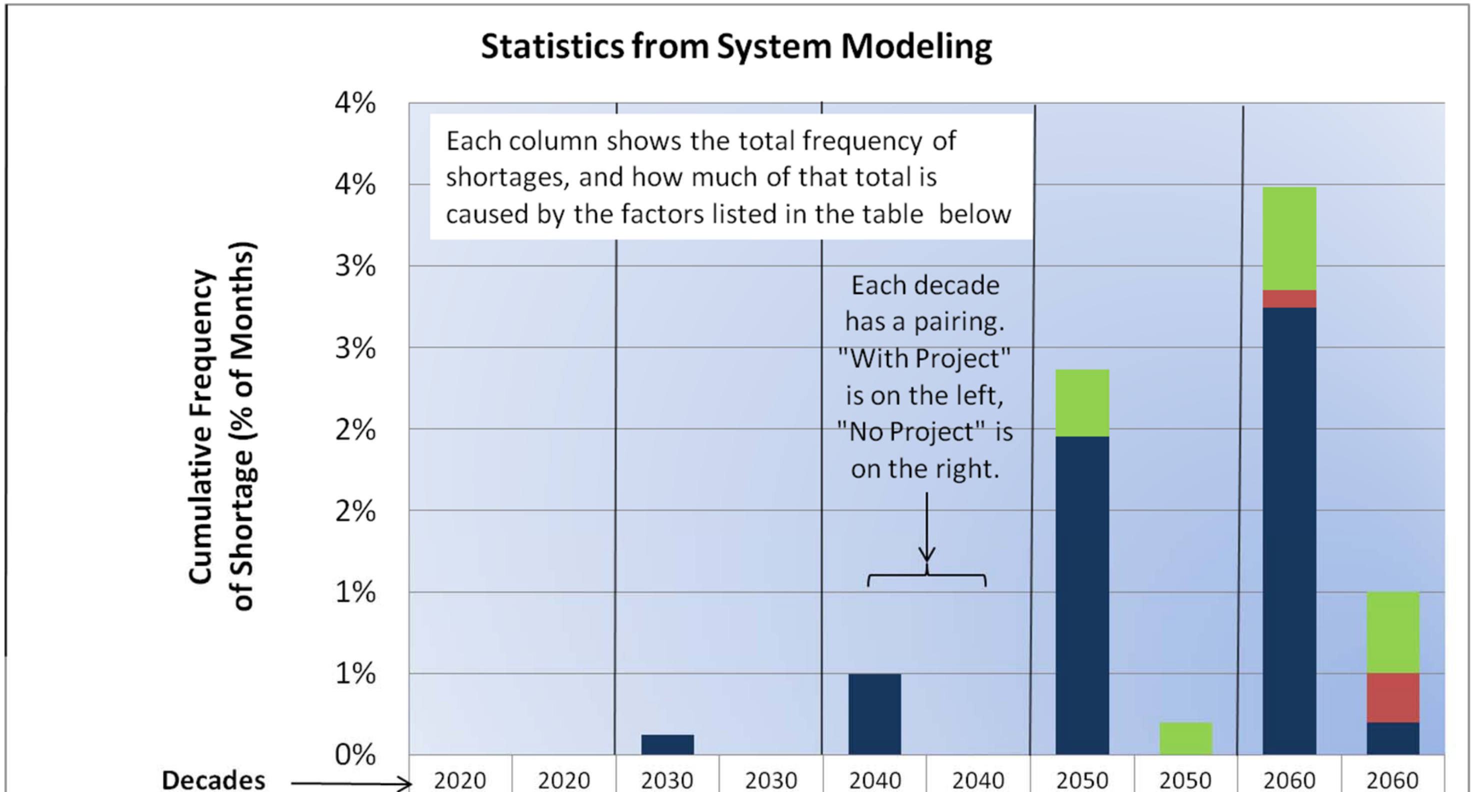


Decade	2010	2020	2030	2040	2050	2060
Maximum	0	0	7	29	72	146
Minimum	0	0	7	12	2	1
Median	0	0	7	21	17	32
Average	0	0	7	21	25	40
Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

Texoma

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.4%		0.6%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.1%	
Pipeline Capacity	0.0%		0.1%		0.5%		2.0%		2.7%	

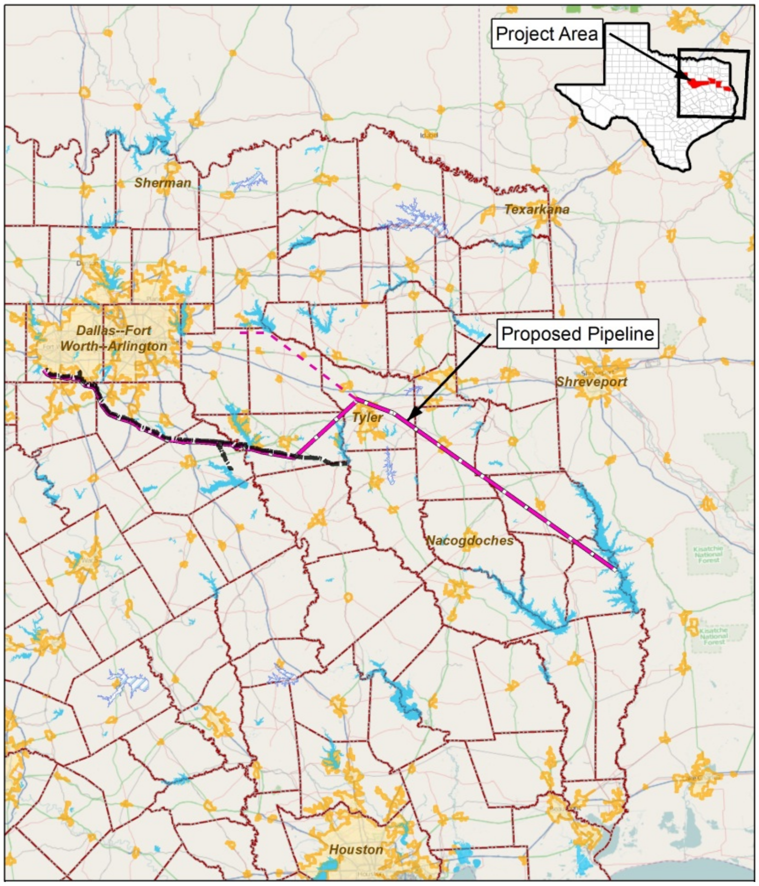
Results Using Recent Trend Extrapolation Demand Projection

Toledo Bend

Description

Toledo Bend Reservoir is an existing reservoir located in the Sabine River Basin on the border between Texas and Louisiana. It was built in the 1960s by the Sabine River Authority of Texas (SRA) and the Sabine River Authority of Louisiana. The yield of the project is split equally between Texas and Louisiana, and Texas' share of the yield is slightly over 1,000,000 acre-feet per year. The SRA holds a Texas water right to divert 750,000 acre-feet per year from Toledo Bend and is seeking the right to divert an additional 293,300 acre-feet per year.

This configuration assumes that the SRA and Dallas-Fort Worth Metroplex water suppliers, (TRWD, NTMWD, and Dallas) would collaborate on a project to deliver 100,000 acre-feet per year of Toledo Bend water to SRA customers in the upper Sabine River Basin and up to 600,000 acre-feet per year to the Metroplex. Recent agreements between the SRA and other entities in Southeastern Texas have reduced the amount of water available to the Metroplex by approximately 200,000 acre-feet/year. This configuration of the Toledo Bend supply strategy assumes that amount could be secured by including a portion of Louisiana's share of Toledo Bend. The assumed supply available to each entity is listed below in acre-feet per year.

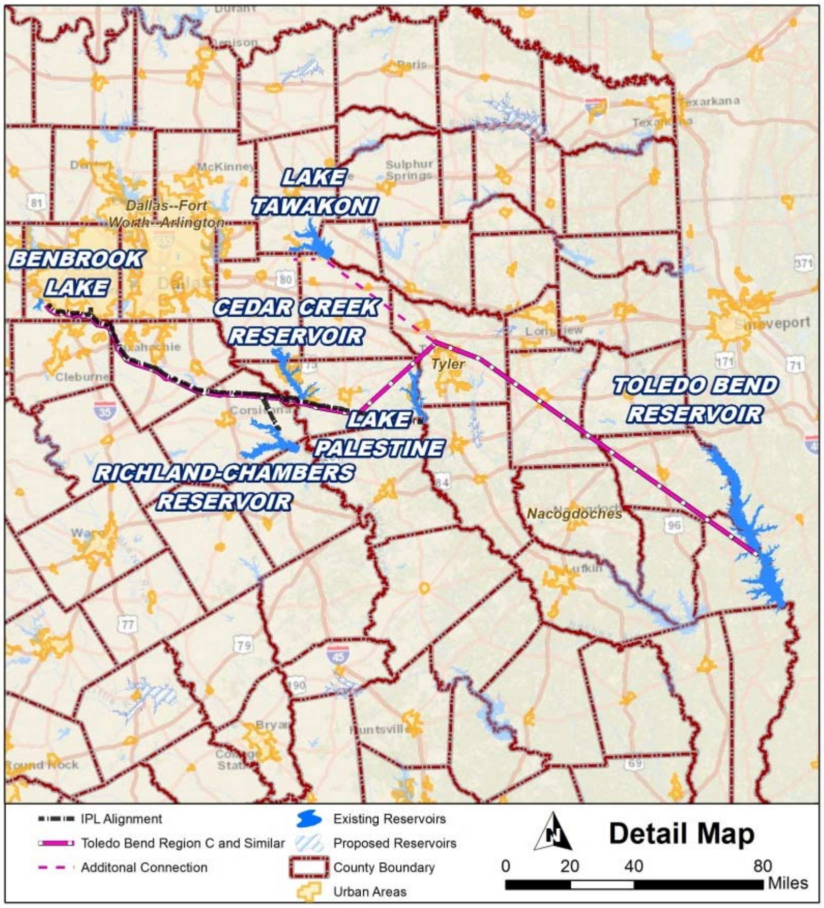


Vicinity Map

- TRWD – 200,000
- NTMWD – 200,000
- DWU – 200,000
- SRA – 100,000

The cost estimate for this configuration of the Toledo Bend supply strategy assumes that a new pipeline is required the entire distance between Toledo Bend and Benbrook Lake.

Because the Integrated Pipeline will not be flowing at full capacity initially, Toledo Bend supply could be delivered through the Integrated Pipeline (IPL). Once the IPL becomes fully utilized by TRWD and Dallas, delivery of Toledo Bend will require a new pipeline. This new pipeline will be built within the IPL right of way and will be designed to also carry other supply sources from Southeast of DFW.



Pipeline Route to Benbrook Lake

Facilities Required (Assuming a New Pipeline from Toledo Bend to Lake Benbrook)

- One 75,200 HP Intake Pump Station at Toledo Bend
- Approximately 132 miles of one 120-inch pipe and one 132-inch pipe in parallel (An additional 23 miles of 120-inch pipeline is needed for Lake Tawakoni branch for other partners)
- Approximately 151 miles of two 96-inch pipes (An additional 6.5 miles of 96-inch pipe is needed for Lake Tawakoni branch for other partners)
- Approximately 10 miles of single 102-inch pipe
- Nine booster pump stations ranging in size from 11,300 HP to 77,600 HP (seven of which would be partially owned/operated by TRWD)
- Nine earthen storage reservoirs ranging in size from 45 million gallons to 156 million gallons (seven of which would be partially owned/operated by TRWD)

- Discharge structure at Lake Benbrook

Yield

200,000 acre-feet per year to TRWD

Total 700,000 acre-feet per year to be shared by four entities

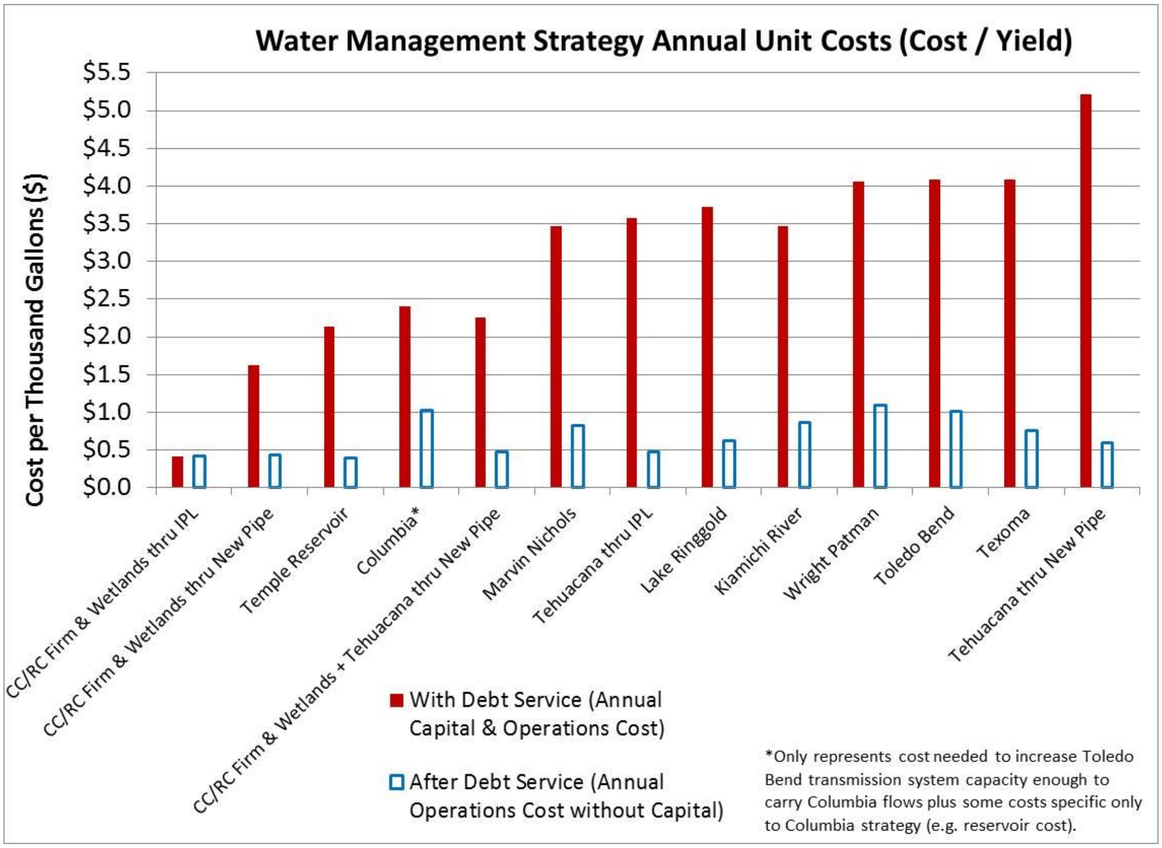
TRWD's Cost (in 2012 dollars)

Capital

$2,751,751,000

Annual

- Total annual cost during debt repayment period - $265,749,000
- Total annual cost after debt is payed – $65,837,000
- Annual unit cost of water until amortization based on 200,000 acft/yr firm yield ($/1000 gal) - $4.08
- Annual unit cost of water after amortization based on 200,000 acft/yr firm yield ($/1000 gal) - $1.01



Comparison to Other Strategies

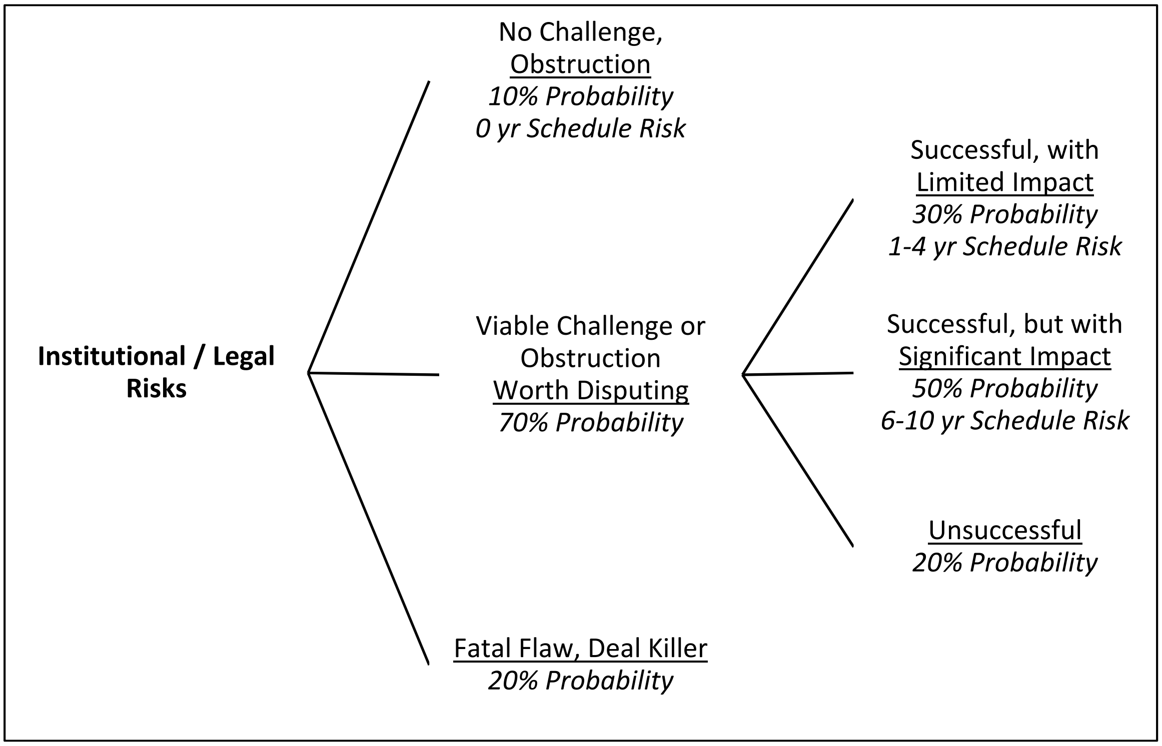
Alternative Strategies for transporting from Toledo Bend to Lake Benbrook

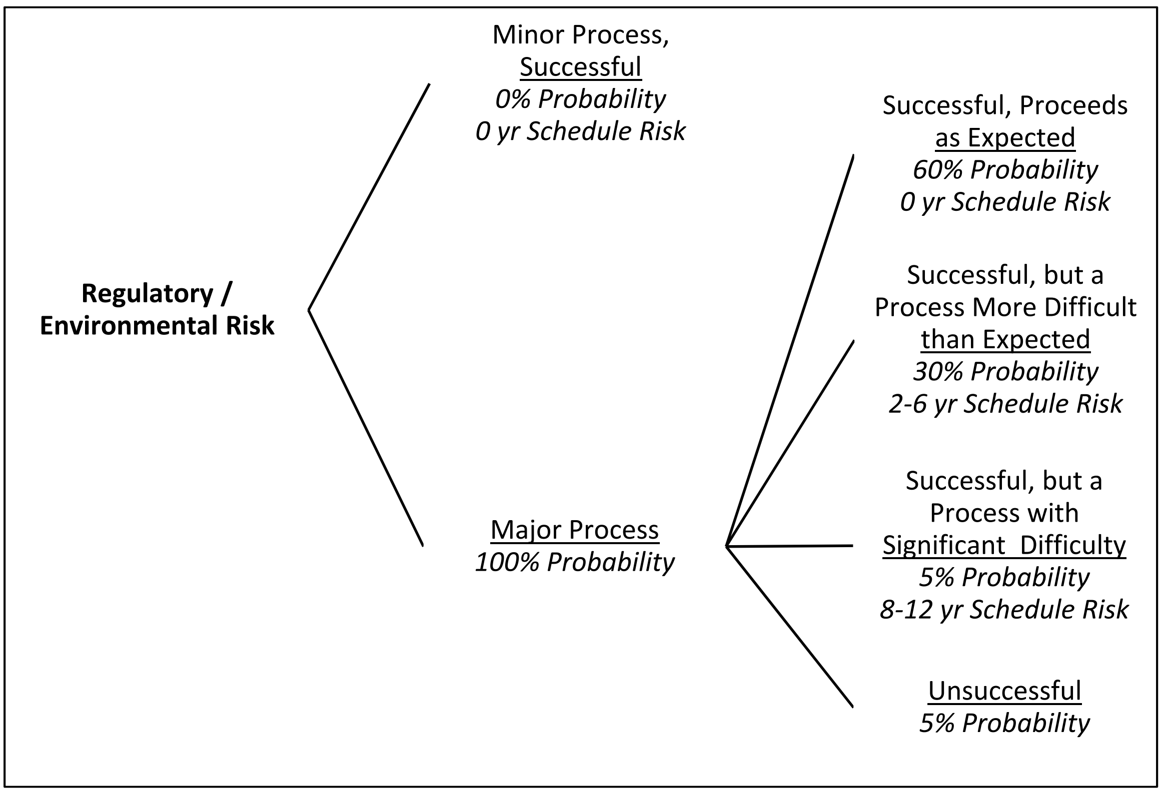
The configuration described above assumes that the SRA and Dallas-Fort Worth Metroplex water suppliers, (TRWD, NTMWD, and Dallas) would collaborate on a project to utilize Toledo Bend water. **For comparative purposes only**, it was assumed that TRWD develops Toledo Bend supply alone in the amounts of 100,000, 200,000, 300,000 or 400,000 acre-feet/year. Pipe alignments, peaking factors, and other assumptions used in the configuration described above were not changed. However, when analyzing the 400,000 acre-feet/year option, it was assumed that 200,000 acre-feet/year would be dropped off prior to the Integrated Pipeline 120" tunnel because it can only convey a maximum flow of 340,000 acre-feet/year (it is assumed that water could be used by Dallas or at Lake Arlington or Fort Worth's Rolling Hills WTP).

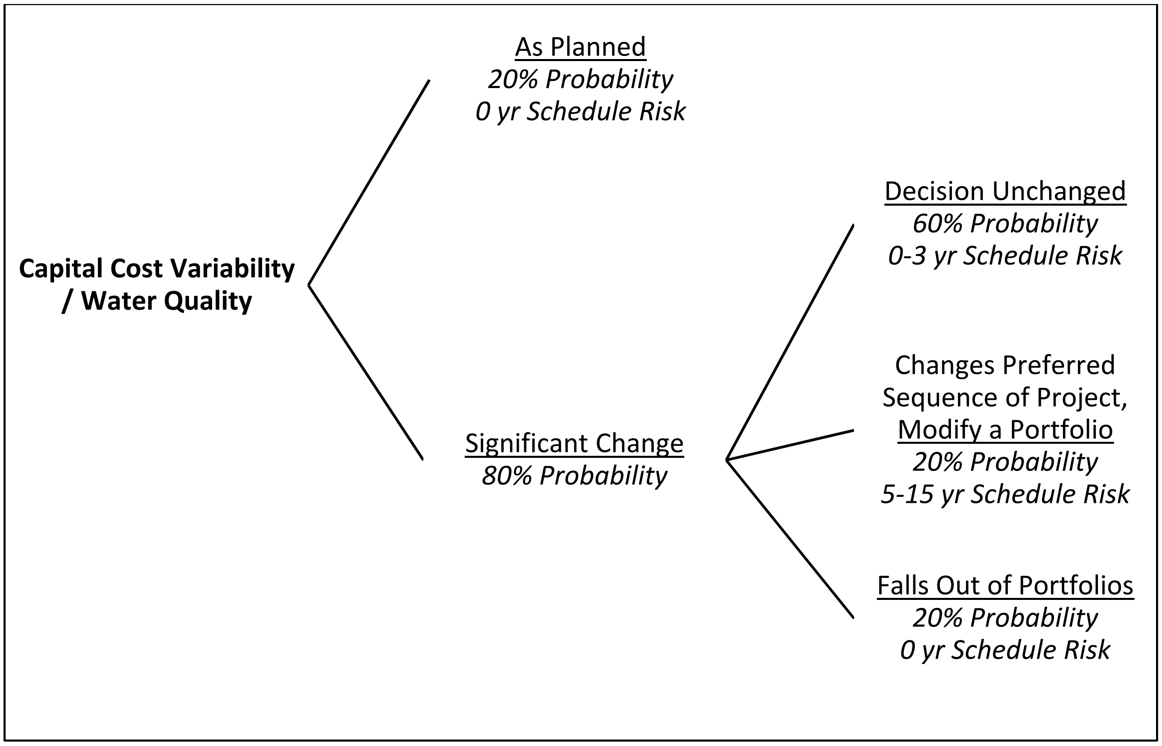
Table 1 – Comparative Costs Assuming TRWD Develops Toledo Bend without Partners

TRWD Supply (ac-ft/yr)	Pipeline Diameter	Capital Cost	Annual Cost		With Debt Service Unit Cost (per 1,000 gal)	w/o Debt Service Unit Cost (per 1,000 gal)
	(inches)	Total	TRWD	TRWD w/o Debt Service	Total	Total
100,000	78	$1,723,619,000	$163,055,000	$37,835,000	$5.00	$1.16
200,000	102	$3,008,720,000	$289,828,000	$71,248,000	$4.45	$1.09
300,000	120	$3,955,372,000	$387,614,000	$100,261,000	$3.96	$1.03
400,000	Two 102 in parallel to takeoff, then one 102	$5,491,705,000	$534,276,000	$135,310,000	$4.10	$1.04
With Partners (Configuration Used in IWSP) Total: 700,000 TRWD Share: 200,000		Total: $7,361,868,000 TRWD: $2,751,751,000	$265,749,000	$65,837,000	$4.08	$1.01

Risk Assessment



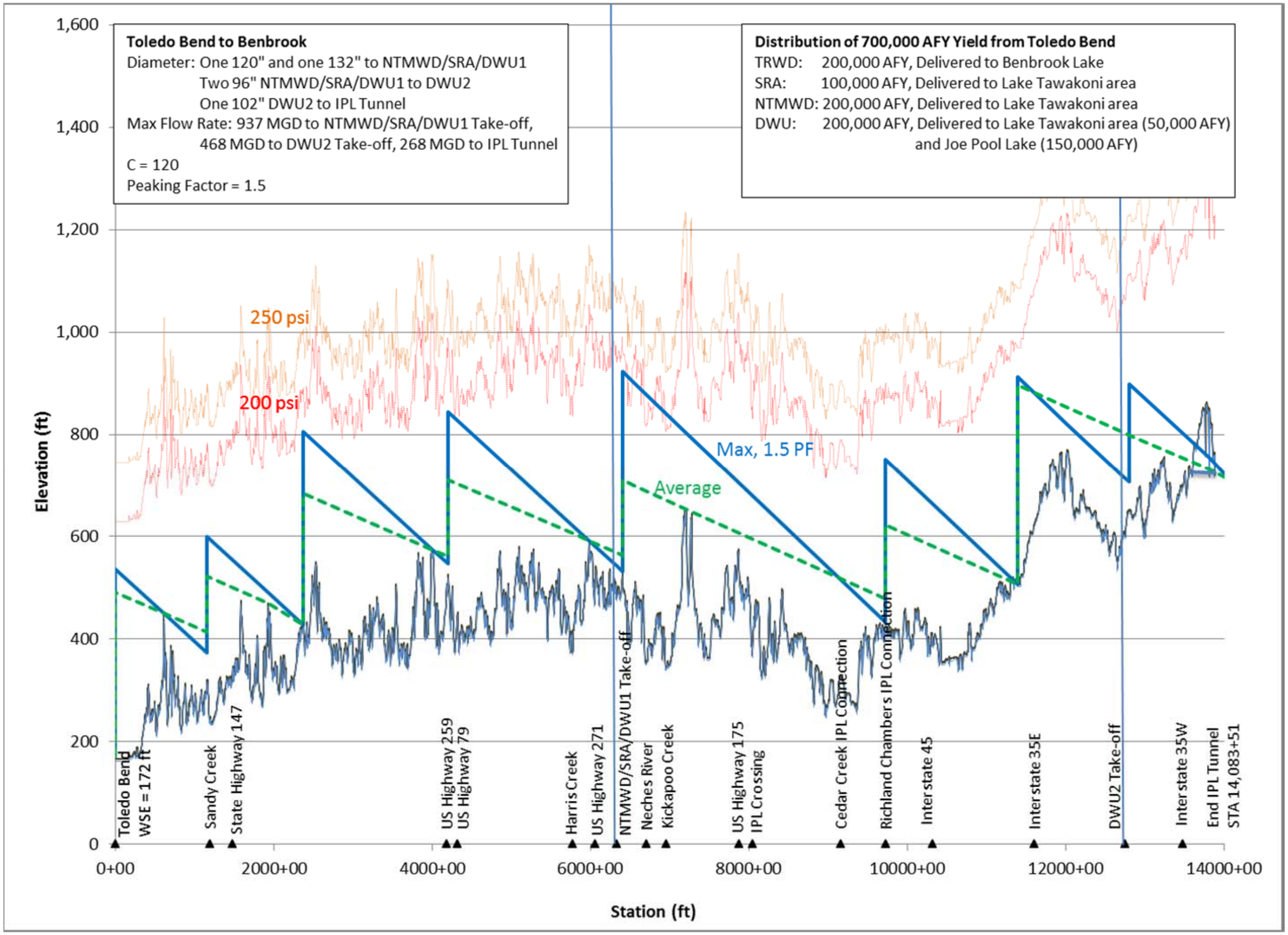




Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
Complex partnering requirements Requires negotiation of acceptable contract with SRA May have interstate water transfer implications	Potential regulatory implications of interstate water transfer Interbasin transfer permit required 404 permit for pipeline required New water right required	Uncertainty in raw water costs

Key Assumptions

- Water supply will be purchased at a reasonable unit price under agreement with SRA Texas and/or SRA Louisiana.
- SRA and Dallas-Fort Worth Metroplex entities can reach an agreement for cost-sharing of the infrastructure.



Hydraulic Grade Line – Toledo Bend to Benbrook

References

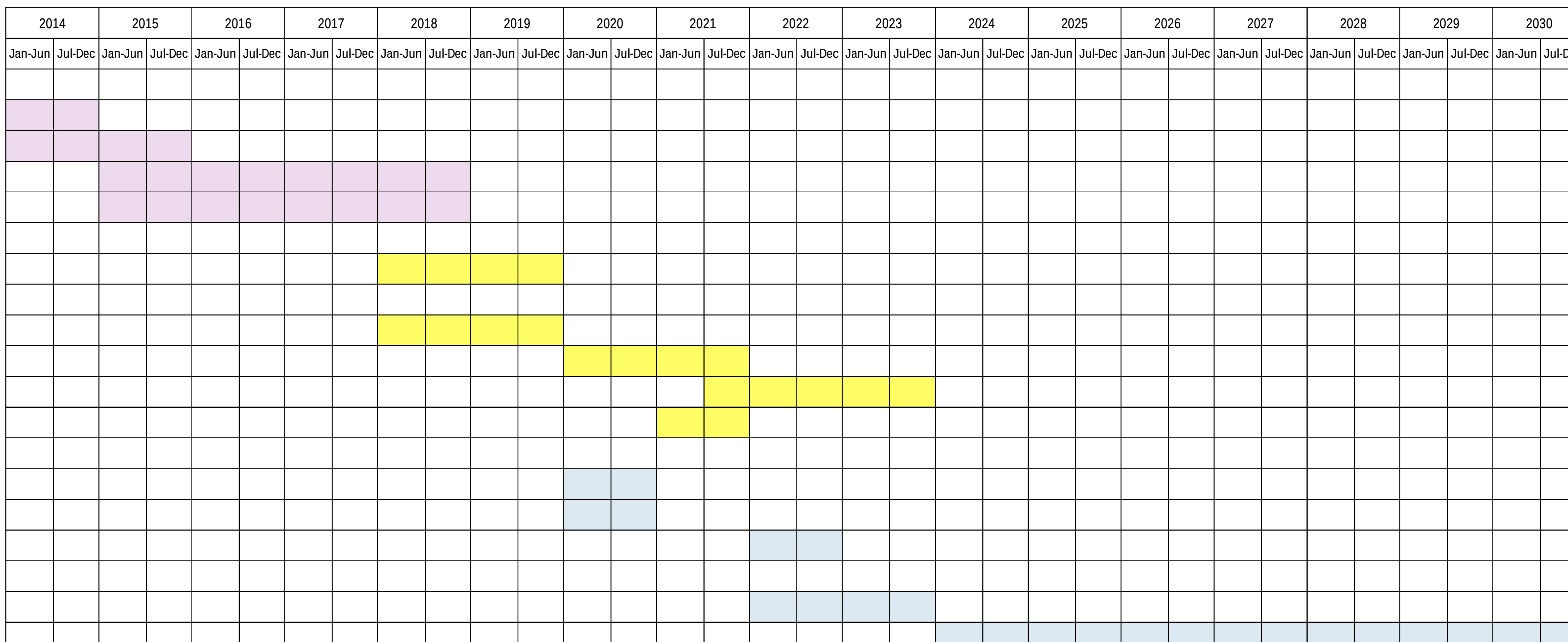
Freese and Nichols, Inc., Alan Plummer Associates, Inc., CP&Y, Inc., and Cooksey Communications Inc.: *2011 Region C Water Plan*, prepared for the Region C water Planning Group, Fort Worth, October 2010.

Toledo Bend Reservoir Implementation Schedule for TRWD IWSP:

Assumptions

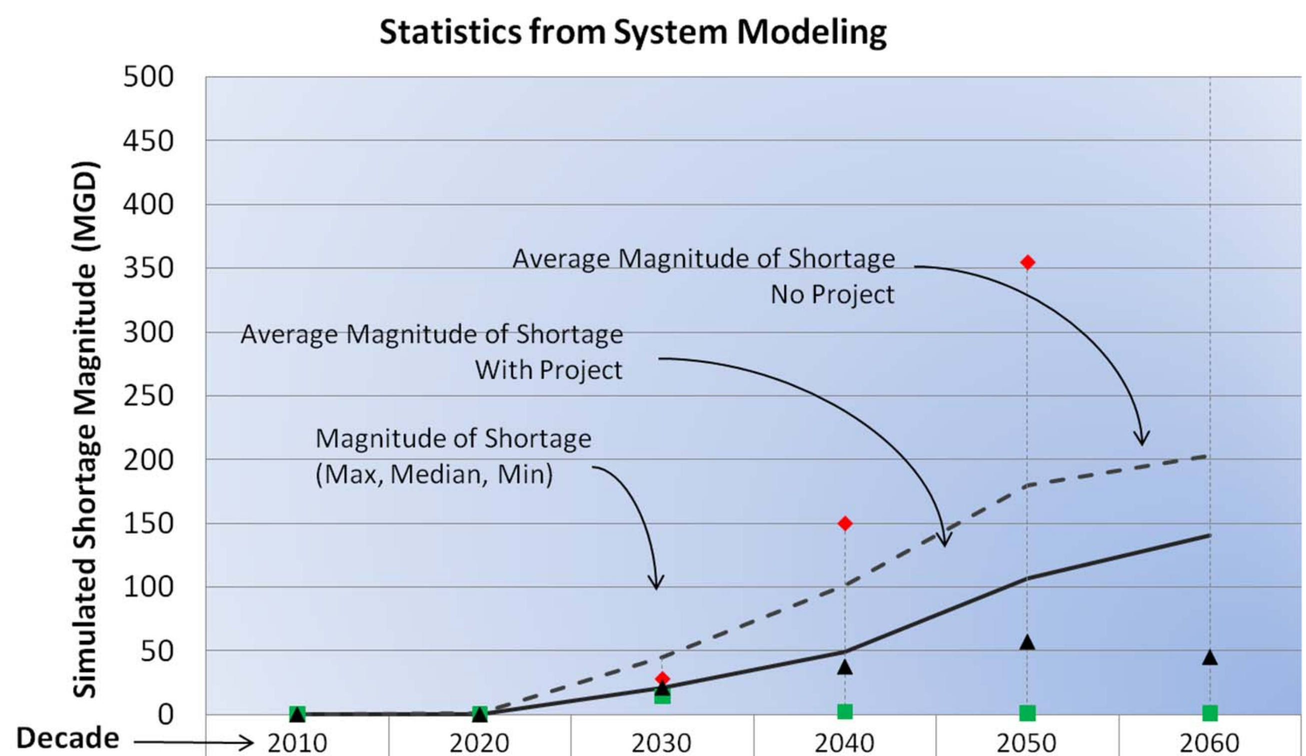
- Toledo Bend supply would be developed in partnership with SRA, DWU and NTMWD
- A new water right would not be required
- An IBT would be required
- A long-term contract with SRA would be required
- Contract negotiations with SRA would be well advanced before starting permit processes
- The Corps would permit water from an interstate reservoir to be transmitted to and stored in Benbrook Lake (invasive species considerations)
- The Toledo Bend pipeline increment would require a Federal 404 permit with an EIS triggered by the pipeline crossing of a National Forest
- The conservation pools (or normal operating levels) of the interim storage reservoirs would not be increased
- IBT and 404 permit process would run concurrently
- Detailed route selection (pipeline) could overlap with permitting processes
- New Toledo Bend pipeline would connect with the IPL vicinity, west of Lake Palestine, to deliver water to the TRWD service area
- A portion of the eventual new pipeline capacity would be constructed in the IPL right-of-way and no additional real estate will be required
- Conceptual design and planning includes preliminary pipeline route selection for permitting purposes

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	1 Year
Negotiate Contract with SRA	January 2014	2 Years
IBT Permit	January 2015	4 Years
404 Permit Application / Approval	January 2015	4 Years
DESIGN TASKS		
Relocations	January 2018	2 Years
Transmission Facilities	January 2018	6 Years
Route Selection	January 2018	2 Years
Survey and Preliminary Design	January 2020	2 Years
Final Design	July 2021	2.5 Years
Design Mitigation Features (if needed)	January 2021	1 Year
CONSTRUCTION TASKS		
Real Estate Acquisition for Pump Stations	Janauary 2020	1 Year
Relocations	January 2020	1 Year
Implement Mitigation (if needed)	January 2022	1 Year
Transmission Facilities	January 2022	9 Years
Easement Acquisition	January 2022	2 Years
Bid and Construction Phase	January 2024	7 Years



Toledo Bend

Magnitude Chart

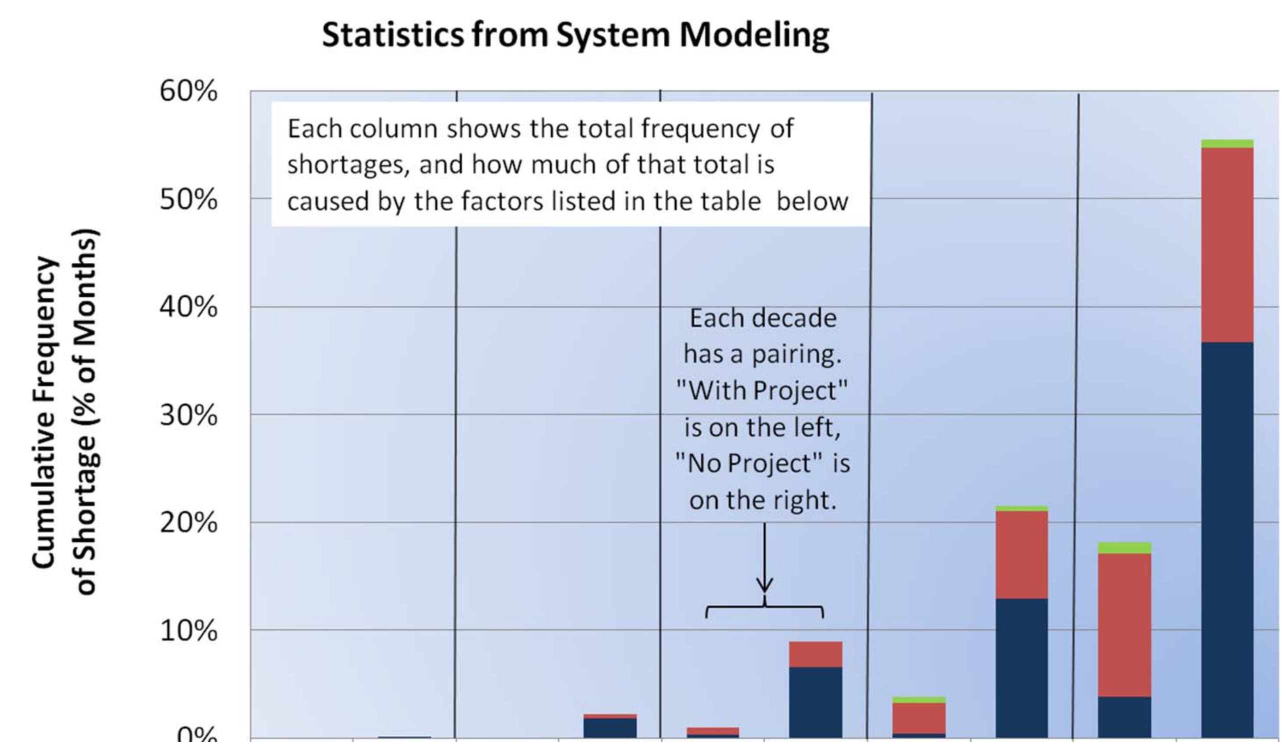


Decade	2010	2020	2030	2040	2050	2060
◆ Maximum	0	0	28	150	355	732
■ Minimum	0	0	14	2	1	1
▲ Median	0	0	21	38	57	45
—— Average	0	0	21	49	107	141
– – Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Toledo Bend

Frequency Chart

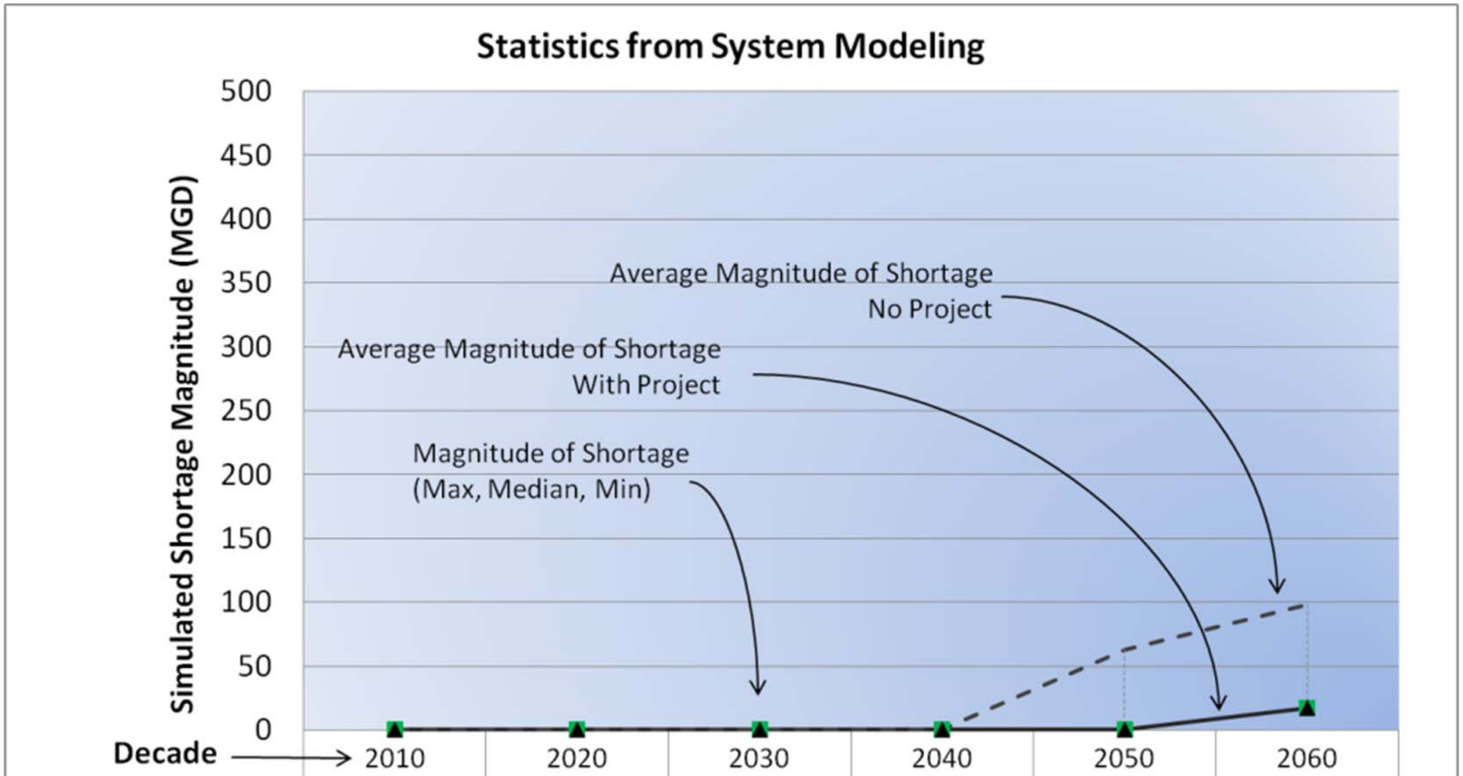


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.6%		1.1%	
Permitted Amount	0.0%		0.0%		0.7%		2.8%		13.3%	
Pipeline Capacity	0.0%		0.0%		0.3%		0.4%		3.8%	

Results Using 2011 Region C Based Demand Projection

Toledo Bend

Magnitude Chart

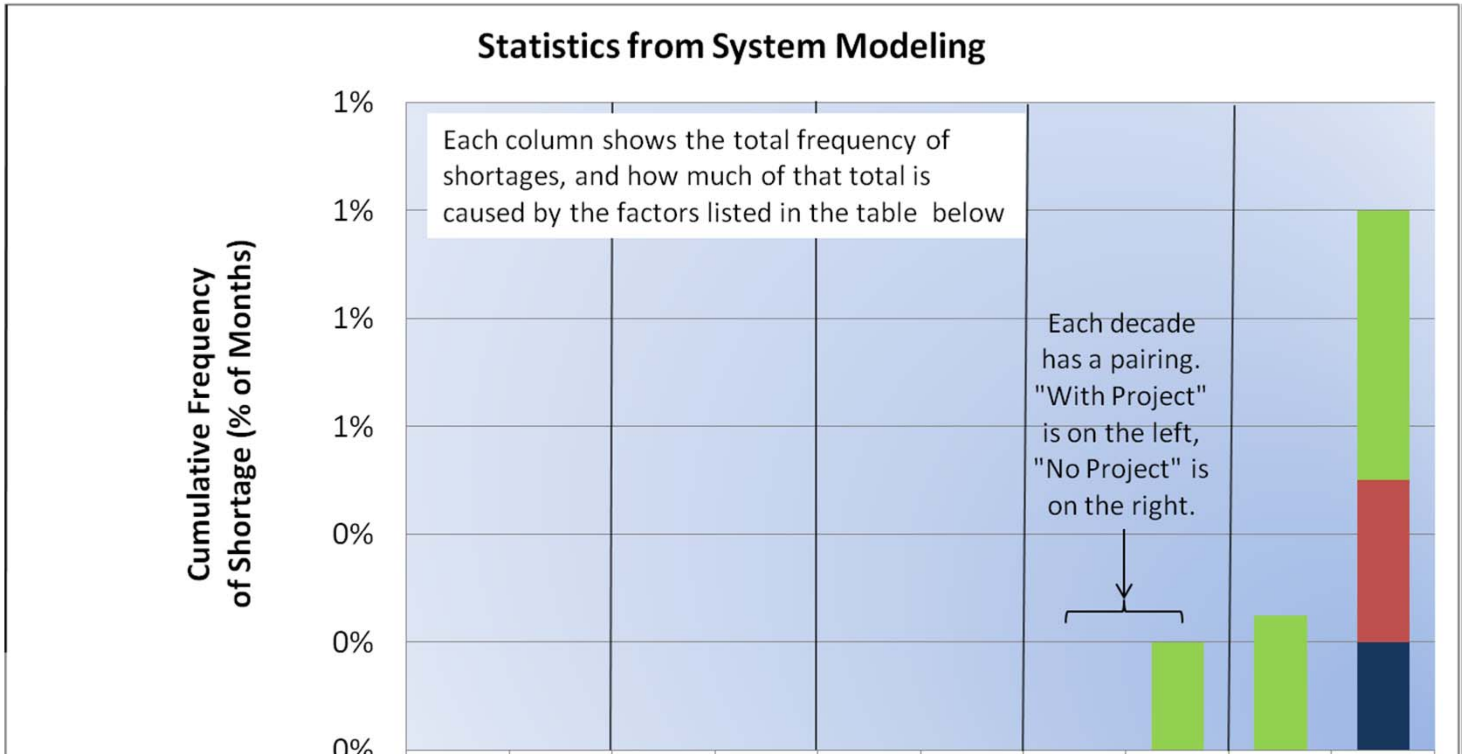


Decade	2010	2020	2030	2040	2050	2060
◆ Maximum	0	0	0	0	0	17
■ Minimum	0	0	0	0	0	17
▲ Median	0	0	0	0	0	17
—— Average	0	0	0	0	0	17
– – Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

Toledo Bend

Frequency Chart



Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.0%		0.2%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.0%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.0%		0.0%	

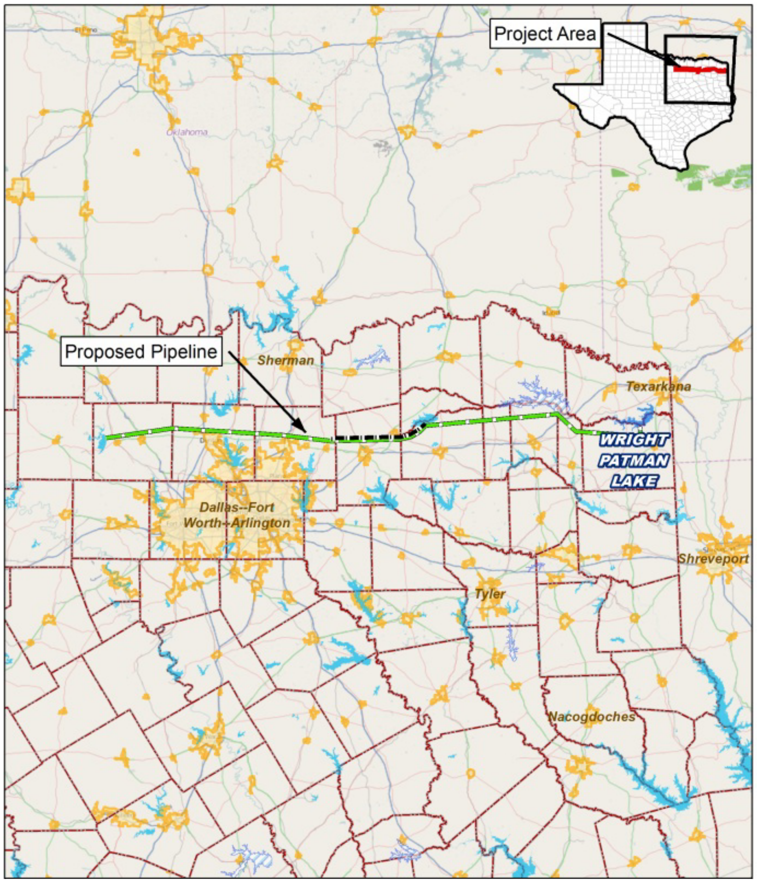
Results Using Recent Trend Extrapolation Demand Projection

Wright Patman Lake

Description

Wright Patman Lake is an existing reservoir in the Sulphur River Basin, approximately 150 miles from the Dallas-Fort Worth Metroplex. It is owned and operated by the U.S. Army Corps of Engineers (USACE). The City of Texarkana has contracted with the USACE for storage in the lake and holds a water right to use up to 180,000 acre-feet per year. According to the 2011 Region C Water Plan, the top of conservation storage in Wright Patman Lake could potentially be raised from the current top of conservation pool (which ranges from 220.6 feet-msl to 227.5 feet-msl depending on the month) to elevation 228.64 feet msl. Raising the conservation pool elevation to 228.64 and using 5 feet of storage below the bottom of the conservation pool (normally reserved for sediment storage) would increase the reservoir yield to 364,000 acre-feet per year, approximately 180,000 acre-feet per year of additional supply that could be used for TRWD or others in Region C. Some form of consideration to acquire the water right held by Texarkana for a portion of this water would be expected to be included in the final project.

Raising the conservation pool above elevation 228.64 feet msl could increase the yield to much more than 364,000 acre-feet per year, but could inundate portions of the White Oak Creek mitigation area, located upstream from Wright Patman Lake. The White Oak Creek Mitigation Area (WOCMA) is approximately 25,000 acres of land owned in fee title by the USACE and managed by the Texas Parks and Wildlife Department (TPWD) under contract to the USACE in fulfillment of the USACE's obligation to mitigate for terrestrial wildlife impacts caused by the construction of Jim Chapman Reservoir. Raising the conservation pool to elevation 228.64 ft msl is also a long-term water supply alternative for City of Dallas.

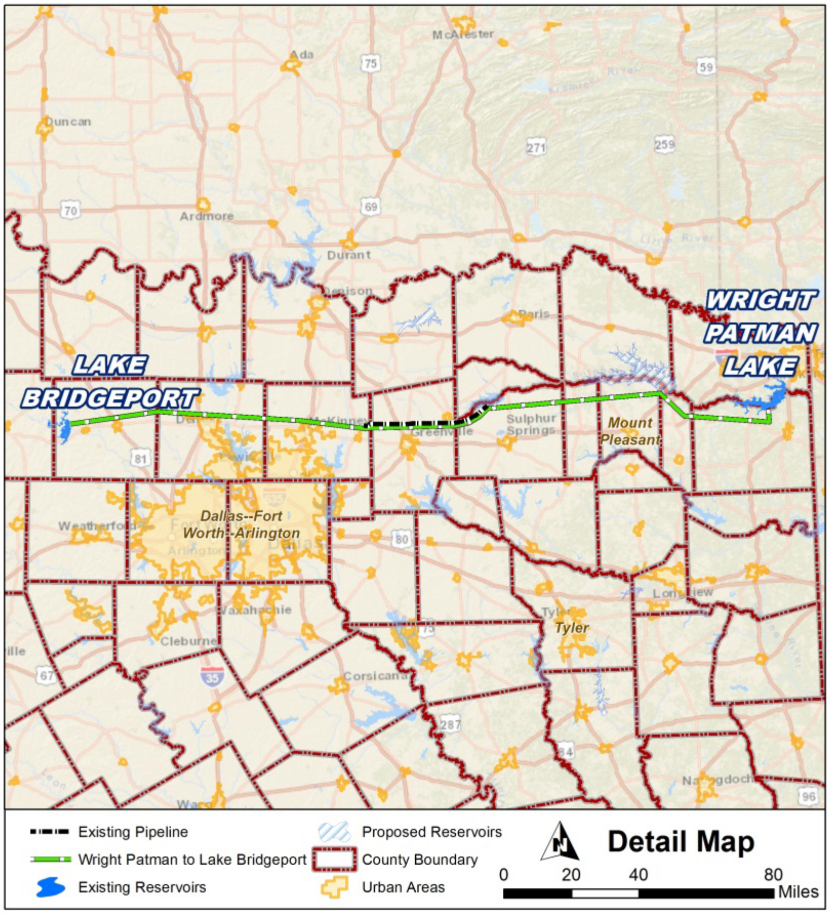


Vicinity Map

Facilities Required

- A 96-inch pipeline from Wright Patman Lake to Lake Bridgeport (approximately

216 miles): assumed route goes from Wright Patman Lake to Jim Chapman Lake then parallel to North Texas Municipal Water District's existing Chapman Pipeline, then continues to a point just north of Lake Lewisville, and then on to Lake Bridgeport.



Pipeline Route to Lake Bridgeport

- One 35,000 HP Intake Pump Station at Eagle Mountain Lake. This pump station was assumed for all strategies that deliver water to Lake Bridgeport. It is sized for the maximum reverse-flow (north to south) capacity of the existing Eagle Mountain Connection Pipeline.
- One 19,600 HP Intake Pump Station at Wright Patman Lake
- Four booster pump stations along the pipeline route: one 18,300 HP, one 18,500 HP, one 17,500 HP, and one 14,600 HP
- Four 40 MG earthen storage reservoirs
- 201 mgd discharge structure at Lake Bridgeport

Supply

180,000 acre-feet per year for TRWD or others in the DFW Metroplex by raising the conservation pool.

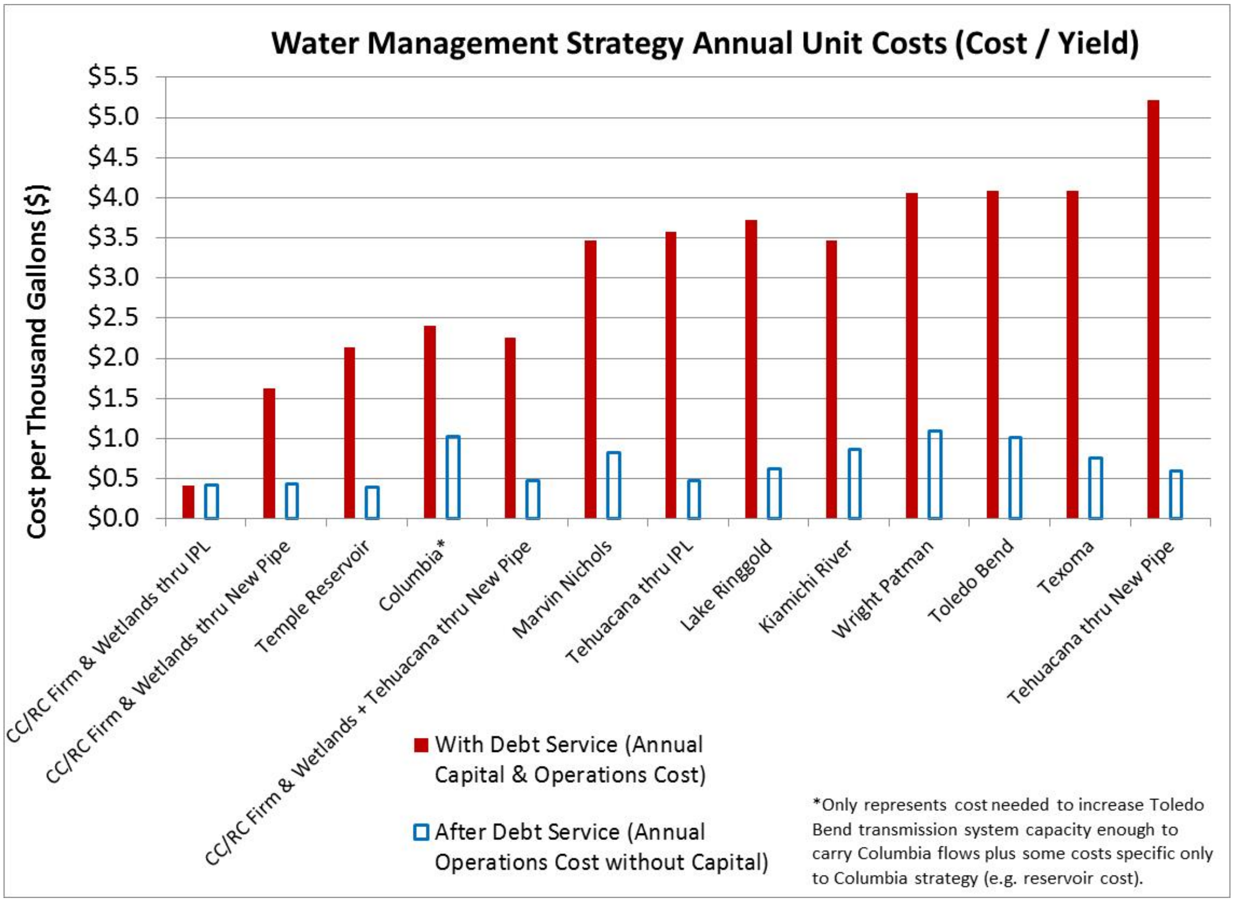
Cost (in 2012 dollars)

Capital

$2,394,849,000

Annual

- Total annual cost during debt repayment period - $238,077,300
- Total annual cost after debt is payed – $64,094,300
- Annual unit cost of water until amortization based on 180,000 acft/yr firm yield ($/1000 gal) - $4.06
- Annual unit cost of water after amortization based on 180,000 acft/yr firm yield ($/1000 gal) - $1.09



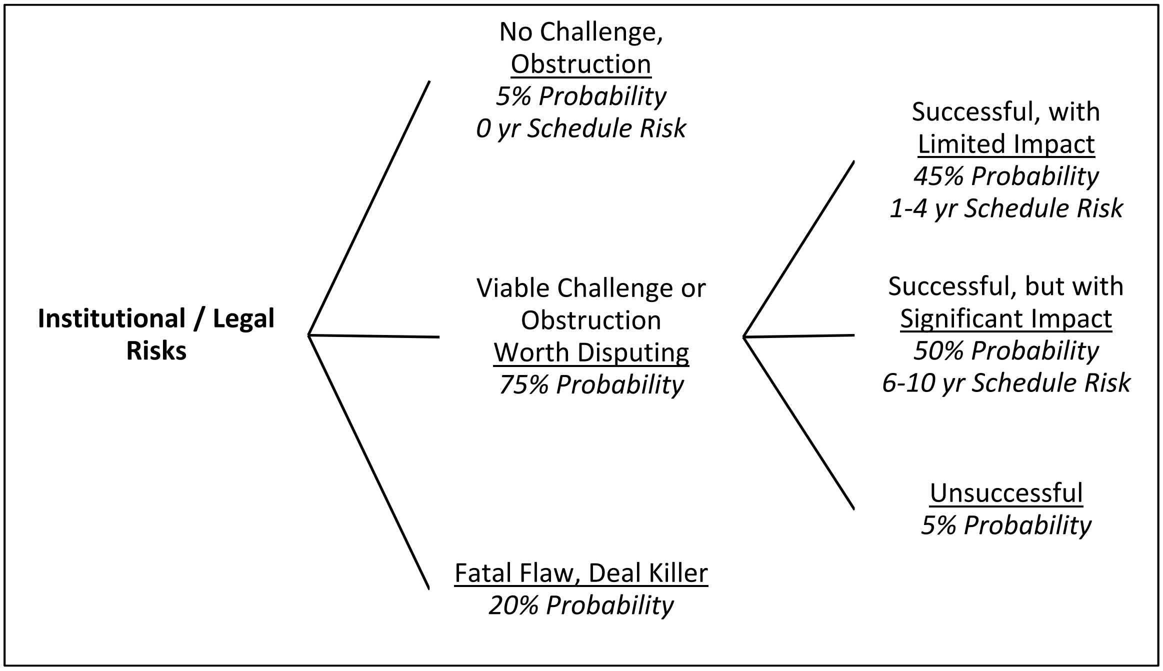
Comparison to Other Strategies

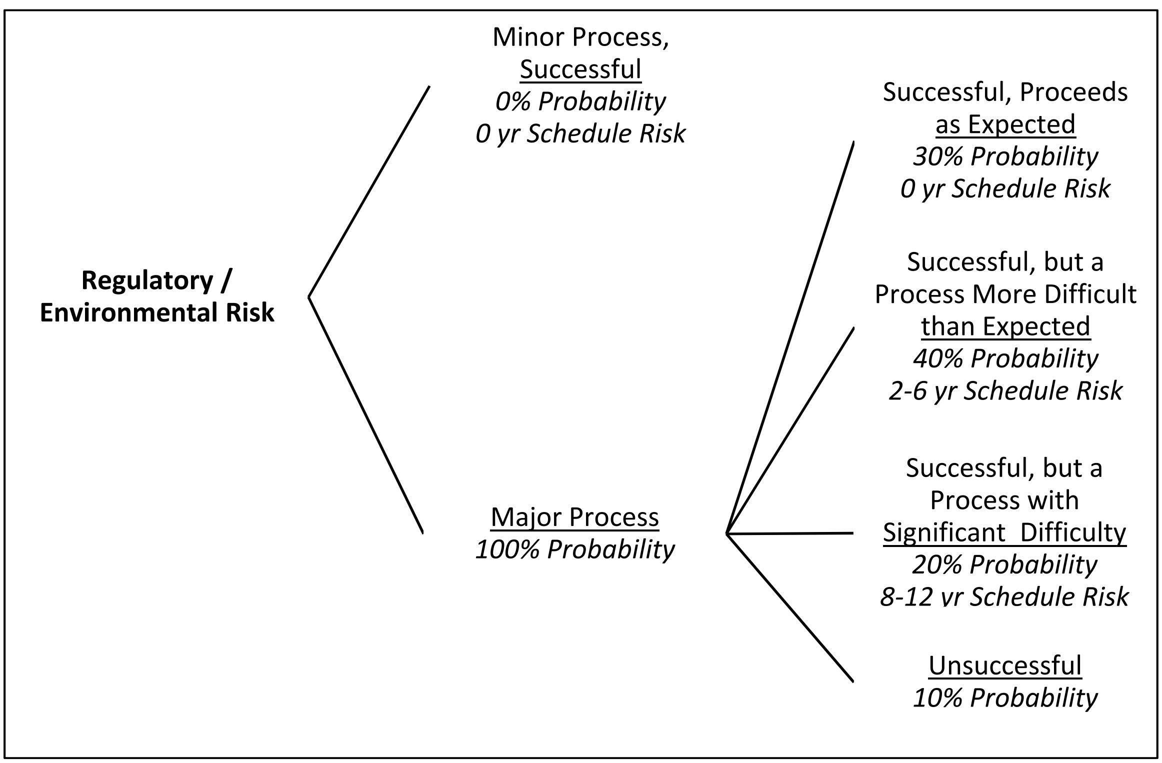
Key Assumptions

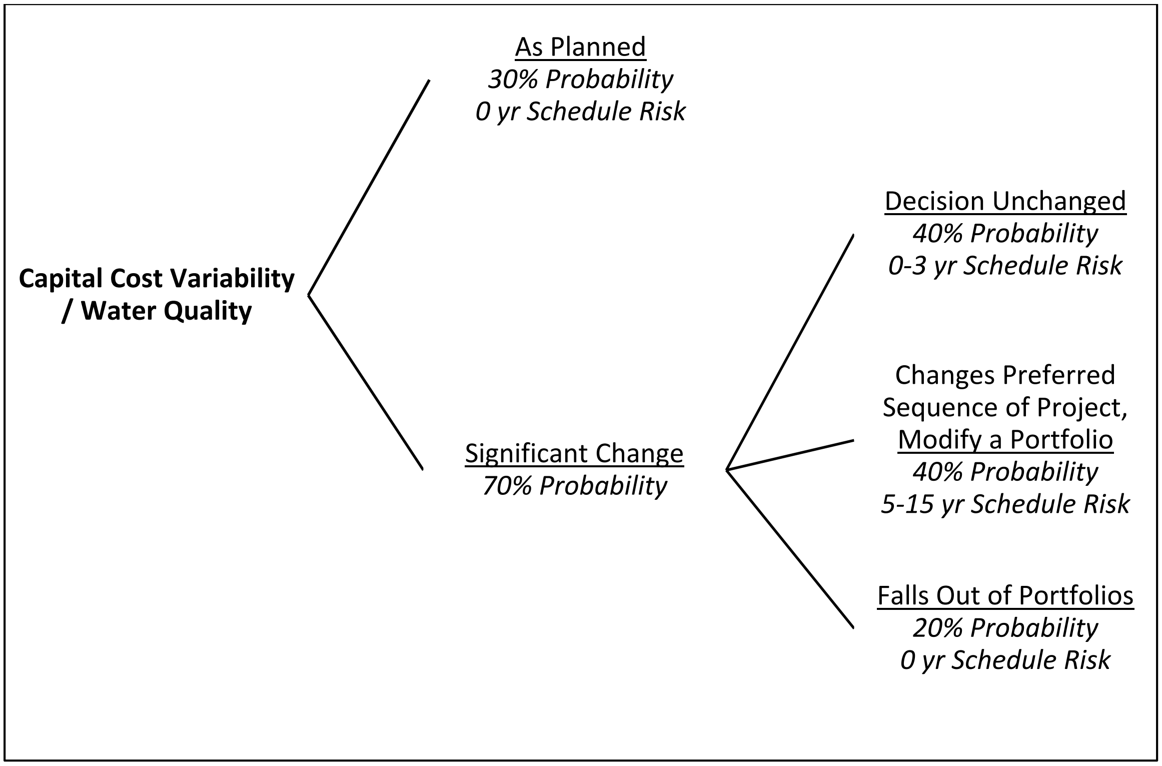
- City of Texarkana would be amenable to modifying their storage contract with the USACE to support a reallocation on behalf of Metroplex water users
- USACE would allow modification of storage contract to utilize storage below elevation 220.0

- USACE will allow reallocation assessments to proceed parallel with resolution of dam safety issues associated with Wright Patman dam
- USACE would support reallocation of flood control storage to water supply storage

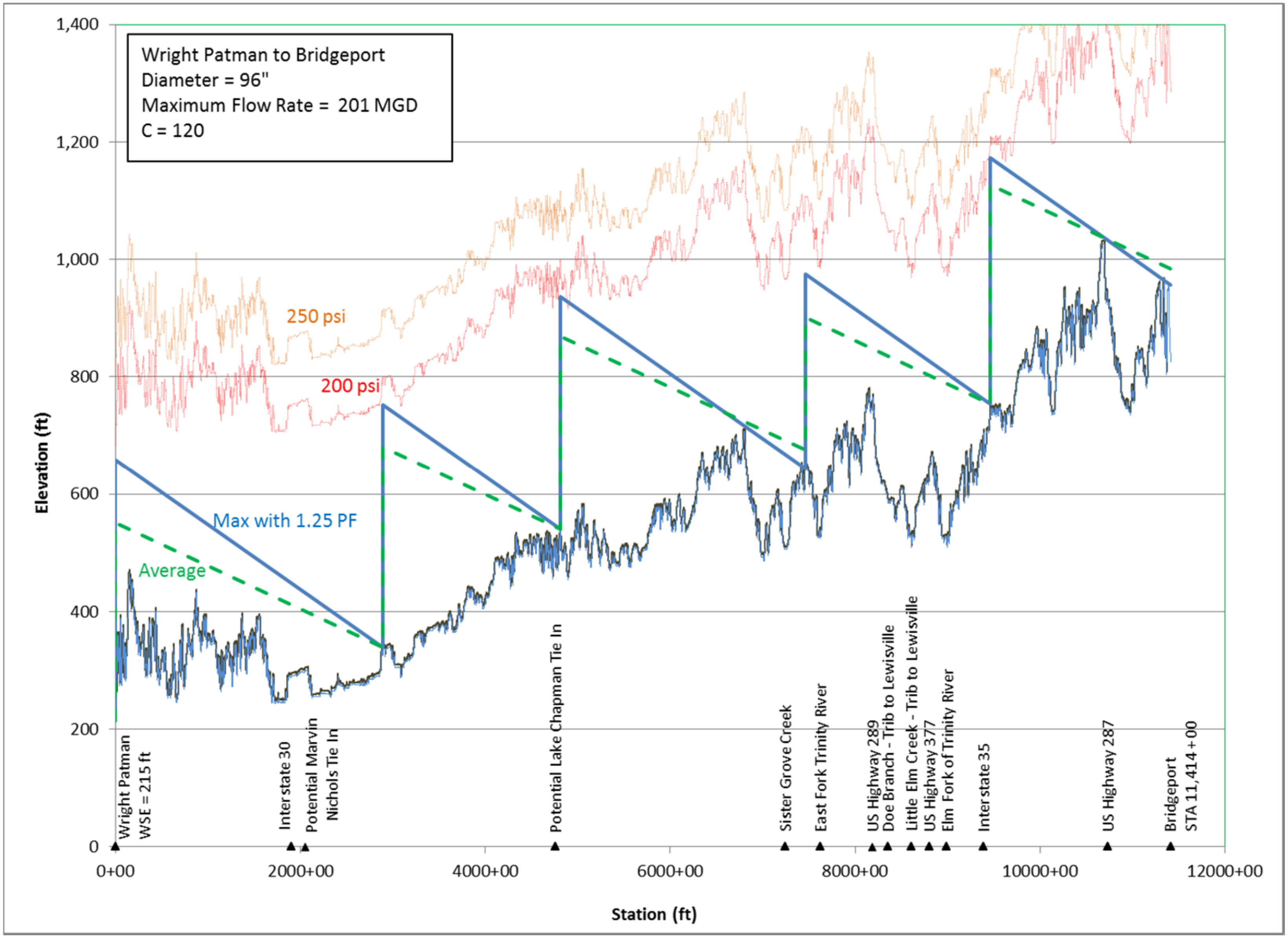
Risk Assessment







Institutional / Legal Risk	Regulatory / Environmental Risk	Capital Cost Variability / Water Quality Risk
Congressional approval required to convert flood storage to conservation storage. New or Amended USACE contract for storage required. May require internal partnering agreement with other Metroplex water users. City of Texarkana would be amenable to modifying their storage contract with the USACE to support a reallocation on behalf of Metroplex water users	Environmental studies, assessment of impacts to flood control and recreation, and other relocation studies needed to support Reallocation study and EIS Potential for some opposition from the timber industry Potential for some opposition from TPWD due to potential for impacts to White Oak Creek Mitigation Area Interbasin transfer permit, water right permit, and 404 permit required	Recent volumetric surveys conducted in Wright Patman Lake indicated that siltation rates exceed expectations and that storage capacity is adversely affected. Wright Patman is currently classified under the USACE Dam Safety program as Class III. USACE would not entertain a reallocation of storage until and unless the Dam Safety classification can be reduced at least to Class IV. The measures needed to reduce risk appropriately, and the costs thereof, are not currently known.



Hydraulic Grade Line – Lake Wright Patman to Lake Bridgeport

References

Freese and Nichols, Inc., Alan Plummer Associates, Inc., CP&Y, Inc., and Cooksey Communications Inc.: *2011 Region C Water Plan*, prepared for the Region C water Planning Group, Fort Worth, October 2010.

Wright Patman Implementation Schedule for TRWD IWSP:

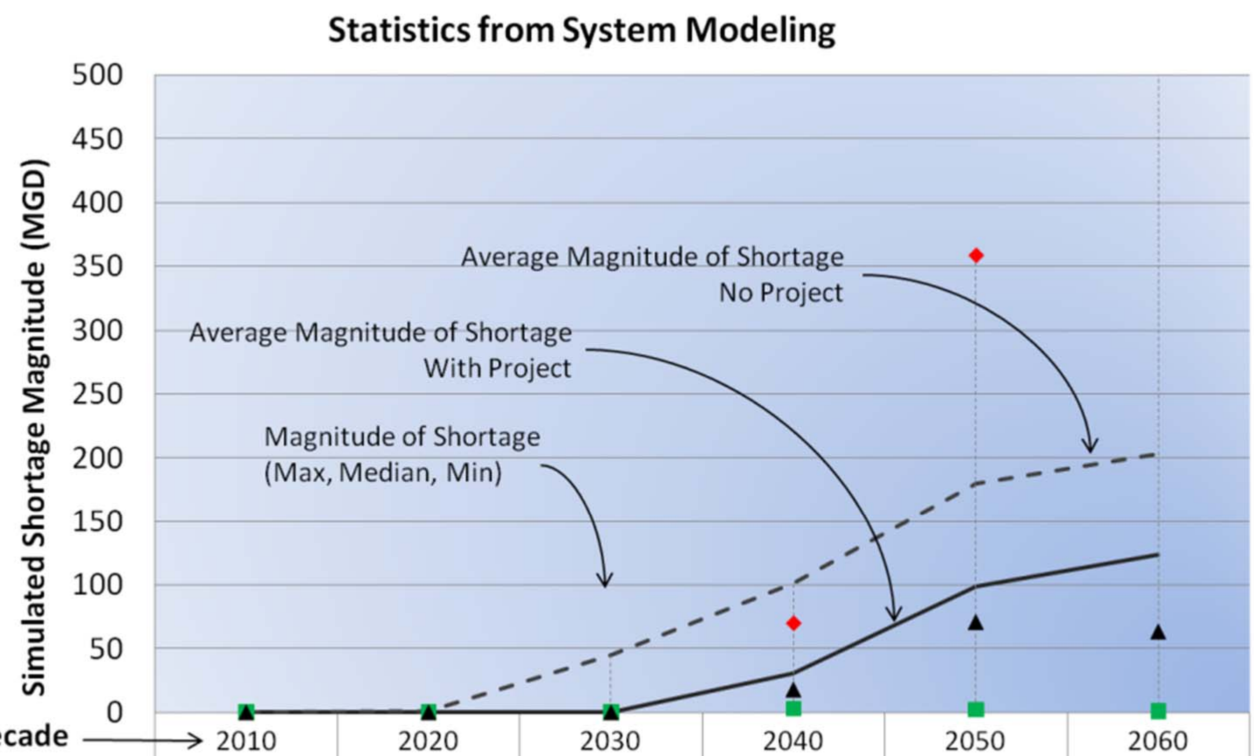
Assumptions:

1. Raising the conservation pool to a flat elevation of 228.64, in conjunction with utilization of 5' of the sediment storage, is a formal reallocation
2. Reallocation exceeds the threshold for the Corps' discretionary authority and would require Congressional approval (Threshold = 50,000 acre feet. See p. 4-11 of Systems Operation report which indicates that a 50,000 acre-foot reallocation is less than what is contemplated in this fact sheet.)
3. Reallocation report and Dam Safety Report could be "bundled" for concurrent approval.
4. Dam Safety "fix" would be sponsor-funded
5. TRWD would negotiate with Texarkana to obtain their water right/storage contract or would enter into a long-term agreement to access water from Texarkana's right/contract
6. TRWD (or Texarkana) would apply for a new water right and Interbasin Transfer for the balance of the reallocation exceeding Texarkana's existing water right.
7. Water right application could run concurrently with development of the Dam Safety/Reallocation Report
8. Detailed design of the dam safety fix and relocations required by the reallocation could run concurrently with the period of Corps/Congressional approval of the Dam Safety/Reallocation action.
9. Conceptual design and planning includes preliminary pipeline route selection for permitting purposes

TASKS	START DATE	DURATION
PLANNING TASKS		
Conceptual Design and Planning	January 2014	1 Year
Reallocation Report	January 2014	3 Years
Dam Safety Report	January 2014	3 Years
NEPA Document	January 2014	3 Years
Water Rights Application/IBT	January 2014	6 Years
Corps Review/Approval	January 2017	1 Year
Congressional Authorization	January 2018	2 Years
Negotiations with Texarkana	January 2014	1.5 Years
404 Permit for Pipeline	January 2018	2 Years
DESIGN TASKS		
Dam Safety Fix	January 2020	1 Year
Relocation Design	January 2020	0.5 Year
Transmission Facilities	July 2018	4.5 Years
Route Selection	July 2018	1.5 Years
Survey and Preliminary Design	January 2020	1.5 Years
Final Design	January 2021	2 Years
Design Mitigation Features	July 2020	1 Year
CONSTRUCTION TASKS		
Dam Safety Fix	July 2020	1 Year
Relocations	July 2020	2 Years
Transmission Facilities	July 2021	8 Years
Easement Acquisition	July 2021	1.5 Years
Bid and Construction Phase	January 2023	6.5 Years
Implement Mitigation	July 2021	1 Year

Wright Patman

Magnitude Chart

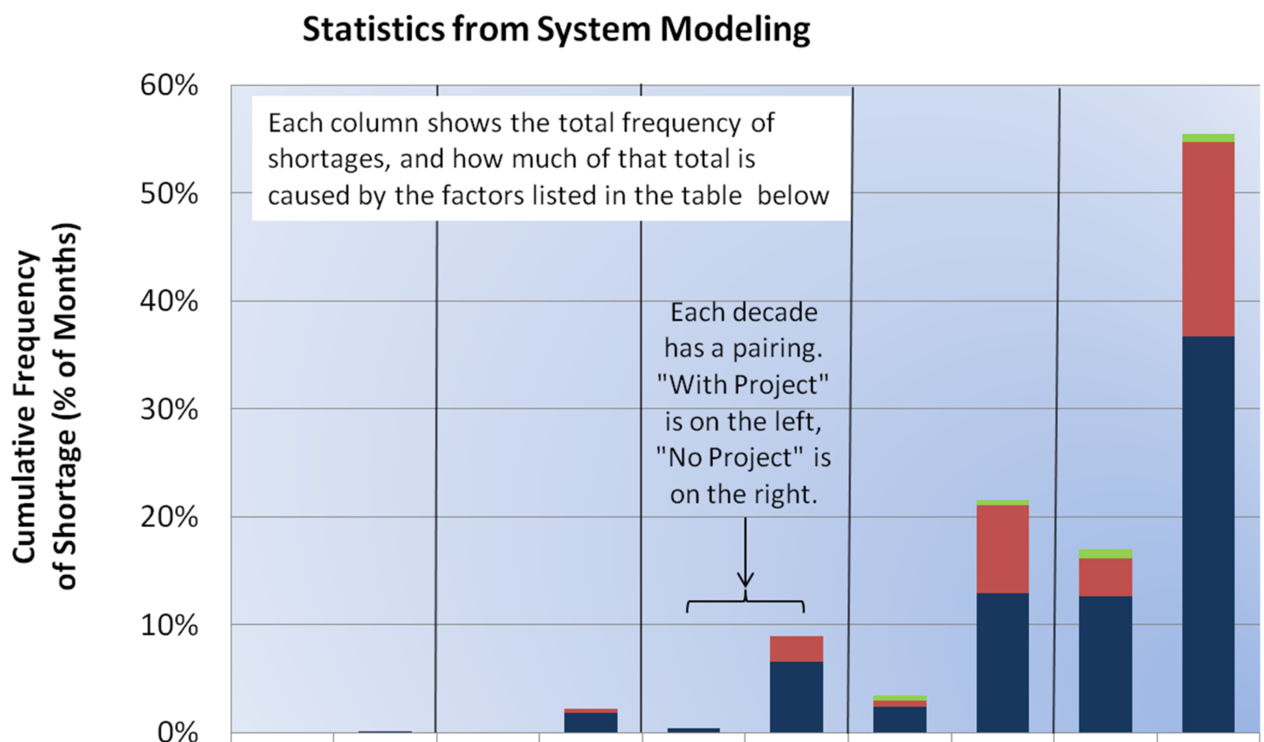


Decade	2010	2020	2030	2040	2050	2060
◆ Maximum	0	0	0	70	359	598
■ Minimum	0	0	0	3	2	1
▲ Median	0	0	0	18	71	64
—— Average	0	0	0	30	99	124
– – Average - No Project	0	1	45	101	180	203

Results Using 2011 Region C Based Demand Projection

Wright Patman

Frequency Chart

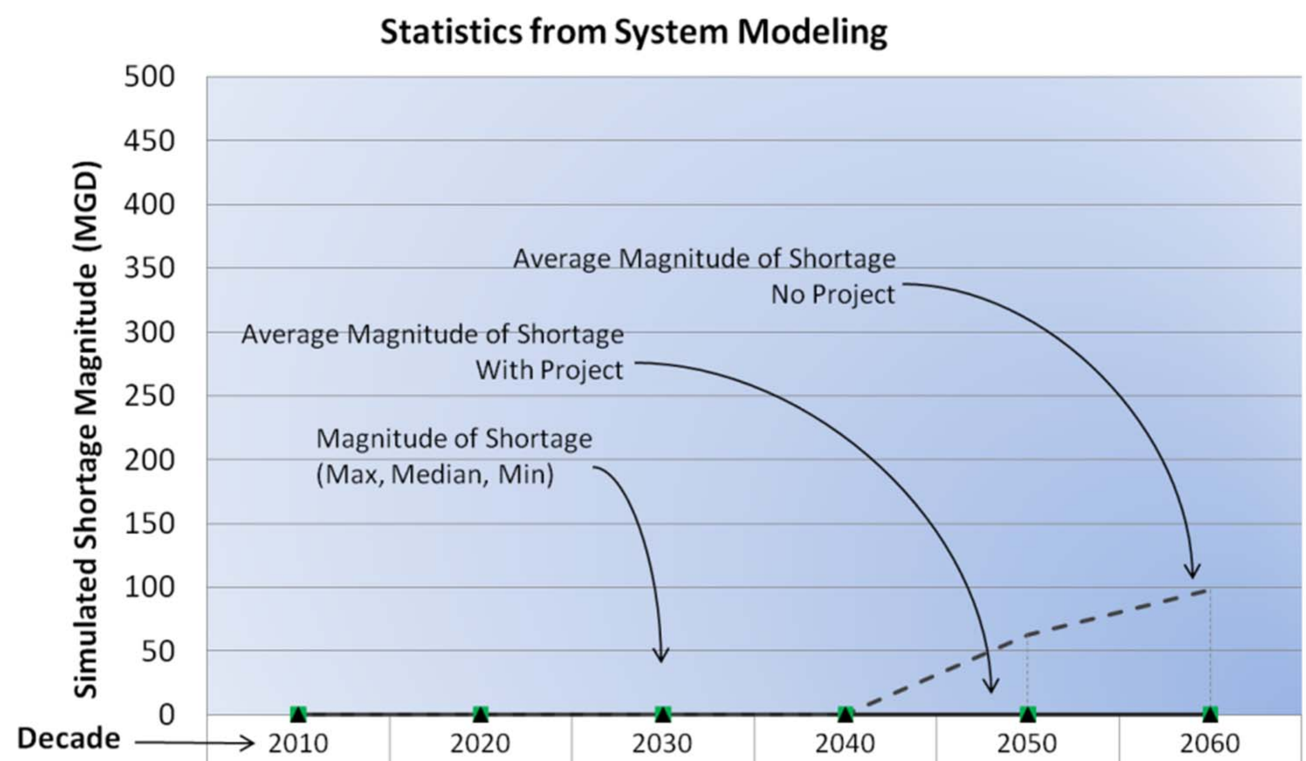


Decades	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.5%		0.7%
Permitted Amount (No Project)		0.0%		0.4%		2.4%		8.1%		18.0%
Pipeline Capacity (No Project)		0.1%		1.8%		6.6%		12.9%		36.7%
Water Levels	0.0%		0.0%		0.0%		0.5%		0.9%	
Permitted Amount	0.0%		0.0%		0.0%		0.6%		3.4%	
Pipeline Capacity	0.0%		0.0%		0.4%		2.4%		12.7%	

Results Using 2011 Region C Based Demand Projection

Wright Patman

Magnitude Chart

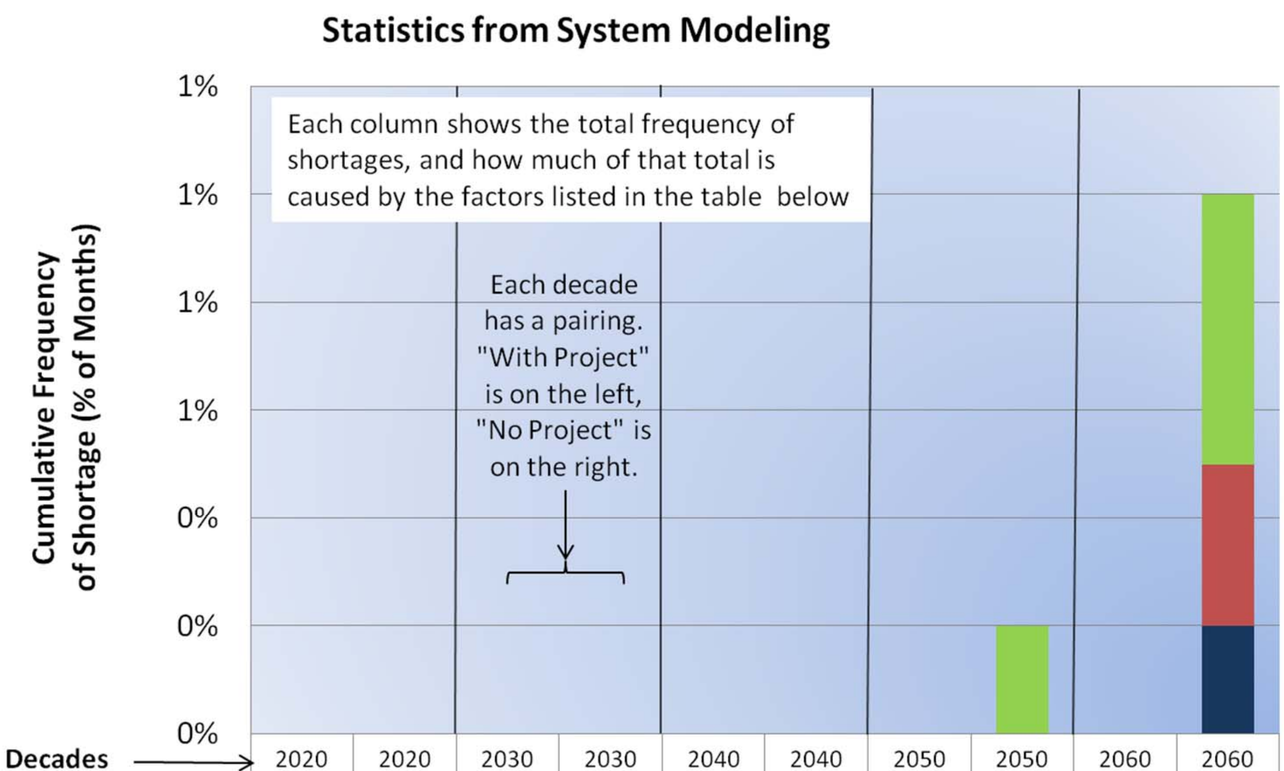


Decade	2010	2020	2030	2040	2050	2060
◆ Maximum	0	0	0	0	0	0
■ Minimum	0	0	0	0	0	0
▲ Median	0	0	0	0	0	0
—— Average	0	0	0	0	0	0
– – Average - No Project	0	0	0	0	63	98

Results Using Recent Trend Extrapolation Demand Projection

Wright Patman

Frequency Chart



	2020	2020	2030	2030	2040	2040	2050	2050	2060	2060
Water Levels (No Project)		0.0%		0.0%		0.0%		0.2%		0.5%
Permitted Amount (No Project)		0.0%		0.0%		0.0%		0.0%		0.3%
Pipeline Capacity (No Project)		0.0%		0.0%		0.0%		0.0%		0.2%
Water Levels	0.0%		0.0%		0.0%		0.0%		0.0%	
Permitted Amount	0.0%		0.0%		0.0%		0.0%		0.0%	
Pipeline Capacity	0.0%		0.0%		0.0%		0.0%		0.0%	

Results Using Recent Trend Extrapolation Demand Projection

Appendix B
Water Demand Projections

Tarrant Regional Water District

Description

This appendix includes a compilation of the different demand projections developed for the Integrated Water Supply Plan (IWSP). Section 3 – *Demand Projections* includes a detailed discussion of the historic and current demand projections developed for the Tarrant Regional Water District (TRWD) service area. A table showing the timeline of historic demands developed for the TRWD service area and the projections are included in this appendix.

The IWSP analysis was completed using two sets of demand projections, the first set based on 2011 *Region C Water Plan* projections and the second set based on an extrapolation of the recent TRWD water use trend. Included in this appendix are tables showing the demand projections at the water treatment plant level.

Table B-1 Historical Demand Projections for Tarrant Regional Water District Service Area[1]

Source	Year	Demand (Acre-feet/year)										
		1960	1970	1980	1990	2000	2010	2020	2030	2040	2050	2060
Report on Water Supply for Fort Worth and Tarrant County	1957	109,858	184,965	265,677	334,058	385,624						
Report on Sources of Additional Water Supply for TCWCID#1	1979			177,118	239,894	294,823	345,268	399,076	451,763			
TCWCID#1 Conservation and Drouth Contingency Plan	1987				239,894	294,823	345,268	399,076	451,763			
TCWCID#1 Regional Water Supply Plan	1990				284,500	371,900	440,700	481,600	537,600	597,700	671,000	
2001 Region C Water Plan	2001					352,437	437,991	494,475	539,095	587,480	619,632	
System Reliability and Enhancement Study	2002					310,077	395,588	452,263	497,015	541,359	570,439	
2006 Region C Water Plan	2006						428,966	518,976	595,992	678,304	779,504	893,510
2011 Region C Water Plan (total/gross demand)	2011						448,806	560,680	657,866	754,210	860,389	985,584
2011 Region C Water Plan (net demand after conservation)	2011						437,350	531,931	615,133	698,831	790,846	898,686

[1]Demands presented in this table represent “Dry Year Demands”

Table B-2 2011 Region C Based Projections, To Be Used in IWSP (in acre-feet/year)[2]

	2010	2015	2020	2025	2030	2040	2050	2060
Holly WTP	61,447	45,497	47,844	49,888	51,948	57,115	63,515	70,993
Eagle Mountain WTP	44,471	73,554	83,993	94,655	105,290	127,097	154,161	186,236
John F. Kubala WTP	40,610	43,305	48,035	49,372	50,710	53,025	53,217	53,819
Pierce Burch WTP	25,317	21,993	23,215	23,853	24,492	25,559	25,442	25,488
Mansfield WTP	11,023	19,517	25,578	29,455	33,331	37,641	40,855	44,069
TRA Mosier Valley	36,606	41,672	41,741	42,905	44,068	44,790	45,388	45,997
Lake Arlington Aggregated (Aggregate of Pierce Burch, TRA Mosier Valley WTPs)[3]	*61,923*	*63,665*	*64,956*	*66,758*	*68,560*	*70,349*	*70,830*	*71,485*
TRA Ellis (Wax/Rockett)	2,421	5,769	9,118	10,945	12,772	18,730	24,880	30,041
TRA Ellis (Midlothian)	0	4,762	9,523	10,507	11,490	13,247	15,192	17,126
TRA Ellis (Ennis)	0	499	998	1,633	2,268	3,507	3,507	4,898
Ellis County Aggregated (Existing Contracts)[3]	*2,421*	*11,030*	*19,639*	*23,085*	*26,530*	*35,484*	*43,579*	*52,065*
Westside WTP	0	13,071	16,548	20,024	23,484	31,354	40,505	51,632
Weatherford	9	2,184	4,358	4,996	5,633	6,827	8,015	9,357
BWSA	3,079	4,403	5,125	5,368	5,610	6,665	7,921	9,394
Southwest WTP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rolling Hills WTP	100,414	122,719	131,351	140,198	149,071	170,185	197,371	230,831
Benbrook Local Use	783	1,165	1,165	1,165	1,165	1,165	1,165	1,165
Worth Local Use	4,175	4,201	4,227	4,213	4,199	4,178	4,171	4,171
Eagle Mountain Local Use	2,921	3,742	4,149	4,662	5,174	6,281	7,459	8,534
Bridgeport Local Use	10,706	23,647	26,526	28,584	30,641	33,859	36,616	39,345
Arlington Local Use	579	621	667	715	768	884	1,017	1,171
Richland Chambers Local Use	4,018	7,014	7,305	7,336	7,367	7,428	7,482	7,544
Cedar Creek Local Use	5,097	6,416	7,390	8,528	11,670	13,302	15,192	17,400
TOTAL	**353,676**	**445,751**	**498,856**	**539,002**	**581,151**	**662,839**	**753,071**	**859,211**

[2]Demands presented in this table represent “Average Year Demands”[3]Demands for Lake Arlington Aggregated and Ellis County Aggregated are sub-totals within the table”

Table B-3 TRWD 'Recent Trend Extrapolation' Demand Projections[2] (in acre-feet/year)

	2010	2015	2020	2025	2030	2040	2050	2060
Holly WTP	54,399	55,488	56,578	54,794	53,011	51,325	50,295	49,706
Eagle Mountain WTP	56,647	64,771	72,894	80,491	88,088	101,546	114,426	126,918
John F. Kubala WTP	42,852	44,272	45,692	46,623	47,555	48,506	49,476	50,466
Pierce Burch WTP	23,074	23,839	24,603	25,105	25,607	26,119	26,641	27,174
Mansfield WTP	11,023	12,858	14,692	15,961	17,229	19,765	22,301	24,837
TRA Mosier Valley	36,606	37,497	38,389	38,642	38,895	39,402	39,908	40,414
Lake Arlington Aggregated (Aggregate of Pierce Burch, TRA Mosier Valley WTPs)[3]	*59,680*	*61,336*	*62,992*	*63,747*	*64,502*	*65,520*	*66,549*	*67,588*
TRA Ellis (Wax/Rockett)	2,405	5,494	8,584	9,881	11,178	15,198	18,368	19,977
TRA Ellis (Midlothian)	0	4,482	8,965	9,510	10,056	10,749	11,216	11,389
TRA Ellis (Ennis)	0	470	940	1,462	1,985	2,846	2,589	3,257
Ellis County Aggregated (Existing Contracts)[3]	*2,405*	*10,446*	*18,488*	*20,853*	*23,218*	*28,793*	*32,172*	*34,623*
Westside WTP	10,811	12,386	13,962	17,483	21,004	27,346	33,227	38,801
Weatherford	9	2,056	4,103	4,516	4,930	5,540	5,917	6,222
BWSA	3,058	3,941	4,825	4,867	4,910	5,408	5,848	6,247
Southwest WTP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rolling Hills WTP	86,917	92,122	97,327	99,728	102,128	107,485	113,223	119,217
Benbrook Local Use	778	937	1,097	1,058	1,020	945	860	775
Worth Local Use	4,147	4,063	3,979	3,827	3,675	3,390	3,079	2,774
Eagle Mountain Local Use	2,901	3,404	3,906	4,217	4,528	5,097	5,507	5,675
Bridgeport Local Use	10,634	17,803	24,971	25,894	26,816	27,474	27,032	26,164
Arlington Local Use	575	602	628	650	672	717	751	779
Richland Chambers Local Use	3,991	5,434	6,877	6,662	6,447	6,027	5,524	5,017
Cedar Creek Local Use	5,063	6,010	6,957	8,585	10,213	10,794	11,216	11,571
Total	**355,889**	**397,929**	**439,968**	**459,957**	**479,945**	**515,679**	**547,402**	**577,379**

[2]Demands presented in this table represent "Average Year Demands"

[3]Demands for Lake Arlington Aggregated and Ellis County Aggregated are sub-totals within the table"

Table B.4 Actual Annual Demands for the TRWD Service Area (Acre-Feet/Year)

Year	Actual Demand (Acre-Feet/Year)
1971	112,270
1972	119,129
1973	103,349
1974	111,251
1975	115,477
1976	129,542
1977	149,464
1978	147,346
1979	159,466
1980	196,579
1981	167,833
1982	170,763
1983	180,150
1984	208,388
1985	209,854
1986	212,478
1987	218,180
1988	227,369
1989	212,022
1990	217,928
1991	215,520

Year	Actual Demand (Acre-Feet/Year)
1992	215,584
1993	236,144
1994	227,316
1995	238,869
1996	260,158
1997	255,708
1998	300,609
1998	300,609
1999	308,174
2000	321,826
2001	310,164
2002	303,077
2003	313,812
2004	299,732
2005	355,968
2006	358,821
2007	299,196
2008	354,671
2009	324,345
2010	346,541
2011	383,944
2012	364,419

Appendix C
User Manual
[Pending]

Appendix D
Cost Analyses

trwd Tarrant Regional Water District

Description

This appendix includes information and assumptions used to develop the cost estimates for the Integrated Water Supply Plan. The appendix is organized into the following sections:

D-1. Cost Parameters Used for the *2011 Region C Water Plan*

D-2. Cost Parameters and Assumptions used for the Integrated Water Supply Plan

D-3. Unit Construction Costs used for the Integrated Water Supply Plan

D-4. Detailed Cost Estimates Developed for the IWSP Study

D-1. Cost Parameters Used for the *2011 Region C Water Plan*

Conveyance Systems

- Wire-to-water pumping efficiency is assumed to be between 72 and 75 percent.
- Peaking factor of 2 times the average demand is to be used for strategies when the water is pumped directly to a water treatment plant. (or historical peaking factor, if available)
- Peaking factor of 1.2 to 1.5 is to be used if there are additional water sources and/or the water is transported to a terminal storage facility.
- Ground storage is to be provided at each booster pump station along the transmission line unless there is a more detailed design.
- Ground storage tanks should provide sufficient storage for 2.5 to 4 hours of pumping at peak capacity.
- When a pipeline discharges into a reservoir or river, use project-specific discharge structure costs if available. If no project-specific information is available, estimated discharge structure unit costs will be used.

Other Costs

- Engineering, contingency, construction management, financial and legal costs are to be estimated at 30 percent of construction cost for pipelines and 35 percent of construction costs for pump stations, treatment facilities and reservoir projects. (TWDB Guidelines)
- Permitting and mitigation for transmission and treatment projects are to be estimated at 1 percent of the total construction costs. For reservoirs, mitigation and permitting costs are assumed equal to twice the land purchase cost, unless site specific data is available.

Annual Costs

- Debt service for all transmission and treatment facilities is to be annualized over 30 years, but not longer than the life of the project. Debt service for reservoirs is to be annualized over 30 years. [Note: uniform amortization periods should be used when evaluating similar projects for an entity.]
- Annual interest rate for debt service is 6 percent.
- Water purchase costs are to be based on wholesale rates reported by the selling entity when possible. In lieu of known rates, a typical regional cost for treated water and raw water will be developed.
- Operation and Maintenance costs are to be calculated based on the construction cost of the capital improvement. Engineering, permitting, etc. should not be included as a basis for this calculation. However, a 20% allowance for construction contingencies should be included for all O&M calculations. Per the "General Guidelines for Regional Water Plan Development (2007-2012)", O&M should be calculated at:
  - 1 percent of the construction costs for pipelines
  - 1.5 percent for dams
  - 2.5 percent of the construction costs for pump stations, storage tanks, meters and SCADA systems
  - Assume O&M costs for treatment facilities are included in the treatment cost
- Pumping costs are to be estimated using an electricity rate of $0.09 per Kilowatt Hour.

Interest during construction is the total of interest accrued at the end of the construction period using a 6 percent annual interest rate on total borrowed funds, less a 4 percent rate of return on investment of unspent funds. This is calculated assuming that the total estimated project cost (excluding interest during construction) would be drawn down at a constant rate per month during the construction period. Factors were determined for different lengths of time for project construction.

D-2. Cost Parameters and Assumptions used for the Integrated Water Supply Plan

As part of Tarrant Regional Water District's (TRWD) Integrated Water Supply Plan (IWSP), capital cost estimates were developed for selected potential future water supply strategies. As part of the development of the capital and annual costs, a spreadsheet (herein referred to as "costing model") was developed with the costs and hydraulic calculations used to develop the costs. This memorandum is a summary of the methodologies and assumptions used in the costing model. Note that the costing methodology used is consistent with the Texas Water Development Board's (TWDB) regional planning guidelines for Region C so that the costs developed in this study can be compared with costs from the *2011 Region C Water Plan*.

Hydraulic Calculations

Hydraulic calculations were performed to size the transmission facilities for each strategy and determine annual energy costs. Planning level pipeline alignments were developed in GIS to obtain ground profile information. The ground profiles were then used to develop hydraulic grade lines.

To size the pump stations and associated facilities, the follow assumptions were made:

- Peaking factor of 1.5 for strategies with multiple partners; peaking factor of 1.25 for TRWD only strategies, with the exception of the Texoma strategy[1].
- Pump station “wire to water” efficiency of 0.72.
- Storage at each booster pump station in an earthen reservoir or open ground storage tank with a capacity of 0.25 times the average daily flow.
- A 35,000 horsepower intake pump station at Eagle Mountain Lake for pumping southward through the Eagle Mountain Connection pipeline was included for all strategies delivering into the TRWD system at Lake Bridgeport. The pump station was sized based on the maximum capacity of the existing Eagle Mountain Connection pipeline operating in “reverse flow” from north to south.

The following assumptions were used to size the pipelines:

- Headloss at average flow (annual yield) of no more than 0.8 feet per thousand feet of pipe length, with the exception of the Columbia strategy.
- Hazen Williams C factor of 120.

Exceptions to the Above Assumptions

The hydraulic calculations that use the Integrated Pipeline (IPL) and the Lake Texoma strategy deviate from the above assumptions as discussed below.

For strategies in which the water is transported to Benbrook Lake through the IPL, the IPL hydraulics provided by TRWD were used for the cost calculations. The IPL operations with and without the flows from the new strategy were compared to determine the difference in pumping costs with the additional flows. This difference in cost was used to calculate the annual electricity costs for both strategies.

[1] See a detailed discussion in “Exceptions to the Above Assumptions.”

For the Columbia strategy, there are certain pipeline sections where the headloss at average flow (annual yield) exceeds 0.8 feet per thousand feet of pipe length because the hydraulics were matched to the IPL hydraulics and the Toledo Bend hydraulics. This was done because it was assumed the Columbia water will be transmitted through some sections of the existing TRWD pipelines.

The Lake Texoma transmission system was sized such that the unit cost of delivering Lake Texoma water is equivalent to the cost of delivering water from Toledo Bend. Yield from Lake Texoma will be blended with Lake Bridgeport water at a 10:1 ratio, making the annual supply from Texoma highly variable because it depends on the amount of water supply in Lake Bridgeport. Thus, the annual and peak flows used for the cost estimate were determined through an iterative process that made the unit cost during amortization match the cost of water from Toledo Bend. The peaking factor was back calculated based on the flows determined through the iterations. It should be noted that although Lake Texoma water cannot currently be transmitted directly to other reservoirs across state lines due to the presence of zebra mussels in Lake Texoma, this strategy assumes that conditions change, allowing the transfer of water between reservoirs.

Costing Methodology

The costing methodology used is consistent with the Texas Water Development Board's (TWDB) regional planning guidelines for Region C so that the costs developed in this study can be compared with the costs from the *2011 Region C Water Plan*.

Capital Costs

The unit costs for the transmission facilities were taken from the TWDB's Costing Tool, developed in 2012, unless more detailed costs were available. Below is a summary of the costs where more detailed costs were available and the TWDB unit costs were not used. All unit costs were indexed to March 2012 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.

Table D-1: Strategies Using Unit Costs Different from TWDB Costing Tool

Strategy	Facility	Source of Information
RC-CC through IPL	IPL Pipelines and Pump Stations	TRWD
Columbia	IPL Pipelines and Pump Stations	TRWD
Kiamichi	Intake at OCSF, Channel Dam, ROR Intake and Pump Station	*Evaluation of Water Supply Alternatives for the Kiamichi River, Cache Creek, and Beaver Creek*, Dec. 2010
Marvin Nichols	Dam and Reservoir	2005 Site Protection Study
Wright Patman	Raw Water Improvements (e.g. storage purchase, relocation costs, NEPA evaluation, etc.)	USACE
Columbia	Dam and Reservoir	2011 Region I Water Plan
Tehuacana	Dam and Reservoir	2011 Region C Water Plan

Tehuacana	IPL Pipelines and Pump Stations	TRWD
Temple	Dam and Reservoir	Technical Memorandum: *Southwest Oklahoma - Preliminary Cost Estimate for Temple Reservoir and Four Water Supply Options*, Feb 2012
Ringgold	Dam and Reservoir	2005 Site Protection Study

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

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

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

- Pipeline right-of-way costs are given in Table 2.

Table D-2: Unit Costs for Pipeline Right-of-Ways

	Cost per Linear Foot		
	Rural County	Suburban County	Urban County
60' Easement (Single Pipe)	$15.2	$36.8	$89.9
100' Easement (Parallel Pipes)	$24.9	$62.8	$149.5

- Engineering and contingencies are assumed to be 35% of pump station and reservoir construction costs and 30% of pipeline construction costs.
- Permitting and mitigation for transmission facilities are assumed to be 1 percent of the total construction cost. However, a 20% allowance for construction contingencies was included for permitting. For reservoirs, mitigation and permitting costs are assumed equal to twice the land purchase cost, unless site specific data was available.

Annual Costs

- Debt service for all transmission and reservoir facilities was annualized over 30 years.
- Annual interest rate for debt service is six percent.
- Where applicable, water purchase costs were assumed to be $0.10 per 1,000 gallons.

- Electricity costs were assumed to be $0.09 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. O&M costs were calculated as follows:
    - 1 percent of the construction costs for pipelines
    - 1.5 percent of the construction costs for dams
    - 2.5 percent of the construction costs for pump stations and storage tanks

Costing model structure

The costs and hydraulic calculations are included in the costing model. The costing model includes an index sheet that contains links to other sheets in the file. Data should be entered in the "Data Input" sheet. Data included in this sheet consists of supply yields, peaking factors, potential project participants, energy costs, raw water costs, debt repayment periods, and debt service. The cost and hydraulic sheets for all strategies are linked to the "data input" so that changes made to this sheet will be applied to respective strategies.

Items to Check If Changes Are Made on the "Data Input" Tab

The hydraulic calculations in the costing model were not automated, so if changes are made to certain information on the Data Input tab some hydraulic calculations need to be checked. Below is a summary of those items.

- If changes are made to the project yield, check that:
    - The headloss at average flow is not greater than 0.8 feet per thousand feet of pipeline.
    - The peak velocity is less than 9 feet per second.
    - The desired pipe pressure class is not exceeded.
    - Intermediate high points are accounted for.
    - The maximum pump station discharge pressure is less than 250 psi.
    - The text boxes on the HGL plot are updated appropriately.
- If changes are made to the peaking factor, check that:
    - The peak velocity is less than 9 feet per second.
    - The desired pipe pressure class is not exceeded.
    - The text boxes on the HGL plot are updated appropriately.

Other Changes

If the pipeline alignments change, the data on the profile sheets in the costing model will need to be updated using GIS or similar methods.

D-3. Unit Construction Costs used for the Integrated Water Supply Plan

The unit construction costs used in the IWSP study are tabulated in this section. All costs are indexed at March, 2012 dollars. Tables D-3.1 to D-3.8 include information for interest rates, price indices, easement costs, reservoir costs, tank costs, pump station costs, and pipeline costs.

Table D-3.1: Interest Rates used in IWSP Cost Analysis

Construction Period	Factor
6 months	0.02167
12 months	0.04167
18 months	0.06167
24 months	0.08167
36 month construction	0.12167
48 month construction	0.16167
60 month construction	0.20167
72 month construction	0.24167
84 month construction	0.28167

Table D-3.2: Price Indices used in IWSP Cost Analysis

Price Index	Type	Date	Value	Comments
PPI Index*	A	Mar-02	137.9	2002: Date for 2006 Region C Water Plan Cost Estimates
PPI Index*	B	Mar-12	215.8	
CCI Index**	A	Sep-05	7518	2005: Date for Site Protection Study Cost Estimates
CCI Index**	A	Sep-08	8557	2008: Date for Kiamichi OCSF from TRWD reports and 2011 Regional Plan Costs
CCI Index**	A	Jun-05	7415	June 2005: Date of Eagle Mountain Connection Costs
CCI Index**	A	Jun-11	9053	2011: Cost for Temple Reservoir from TRWD reports
CCI Index**	B	Mar-12	9267.57	

*Producer Price Index (PPI) - This index is to be used for pipelines. Go to Bls.gov/ppi
**Construction Cost Index (CCI) - This index is to be used for reservoirs, tanks, pump station, water treatment plants and wells. Go to ENR.com

Table D-3.3: Easement Costs used in IWSP Cost Analysis

Pipeline Diameter (inches)	Cost per Linear Foot (Indexed to March, 2012 Dollars)			
	Rural County	Suburban County	Urban County	Highly Urbanized Area
60' Easement (single pipe)	$15.16	$36.82	$89.9	Evaluate on a case-by-case basis
100' Easement (Parallel Pipes)	$24.91	$62.82	$149.46	

Table D-3.4: Cost for Discharge Structures used in IWSP Cost Analysis

Discharge Capacity (MGD)	Cost (Indexed to March, 2012 Dollars
0.5	$46,000
1	$47,000
2	$53,000
5	$61,000
10	$77,000
60	$200,000
80	$356,000
120	$713,000
191	$1,563,000
250	$3,125,000
268	$3,561,000
379	$5,400,000

Table D-3.5: Cost for Terminal Storage Reservoirs used in IWSP Cost Analysis

Terminal Storage Reservoirs		
Storage (ac-ft)	Storage (MG)	Cost (Indexed to March 2012 $)
50	16.3	$4,285,000
100	32.6	$7,146,000
200	65.2	$12,383,000

300	97.8	$16,969,000
400	130.4	$20,900,000
500	163	$24,182,000

Table D-3.6: Cost for Ground Storage Tanks used in IWSP Cost Analysis

Ground Storage Tanks (Cost Indexed to March 2012 Dollars)		
Size (MG)	Cost With Roof	Cost Without Roof
0.05	$247,000	$115,000
0.1	$267,000	$169,000
0.5	$570,000	$363,000
1	$966,000	$600,000
1.5	$1,338,000	$654,000
2	$1,710,000	$780,000
2.5	$1,853,000	$895,000
3	$1,996,000	$1,010,000
3.5	$2,281,000	$1,120,000
4	$2,566,000	$1,230,000
5	$2,851,000	$1,420,000
6	$3,278,000	$1,700,000
7	$3,849,000	$1,950,000
8	$4,419,000	$2,300,000
10	$5,529,000	$2,980,000
12	$6,911,000	$3,800,000
14	$8,327,000	$4,600,000

Table D-3.7: Cost for Pump Stations used in IWSP Cost Analysis

Costs Indexed to March, 2012 Dollars		
Horsepower	Booster Pump Station Costs	Intake Pump Station Costs
5	$752,000	
10	$847,000	
20	$921,000	
25	$998,000	
50	$1,075,000	

100	$1,228,000	
200	$1,962,000	$2,500,000
300	$2,209,000	$3,250,000
400	$2,691,000	$4,000,000
500	$2,989,000	$4,625,000
600	$3,536,000	$5,625,000
700	$4,084,000	$6,625,000
800	$4,910,000	$7,500,000
900	$5,493,000	$8,375,000
1,000	$6,075,000	$9,500,000
2,000	$7,401,000	$12,050,000
3,000	$8,726,000	$13,775,000
4,000	$10,551,000	$16,000,000
5,000	$12,876,000	$18,500,000
6,000	$15,702,000	$21,500,000
7,000	$18,527,000	$24,250,000
8,000	$21,352,000	$27,000,000
9,000	$24,177,000	$29,750,000
10,000	$29,000,000	$35,000,000
20,000	$38,004,000	$43,500,000
30,000	$43,855,000	$52,750,000
40,000	$51,506,000	$62,750,000
50,000	$60,507,000	$72,000,000
60,000	$69,508,000	$81,250,000
70,000	$78,508,000	$90,250,000
80,000	$87,508,000	$99,250,000
90,000	$96,508,000	$108,250,000
100,000	$105,508,000	$117,250,000

Table D-3.8: Cost for Pipelines used in IWSP Cost Analysis

Diameter	Rural Cost with Appurtenances - Soil	Rural Cost with Appurtenances - Rock	Rural Cost with Appurtenances - Average of Rock and Soil	Urban Cost with Appurtenances - Soil	Urban Cost with Appurtenances - Rock	Urban Cost with Appurtenances - Average of Rock and Soil
(inches)	($/Foot)	($/Foot)	($/Foot)	($/Foot)	($/Foot)	($/Foot)
6	$18	$22	$20	$25	$30	$28
8	$28	$34	$31	$39	$47	$43
10	$31	$38	$35	$44	$53	$49
12	$35	$41	$38	$48	$58	$53
14	$46	$55	$51	$64	$77	$71
16	$57	$68	$63	$80	$96	$88
18	$68	$82	$75	$96	$115	$106
20	$80	$95	$88	$111	$134	$123
24	$102	$122	$112	$143	$171	$157
30	$136	$163	$150	$190	$228	$209
36	$169	$203	$186	$237	$285	$261
42	$203	$244	$224	$284	$341	$313
48	$237	$284	$261	$332	$398	$365
54	$271	$325	$298	$379	$454	$417
60	$304	$365	$335	$426	$511	$469
66	$356	$427	$392	$498	$598	$548
72	$416	$500	$458	$583	$700	$642
78	$487	$585	$536	$682	$819	$751
84	$570	$684	$627	$798	$958	$878
90	$667	$800	$734	$934	$1,121	$1,028
96	$767	$921	$844	$1,074	$1,289	$1,182
102	$859	$1,031	$945	$1,203	$1,443	$1,323
108	$945	$1,134	$1,040	$1,323	$1,588	$1,456
114	$1,040	$1,247	$1,144	$1,455	$1,746	$1,601
120	$1,144	$1,372	$1,258	$1,601	$1,921	$1,761
132	$1,315	$1,578	$1,447	$1,841	$2,209	$2,025
144	$1,512	$1,815	$1,664	$2,117	$2,541	$2,329

D-4. Detailed Cost Estimates Developed for the IWSP Study

This section includes a compilation of the detailed cost estimates that were developed for the water supply strategies analyzed in the IWSP study. The costing methodology used is consistent with the Texas Water Development Board's (TWDB) regional planning guidelines that were used for Region C, so that the costs developed in this study can be compared with the costs from the *2011 Region C Water Plan*. Details of the cost basis and cost assumptions used for this analysis are included in Sections D-2 and D-3 of this appendix. The cost estimates included in this section were obtained from the "Costing Model", a spreadsheet tool used for developing IWSP costs and hydraulic calculations.

This appendix contains individual cost estimates for the following strategies:

- Lake Columbia
- Kiamichi River
- Marvin Nichols Reservoir
- Lake Ringgold
- Temple Reservoir
- Lake Texoma
- Toledo Bend Reservoir
- Lake Wright Patman

Cost estimates for the Conservation and EXFLO strategies were not developed and hence not included. The cost estimates for strategies delivered through Integrated Pipeline (IPL) and a proposed new pipeline parallel to IPL were developed for multiple combinations in which they could be delivered. The strategies with combined cost estimates are as follows:

- Unpermitted Firm Yield in Cedar Creek (CC) and Richland-Chambers (RC) Reservoirs
- Cedar Creek and Richland-Chambers Reservoirs Constructed Wetlands Full Yield Permits
- Lake Tehuacana

Cost estimates were developed for the following combinations of the three strategies listed above.

- Unpermitted RC & CC Firm Yield through IPL
- Unpermitted RC & CC Firm Yield through New Pipeline
- Unpermitted RC & CC wetlands through IPL

- Unpermitted RC & CC wetlands through new pipeline
- Tehuacana through IPL
- Tehuacana through new pipeline
- Unpermitted RC & CC Firm Yield + Tehuacana though new pipeline
- Unpermitted RC & CC Wetlands + Tehuacana though new pipeline
- Unpermitted RC & CC Wetlands + Firm Yield though new pipeline
- Unpermitted RC & CC Wetlands + Firm Yield + Tehuacana though new pipeline
- Unpermitted RC & CC Wetlands + Firm Yield though IPL

One of the branches of the decision tree includes potential implementation of Toledo Bend strategy and Tehuacana strategy. If these strategies are selected as TRWD's proposed supply sources, the infrastructure for the strategies will be developed jointly. A separate cost estimate was developed for this option. J.16 includes the detailed cost breakdown for this combination.

Each cost estimate includes a detailed breakdown of the construction and transmission facilities costs, annual costs, and unit costs.

D-4.1 Lake Columbia

Lake Columbia to Benbrook Lake

Probable Owner:	**TRWD**	**40,188**	**Acre-Feet per Year**		
Peak Delivery:		**45**	**MGD**	Peaking Factor =	1.25

CONSTRUCTION COSTS

DAM	**Cost**
Embankment	$29,348,085
Internal Drainage	$622,768
Soil Cement Slope Protection	$3,348,868
Service Spillway	$6,126,956
Outlet Works	$1,262,866
Misc. Items	$5,382,883
Subtotal	*$46,092,425*
Engineering and Contingencies (35%)	$16,132,000
Geotechnical Investigations	$633,599
Subtotal for Dam	**$62,858,024**
Conflicts	
Communications	$2,557,140
Electric Utilities	$15,688,342
Oil & Gas	$3,975,969
Water Utilities	$167,877
State and County Roads	$38,063,590
Railroad	$29,902,619
Road and Railroad Erosion Protection	$4,352,879
Subtotal	*$94,708,415*
Engineering and Contingencies (35%)	$33,148,000
Subtotal of Conflicts	**$127,856,415**
Land	
Land and Easement Purchase	$25,447,932
Survey, Appraisal, Legal costs	$2,819,244
Subtotal	*$28,267,176*
Contingencies (20%)	$564,000
Subtotal for Land	**$28,831,176**
Mitigation	
Archeological/Historical Resources	$11,941,986
Aquatic/Terrestrial Resources	$17,908,646
Subtotal for Mitigation	**$29,850,632**
Total Reservoir Construction Cost	**$249,396,247**
TRWD's Portion of the Reservoir Construction Cost (47%; other 53% of yield is for inbasin use)	**$117,216,236**

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Lake Columbia to Lake Palestine					
Pipeline (Rural)	54 in	119,713	LF	$298	$35,674,429
ROW Easements (Rural)		119,713	LF	$15	$1,815,212
Permitting and Mitigation					$428,000
Engineering and Contingencies (30%)					$10,702,000
Subtotal of Pipeline					**$48,619,641**
Pump Station(s)	**Size**	**Quantity**	**Unit**		
Intake Pump Station at Lake Columbia	4200 HP	1	LS	$16,500,000	$16,500,000
Booster Pump Station	2500 HP	1	LS	$8,064,000	$8,064,000
Open Storage Tank at Booster Pump Station	9 MG	1	LS	$2,627,000	$2,627,000
Upsize BPS on Toledo Bend PL	40900 HP	1	LS	$6,319,000	$6,319,000

Upsize BPS on Toledo Bend PL	48200 HP	1	LS	$5,851,000	$5,851,000
Upsize BPS on Toledo Bend PL	16000 HP	1	LS	$4,231,000	$4,231,000
Permitting and Mitigation					$523,000
Engineering and Contingencies (35%)					$13,078,000
Subtotal of Pump Stations					**$57,193,000**
TRWD CONSTRUCTION TOTAL					**$223,029,000**
Interest During Construction	**(36 months)**				**$27,136,000**
TRWD TOTAL COST					**$250,165,000**
ANNUAL COSTS					
Debt Service (6% for 30 years)					$18,174,000
Electricity ($0.09 per kWh)					$9,456,000
Operation & Maintenance					$2,566,000
Raw Water Purchase ($0.10/1,000 gal)					$1,309,500
Total Annual Costs					**$31,505,500**
UNIT COSTS (Until Amortized)					
Per Acre-Foot					$784
Per 1,000 Gallons					$2.41
UNIT COSTS (After Amortization)					
Per Acre-Foot					$332
Per 1,000 Gallons					$1.02

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.2 Kiamichi River

Kiamichi River, Eastern Oklahoma to Lake Bridgeport
North Texas MWD, Tarrant Regional WD, and Dallas Water Utilities

Total Yield =	310,000	acre-feet per year				Peaking Factor = 1.5
		NTMWD	77,500	AF/Y	25.0 %	
		TRWD	155,000	AF/Y	50.0 %	
		DWU	77,500	AF/Y	25.0 %	
		Total	310,000	AF/Y		

CONSTRUCTION COSTS					
STORAGE AND DIVERSION FACILITIES	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Run-of-River Intake and Pump Station	46630 HP	1	LS	$208,594,000	$208,594,000
Channel Dam		1	LS	$8,665,000	$8,665,000
Engineering and Contingencies (35%)					$76,041,000
Permitting & Mitigation					$2,607,000
Subtotal of Diversion Facilities					**$295,907,000**
Off-Channel Storage Facility (OCSF)	80000 Ac-Ft	1	LS	$20,037,000	$20,037,000
Total of Storage and Diversion Facilities					**$315,944,000**
NTMWD Portion of OCSF	*25%*				*$78,986,000*
TRWD Portion of OCSF	*50%*				*$157,972,000*
DWU Portion of OCSF	*25%*				*$78,986,000*
Total Check					*$315,944,000*
TRANSMISSION FACILITIES*					
Pipeline	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Segment 1 - Kiamichi River to OCSF					
Pipeline Rural	144 in	10,560	LF	$1,664	$35,133,000
Right of Way Easement Rural (ROW)		10,560	LF	$15	$320,000
Engineering and Contingencies (30%)					$10,540,000
Permitting and Mitigation					$422,000
Subtotal of Segment 1					**$46,415,000**
Segment 2 - Kiamichi to Lower Bois D'Arc					
Pipeline Rural	120 in	278,120	LF	$1,258	$349,874,000
Pipeline Urban	120 in	26,580	LF	$1,761	$46,808,000
Right of Way Easements Rural (ROW)		278,120	LF	$15	$4,217,000
Right of Way Easements Urban (ROW)		26,580	LF	$37	$979,000
Engineering and Contingencies (30%)					$119,005,000
Permitting & Mitigation					$4,760,000
Subtotal of Pipeline Segment 2					**$525,643,000**
Segment 3 - Lower Bois D'Arc to Ray Roberts					
Pipeline Rural	108 in	296,902	LF	$1,040	$308,630,000
Pipeline Urban	108 in	17,698	LF	$1,456	$25,760,000
Right of Way Easements Rural (ROW)		296,902	LF	$15	$4,502,000
Right of Way Easements Urban (ROW)		17,698	LF	$37	$652,000
Engineering and Contingencies (30%)					$100,317,000
Permitting & Mitigation					$4,013,000
Subtotal of Pipeline Segment 3					**$443,874,000**
Segment 4 - Ray Roberts to Bridgeport					
Discharge Structure at Lake Bridgeport	207 MGD	1	LS	$1,997,000	$1,997,000
Pipeline Rural	90 in	332,394	LF	$734	$243,811,000
Pipeline Urban	90 in	19,341	LF	$1,028	$19,873,000
Right of Way Easements Rural (ROW)		332,394	LF	$15	$5,040,000
Right of Way Easements Urban (ROW)		19,341	LF	$47	$918,000
Engineering and Contingencies (30%)					$79,704,000
Permitting & Mitigation					$3,188,000

Subtotal of Pipeline Segment 4					**$354,531,000**
Total Pipeline Cost					**$1,370,463,000**
NTMWD Portion of Pipeline	*25% (Segment 1 & 2)*				*$143,015,000*
TRWD Portion of Pipeline	*50% (Segment 1 & 2) & 66.67% (Segment 3) & 100% (Segment 4)*				*$936,490,000*
DWU Portion of Pipeline	*25% (Segment 1 & 2) & 33.33% (Segment 3)*				*$290,958,000*
Total Check					*$1,370,463,000*

Pump Station(s)	**Size (per PS)**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Intake Pump Station at Eagle Mountain Lake	35000 HP	1	LS	$57,750,000	$57,750,000
Intake Pump Station at Kiamichi OCSF	50000 HP	1	LS	$209,074,000	$209,074,000
Booster Pump Station 1	38840 HP	1	LS	$50,618,000	$50,618,000
Booster Pump Station 2	29200 HP	1	LS	$43,387,000	$43,387,000
Booster Pump Station 3	25200 HP	1	LS	$41,047,000	$41,047,000
Storage Reservoir at booster station 1	69 MG	1	EA	$12,937,000	$12,937,000
Storage Reservoir at booster station 2	52 MG	1	EA	$10,239,000	$10,239,000
Storage Reservoir at booster station 3	35 MG	1	EA	$7,462,000	$7,462,000
Engineering and Contingencies (35%)					$151,380,000
Permitting & Mitigation					$5,190,000
Subtotal of Pump Station(s)					**$589,084,000**

Total Pump Station Costs (Including Storage Reservoirs)		**$589,084,000**
NTMWD	*25% (BPS and Storage 1 & Kiamichi Intake)*	*$92,830,000*
TRWD	*50% (BPS and Storage 1 & Kiamichi Intake) & 66.67% (BPS and Storage 2) & 100% (BPS and Storage 3 & Eagle Mtn. Intake)*	*$379,080,000*
DWU	*25% (BPS and Storage 1 & Kiamichi Intake) & 33.33% (BPS and Storage 2)*	*$117,174,000*
Total Check		*$589,084,000*

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

CONSTRUCTION TOTAL		**$2,275,491,000**
Interest During Construction	**(72 months - pipeline)** **(36 months - OCSF)**	**$512,005,000**
TOTAL COST		**$2,787,496,000**
NTMWD		*$381,438,000*
TRWD		*$1,810,696,000*
DWU		*$595,362,000*
Total Check		*$2,787,496,000*

TOTAL COST ANALYSIS	
NTMWD	**Cost**
Debt Service (6% for 30 years)	$27,711,000
Electricity ($0.09 kWh)	$6,032,000
Operation & Maintenance	$2,829,000
Total Annual Costs (NTMWD)	**$36,572,000**
TRWD	
Debt Service (6% for 30 years)	$131,545,000
Electricity ($0.09 kWh)	$23,762,000
Operation & Maintenance	$20,113,000
Total Annual Costs (TRWD)	**$175,420,000**
DWU	
Debt Service (6% for 30 years)	$43,252,000
Electricity ($0.09 kWh)	$8,086,000
Operation & Maintenance	$6,868,000
Total Annual Costs (DWU)	**$58,206,000**

TOTAL ANNUAL

Debt Service (6% for 30 years)	$202,508,000
Electricity ($0.09 per kWh)	$37,880,000
Operation & Maintenance	$29,810,000
Total Annual Costs (All Users)	**$270,198,000**
UNIT COSTS (During Amortization)	
NTMWD	
Per Acre-Foot	$472
Per 1,000 Gallons	$1.45
TRWD	
Per Acre-Foot	$1,132
Per 1,000 Gallons	$3.47
DWU	
Per Acre-Foot	$751
Per 1,000 Gallons	$2.30
Total All Users	
Per Acre-Foot	$872
Per 1,000 Gallons	$2.67
ANNUAL COSTS (After Amortization)	
NTMWD	**Cost**
Electricity ($0.09 kWh)	$6,032,000
Operation & Maintenance	$2,829,000
Total Annual Costs (NTMWD)	**$8,861,000**
TRWD	
Electricity ($0.09 kWh)	$23,762,000
Operation & Maintenance	$20,113,000
Total Annual Costs (TRWD)	**$43,875,000**
DWU	
Electricity ($0.09 kWh)	$8,086,000
Operation & Maintenance	$6,868,000
Total Annual Costs (DWU)	**$14,954,000**
Total All Users	
Electricity ($0.09 kWh)	$37,880,000
Operation & Maintenance	$29,810,000
Total Annual Costs (All Users)	**$67,690,000**
UNIT COSTS (After Amortization)	
NTMWD	
Per Acre-Foot	$114
Per 1,000 Gallons	$0.35
TRWD	
Per Acre-Foot	$283
Per 1,000 Gallons	$0.87
DWU	
Per Acre-Foot	$193
Per 1,000 Gallons	$0.59
All Users	
Per Acre-Foot	$218
Per 1,000 Gallons	$0.67

D-4.3 Marvin Nichols Reservoir

Marvin Nichols IA Reservoir and Transmission System to Bridgeport

North Texas MWD, Tarrant Regional WD, Dallas Water Utilities, Irving, Upper Trinity RWD, Local Users

Peaking Factor = 1.5

					Region C Portion
Probable Owner:	NTMWD	142,850	AF/Y	23.3%	29.2%
	TRWD	142,850	AF/Y	23.3%	29.2%
	Dallas	142,850	AF/Y	23.3%	29.2%
	Irving	26,451	AF/Y	4.3%	5.4%
	Upper Trinity RWD	34,779	AF/Y	5.7%	7.1%
	Local Users	122,521	AF/Y	20.0%	
	Total	612,300	AF/Y		

CONSTRUCTION COSTS

DAM & RESERVOIR	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Land Purchase Costs		77,427	AC	$1,479	$114,530,000
Mobilization		1	LS	$9,311,000	$9,311,000
Spillway Construction					
Mass Concrete		87,300	CY	$178	$15,555,000
Reinforced Concrete		26,800	CY	$677	$18,145,000
Soil Cement		3,600	CY	$45	$162,000
Spillway Bridge		640	LF	$1,568	$1,003,000
Gates, Including Anchoring System		14,040	SF	$335	$4,703,000
Gate Hoist and Operating System		13	EA	$320,717	$4,169,000
Stop Gate and Lift Beam		640	LF	$2,281	$1,460,000
Instrumentation		1	LS	$783,975	$784,000
Excavation		2,894,000	CY	$4	$12,375,000
Structural Fill		121,000	CY	$17	$2,070,000
Subtotal of Spillway Construction					**$60,426,000**
Embankment Construction					
Random Fill		6,049,600	CY	$2.90	$17,544,000
Impervious Core		1,455,000	CY	$3.60	$5,238,000
Borrow		4,731,600	CY	$2.90	$13,722,000
Foundation Drain (Filter Material)		502,500	CY	$44.20	$22,211,000
Soil Cement		337,800	CY	$49.90	$16,856,000
Slurry Trench Cutoff		1,770,000	SF	$12.10	$21,417,000
Asphalt Paving on Embankment Crest		68,350	SY	$24.90	$1,702,000
Containment Levee		79,100	CY	$3.60	$285,000
Subtotal of Embankment Construction					**$98,975,000**
Other Items					
Barrier Warning System		640	LF	$128	$82,000
Electrical System		1	LS	$712,705	$713,000
Power Drop		1	LS	$285,082	$285,000
Spillway Low-Flow System		1	LS	$498,893	$499,000
Stop Gate Monorail System		640	LF	$1,140	$730,000
Grassing		100	AC	$5,547	$555,000
Clearing and Grubbing/ Site Preparation		27960	LF	$43	$1,202,000
Care of Water (3% of construction)		1	LS	$4,782,000	$4,782,000
Reservoir Land Clearing		16800	AC	$1,070	$17,976,000
Subtotal of Other Items					**$26,824,000**
Conflicts		1	LS	$ 75,102,000	$75,102,000
Engineering and Contingencies (35%)					$94,723,000
Permitting and Mitigation					$229,060,000
Total Dam and Reservoir					**$708,951,000**
Subtotal for Region C Part of Dam & Reservoir (80%)					**$567,161,000**
NTMWD Portion of Dam & Reservoir	*29.2%*				*$165,419,000*

Dallas Portion of Dam & Reservoir	*29.2%*	*$165,419,000*
TRWD Portion of Dam & Reservoir	*29.2%*	*$165,419,000*
Irving Portion of Dam & Reservoir	*5.4%*	*$30,631,000*
Upper Trinity RWD Portion Dam & Reservoir	*7.1%*	*$40,273,000*
Subtotal Check		*$567,161,000*

TRANSMISSION FACILITIES*

Pipeline	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Pipeline Rural (Reservoir to Lk. Lavon) x 2	108 in	1,119,010	LF	$1,040	$1,163,211,000
Pipeline Urban (Reservoir to Lk. Lavon) x 2	108 in	22,226	LF	$1,456	$32,350,000
Right of Way Easements Rural (ROW)		559,505	LF	$25	$13,938,000
Right of Way Easements Urban (ROW)		11,113	LF	$63	$698,000
Engineering and Contingencies (30%)					$358,668,000
Permitting & Mitigation					$14,347,000
Subtotal of Pipeline (Reservoir to Lake Lavon)					**$1,583,212,000**
Pipeline Rural (Lake Lavon to Lewisville) x 2	96 in	283,051	LF	$844	$238,895,000
Pipeline Urban (Lake Lavon to Lewisville) x 2	96 in	14,138	LF	$1,182	$16,703,000
Right of Way Easements Rural (ROW)		141,526	LF	$25	$3,526,000
Right of Way Easements Urban (ROW)		7,069	LF	$63	$444,000
Engineering and Contingencies (30%)					$76,679,000
Permitting & Mitigation					$3,067,000
Subtotal of Pipeline (Lake Lavon to Lake Lewisville)					**$339,314,000**
Discharge Structure at Lake Bridgeport	191 MGD	1	LS	$1,569,000	$1,569,000
Pipeline Rural (Lake Lewisville to Lake Bridgeport)	96 in	303,841	LF	$844	$256,442,000
Pipeline Urban (Lake Lewisville to Lake Bridgeport)	96 in	6,402	LF	$1,182	$7,565,000
Right of Way Easements Rural (ROW)		303,841	LF	$15	$4,607,000
Right of Way Easements Urban (ROW)		6,402	LF	$47	$304,000
Engineering and Contingencies (30%)					$79,673,000
Permitting & Mitigation					$3,187,000
Subtotal of Pipeline (Lake Lewisville to Lake Bridgeport)					**$353,347,000**
Total Pipeline Cost**					**$2,275,873,000**

NTMWD Portion of Pipeline	*29.2% (Res to Lavon)*	*$461,762,000*
Dallas Portion of Pipeline	*29.2% (Res to Lavon) & 41.2% (Lavon to Lewisville)*	*$601,476,000*
TRWD Portion of Pipeline	*29.2% (Res to Lavon) & 41.2% (Lavon to Lewisville) & 100% (Lewisville to Bridgeport)*	*$954,823,000*
Irving Portion of Pipeline	*5.4% (Res to Lavon) & 7.62% (Lavon to Lewisvville)*	*$111,375,000*
Upper Trinity RWD Portion of Pipeline	*7.1% (Res to Lavon) & 10% (Lavon to Lewisville)*	*$146,437,000*
Total Check		*$2,275,873,000*

Pump Station(s)	**Size (per PS)**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Intake Pump Station at Eagle Mountain Lake	35000 HP	1	LS	$57,750,000	$57,750,000
Intake Pump Station at Marvin Nichols Reservoir	58500 HP	1	LS	$79,863,000	$79,863,000
Booster Pump Station 1	68800 HP	1	LS	$77,428,000	$77,428,000
Booster Pump Station 2	76300 HP	1	LS	$84,178,000	$84,178,000
Booster Pump Station 3	20500 HP	1	LS	$38,297,000	$38,297,000
Storage Reservoir at booster station 1	109 MG	1	EA	$18,349,000	$18,349,000
Storage Reservoir at booster station 2	109 MG	1	EA	$18,349,000	$18,349,000
Storage Reservoir upstream of booster station 3	77 MG	1	EA	$14,097,000	$14,097,000
Engineering and Contingencies (35%)					$135,909,000
Permitting & Mitigation					$4,660,000
Total Pump Station Costs (Including Storage)					**$528,880,000**

NTMWD	*29.2% (Res to Lavon)*	*$110,500,000*
Dallas	*29.2% (Res to Lavon) & 41.2% (Lavon to Lewisville)*	*$110,500,000*
TRWD	*29.2% (Res to Lavon) & 41.2% (Lavon to Lewisville) & 100% (Lewisville to Bridgeport)*	*$260,516,000*
Irving	*5.4% (Res to Lavon) & 7.62% (Lavon to Lewisville)*	*$20,461,000*

UTRWD	*7.1% (Res to Lavon) & 10% (Lavon to Lewisville)*	*$26,903,000*
Total Check		*$528,880,000*
CONSTRUCTION TOTAL		**$3,371,914,000**
Interest During Construction	**(72 months - pipeline) (48 months for reservoir)**	**$769,518,000**
TOTAL COST		**$4,141,432,000**
NTMWD		*$906,030,000*
Dallas		*$1,077,629,000*
TRWD		*$1,695,867,000*
Irving		*$199,544,000*
Upper Trinity RWD		*$262,362,000*
Total Check		*$4,141,432,000*
TOTAL COST ANALYSIS		
NTMWD		**Cost**
Debt Service (6% for 30 years)		$65,822,000
Electricity ($0.09 kWh)		$16,085,000
Operation & Maintenance		$7,400,000
Total Annual Costs (NTMWD)		**$89,307,000**
Dallas		
Debt Service (6% for 30 years)		$78,289,000
Electricity ($0.09 per kWh)		$16,085,000
Operation & Maintenance		$8,663,000
Total Annual Costs (Dallas)		**$103,037,000**
TRWD		
Debt Service (6% for 30 years)		$123,203,000
Electricity ($0.09 kWh)		$23,248,000
Operation & Maintenance		$15,154,000
Total Annual Costs (TRWD)		**$161,605,000**
Irving		
Debt Service (6% for 30 years)		$14,497,000
Electricity ($0.09 kWh)		$2,978,000
Operation & Maintenance		$1,605,000
Total Annual Costs (Irving)		**$19,080,000**
Upper Trinity RWD		
Debt Service (6% for 30 years)		$19,060,000
Electricity ($0.09 kWh)		$3,916,000
Operation & Maintenance		$2,109,000
Total Annual Costs (Upper Trinity RWD)		**$25,085,000**
TOTAL ANNUAL		
Debt Service (6% for 30 years)		$300,871,000
Electricity ($0.09 kWh)		$62,312,000
Operation & Maintenance		$34,931,000
Total Annual Costs (All Users)		**$398,114,000**
UNIT COSTS (Before Amortization)		
NTMWD		
Per Acre-Foot		$625
Per 1,000 Gallons		$1.92
Dallas		
Per Acre-Foot		$721

Per 1,000 Gallons	$2.21
TRWD	
Per Acre-Foot	$1,131
Per 1,000 Gallons	$3.47
Irving	
Per Acre-Foot	$721
Per 1,000 Gallons	$2.21
Upper Trinity RWD	
Per Acre-Foot	$721
Per 1,000 Gallons	$2.21
TOTAL ALL USERS	
Per Acre-Foot	$813
Per 1,000 Gallons	$2.49
ANNUAL COSTS (After Amortization)	
NTMWD	**Cost**
Electricity ($0.09 kWh)	$16,085,000
Operation & Maintenance	$7,400,000
Total Annual Costs (NTMWD)	**$23,485,000**
Dallas	
Electricity ($0.09 kWh)	$16,085,000
Operation & Maintenance	$8,663,000
Total Annual Costs (Dallas)	**$24,748,000**
TRWD	
Electricity ($0.09 kWh)	$23,248,000
Operation & Maintenance	$15,154,000
Total Annual Costs (TRWD)	**$38,402,000**
Irving	
Electricity ($0.09 kWh)	$2,978,000
Operation & Maintenance	$1,605,000
Total Annual Costs (Irving)	**$4,583,000**
Upper Trinity RWD	
Electricity ($0.09 kWh)	$3,916,000
Operation & Maintenance	$2,109,000
Total Annual Costs (Upper Trinity RWD)	**$6,025,000**
TOTAL ALL USERS	
Electricity ($0.09 kWh)	$62,312,000
Operation & Maintenance	$34,931,000
Total Annual Costs	**$97,243,000**
UNIT COSTS (After Amortization)	
NTMWD	
Per Acre-Foot	$164
Per 1,000 Gallons	$0.50
Dallas	
Per Acre-Foot	$173
Per 1,000 Gallons	$0.53
TRWD	
Per Acre-Foot	$269
Per 1,000 Gallons	$0.82
Irving	
Per Acre-Foot	$173
Per 1,000 Gallons	$0.53
Upper Trinity RWD	

Per Acre-Foot	$173
Per 1,000 Gallons	$0.53
TOTAL ALL USERS	
Per Acre-Foot	$199
Per 1,000 Gallons	$0.61

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

**Does not include discharge structures for partners other than TRWD.

D-4.4 Lake Ringgold

Ringgold Reservoir to Lake Bridgeport

Probable Owner:	TRWD	28,600	Acre-Feet per Year		
Peak Delivery:		32	MGD	Peaking factor =	1.25

CONSTRUCTION COSTS

DAM AND RESERVOIR

	Quantity	Unit	Unit Price	Cost
Unclassified Excavation	2,591,000	CY	$3.08	$7,985,000
Structural Excavation	700,000	CY	$3.08	$2,157,000
Fill				
Random Compacted Fill	2,229,000	CY	$3.08	$6,869,000
Impervious Fill	743,000	CY	$3.70	$2,748,000
Filter	337,000	CY	$43.14	$14,539,000
Bridge	240	LF	$1,602.47	$385,000
Roadway	23,333	SY	$24.65	$575,000
Slurry Trench	118,000	SF	$18.49	$2,182,000
Soil Cement	121,000	CY	$80.12	$9,695,000
Gates				
Gate & Anchor	5,000	SF	$339	$1,695,000
Stop Gate & Lift	200	LF	$2,465	$493,000
Hoist	5	Ea	$308,168	$1,541,000
Electrical	1	LS	$677,969	$678,000
Power Drop	1	LS	$308,168	$308,000
Spillway Low-Flow System	1	LS	$493,069	$493,000
Embankment Internal Drainage	15,400	LF	$74	$1,139,000
Guardrail	480	LF	$37	$18,000
Grassing	50	Ac	$5,547	$277,000
Concrete (mass)	54,747	CY	$185	$10,123,000
Reinforced Concrete (formed)	14,160	CY	$586	$8,291,000
Subtotal				*$72,191,000*
Mobilization (5% of subtotal)				$3,610,000
Care of water (3% of subtotal)				$2,166,000
Clearing and Grubbing	150	Ac	$4,931	$740,000
Land Clearing	425	Ac	$1,233	$524,000
Engineering and Contingencies (35%)				$27,731,000
Conflicts				
Highways	6650	LF	$185	$1,230,000
Pipelines				
4.5-in crude oil	58,900	LF	$21	$1,234,000
16-inch gas	55,800	LF	$52	$2,889,000
8.63-inch crude oil	23,800	LF	$31	$733,000
Oil & gas well (plug & abandon)	1	EA	$30,817	$31,000
Power Lines	240	LF	$555	$133,000
Engineering and Contingencies (35%)				$1,710,000
Subtotal of Conflicts				**$7,960,000**
Land Acquisition	17,000	AC	$1,048	$17,812,000
Environmental Studies and Mitigation Lands	17,000	AC	$2,096	$35,624,000
Total Reservoir Construction Cost				**$168,358,000**

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Discharge Structure at Lake Bridgeport	32 MGD	1	LS	$131,000	$131,000
Pipeline (Rural)	48 in	243,280	LF	$261	$63,374,000
Pipeline (Urban)	48 in	1,158	LF	$365	$423,000
ROW Easements (Rural)		243,280	LF	$15	$3,689,000
ROW Easements (Urban)		1,158	LF	$37	$43,000
Permitting and Mitigation					$767,000
Engineering and Contingencies (30%)					$19,178,000
Subtotal of Pipeline					**$87,605,000**
Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Eagle Mountain Lake	35000 HP	1	LS	$57,750,000	$57,750,000
Intake Pump Station at Ringgold Reservoir	3400 HP	1	LS	$14,665,000	$14,665,000
Permitting and Mitigation					$869,000
Engineering and Contingencies (35%)					$25,345,000
Subtotal of Pump Stations					**$98,629,000**
CONSTRUCTION TOTAL					**$354,592,000**
Interest During Construction	**(36 months - pipeline) (36 months - Reservoir)**				**$43,143,000**
TOTAL COST					**$397,735,000**
ANNUAL COSTS					
Debt Service (6% for 30 years)					$28,895,000
Electricity ($0.09 per kWh)					$1,548,000
Operation & Maintenance					$4,239,000
Total Annual Costs					**$34,682,000**
UNIT COSTS (Until Amortized)					
Per Acre-Foot					$1,213
Per 1,000 Gallons					$3.72
UNIT COSTS (After Amortization)					
Per Acre-Foot					$202
Per 1,000 Gallons					$0.62

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.5 Temple Reservoir

Southwest Oklahoma (Temple Reservoir) to Lake Bridgeport

Probable Owner:	TRWD	125,000	Acre-Feet per Year		
Peak Delivery:		139	MGD	Peaking factor =	1.25

CONSTRUCTION COSTS

DAM AND RESERVOIR

	Size	Quantity	Unit	Unit Price	Cost
Zoned Earthfill Dam and Emergency Spillway			L.S.	$72,480,951	$72,481,000
Slope Protection			L.S.	$14,844,263	$14,844,000
Gated Service Spillway			L.S.	$21,293,839	$21,294,000
Outlet Works, Electrical and SCADA			L.S.	$1,535,613	$1,536,000
Project Access Road and Ancillary Facilities			L.S.	$1,228,491	$1,228,000
Relocations			L.S.	$73,709,442	$73,709,000
Land Acquisition and Surveying			L.S.	$30,405,145	$30,405,000
Permitting and Mitigation			L.S.	$49,856,247	$49,856,000
Engineering, Acquisition and Contingencies			L.S.	$85,687,226	$85,687,000
Subtotal of Dam and Reservoir					**$351,040,000**

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Discharge Structure at Lake Bridgeport	139 MGD	1	LS	$945,000	$945,000
Pipeline (Rural)	84 in	395,916	LF	$627	$248,239,000
Pipeline (Urban)	84 in	1,884	LF	$878	$1,654,000
ROW Easements (Rural)		395,916	LF	$15	$6,003,000
ROW Easements (Urban)		1,884	LF	$37	$69,000
Permitting and Mitigation					$3,010,000
Engineering and Contingencies (30%)					$75,251,000
Subtotal of Pipeline					**$335,171,000**

Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Eagle Mountain Lake	35000 HP	1	LS	$57,750,000	$57,750,000
Intake Pump Station at Temple Reservoir	8400 HP	1	LS	$28,100,000	$28,100,000
Booster Pump Station	9700 HP	1	LS	$27,553,000	$27,553,000
Storage Reservoir	28 MG	1	LS	$6,316,994	$6,317,000
Permitting and Mitigation					$1,437,000
Engineering and Contingencies (35%)					$41,902,000
Subtotal of Pump Stations					**$163,059,000**

CONSTRUCTION TOTAL		**$849,270,000**
Interest During Construction	**(48 months - pipeline)** **(36 months - Reservoir)**	**$123,260,000**
TOTAL COST		**$972,530,000**

ANNUAL COSTS

Debt Service (6% for 30 years)	$70,653,000

Electricity ($0.09 per kWh)	$7,671,000
Operation & Maintenance	$8,607,000
Total Annual Costs	**$86,931,000**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$695
Per 1,000 Gallons	$2.13
UNIT COSTS (After Amortization))	
Per Acre-Foot	$130
Per 1,000 Gallons	$0.40

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.6 Lake Texoma

Texoma to Lake Bridgeport

Probable Owner:	TRWD	21,050	Acre-Feet per Year			
Peak Delivery:		67	MGD	3.57	Peaking Factor	

CONSTRUCTION COSTS

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Discharge Structure at Lake Bridgeport	67 MGD	1	LS	$255,000	$255,000
Pipeline (Rural)	60 in	422,167	LF	$335	$141,215,000
Pipeline (Urban)	60 in	10,967	LF	$469	$5,138,000
ROW Easements (Rural)		422,167	LF	$15	$6,401,000
ROW Easements (Urban)		10,967	LF	$37	$404,000
Permitting and Mitigation					$1,759,000
Engineering and Contingencies (30%)					$43,982,000
Subtotal of Pipelines					**$199,154,000**

Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Lake Texoma	6000 HP	1	LS	$21,500,000	$21,500,000
Booster Pump Station	7800 HP	1	LS	$20,787,000	$20,787,000
Storage Tank	9 MG	1	LS	$2,772,000	$2,772,000
Permitting and Mitigation					$541,000
Engineering and Contingencies (35%)					$15,771,000
Subtotal of Pump Stations					**$61,371,000**

CONSTRUCTION TOTAL		**$260,525,000**
Interest During Construction	**(60 months - pipeline)**	**$52,540,000**
TOTAL COST		**$313,065,000**
ANNUAL COSTS		
Debt Service (6% for 30 years)		$22,744,000
Electricity ($0.09 per kWh)		$1,430,000
Operation & Maintenance		$3,111,000
Raw Water Purchase ($0.10/1,000 gal)		$685,900
Total Annual Costs		**$27,970,900**
UNIT COSTS (Until Amortized)		
Per Acre-Foot		$1,329
Per 1,000 Gallons		$4.08
UNIT COSTS (After Amortization)		
Per Acre-Foot		$248
Per 1,000 Gallons		$0.76

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.7 Toledo Bend Reservoir

Toledo Bend Pipeline Project to Benbrook
North Texas MWD, Tarrant Regional WD, Dallas Water Utilities and Sabine River Authority

Total Yield =	700,000	acre-feet per year				Peaking Factor =	1.5
		NTMWD	200,000	AF/Y	28.6%		
		TRWD	200,000	AF/Y	28.6%		
		DWU	200,000	AF/Y	28.6%		
		SRA	100,000	AF/Y	14.3%		
		Total	700,000	AF/Y			

CONSTRUCTION COSTS

TRANSMISSION FACILITIES*

Pipeline	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Segment 1 - Toledo Bend to NTMWD/SRA/DWU1					
Pipeline Rural	120 in	660,110	LF	$1,258	$830,418,000
Pipeline Urban	120 in	36,927	LF	$1,761	$65,028,000
Right of Way Easements Rural (ROW)		660,110	LF	$25	$16,444,000
Right of Way Easements Urban (ROW)		36,927	LF	$63	$2,320,000
Engineering and Contingencies (30%)					$268,634,000
Permitting & Mitigation					$10,745,000
Subtotal of Pipeline Segment 1 (Parallel to 132" Pipeline)					**$1,193,589,000**
Segment 1 - Toledo Bend to NTMWD/SRA/DWU1					
Pipeline Rural	132 in	660,110	LF	$1,447	$954,849,000
Pipeline Urban	132 in	36,927	LF	$2,025	$74,777,000
Right of Way Easements Rural (ROW)		660,110	LF	$0	$0
Right of Way Easements Urban (ROW)		36,927	LF	$0	$0
Engineering and Contingencies (30%)					$308,888,000
Permitting & Mitigation					$12,356,000
Subtotal of Pipeline Segment 1 (Parallel to 120" Pipeline)					**$1,350,870,000**
Segment 2 - NTMWD/SRA/DWU1 to IPL ROW					
Pipeline Rural x 2	96 in	364,912	LF	$844	$307,986,000
Pipeline Urban x 2	96 in	11,209	LF	$1,182	$13,243,000
Right of Way Easements Rural (ROW)		182,456	LF	$25	$4,545,000
Right of Way Easements Urban (ROW)		5,605	LF	$63	$352,000
Engineering and Contingencies (30%)					$96,369,000
Permitting & Mitigation					$3,855,000
Subtotal of Pipeline Segment 2					**$426,350,000**
Segment 3 - IPL ROW to Take-off to DWU2					
Pipeline Rural x 2	96 in	1,000,765	LF	$844	$844,645,000
Pipeline Urban x 2	96 in	30,741	LF	$1,182	$36,320,000
Right of Way Easements Rural (ROW)		0	LF		$0
Right of Way Easements Urban (ROW)		0	LF		$0
Engineering and Contingencies (30%)					$264,290,000
Permitting & Mitigation					$10,572,000
Subtotal of Pipeline Segment 3					**$1,155,827,000**
Segment 4 - DWU2 Take-off to IPL Tunnel					
Pipeline Rural	102 in	115,710	LF	$945	$109,346,000
Pipeline Urban	102 in	3,564	LF	$1,323	$4,715,000
Right of Way Easements Rural (ROW)		0	LF		$0
Right of Way Easements Urban (ROW)		0	LF		$0
Engineering and Contingencies (30%)					$34,218,000
Permitting & Mitigation					$1,369,000
Subtotal of Pipeline Segment 4					**$149,648,000**
Segment 5 - IPL Tunnel					
No Cost					

Segment 6 - From End of IPL Tunnel to Lake Benbrook					
Discharge Structure at Lake Benbrook	268 MGD	1	LS	$3,552,000	$3,552,000
Pipeline Rural	102 in	0	LF	$945	$0
Pipeline Urban	102 in	5,720	LF	$1,323	$7,568,000
Right of Way Easements Rural (ROW)		0	LF	$15	$0
Right of Way Easements Urban (ROW)		5,720	LF	$90	$514,000
Engineering and Contingencies (30%)					$3,336,000
Permitting & Mitigation					$133,000
Subtotal of Pipeline Segment 6					**$15,103,000**
Segment 7 - NTMWD/SRA/DWU1 to Lake Tawakoni					
Pipeline Rural	120 in	233,427	LF	$1,258	$293,651,000
Pipeline Urban	120 in	13,058	LF	$1,761	$22,995,000
Right of Way Easements Rural (ROW)		233,427	LF	$25	$5,815,000
Right of Way Easements Urban (ROW)		13,058	LF	$63	$820,000
Engineering and Contingencies (30%)					$94,994,000
Permitting & Mitigation					$3,800,000
Subtotal of Pipeline Segment 7					**$422,075,000**
Segment 8 - Lake Tawakoni to NTMWD Take-Off					
Pipeline Rural	96 in	65,869	LF	$844	$55,594,000
Pipeline Urban	96 in	3,685	LF	$1,182	$4,354,000
Right of Way Easements Rural (ROW)		65,869	LF	$25	$1,641,000
Right of Way Easements Urban (ROW)		3,685	LF	$63	$231,000
Engineering and Contingencies (30%)					$17,984,000
Permitting & Mitigation					$719,000
Subtotal of Pipeline Segment 8					**$80,523,000**
Total Pipeline Cost					**$4,793,985,000**

NTMWD Portion of Pipeline	*28.6% (Segment 1) & 57.1% Segment 7 & 100% Segment 8*	*$1,048,685,000*
TRWD Portion of Pipeline	*28.6% (Segment 1) & 57.14% (Segment 2 & 3) & 100% (Segments 4 and 5)*	*$1,795,795,000*
DWU Portion of Pipeline	*28.6% (Segment 1) & 42.86% (Segment 2 & 3) & 14.3% Segment 7*	*$1,465,424,000*
SRA Portion of Pipeline	*14.3% (Segment 1) & 28.6% Segment 7*	*$484,081,000*
Total Check		*$4,793,985,000*

Pump Station(s)	**Size (per PS)**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Intake Pump Station at Toledo Bend Reservoir	75200 HP	1	LS	$94,930,000	$94,930,000
Booster Pump Station 1	46600 HP	1	LS	$57,447,000	$57,447,000
Booster Pump Station 2	77600 HP	1	LS	$85,348,000	$85,348,000
Booster Pump Station 3	61000 HP	1	LS	$70,408,000	$70,408,000
Booster Pump Station 4	40200 HP	1	LS	$51,686,000	$51,686,000
Booster Pump Station 5	32800 HP	1	LS	$45,997,000	$45,997,000
Booster Pump Station 6	41700 HP	1	LS	$53,036,000	$53,036,000
Booster Pump Station 7	11300 HP	1	LS	$30,171,000	$30,171,000
Booster Pump Station 8	14000 HP	1	LS	$32,602,000	$32,602,000
Booster Pump Station 9	12000 HP	1	LS	$30,801,000	$30,801,000
Storage Reservoir at booster station 1	156 MG	1	EA	$23,488,000	$23,488,000
Storage Reservoir at booster station 2	156 MG	1	EA	$23,488,000	$23,488,000
Storage Reservoir at booster station 3	156 MG	1	EA	$23,488,000	$23,488,000
Storage Reservoir at booster station 4	78 MG	1	EA	$14,191,000	$14,191,000
Storage Reservoir at booster station 5	78 MG	1	EA	$14,191,000	$14,191,000
Storage Reservoir at booster station 6	78 MG	1	EA	$14,191,000	$14,191,000
Storage Reservoir at booster station 7	45 MG	1	EA	$9,074,000	$9,074,000
Storage Reservoir at booster station 8	76 MG	1	EA	$13,878,000	$13,878,000
Storage Reservoir at booster station 9	45 MG	1	EA	$9,074,000	$9,074,000
Engineering and Contingencies (35%)					$244,121,000
Permitting & Mitigation					$8,370,000
Subtotal of Pump Station(s)					**$949,980,000**
Total Pump Station Costs (Including Storage Reservoirs)					**$949,980,000**

NTMWD	*28.6% (Intake Pump Station, Boosters and Storage at 1,2, & 3) & 57.1% (Booster and Storage at 8) & 100% (Booster and Storage at 9)*	*$237,810,000*

TRWD	*28.6% (Intake, Boosters and Storage at 1,2, & 3) & 57.14% (Boosters and Storage at 4, 5, & 6) & 100% (Booster and Storage at 7)*	*$351,209,000*
DWU	*28.6% (Intake Pump Station, Boosters and Storage at 1,2, & 3) & 42.86% (Boosters and Storage at 4, 5, & 6) & 14.3% (Booster and Storage at 8)*	*$269,210,000*
SRA	*14.3% (Intake Pump Station, Boosters and Storage at 1,2, & 3) & 28.6% (Booster and Storage at 8)*	*$91,751,000*
Total Check		*$949,980,000*

** For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.*

CONSTRUCTION TOTAL		**$5,743,965,000**
Interest During Construction	**(84 months - pipeline)**	**$1,617,903,000**
TOTAL COST		**$7,361,868,000**
NTMWD		*$1,648,862,000*
TRWD		*$2,751,751,000*
DWU		*$2,223,228,000*
SRA		*$738,027,000*
Total Check		*$7,361,868,000*

TOTAL COST ANALYSIS

NTMWD	**Cost**
Debt Service (6% for 30 years)	$119,788,000
Electricity ($0.09 kWh)	$28,326,000
Operation & Maintenance	$8,056,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (NTMWD)	**$162,687,000**
TRWD	
Debt Service (6% for 30 years)	$199,912,000
Electricity ($0.09 kWh)	$38,769,000
Operation & Maintenance	$20,551,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (TRWD)	**$265,749,000**
DWU	
Debt Service (6% for 30 years)	$161,515,000
Electricity ($0.09 kWh)	$34,767,000
Operation & Maintenance	$15,726,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (DWU)	**$218,525,000**
SRA	
Debt Service (6% for 30 years)	$53,617,000
Electricity ($0.09 kWh)	$11,378,000
Operation & Maintenance	$4,642,000
Raw Water Purchase ($0.10/1,000 gal)	$0
Total Annual Costs (SRA)	**$69,637,000**
TOTAL ANNUAL	
Debt Service (6% for 30 years)	$534,832,000
Electricity ($0.09 per kWh)	$113,240,000
Operation & Maintenance	$48,975,000
Raw Water Purchase ($0.10/1,000 gal)	$19,551,000
Total Annual Costs (All Users)	**$716,598,000**

UNIT COSTS (During Amortization)	
NTMWD	
Per Acre-Foot	$813
Per 1,000 Gallons	$2.50
TRWD	
Per Acre-Foot	$1,329
Per 1,000 Gallons	$4.08
DWU	
Per Acre-Foot	$1,093
Per 1,000 Gallons	$3.35
SRA	
Per Acre-Foot	$696
Per 1,000 Gallons	$2.14
Total All Users	
Per Acre-Foot	$1,024
Per 1,000 Gallons	$3.14
ANNUAL COSTS (After Amortization)	
NTMWD	**Cost**
Electricity ($0.09 kWh)	$28,326,000
Operation & Maintenance	$8,056,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (NTMWD)	**$42,899,000**
TRWD	
Electricity ($0.09 kWh)	$38,769,000
Operation & Maintenance	$20,551,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (TRWD)	**$65,837,000**
DWU	
Electricity ($0.09 kWh)	$34,767,000
Operation & Maintenance	$15,726,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (DWU)	**$57,010,000**
SRA	
Electricity ($0.09 kWh)	$11,378,000
Operation & Maintenance	$4,642,000
Raw Water Purchase ($0.10/1,000 gal)	$0
Total Annual Costs (SRA)	**$16,020,000**
Total All Users	
Electricity ($0.09 kWh)	$113,240,000
Operation & Maintenance	$48,975,000
Raw Water Purchase ($0.10/1,000 gal)	$19,551,000
Total Annual Costs (All Users)	**$181,766,000**
UNIT COSTS (After Amortization)	
NTMWD	
Per Acre-Foot	$214
Per 1,000 Gallons	$0.66
TRWD	
Per Acre-Foot	$329
Per 1,000 Gallons	$1.01

DWU	
Per Acre-Foot	$285
Per 1,000 Gallons	$0.87
SRA	
Per Acre-Foot	$160
Per 1,000 Gallons	$0.49
All Users	
Per Acre-Foot	$260
Per 1,000 Gallons	$0.80

D-4.8 Lake Wright Patman

Wright Patman to Lake Bridgeport
Develop 180,000* Acre-Feet per Year from Lake Wright Patman

Probable Owner:	TRWD	180,000	Acre-Feet per Year			
Peak Delivery:		201	MGD		Peaking Factor =	1.25
Note: Pipeline to Lake Bridgeport						

CONSTRUCTION COSTS

RAW WATER IMPROVEMENTS

	Size	Quantity	Unit	Unit Price	Cost
Storage Purchase from COE		1	L.S.	$15,680,000	$15,680,000
Real Estate Purchase from COE		1	L.S.	$14,254,000	$14,254,000
Relocation Cost (facilities)		1	L.S.	$18,530,000	$18,530,000
Mitigation		1	L.S.	$28,508,000	$28,508,000
NEPA Evaluation		1	L.S.	$2,673,000	$2,673,000
Engineering, Acquisition and Contingencies (35%)			L.S.	$27,876,000	$27,876,000
Subtotal of Raw Water Improvements					**$107,521,000**

TRANSMISSION FACILITIES

Pipeline**	Size	Quantity	Unit	Unit Price	Cost
Discharge Structure at Lake Bridgeport	201 MGD	1	LS	$1,820,000	$1,820,000
Pipeline (Rural)	96 in	1,221,081	LF	$844	$1,030,592,000
Pipeline (Urban)	96 in	34,470	LF	$1,182	$40,726,000
ROW Easements (Rural)		1,221,081	LF	$15	$18,515,000
ROW Easements (Urban)		34,470	LF	$42	$1,452,000
Permitting and Mitigation					$12,878,000
Engineering and Contingencies (30%)					$321,941,000
Subtotal of Pipeline					**$1,427,924,000**

Pump Station(s)	Size (per PS)	Quantity	Unit		Cost
New Pump Station for Texarkana	2200 HP	1	LS	$12,395,000	$12,395,000
Intake Pump Station at Eagle Mountain Lake	35000 HP	1	LS	$57,750,000	$57,750,000
Intake Pump Station at Lake Wright Patman	19600 HP	1	LS	$43,160,000	$43,160,000
Booster Pump Stations	18300 HP	1	Ea	$36,473,000	$36,473,000
Booster Pump Stations	17500 HP	1	Ea	$35,753,000	$35,753,000
Booster Pump Stations	14600 HP	1	Ea	$33,142,000	$33,142,000
Booster Pump Stations	18500 HP	1	Ea	$36,653,000	$36,653,000
Storage Reservoir	40 MG	4	Ea	$8,357,696	$33,431,000
Permitting and Mitigation					$3,465,000
Engineering and Contingencies (35%)					$101,065,000
Subtotal of Pump Stations					**$393,287,000**

CONSTRUCTION TOTAL		**$1,928,732,000**
Interest During Construction	**(72 months)**	**$466,117,000**
TOTAL COST		**$2,394,849,000**

ANNUAL COSTS

Debt Service (6% for 30 years)	$173,983,000
Electricity ($0.09 per kWh)	$37,060,000
Operation & Maintenance	$21,169,000

Raw Water Purchase ($0.10/1,000 gal)	$5,865,300
Total Annual Costs	**$238,077,300**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$1,323
Per 1,000 Gallons	$4.06
UNIT COSTS (After Amortization)	
Per Acre-Foot	$356
Per 1,000 Gallons	$1.09

*This amount is in addition to the water already authorized to Texarkana
**For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.9 Richland-Chambers and Cedar Creek Firm Yields Delivered to Lake Benbrook through IPL

Additional RC and CC Firm Yields Delivered to Benbrook Lake through IPL

Probable Owner:	TRWD	64,032	Acre-Feet per Year

CONSTRUCTION COSTS

NONE

ANNUAL COSTS	
Debt Service (6% for 30 years)	$0
Electricity ($0.09 per kWh)	$8,841,000
Operation & Maintenance	$0
Total Annual Costs	**$8,841,000**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$138
Per 1,000 Gallons	$0.42
UNIT COSTS (After Amortization)	
Per Acre-Foot	$138
Per 1,000 Gallons	$0.42

D-4.10 Richland-Chambers and Cedar Creek Wetlands Full Yield Permits Delivered to Lake Benbrook through IPL

RC/CC Wetlands Full Yield Permits Delivered to Benbrook Lake through IPL

Probable Owner:	TRWD	73,024	Acre-Feet per Year

CONSTRUCTION COSTS

NONE

ANNUAL COSTS	
Debt Service (6% for 30 years)	$0
Electricity ($0.09 per kWh)	$10,700,000
Operation & Maintenance	$0
Total Annual Costs	**$10,700,000**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$147
Per 1,000 Gallons	$0.45
UNIT COSTS (After Amortization)	
Per Acre-Foot	$147
Per 1,000 Gallons	$0.45

D-4.11 Lake Tehuacana Delivered to Lake Benbrook through IPL

Lake Tehuacana Delivered to Benbrook Lake through IPL

Probable Owner:	TRWD	41,900	Acre-Feet per Year			
Peak Delivery:		47	MGD		Peaking Factor =	1.25

	Size	Quantity	Unit	Unit Price	Cost
CONSTRUCTION COSTS					
TEHUACANA DAM AND RESERVOIR					
Excavation					
Channel		2,250,000	C.Y.	$2.85	$6,414,000
Core trench & borrow		1,764,000	C.Y.	$2.85	$5,029,000
Fill Material					
Embankment		3,488,000	C.Y.	$3.56	$12,430,000
Waste Material		80,000	C.Y.	$2.85	$228,000
Filter, 1 & 2 (foundation drainage)		181,800	C.Y.	$42.76	$7,774,000
Stabilized base roadway		59,555	S.Y.	$25.66	$1,528,000
Cutoff slurry trench		514,800	S.F.	$17.10	$8,806,000
Soil cement including cement		137,800	C.Y.	$92.65	$12,767,000
Guard posts		1,680	each	$36.02	$61,000
Grassing		34	acres	$5,547	$189,000
Subtotal of Dam and Reservoir					**$55,226,000**
Conflicts					**$49,952,000**
Engineering and Contingencies (35%)					**$36,812,000**
Construction Total					**$141,990,000**
Land and Lignite Acquisition		**1**	**L.S.**	**$118,794,000**	**$118,794,000**
Permitting and Mitigation of Reservoir					**$237,588,000**
TOTAL RESERVOIR COST					**$498,372,000**

Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Pump Station at Tehuacana/R-C Channel	80 HP	1	LS	$1,167,000	$1,167,000
Permitting and Mitigation					$14,000
Engineering and Contingencies (35%)					$408,000
Subtotal of Pump Stations					**$1,589,000**
CONSTRUCTION TOTAL					**$499,961,000**
Interest During Construction	**(48 months)**				**$80,829,000**
TOTAL COST					**$580,790,000**

ANNUAL COSTS	
Debt Service (6% for 30 years)	$42,194,000
Electricity ($0.09 per kWh)	$5,593,000
Operation & Maintenance	$994,000
Total Annual Costs	**$48,781,000**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$1,164
Per 1,000 Gallons	$3.57
UNIT COSTS (After Amortization)	
Per Acre-Foot	$157
Per 1,000 Gallons	$0.48

D-4.12 Richland-Chambers and Cedar Creek Firm Yields Delivered to Lake Benbrook in a New Pipeline

Richland Chambers and Cedar Creek Additional Firm Yields in a New Pipeline

Probable Owner:	TRWD	64,032	Acre-Feet per Year		
Peak Delivery:		71	MGD	Peaking Factor =	1.25

CONSTRUCTION COSTS

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity***	**Unit**	**Unit Price**	**Cost**
Segment 1 - Cedar Creek to RC/CC Tie-in					
Pipeline (Rural)	60 in	62,464	LF	$335	$20,894,000
ROW Easements (Rural)		62,464	LF	$15	$947,000
Subtotal of Segment 1					**$21,841,000**
Segment 2 - R-C to RC/CC Tie-in					
Pipeline (Rural)	42 in	70,668	LF	$224	$15,794,000
ROW Easements (Rural)		70,668	LF	$15	$1,072,000
Subtotal of Segment 2					**$16,866,000**
Segment 3 - RC/CC Tie-in to IPL Tunnel					
Pipeline (Rural)	66 in	437,054	LF	$392	$171,107,000
Pipeline (Urban)	66 in	0	LF	$548	$0
ROW Easements (Rural)		0	LF	$15	$0
ROW Easements (Urban)		0	LF		$0
Subtotal of Segment 3					**$171,107,000**
Segment 4 - IPL Tunnel					
No Cost					
Segment 5 - From End of IPL Tunnel to Benbrook Lake					
Pipeline (Urban)	96 in	5,720	LF	$1,182	$6,758,000
ROW Easements (Urban)		5,720	LF	$90	$514,000
Subtotal of Segment 5					**$7,272,000**
Discharge Structure at Lake Benbrook	80 MGD	1	LS	$356,000	$356,000
Permitting and Mitigation					$2,579,000
Engineering and Contingencies (30%)					$64,473,000
Subtotal of Pipeline					**$284,494,000**
Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Cedar Creek	5000 HP	1	LS	$18,500,000	$18,500,000
Intake Pump Station at Richland-Chambers	1900 HP	1	LS	$11,795,000	$11,795,000
Booster Pump Station	7100 HP	1	LS	$18,810,000	$18,810,000
Open Storage Tank	14 MG	1	Ea	$4,600,000	$4,600,000
Permitting and Mitigation					$644,000
Engineering and Contingencies (35%)					$18,797,000
Subtotal of Pump Stations					**$73,146,000**
CONSTRUCTION TOTAL					**$357,640,000**
Interest During Construction	**(48 months)**				**$57,820,000**
TOTAL COST					**$415,460,000**

ANNUAL COSTS

Debt Service (6% for 30 years)	$30,183,000
Electricity ($0.09 per kWh)	$5,956,000
Operation & Maintenance	$4,190,000
Total Annual Costs	**$40,329,000**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$630
Per 1,000 Gallons	$1.93
UNIT COSTS (After Amortization)	
Per Acre-Foot	$158
Per 1,000 Gallons	$0.49

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.13 Richland-Chambers and Cedar Creek Wetlands Full Yield Permits Delivered to Lake Benbrook in a New Pipeline

Richland Chambers and Cedar Creek Additional Wetlands in a New Pipeline

Probable Owner:	TRWD	73,024	Acre-Feet per Year		
Peak Delivery:		81	MGD	Peaking Factor =	1.25

CONSTRUCTION COSTS

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity***	**Unit**	**Unit Price**	**Cost**
Segment 1 - Cedar Creek to RC/CC Tie-in					
Pipeline (Rural)	54 in	62,464	LF	$298	$18,614,000
ROW Easements (Rural)		62,464	LF	$15	$947,000
Subtotal of Segment 1					**$19,561,000**
Segment 2 - R-C to RC/CC Tie-in					
Pipeline (Rural)	54 in	70,668	LF	$298	$21,059,000
ROW Easements (Rural)		70,668	LF	$15	$1,072,000
Subtotal of Segment 2					**$22,131,000**
Segment 3 - RC/CC Tie-in to IPL Tunnel					
Pipeline (Rural)	72 in	437,054	LF	$458	$200,171,000
Pipeline (Urban)	72 in	0	LF	$642	$0
ROW Easements (Rural)		0	LF	$15	$0
ROW Easements (Urban)		0	LF		$0
Subtotal of Segment 3					**$200,171,000**
Segment 4 - IPL Tunnel					
No Cost					
Segment 5 - From End of IPL Tunnel to Benbrook Lake					
Pipeline (Urban)	96 in	5,720	LF	$1,182	$6,758,000
ROW Easements (Urban)		5,720	LF	$90	$514,000
Subtotal of Segment 5					**$7,272,000**
Discharge Structure at Lake Benbrook	90 MGD	1	LS	$445,250	$445,000
Permitting and Mitigation					$2,965,000
Engineering and Contingencies (30%)					$74,114,000
Subtotal of Pipeline					**$326,659,000**
Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Cedar Creek	3500 HP	1	LS	$14,888,000	$14,888,000
Intake Pump Station at Richland-Chambers	3900 HP	1	LS	$15,778,000	$15,778,000
Booster Pump Station	7400 HP	1	LS	$19,657,000	$19,657,000
Storage Reservoir	16 MG	1	Ea	$3,970,000	$3,970,000
Permitting and Mitigation					$652,000
Engineering and Contingencies (35%)					$19,003,000
Subtotal of Pump Stations					**$73,948,000**
CONSTRUCTION TOTAL					**$400,607,000**
Interest During Construction	**(48 months)**				**$64,766,000**
TOTAL COST					**$465,373,000**
ANNUAL COSTS					
Debt Service (6% for 30 years)					$33,809,000

Electricity ($0.09 per kWh)	$6,438,000
Operation & Maintenance	$4,593,000
Total Annual Costs	**$44,840,000**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$614
Per 1,000 Gallons	$1.88
UNIT COSTS (After Amortization)	
Per Acre-Foot	$151
Per 1,000 Gallons	$0.46

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.14 Lake Tehuacana Delivered to Lake Benbrook in a New Pipeline

Lake Tehuacana in a New Pipeline

Probable Owner:	TRWD	41,900	Acre-Feet per Year		
Peak Delivery:		47	MGD	Peaking Factor =	1.25

CONSTRUCTION COSTS

TEHUACANA DAM AND RESERVOIR

	Size	Quantity	Unit	Unit Price	Cost
Excavation					
Channel		2,250,000	C.Y.	$2.85	$6,414,000
Core trench & borrow		1,764,000	C.Y.	$2.85	$5,029,000
Fill Material					
Embankment		3,488,000	C.Y.	$3.56	$12,430,000
Waste Material		80,000	C.Y.	$2.85	$228,000
Filter, 1 & 2 (foundation drainage)		181,800	C.Y.	$42.76	$7,774,000
Stabilized base roadway		59,555	S.Y.	$25.66	$1,528,000
Cutoff slurry trench		514,800	S.F.	$17.10	$8,806,000
Soil cement including cement		137,800	C.Y.	$92.65	$12,767,000
Guard posts		1,680	each	$36.02	$61,000
Grassing		34	acres	$5,547	$189,000
Subtotal of Dam and Reservoir					**$55,226,000**
Conflicts					**$49,952,000**
Engineering and Contingencies (35%)					**$36,812,000**
Construction Total					**$141,990,000**
Land and Lignite Acquisition		**1**	**L.S.**	**$118,794,000**	**$118,794,000**
Permitting and Mitigation of Reservoir					**$237,588,000**
TOTAL RESERVOIR COST					**$498,372,000**

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity***	**Unit**	**Unit Price**	**Cost**
Segment 1 - R-C to IPL Tie-in					
Pipeline (Rural)	54 in	70,668	LF	$298	$21,059,000
ROW Easements (Rural)		70,668	LF	$15	$1,072,000
Subtotal of Segment 2					**$22,131,000**
Segment 2 - IPL Tie-in to IPL Tunnel					
Pipeline (Rural)	54 in	428,850	LF	$298	$127,797,000
Pipeline (Urban)	54 in	0	LF	$417	$0
ROW Easements (Rural)		0	LF	$15	$0
ROW Easements (Urban)		0	LF		$0
Subtotal of Segment 3					**$127,797,000**
Segment 4 - IPL Tunnel					
No Cost					
Segment 5 - From End of IPL Tunnel to Benbrook Lake					
Pipeline (Urban)	54 in	5,720	LF	$417	$2,382,000
ROW Easements (Urban)		5,720	LF	$90	$514,000
Subtotal of Segment 5					**$2,896,000**
Discharge Structure at Lake Benbrook	50 MGD	1	LS	$175,400	$175,000
Permitting and Mitigation					$1,817,000
Engineering and Contingencies (30%)					$45,424,000

Subtotal of Pipeline					**$200,240,000**
Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Richland-Chambers	5100 HP	1	LS	$18,800,000	$18,800,000
Pump Station at Tehuacana/R-C Channel	80 HP	1	LS	$1,167,000	$1,167,000
Booster Pump Station	5100 HP	1	LS	$13,159,000	$13,159,000
Open Storage Tank	9 MG	1	Ea	$2,757,074	$2,757,000
Permitting and Mitigation					$431,000
Engineering and Contingencies (35%)					$12,559,000
Subtotal of Pump Stations					**$48,873,000**
CONSTRUCTION TOTAL					**$747,485,000**
Interest During Construction	**(48 months)**				**$120,846,000**
TOTAL COST					**$868,331,000**
ANNUAL COSTS					
Debt Service (6% for 30 years)					$63,083,000
Electricity ($0.09 per kWh)					$4,337,000
Operation & Maintenance					$3,888,000
Total Annual Costs					**$71,308,000**
UNIT COSTS (Until Amortized)					
Per Acre-Foot					$1,702
Per 1,000 Gallons					$5.22
UNIT COSTS (After Amortization)					
Per Acre-Foot					$196
Per 1,000 Gallons					$0.60

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.15 Combined Cost Estimates for Richland-Chambers/Cedar Creek Wetlands Full Yields, Richland-Chambers/Cedar Creek Firm Yields, and Lake Tehuacana Strategies

D-4.15.1 CC/RC Wetlands Full Permits and CC/RC Unpermitted Firm Yield Delivered to Lake Benbrook through IPL

Additional RC, CC Firm Yields, and Wetlands Full Yields Delivered to Benbrook Lake through IPL

Probable Owner:	TRWD	137,056	Acre-Feet per Year

CONSTRUCTION COSTS	
NONE	
ANNUAL COSTS	
Debt Service (6% for 30 years)	$0
Electricity ($0.09 per kWh)	$28,832,000
Operation & Maintenance	$0
Total Annual Costs	**$28,832,000**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$210
Per 1,000 Gallons	$0.65
UNIT COSTS (After Amortization)	
Per Acre-Foot	$210
Per 1,000 Gallons	$0.65

D-4.15.2 CC/RC Wetlands Full Permits and CC/RC Unpermitted Firm Yield Delivered to Lake Benbrook through New Pipeline

Richland Chambers and Cedar Creek Wetlands and Additional Firm Yields in a New Pipeline

Probable Owner:	TRWD	137,056	Acre-Feet per Year		
Peak Delivery:		153	MGD	Peaking Factor =	1.25

CONSTRUCTION COSTS

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity***	**Unit**	**Unit Price**	**Cost**
Segment 1 - Cedar Creek to RC/CC Tie-in					
Pipeline (Rural)	72 in	62,464	LF	$458	$28,608,000
ROW Easements (Rural)		62,464	LF	$15	$947,000
Subtotal of Segment 1					**$29,555,000**
Segment 2 - R-C to RC/CC Tie-in					
Pipeline (Rural)	60 in	70,668	LF	$335	$23,639,000
ROW Easements (Rural)		70,668	LF	$15	$1,072,000
Subtotal of Segment 2					**$24,711,000**
Segment 3 - R-C Tie-in to IPL Tunnel					
Pipeline (Rural)	90 in	437,054	LF	$734	$320,579,000
Pipeline (Urban)	90 in	0	LF	$1,028	$0
ROW Easements (Rural)		0	LF	$15	$0
ROW Easements (Urban)		0	LF		$0
Subtotal of Segment 3					**$320,579,000**
Segment 4 - IPL Tunnel					
No Cost					
Segment 5 - From End of IPL Tunnel to Benbrook Lake					
Pipeline (Urban)	96 in	5,720	LF	$1,182	$6,758,000
ROW Easements (Urban)		5,720	LF	$90	$514,000
Subtotal of Segment 5					**$7,272,000**
Discharge Structure at Lake Benbrook	160 MGD	1	LS	$1,191,873	$1,192,000
Permitting and Mitigation					$4,569,000
Engineering and Contingencies (30%)					$114,233,000
Subtotal of Pipeline					**$502,111,000**
Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Cedar Creek	8600 HP	1	LS	$28,650,000	$28,650,000
Intake Pump Station at Richland-Chambers	6000 HP	1	LS	$21,500,000	$21,500,000
Booster Pump Station	14400 HP	1	LS	$32,962,000	$32,962,000
Storage Reservoir	31 MG	1	Ea	$6,788,913	$6,789,000
Permitting and Mitigation					$1,079,000
Engineering and Contingencies (35%)					$31,465,000
Subtotal of Pump Stations					**$122,445,000**
CONSTRUCTION TOTAL					**$624,556,000**
Interest During Construction	**(48 months)**				**$100,972,000**
TOTAL COST					**$725,528,000**

ANNUAL COSTS	
Debt Service (6% for 30 years)	$52,709,000
Electricity ($0.09 per kWh)	$12,495,000
Operation & Maintenance	$7,266,000
Total Annual Costs	**$72,470,000**
UNIT COSTS (Until Amortized)	
Per Acre-Foot	$529
Per 1,000 Gallons	$1.62
UNIT COSTS (After Amortization)	
Per Acre-Foot	$144
Per 1,000 Gallons	$0.44

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.15.3 Lake Tehuacana and CC/RC Unpermitted Firm Yield Delivered to Lake Benbrook through New Pipeline

Lake Tehuacana and Additional Richland Chambers and Cedar Creek in a New Pipeline

Probable Owner:	TRWD	105,932	Acre-Feet per Year		
Peak Delivery:		118	MGD	Peaking Factor =	1.25

CONSTRUCTION COSTS

TEHUACANA DAM AND RESERVOIR

	Size	Quantity	Unit	Unit Price	Cost
Excavation					
Channel		2,250,000	C.Y.	$2.85	$6,414,000
Core trench & borrow		1,764,000	C.Y.	$2.85	$5,029,000
Fill Material					
Embankment		3,488,000	C.Y.	$3.56	$12,430,000
Waste Material		80,000	C.Y.	$2.85	$228,000
Filter, 1 & 2 (foundation drainage)		181,800	C.Y.	$42.76	$7,774,000
Stabilized base roadway		59,555	S.Y.	$25.66	$1,528,000
Cutoff slurry trench		514,800	S.F.	$17.10	$8,806,000
Soil cement including cement		137,800	C.Y.	$92.65	$12,767,000
Guard posts		1,680	each	$36.02	$61,000
Grassing		34	acres	$5,547	$189,000
Subtotal of Dam and Reservoir					**$55,226,000**
Conflicts					**$49,952,000**
Engineering and Contingencies (35%)					**$36,812,000**
Construction Total					**$141,990,000**
Land and Lignite Acquisition		**1**	**L.S.**	**$118,794,000**	**$118,794,000**
Permitting and Mitigation of Reservoir					**$237,588,000**
TOTAL RESERVOIR COST					**$498,372,000**

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity***	**Unit**	**Unit Price**	**Cost**
Segment 1 - Cedar Creek to RC/CC Tie-in					
Pipeline (Rural)	60 in	62,464	LF	$335	$20,894,000
ROW Easements (Rural)		62,464	LF	$15	$947,000
Subtotal of Segment 1					**$21,841,000**
Segment 2 - R-C to RC/CC Tie-in					
Pipeline (Rural)	66 in	70,668	LF	$392	$27,667,000
ROW Easements (Rural)		70,668	LF	$15	$1,072,000
Subtotal of Segment 2					**$28,739,000**
Segment 3 - R-C Tie-in to IPL Tunnel					
Pipeline (Rural)	78 in	437,054	LF	$536	$234,261,000
Pipeline (Urban)	78 in	0	LF	$751	$0
ROW Easements (Rural)		0	LF	$15	$0
ROW Easements (Urban)		0	LF		$0
Subtotal of Segment 3					**$234,261,000**
Segment 4 - IPL Tunnel					
No Cost					
Segment 5 - From End of IPL Tunnel to Benbrook Lake					
Pipeline (Urban)	96 in	5,720	LF	$1,182	$6,758,000
ROW Easements (Urban)		5,720	LF	$90	$514,000

Subtotal of Segment 5					**$7,272,000**
Discharge Structure at Lake Benbrook	120 MGD	1	LS	$713,000	$713,000
Permitting and Mitigation					$3,484,000
Engineering and Contingencies (30%)					$87,088,000
Subtotal of Pipeline					**$383,398,000**
Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Cedar Creek	5300 HP	1	LS	$19,400,000	$19,400,000
Intake Pump Station at Richland-Chambers	6800 HP	1	LS	$23,700,000	$23,700,000
Pump Station at Tehuacana/R-C Channel	80 HP	1	LS	$1,167,000	$1,167,000
Booster Pump Station	12400 HP	1	LS	$31,161,000	$31,161,000
Storage Reservoir	24 MG	1	Ea	$5,570,597	$5,571,000
Permitting and Mitigation					$972,000
Engineering and Contingencies (35%)					$28,350,000
Subtotal of Pump Stations					**$110,321,000**
CONSTRUCTION TOTAL					**$992,091,000**
Interest During Construction	**(48 months)**				**$160,391,000**
TOTAL COST					**$1,152,482,000**
ANNUAL COSTS					
Debt Service (6% for 30 years)					$83,727,000
Electricity ($0.09 per kWh)					$10,404,000
Operation & Maintenance					$6,908,000
Total Annual Costs					**$101,039,000**
UNIT COSTS (Until Amortized)					
Per Acre-Foot					$954
Per 1,000 Gallons					$2.93
UNIT COSTS (After Amortization)					
Per Acre-Foot					$163
Per 1,000 Gallons					$0.50

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.15.4 Lake Tehuacana and CC/RC Wetlands Full Yield Permits Delivered to Lake Benbrook through New Pipeline

Lake Tehuacana and Richland Chambers and Cedar Creek Wetlands in a New Pipeline

Probable Owner:	TRWD	114,924	Acre-Feet per Year		
Peak Delivery:		128	MGD	Peaking Factor =	1.25

CONSTRUCTION COSTS

TEHUACANA DAM AND RESERVOIR

	Size	Quantity	Unit	Unit Price	Cost
Excavation					
Channel		2,250,000	C.Y.	$2.85	$6,414,000
Core trench & borrow		1,764,000	C.Y.	$2.85	$5,029,000
Fill Material					
Embankment		3,488,000	C.Y.	$3.56	$12,430,000
Waste Material		80,000	C.Y.	$2.85	$228,000
Filter, 1 & 2 (foundation drainage)		181,800	C.Y.	$42.76	$7,774,000
Stabilized base roadway		59,555	S.Y.	$25.66	$1,528,000
Cutoff slurry trench		514,800	S.F.	$17.10	$8,806,000
Soil cement including cement		137,800	C.Y.	$92.65	$12,767,000
Guard posts		1,680	each	$36.02	$61,000
Grassing		34	acres	$5,547	$189,000
Subtotal of Dam and Reservoir					**$55,226,000**
Conflicts					**$49,952,000**
Engineering and Contingencies (35%)					**$36,812,000**
Construction Total					**$141,990,000**
Land and Lignite Acquisition		**1**	**L.S.**	**$118,794,000**	**$118,794,000**
Permitting and Mitigation of Reservoir					**$237,588,000**
TOTAL RESERVOIR COST					**$498,372,000**

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity***	**Unit**	**Unit Price**	**Cost**
Segment 1 - Cedar Creek to RC/CC Tie-in					
Pipeline (Rural)	54 in	62,464	LF	$298	$18,614,000
ROW Easements (Rural)		62,464	LF	$15	$947,000
Subtotal of Segment 1					**$19,561,000**
Segment 2 - R-C to RC/CC Tie-in					
Pipeline (Rural)	72 in	70,668	LF	$458	$32,366,000
ROW Easements (Rural)		70,668	LF	$15	$1,072,000
Subtotal of Segment 2					**$33,438,000**
Segment 3 - R-C Tie-in to IPL Tunnel					
Pipeline (Rural)	84 in	437,054	LF	$627	$274,033,000
Pipeline (Urban)	84 in	0	LF	$878	$0
ROW Easements (Rural)		0	LF	$15	$0
ROW Easements (Urban)		0	LF		$0
Subtotal of Segment 3					**$274,033,000**
Segment 4 - IPL Tunnel					
No Cost					
Segment 5 - From End of IPL Tunnel to Benbrook Lake					
Pipeline (Urban)	96 in	5,720	LF	$1,182	$6,758,000
ROW Easements (Urban)		5,720	LF	$90	$514,000

Subtotal of Segment 5					**$7,272,000**
Discharge Structure at Lake Benbrook	130 MGD	1	LS	$832,718	$833,000
Permitting and Mitigation					$3,991,000
Engineering and Contingencies (30%)					$99,781,000
Subtotal of Pipeline					**$438,909,000**
Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Cedar Creek	3600 HP	1	LS	$15,110,000	$15,110,000
Intake Pump Station at Richland-Chambers	8500 HP	1	LS	$28,375,000	$28,375,000
Pump Station at Tehuacana/R-C Channel	80 HP	1	LS	$1,167,000	$1,167,000
Booster Pump Station	12100 HP	1	LS	$30,891,000	$30,891,000
Storage Reservoir	26 MG	1	Ea	$5,922,579	$5,923,000
Permitting and Mitigation					$978,000
Engineering and Contingencies (35%)					$28,513,000
Subtotal of Pump Stations					**$110,957,000**
CONSTRUCTION TOTAL					**$1,048,238,000**
Interest During Construction	**(48 months)**				**$169,469,000**
TOTAL COST					**$1,217,707,000**
ANNUAL COSTS					
Debt Service (6% for 30 years)					$88,465,000
Electricity ($0.09 per kWh)					$10,516,000
Operation & Maintenance					$7,429,000
Total Annual Costs					**$106,410,000**
UNIT COSTS (Until Amortized)					
Per Acre-Foot					$926
Per 1,000 Gallons					$2.84
UNIT COSTS (After Amortization)					
Per Acre-Foot					$156
Per 1,000 Gallons					$0.48

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.15.5 Lake Tehuacana, CC/RC Wetlands Full Yields and CC/RC Unpermitted Firm Yield Delivered to Lake Benbrook through New Pipeline

Lake Tehuacana and Richland Chambers and Cedar Creek Wetlands and CC/RC Firm Yields in a New Pipeline

Probable Owner:	TRWD	178,956	Acre-Feet per Year			
Peak Delivery:		200	MGD	Peaking Factor =	1.25	

CONSTRUCTION COSTS

TEHUACANA DAM AND RESERVOIR

	Size	Quantity	Unit	Unit Price	Cost
Excavation					
Channel		2,250,000	C.Y.	$2.85	$6,414,000
Core trench & borrow		1,764,000	C.Y.	$2.85	$5,029,000
Fill Material					
Embankment		3,488,000	C.Y.	$3.56	$12,430,000
Waste Material		80,000	C.Y.	$2.85	$228,000
Filter, 1 & 2 (foundation drainage)		181,800	C.Y.	$42.76	$7,774,000
Stabilized base roadway		59,555	S.Y.	$25.66	$1,528,000
Cutoff slurry trench		514,800	S.F.	$17.10	$8,806,000
Soil cement including cement		137,800	C.Y.	$92.65	$12,767,000
Guard posts		1,680	each	$36.02	$61,000
Grassing		34	acres	$5,547	$189,000
Subtotal of Dam and Reservoir					**$55,226,000**
Conflicts					**$49,952,000**
Engineering and Contingencies (35%)					**$36,812,000**
Construction Total					**$141,990,000**
Land and Lignite Acquisition		**1**	**L.S.**	**$118,794,000**	**$118,794,000**
Permitting and Mitigation of Reservoir					**$237,588,000**
TOTAL RESERVOIR COST					**$498,372,000**

TRANSMISSION FACILITIES

Pipeline	**Size**	**Quantity***	**Unit**	**Unit Price**	**Cost**
Segment 1 - Cedar Creek to RC/CC Tie-in					
Pipeline (Rural)	72 in	62,464	LF	$458	$28,608,000
ROW Easements (Rural)		62,464	LF	$15	$947,000
Subtotal of Segment 1					**$29,555,000**
Segment 2 - R-C to RC/CC Tie-in					
Pipeline (Rural)	78 in	70,668	LF	$536	$37,878,000
ROW Easements (Rural)		70,668	LF	$15	$1,072,000
Subtotal of Segment 2					**$38,950,000**
Segment 3 - R-C Tie-in to IPL Tunnel					
Pipeline (Rural)	96 in	437,054	LF	$844	$368,874,000
Pipeline (Urban)	96 in	0	LF	$1,182	$0
ROW Easements (Rural)		0	LF	$15	$0
ROW Easements (Urban)		0	LF		$0
Subtotal of Segment 3					**$368,874,000**
Segment 4 - IPL Tunnel					
No Cost					
Segment 5 - From End of IPL Tunnel to Benbrook Lake					
Pipeline (Urban)	96 in	5,720	LF	$1,182	$6,758,000

ROW Easements (Urban)		5,720	LF	$90	$514,000
Subtotal of Segment 5					**$7,272,000**
Discharge Structure at Lake Benbrook	200 MGD	1	LS	$1,801,271	$1,801,000
Permitting and Mitigation					$5,327,000
Engineering and Contingencies (30%)					$133,176,000
Subtotal of Pipeline					**$584,955,000**
Pump Station(s)	**Size**	**Quantity**	**Unit**		**Cost**
Intake Pump Station at Cedar Creek	9300 HP	1	LS	$31,325,000	$31,325,000
Intake Pump Station at Richland-Chambers	11100 HP	1	LS	$35,935,000	$35,935,000
Pump Station at Tehuacana/R-C Channel	80 HP	1	LS	$1,167,000	$1,167,000
Booster Pump Station	20500 HP	1	LS	$38,297,000	$38,297,000
Storage Reservoir	40 MG	1	Ea	$8,320,293	$8,320,000
Permitting and Mitigation					$1,381,000
Engineering and Contingencies (35%)					$40,265,000
Subtotal of Pump Stations					**$156,690,000**
CONSTRUCTION TOTAL					**$1,240,017,000**
Interest During Construction	**(48 months)**				**$200,474,000**
TOTAL COST					**$1,440,491,000**
ANNUAL COSTS					
Debt Service (6% for 30 years)					$104,650,000
Electricity ($0.09 per kWh)					$17,377,000
Operation & Maintenance					$9,772,000
Total Annual Costs					**$131,799,000**
UNIT COSTS (Until Amortized)					
Per Acre-Foot					$736
Per 1,000 Gallons					$2.26
UNIT COSTS (After Amortization)					
Per Acre-Foot					$152
Per 1,000 Gallons					$0.47

*For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.

D-4.16 Toledo Bend Reservoir (With Partners) and Tehuacana (TRWD Only)

Toledo Bend Pipeline Project (With Partners) and Tehuacana (TRWD Only) to Benbrook
North Texas MWD, Tarrant Regional WD, Dallas Water Utilities and Sabine River Authority

Total Yield = 741,900 acre-feet per year   Peaking Factor = 1.5

Tehuacana Yield (100% TRWD)

TRWD	41,900	AF/Y	
Toledo Bend Project Yield Distribution			
NTMWD	200,000	AF/Y	28.6%
TRWD	200,000	AF/Y	28.6%
DWU	200,000	AF/Y	28.6%
SRA	100,000	AF/Y	14.3%
Total	700,000	AF/Y	

CONSTRUCTION COSTS

TEHUACANA DAM AND RESERVOIR

	Size	Quantity	Unit	Unit Price	Cost
Excavation					
Channel		2,250,000	C.Y.	$2.85	$6,414,000
Core trench & borrow		1,764,000	C.Y.	$2.85	$5,029,000
Fill Material					
Embankment		3,488,000	C.Y.	$3.56	$12,430,000
Waste Material		80,000	C.Y.	$2.85	$228,000
Filter, 1 & 2 (foundation drainage)		181,800	C.Y.	$42.76	$7,774,000
Stabilized base roadway		59,555	S.Y.	$25.66	$1,528,000
Cutoff slurry trench		514,800	S.F.	$17.10	$8,806,000
Soil cement including cement		137,800	C.Y.	$92.65	$12,767,000
Guard posts		1,680	each	$36.02	$61,000
Grassing		34	acres	$5,547	$189,000
Subtotal of Dam and Reservoir					**$55,226,000**
Conflicts					**$49,952,000**
Engineering and Contingencies (35%)					**$36,812,000**
Construction Total					**$141,990,000**
Land and Lignite Acquisition		**1**	**L.S.**	**$118,794,000**	**$118,794,000**
Permitting and Mitigation of Reservoir					**$237,588,000**
TOTAL RESERVOIR COST					**$498,372,000**

PUMP STATION AT TEHUACANA/R-C CHANNEL	**Size**	**Quantity**	**Unit**		**Cost**
Pump Station at Tehuacana/R-C Channel	80 HP	1	LS	$1,167,000	$1,167,000
Permitting and Mitigation					$14,000
Engineering and Contingencies (35%)					$408,000
TOTAL PUMP STATION AT TEHUACANA/R-C CHANNEL COST					**$1,589,000**

TRANSMISSION FACILITIES*

Pipeline	**Size**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Segment 1 - Toledo Bend to NTMWD/SRA/DWU1					
Pipeline Rural	120 in	660,110	LF	$1,258	$830,418,000
Pipeline Urban	120 in	36,927	LF	$1,761	$65,028,000
Right of Way Easements Rural (ROW)		660,110	LF	$25	$16,444,000

Right of Way Easements Urban (ROW)		36,927	LF	$63	$2,320,000
Engineering and Contingencies (30%)					$268,634,000
Permitting & Mitigation					$10,745,000
Subtotal of Pipeline Segment 1 (Parallel to 132" Pipeline)					**$1,193,589,000**
Segment 1 - Toledo Bend to NTMWD/SRA/DWU1					
Pipeline Rural	132 in	660,110	LF	$1,447	$954,849,000
Pipeline Urban	132 in	36,927	LF	$2,025	$74,777,000
Right of Way Easements Rural (ROW)		660,110	LF	$0	$0
Right of Way Easements Urban (ROW)		36,927	LF	$0	$0
Engineering and Contingencies (30%)					$308,888,000
Permitting & Mitigation					$12,356,000
Subtotal of Pipeline Segment 1 (Parallel to 120" Pipeline)					**$1,350,870,000**
Segment 2 - NTMWD/SRA/DWU1 to IPL ROW					
Pipeline Rural x 2	96 in	364,912	LF	$844	$307,986,000
Pipeline Urban x 2	96 in	11,209	LF	$1,182	$13,243,000
Right of Way Easements Rural (ROW)		182,456	LF	$25	$4,545,000
Right of Way Easements Urban (ROW)		5,605	LF	$63	$352,000
Engineering and Contingencies (30%)					$96,369,000
Permitting & Mitigation					$3,855,000
Subtotal of Pipeline Segment 2					**$426,350,000**
Segment 3a - IPL ROW to R-C/Tehuacana Tie-in					
Pipeline Rural x 2	96 in	358,553	LF	$844	$302,619,000
Pipeline Urban x 2	96 in	11,014	LF	$1,182	$13,013,000
Right of Way Easements Rural (ROW)		0	LF		$0
Right of Way Easements Urban (ROW)		0	LF		$0
Engineering and Contingencies (30%)					$94,690,000
Permitting & Mitigation					$3,788,000
Subtotal of Pipeline Segment 3a					**$414,110,000**
Segment 3b - R-C/Tehuacana Tie-in to Take-off to DWU2					
Pipeline Rural x 2	102 in	642,211	LF	$945	$606,890,000
Pipeline Urban x 2	102 in	19,727	LF	$1,323	$26,099,000
Right of Way Easements Rural (ROW)		0	LF		$0
Right of Way Easements Urban (ROW)		0	LF		$0
Engineering and Contingencies (30%)					$189,897,000
Permitting & Mitigation					$7,596,000
Subtotal of Pipeline Segment 3b					**$830,482,000**
Segment 4 - DWU2 Take-off to IPL Tunnel					
Pipeline Rural	108 in	115,710	LF	$1,040	$120,280,000
Pipeline Urban	108 in	3,564	LF	$1,456	$5,188,000
Right of Way Easements Rural (ROW)		0	LF		$0
Right of Way Easements Urban (ROW)		0	LF		$0
Engineering and Contingencies (30%)					$37,640,000
Permitting & Mitigation					$1,506,000
Subtotal of Pipeline Segment 4					**$164,614,000**
Segment 5 - IPL Tunnel					
No Cost					
Segment 6 - From End of IPL Tunnel to Lake Benbrook					
Discharge Structure at Lake Benbrook	324 MGD	1	LS	$4,484,000	$4,484,000
Pipeline Rural	108 in	0	LF	$1,040	$0
Pipeline Urban	108 in	5,720	LF	$1,456	$8,325,000
Right of Way Easements Rural (ROW)		0	LF	$15	$0
Right of Way Easements Urban (ROW)		5,720	LF	$90	$514,000
Engineering and Contingencies (30%)					$3,843,000
Permitting & Mitigation					$154,000
Subtotal of Pipeline Segment 6					**$17,320,000**
Segment 7 - NTMWD/SRA/DWU1 to Lake Tawakoni					
Pipeline Rural	120 in	233,427	LF	$1,258	$293,651,000

Pipeline Urban	120 in	13,058	LF	$1,761	$22,995,000
Right of Way Easements Rural (ROW)		233,427	LF	$25	$5,815,000
Right of Way Easements Urban (ROW)		13,058	LF	$63	$820,000
Engineering and Contingencies (30%)					$94,994,000
Permitting & Mitigation					$3,800,000
Subtotal of Pipeline Segment 7					**$422,075,000**
Segment 8 - Lake Tawakoni to NTMWD Take-Off					
Pipeline Rural	96 in	65,869	LF	$844	$55,594,000
Pipeline Urban	96 in	3,685	LF	$1,182	$4,354,000
Right of Way Easements Rural (ROW)		65,869	LF	$25	$1,641,000
Right of Way Easements Urban (ROW)		3,685	LF	$63	$231,000
Engineering and Contingencies (30%)					$17,984,000
Permitting & Mitigation					$719,000
Subtotal of Pipeline Segment 8					**$80,523,000**
Total Pipeline Cost					**$4,899,933,000**

NTMWD Portion of Pipeline	*28.6% (Segment 1) & 57.1% Segment 7 & 100% Segment 8*	*$1,048,685,000*
TRWD Portion of Pipeline	*28.6% (Segment 1) & 57.14% (Segment 2 & 3a) & 61.72% (Segment 3b) & 100% (Segments 4 and 6)*	*$1,901,735,000*
DWU Portion of Pipeline	*28.6% (Segment 1) & 42.86% (Segment 2 & 3a) & 38.28% (Segment 3b) & (14.3% Segment 7)*	*$1,465,432,000*
SRA Portion of Pipeline	*14.3% (Segment 1) & 28.6% Segment 7*	*$484,081,000*
Total Check		*$4,899,933,000*

Transmission System Pump Station(s)	**Size (per PS)**	**Quantity**	**Unit**	**Unit Price**	**Cost**
Intake Pump Station at Toledo Bend Reservoir	75200 HP	1	LS	$94,930,000	$94,930,000
Booster Pump Station 1	46600 HP	1	LS	$57,447,000	$57,447,000
Booster Pump Station 2	77600 HP	1	LS	$85,348,000	$85,348,000
Booster Pump Station 3	61000 HP	1	LS	$70,408,000	$70,408,000
Booster Pump Station 4	40200 HP	1	LS	$51,686,000	$51,686,000
Booster Pump Station 5	34200 HP	1	LS	$47,068,000	$47,068,000
Booster Pump Station 6	45800 HP	1	LS	$56,727,000	$56,727,000
Booster Pump Station 7	13800 HP	1	LS	$32,422,000	$32,422,000
Booster Pump Station 8	14000 HP	1	LS	$32,602,000	$32,602,000
Booster Pump Station 9	12000 HP	1	LS	$30,801,000	$30,801,000
Storage Reservoir at booster station 1	156 MG	1	EA	$23,488,000	$23,488,000
Storage Reservoir at booster station 2	156 MG	1	EA	$23,488,000	$23,488,000
Storage Reservoir at booster station 3	156 MG	1	EA	$23,488,000	$23,488,000
Storage Reservoir at booster station 4	78 MG	1	EA	$14,191,000	$14,191,000
Storage Reservoir at booster station 5	87 MG	1	EA	$15,506,000	$15,506,000
Storage Reservoir at booster station 6	87 MG	1	EA	$15,506,000	$15,506,000
Storage Reservoir at booster station 7	54 MG	1	EA	$10,575,000	$10,575,000
Storage Reservoir at booster station 8	76 MG	1	EA	$13,878,000	$13,878,000
Storage Reservoir at booster station 9	54 MG	1	EA	$10,575,000	$10,575,000
Engineering and Contingencies (35%)					$248,547,000
Permitting & Mitigation					$8,522,000
Subtotal of Pump Station(s)					**$967,203,000**

Total Transmission System Pump Station Costs (Including Storage Reservoirs)		**$967,203,000**
NTMWD	*28.6% (Intake Pump Station, Boosters and Storage at 1,2, & 3) & 57.1% (Booster and Storage at 8) & 100% (Booster and Storage at 9)*	*$239,855,000*
TRWD	*28.6% (Intake, Boosters and Storage at 1,2, & 3), 57.1% (Booster and Storage at 4), 61.7% (Boosters and Storage at 5 &6) & 100% (Booster and Storage at 7)*	*$370,481,000*
DWU	*28.6% (Intake Pump Station, Boosters and Storage at 1,2, & 3) & 42.86% (Booster and Storage at 4) & 38.28% (Boosters and Storage at 5 & 6) & 14.3% (Booster and Storage at 8)*	*$265,116,000*
SRA	*14.3% (Intake Pump Station, Boosters and Storage at 1,2, & 3) & 28.6% (Booster and Storage at 8)*	*$91,751,000*
Total Check		*$967,203,000*

** For cost estimating purposes, 10% was added to the pipeline lengths to account for slope distances and routing around obstacles.*

CONSTRUCTION TOTAL		**$6,367,097,000**
Interest During Construction	**(84 months - pipeline)**	**$1,793,420,000**
TOTAL COST		**$8,160,517,000**
NTMWD		*$1,651,483,000*
TRWD		*$3,553,016,000*
DWU		*$2,217,991,000*
SRA		*$738,027,000*
Total Check		*$8,160,517,000*

TOTAL COST ANALYSIS

NTMWD	**Cost**
Debt Service (6% for 30 years)	$119,978,000
Electricity ($0.09 kWh)	$28,326,000
Operation & Maintenance	$11,604,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (NTMWD)	**$166,425,000**
TRWD	
Debt Service (6% for 30 years)	$258,123,000
Electricity ($0.09 kWh)	$43,280,000
Operation & Maintenance	$27,167,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (TRWD)	**$335,087,000**
DWU	
Debt Service (6% for 30 years)	$161,135,000
Electricity ($0.09 kWh)	$34,519,000
Operation & Maintenance	$19,166,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (DWU)	**$221,337,000**
SRA	
Debt Service (6% for 30 years)	$53,617,000

Electricity ($0.09 kWh)	$11,378,000
Operation & Maintenance	$6,407,000
Raw Water Purchase ($0.10/1,000 gal)	$0
Total Annual Costs (SRA)	**$71,402,000**
TOTAL ANNUAL	
Debt Service (6% for 30 years)	$592,853,000
Electricity ($0.09 per kWh)	$117,503,000
Operation & Maintenance	$64,344,000
Raw Water Purchase ($0.10/1,000 gal)	$19,551,000
Total Annual Costs (All Users)	**$794,251,000**
UNIT COSTS (During Amortization)	
NTMWD	
Per Acre-Foot	$832
Per 1,000 Gallons	$2.55
TRWD	
Per Acre-Foot	$1,385
Per 1,000 Gallons	$4.25
DWU	
Per Acre-Foot	$1,107
Per 1,000 Gallons	$3.39
SRA	
Per Acre-Foot	$714
Per 1,000 Gallons	$2.19
Total All Users	
Per Acre-Foot	$1,135
Per 1,000 Gallons	$3.48
ANNUAL COSTS (After Amortization)	
NTMWD	**Cost**
Electricity ($0.09 kWh)	$28,326,000
Operation & Maintenance	$11,604,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (NTMWD)	**$46,447,000**
TRWD	
Electricity ($0.09 kWh)	$43,280,000
Operation & Maintenance	$27,167,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (TRWD)	**$76,964,000**
DWU	
Electricity ($0.09 kWh)	$34,519,000
Operation & Maintenance	$19,166,000
Raw Water Purchase ($0.10/1,000 gal)	$6,517,000
Total Annual Costs (DWU)	**$60,202,000**
SRA	
Electricity ($0.09 kWh)	$11,378,000
Operation & Maintenance	$6,407,000
Raw Water Purchase ($0.10/1,000 gal)	$0
Total Annual Costs (SRA)	**$17,785,000**

Total All Users	
Electricity ($0.09 kWh)	$117,503,000
Operation & Maintenance	$64,344,000
Raw Water Purchase ($0.10/1,000 gal)	$19,551,000
Total Annual Costs (All Users)	**$201,398,000**
UNIT COSTS (After Amortization)	
NTMWD	
Per Acre-Foot	$232
Per 1,000 Gallons	$0.71
TRWD	
Per Acre-Foot	$318
Per 1,000 Gallons	$0.98
DWU	
Per Acre-Foot	$301
Per 1,000 Gallons	$0.92
SRA	
Per Acre-Foot	$178
Per 1,000 Gallons	$0.55
All Users	
Per Acre-Foot	$288
Per 1,000 Gallons	$0.88

Appendix E
IWSP System Simulation Model Documentation

Appendix E – IWSP System Simulation Model Documentation

The IWSP System Simulation Model (model) was originally developed for the Integrated Pipeline Study (IPL) in 2009, and the model has been updated over time as changes or improvements were needed. Previous reports thoroughly document the development and changes that have been made to the model during the IPL Study. This Appendix discusses the adaptation of the IPL model to the IWSP Study, and recent improvements/changes that were made to the model.

Please see the following reports for any additional documentation:

- *IPL Operations Study – STELLA Model Enhancements for Operations*, CDM Smith, November 2011.
- *Integrated Pipeline Project Conceptual Design Operations Study Final Report*, CDM Smith, April 2012.
- *Integrated Pipeline Project Conceptual Design Operations Study Operations Model User's Manual*, CDM Smith, July 2012.

The model was originally developed as a tool to guide planning with monthly timesteps and operational level detail, but it is adapted for the IWSP purposes to study more general availability of new sources and how these might be integrated into the existing and planned TRWD transmission system. Operating rules for new sources were developed but not optimized, and results can best be interpreted as annual average conditions.

The model simulates a historical period of hydrology from 1941-2007, and superimposes any future demand level by decade through 2060 (for example, 2050 demands can be tested over the full hydrologic record in a single model simulation). In this way, the model projects the probability of meeting demands in a future decade based on the frequency in which simulated future demands are satisfied over the historical hydrologic period of record.

Relevant features of the model that were added to support the IWSP analysis include the following:

- The IWSP water management strategies along with switches to activate or deactivate each strategy;
- The ability to import different demand projections;
- Options to decrease reservoir inflows and increase evaporation rates.

Also, the following improvements/changes have been made to the model:

- Projected sedimentation rates were added to change the storage volume available over time in the existing TRWD reservoirs.

- Programming was adjusted related to water management strategies connected to Cedar Creek and Richland-Chambers Reservoirs and the Integrated Pipeline (IPL).

The following sections discuss in more detail the features and improvements/changes listed above.

E.1 New Water Management Strategies

The model allows for several water management strategies to be turned on or off during a simulation. This was a necessary feature in order to assess the different implementation plans. Specifics of each strategy are discussed below and are explained further in Section 4.1 of the main report.

- **Unpermitted Firm Yield and Constructed Wetlands Full Yield Permits for Cedar Creek and Richland-Chambers Reservoirs**: These strategies increase the permitted yield that can be utilized from these reservoirs. These supplies are impacted by sedimentation; therefore, the supply available decreases over time. This is accounted for in the model. They are routed through the IPL in the model because they will potentially be delivered through the IPL until current supply sources fully utilize the line. Eventually additional transmission capacity may be needed, and the model has been programmed to allow for such increases in capacity.

- **Lake Columbia**: This is a proposed reservoir to be located east of Lake Palestine. It could initially be conveyed through the IPL, but will eventually require a new pipeline. The ability to increase transmission capacity for this source is included in the model. Use of this source is not initiated until a certain user-specified (but not optimized) percentage of the permitted yield from Cedar Creek and Richland-Chambers Reservoirs is utilized each year. This percentage can be adjusted in the model for experimental purposes. Once the supply from Lake Columbia is initiated, Cedar Creek and Richland-Chambers provide water only by way of their current pipelines, while Lake Columbia provides water to the IPL (at its planned capacity or at a capacity set by the user).

- **Excess flow Optimization (EXFLO)**: This option allows for additional water supply to be obtained from Eagle Mountain Lake and Lake Benbrook during high flow conditions. This supply is routed through existing infrastructure. The availability of EXFLO water was computed outside of the IWSP model. For the simulated historical years of 1941-1979, it was estimated using results from the WAM model (per TRWD's EXFLO Water Rights Application, Supplemental Statement Attachment 1, Table 4-2). For the simulated historical years of 1980-2007, it was estimated using results from TRWD's RiverWare model. Timeseries of available surplus water were then added to the IWSP model on a monthly basis. If EXFLO water is available in a given month, it can be taken to help satisfy demands but is not counted against the annual permits for individual reservoirs or the West Fork System.

- **Kiamichi River**: The Kiamichi River supply is modeled explicitly using hydrological data as opposed to a hard-coded yield, like other strategies in the model. River flows are diverted to an 80,000 acre-foot off-channel storage facility, then delivered to Lake

Bridgeport. Inflows, evaporation, instream flow requirements, and pumping limitations are all modeled.

- **Marvin Nichols Reservoir**: This is a proposed reservoir to be located in North East Texas, and it would require a new transmission pipeline to Lake Bridgeport. The supply and pipeline would be shared by others, but only TRWD's share was considered in the model. This reservoir is only modeled as a source with a fixed annual capacity based on the supply available for TRWD. The model does not route this supply through any existing infrastructure or the IPL; the model instead distributes it volumetrically to Eagle Mountain, West Side, Holly, and Benbrook Water Treatment Plants, in that order.

- **Lake Ringgold**: This is a proposed reservoir to be located north of Lake Bridgeport near the Texas-Oklahoma border. This supply requires a new transmission to Lake Bridgeport. Unlike some of the other sources, the Lake Ringgold system is modeled using hydrological data as opposed to a hard-coded yield because the data were available and it was originally considered useful to be able to analyze operational compatibility between Lake Ringgold and Temple Reservoir (see below).

- **Lake Tehuacana**: This is a proposed reservoir to be located just south of the Richland-Chambers Reservoir. It could initially utilize the IPL, but will eventually require a new pipeline. The ability to increase transmission capacity for this source is included in the model. Because it would be hydraulically connected to Richland Chambers Reservoir, it is simulated in the model simply as an additional source of runoff into Richland-Chambers (based on the drainage area to Lake Tehuacana). The storage-area-elevation curve of Richland-Chambers is then adjusted to account for the additional storage capacity of Tehuacana, and effectively the two reservoirs are simulated as one larger reservoir.

- **Temple Reservoir**: Like the Kiamichi River modeling, Temple Reservoir is modeled explicitly using hydrological data as opposed to a hard-coded yield. Inflows, evaporation, instream flow requirements, and pumping limitations are all modeled. Water is delivered from Temple Reservoir in Southwestern Oklahoma to Lake Bridgeport.

- **Lake Texoma**: This is an existing reservoir located north of Dallas on the Texas-Oklahoma border, and it would require a new transmission pipeline to Lake Ray Roberts and then on to Lake Bridgeport. The supply and pipeline would be shared by others, but only TRWD's share was considered in the model. The model does not route this supply through any existing infrastructure or the IPL, but rather distributes it volumetrically to Eagle Mountain, West Side, Holly, and Benbrook Water Treatment Plants, in that order. Lake Texoma has elevated levels of dissolved solids; it must therefore be blended with higher quality water or desalinated for municipal use. The model uses a minimum 10 to 1 blending factor when blending water in TRWD's West Fork system with Lake Texoma water.

- **Toledo Bend Reservoir**: This is an existing reservoir located east of Lake Palestine along the Texas-Louisiana border. A new pipeline would be require to convey this supply. The supply and pipeline would be shared by others, but only TRWD's share was considered in the model. The ability to increase transmission capacity for this source is included in the model. Use of this source is not initiated until a certain user-defined (but not optimized) percentage of the permitted yield from Cedar Creek and Richland-Chambers Reservoirs is utilized each year. This percentage can be adjusted in the model for experimental purposes. Once the supply from Toledo Bend Reservoir is initiated, Cedar Creek and Richland-Chambers provide water only by way of their current pipelines, while Toledo Bend Reservoir provides water to the IPL (at its planned capacity or at a capacity set by the user to account for the new pipeline to be built parallel to the IPL).

- **Lake Wright Patman**: This is an existing reservoir located in North East Texas and further east of the proposed Marvin Nichols Reservoir. It would require a new transmission pipeline to Lake Bridgeport. This reservoir is only modeled as a source based on the supply available for TRWD. The model does not route this supply through any existing infrastructure or the IPL, but rather distributes it volumetrically to Eagle Mountain, West Side, Holly, and Benbrook Water Treatment Plants, in that order.

E.2 Water Demand Projections

There were two sets of water demand projections considered in this study, as discussed in Section 3. Model users can import either demand projection from a spreadsheet set up for this purpose. Both of the demand projections were used to evaluate different future scenarios.

E.3 Climate Change Options

The model allows for a simplified adjustment to historic hydrologic conditions to simulate possible climate change impacts to current TRWD water sources. Input variables on the interface allow the user to adjust evaporation and streamflow by percentages, which are then applied uniformly, in all months, to each existing source. For analysis of the "stressed system scenarios" as described in Section 5.2, evaporation was increased by 15 percent and stream flow was decreased by 15 percent.

E.4 Sedimentation Projections

Projections for how sedimentation will ultimately impact the maximum conservation storage for existing TRWD reservoirs were used to modify the availability of reservoir storage. The reservoirs impacted include Cedar Creek Reservoir, Richland-Chambers Reservoir, Lake Bridgeport, Eagle Mountain Lake, Lake Benbrook, and Lake Worth. The projections were developed from the latest volumetric survey and sedimentation rates from the Texas Water Development Board (TWDB). Elevation-area-capacity curves were calculated for years 2000, 2030, and 2060 based on the TWDB projections.

Although reservoir elevation-area-capacity curves are used in the model, it was determined that, at this time, the most relevant change that needed to be made was to the maximum conservation storage values, which would limit the supply available over time. Updates to the actual curves and programming in multiple curves to account for sedimentation projections would result in nearly identical results as compared to modifying the maximum conservation storage values in the model. Because the model can be simulated for any 10-year increment from 2010 to 2060, the projected maximum conservation storage was interpolated linearly for each decade between 2000, 2030, and 2060. Some additional information that was accounted for in the interpolation was a 2005 survey for Cedar Creek and a 2007 survey for Richland-Chambers. Table E.1 shows the maximum conservation storage included in the model for each reservoir at each decade.

Table E.1: Maximum Conservation Storage Projections by Decade for TRWD Reservoirs (Acre-Feet)

Decade	Cedar Creek	Richland-Chambers	Bridgeport	Eagle Mountain	Benbrook	Worth
2010	640,945	1,106,568	361,714	179,370	85,034	32,435
2020	633,265	1,085,918	357,191	176,707	84,419	31,375
2030	625,585	1,065,268	352,669	174,044	83,805	30,315
2040	617,905	1,044,618	347,895	171,381	83,229	29,206
2050	610,225	1,023,968	343,121	168,719	82,653	28,096
2060	602,545	1,003,318	338,347	166,056	82,077	26,987

There is a table in the user interface that shows "TRWD Max Conservation Storage (AF)" where the user could previously edit the values as needed. These values can no longer be edited. They are instead based on equations that adjust the maximum conservation storage according the simulation decade as shown in Table E.1.

E.5 Programming Changes Related to Cedar Creek and Richland-Chambers Reservoirs

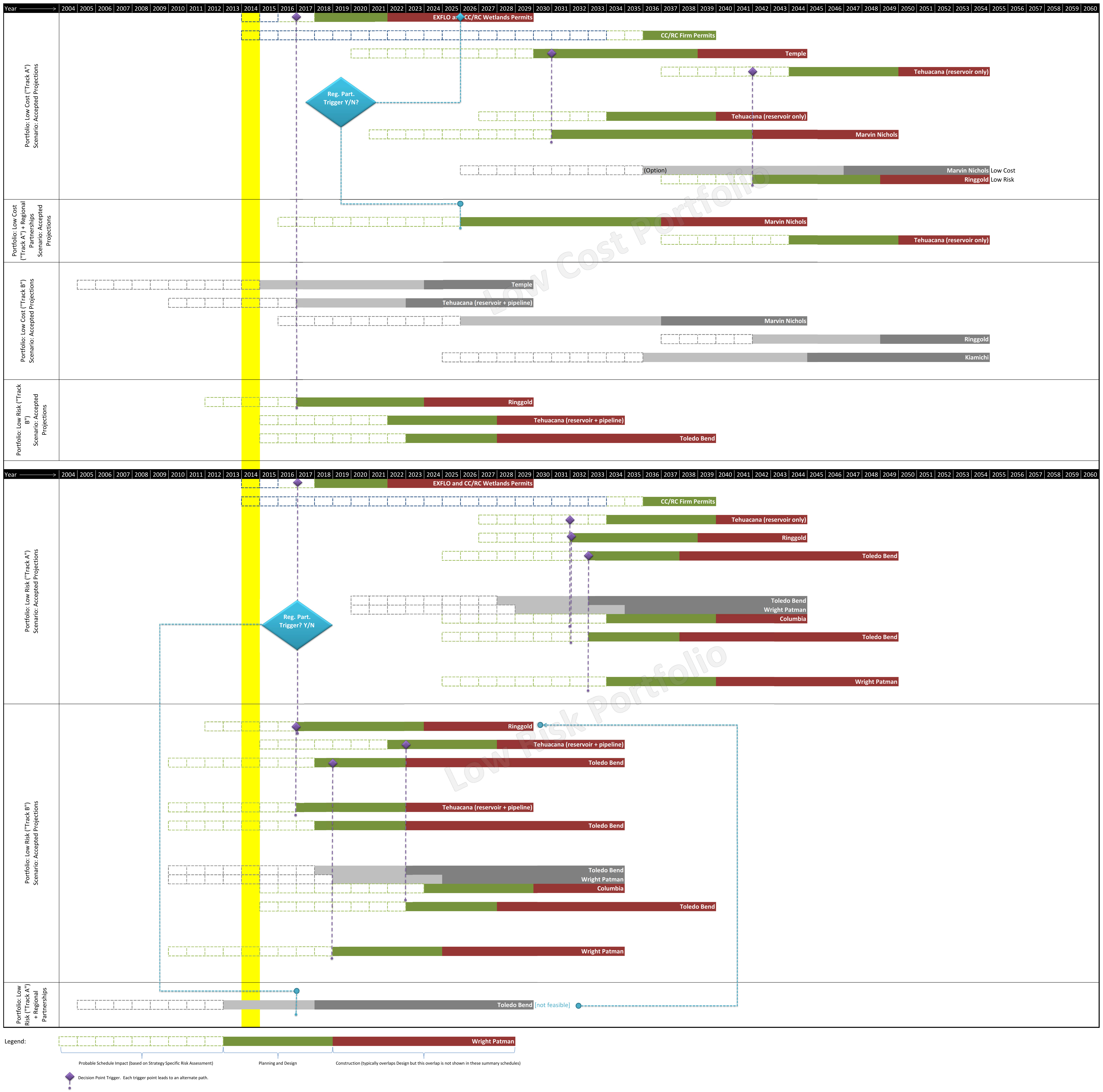
A number of changes were made to the model to appropriately simulate the availability of multiple water supply strategies that are associated with the Cedar Creek and Richland-Chambers Reservoirs and the IPL. Changes include adding options to increase the capacity of the IPL, adjusting the programming to allow full utilization of conservation storage under certain circumstances, and removing Dallas supply sources to limit the analysis to only TRWD supplies.

The currently planned capacity of the IPL is committed to specific sources, but the IPL may be used to convey other sources until it is fully utilized. Later, if additional supplies are developed in the East, it will be necessary to build another pipeline parallel to the IPL. For this reason, an option was added to the model to increase the capacity of the IPL. This is being used as a proxy in the model for a new parallel pipeline. The model includes options to increase the capacity for Columbia, Toledo Bend, Tehuacana and for additional water from Cedar Creek and Richland-Chambers Reservoirs.

The model interface allows the user to set a percent of the conservation pools to remain for Cedar Creek and Richland-Chambers reservoirs when running a model simulation. When water supply strategies to increase the permitted yield out of these reservoirs are included in the simulation, the model fixes these percentages to zero. This is required because increasing the permitted yield means that these sources should be used in their entirety when evaluating them as a future water supply.

The last change that was made related to the Cedar Creek and Richland-Chambers reservoirs impacts the simulated flows in the IPL. The model simulates water supply transmission for the City of Dallas in the IPL for their portion of the capacity. For the purposes of this project, it was necessary to remove these flows from the IPL to isolate the operating costs related to TRWD supplies only.

Appendix G
Detailed Decision Tree
Accepted Projections Scenario



Year
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060
Portfolio: Low Cost ("Track A") Scenario: Accepted Projections
EXFLO and CC/RC Wetlands Permits
CC/RC Firm Permits
Temple
Tehuacana (reservoir only)
Reg. Part. Trigger Y/N?
Tehuacana (reservoir only)
Marvin Nichols
(Option)
Marvin Nichols
Low Cost
Ringgold
Low Risk
Portfolio: Low Cost ("Track A") + Regional Partnerships Scenario: Accepted Projections
Marvin Nichols
Tehuacana (reservoir only)
Portfolio: Low Cost ("Track B") Scenario: Accepted Projections
Temple
Tehuacana (reservoir + pipeline)
Marvin Nichols
Ringgold
Kiamichi
Portfolio: Low Risk ("Track B") Scenario: Accepted Projections
Ringgold
Tehuacana (reservoir + pipeline)
Toledo Bend
Low Cost Portfolio
Year
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060
Portfolio: Low Risk ("Track A") Scenario: Accepted Projections
EXFLO and CC/RC Wetlands Permits
CC/RC Firm Permits
Tehuacana (reservoir only)
Ringgold
Toledo Bend
Toledo Bend
Wright Patman
Columbia
Reg. Part. Trigger? Y/N
Toledo Bend
Wright Patman
Portfolio: Low Risk ("Track B") Scenario: Accepted Projections
Ringgold
Tehuacana (reservoir + pipeline)
Toledo Bend
Tehuacana (reservoir + pipeline)
Toledo Bend
Toledo Bend
Wright Patman
Columbia
Toledo Bend
Wright Patman
Portfolio: Low Risk ("Track A") + Regional Partnerships
Toledo Bend
[not feasible]
Low Risk Portfolio
Legend:
Wright Patman
Probable Schedule Impact (based on Strategy Specific Risk Assessment)
Planning and Design
Construction (typically overlaps Design but this overlap is not shown in these summary schedules)
Decision Point Trigger. Each trigger point leads to an alternate path.

Appendix H
Power Cost Projections

TARRANT REGIONAL WATER DISTRICT/CITY OF DALLAS

PHASE I STUDY OF PALESTINE RAW WATER

PROJECTED GENERATION AND TRANSMISSION COSTS

Based on the proposed scope of services related to forecasting electric generation costs, we have reviewed existing pricing analyses for the ERCOT and SPP regions, conducted a series of interviews concerning these analyses, and evaluated the extent to which new generation will be required through 2030, with estimated pricing impacts. In addition, historical ranges between average and peak pricing as well as zonal pricing have been reviewed to assist in providing a range of costs for the integrated pipeline project.

ERCOT REGION ANALYSIS

A. Existing Average Pricing Models

The Energy Information Administration ("EIA") provides forecasted energy prices annually that are trended through 2030. The Annual Energy Outlook 2009 ("AEO2009") was released in December 2008 and begins with a combination of 2007 and 2008 historical information as well of inclusion of electric generation facilities that have begun construction as of 2008.

As of the writing of this report, only the reference case of the AEO2009 has been released. However, EIA releases additional scenarios, which will take into account a variety of impacts for different plant construction activities and fuel pricing. When these scenarios become available, we will review the extent to which any additional reported information is relevant to the projections made for the integrated pipeline project.

a. ERCOT Regional Information from EIA

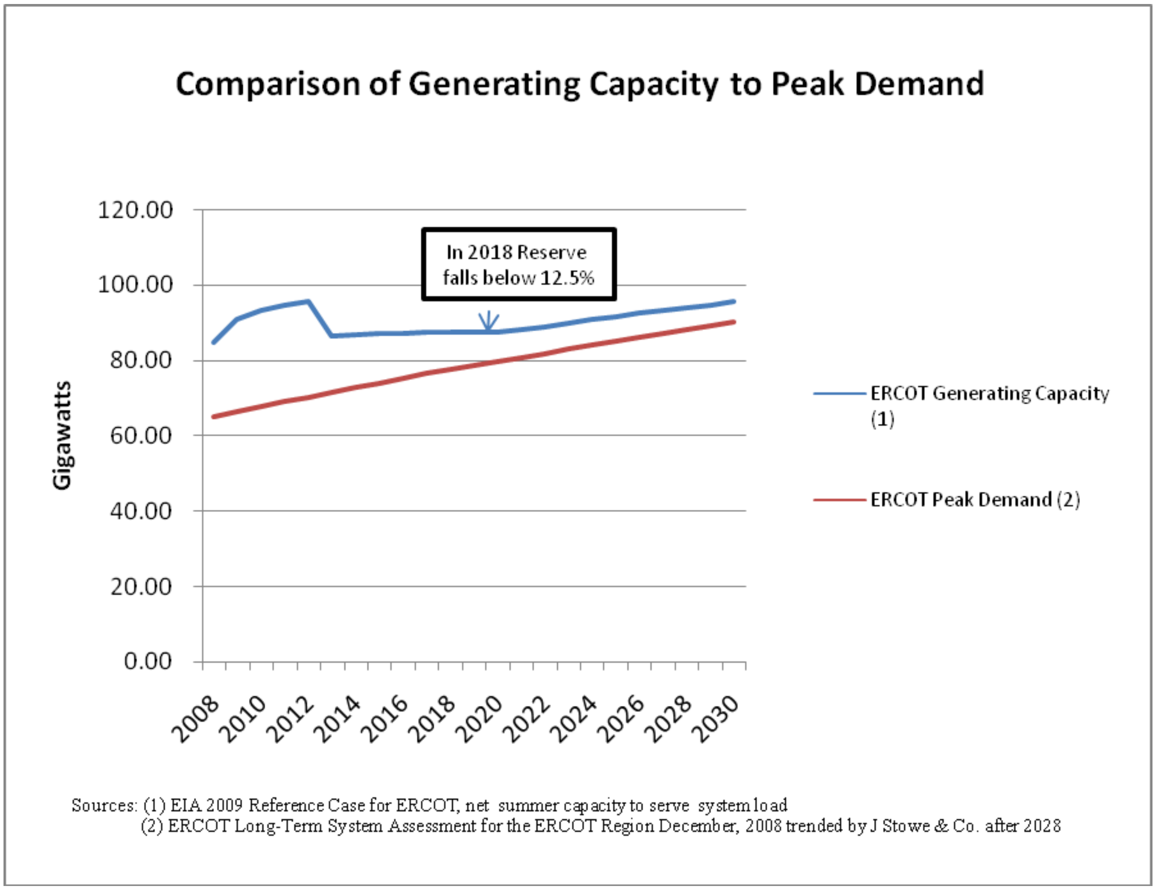
The AEO2009 Reference Case provides the information for the nation as a whole, as well as for each specific electric market region. For purposes of our analysis, the information specific to ERCOT was reviewed. The primary information used in our pricing model included the following:

- Electricity Generating Capacity (Gigawatts) – net summer generating capacity that has been trended to include only those additional facilities that had begun construction in 2008
- Generation by Fuel Type – billion kilowatt hours of generation trended to reflect generating capacity by fuel type
- Prices by Service Category – 2007 dollars per kilowatt hour, broken down by generation, transmission and distribution

b. **ERCOT Long Term Planning Information**

The AEO2009 reference case does not take into consideration any future needs in generating capacity based on increased demand. In order to estimate increased demand, we used long range planning information developed by ERCOT. *The Long-Term Assessment for the ERCOT Region* report, released in December 2008, provides a ten-year-out assessment of generation and transmission project needs. The report is not premised on developing actual prices for these services, but rather the economics of building certain fuel type plants and long range transmission planning needs assuming certain increases in population and energy demand.

Beginning with 2008, the ERCOT report provided annual Megawatt demand through 2018 and then every five years through 2028.[1] From 2008 through 2028, ERCOT showed an average annual increase in demand of approximately 2.14%. The following table provides a comparison between the trended net generating capacity included in the AEO2009 case and the trended demand put forth by ERCOT.



[1] We continued the average annual increase demonstrated by ERCOT from 2023 to 2028 for the next two years through 2030. We note that the ERCOT's estimation for percentage increases in demand are slightly lower that the State of Texas' estimated population growth.

As shown, the ERCOT projected demand will necessitate additional construction of electric generating facilities by 2018 in order to maintain a 12.5% reserve. In order to account for this need, it is that estimated additional generating capacity will be brought on line so that the reserve remains at or above the 12.5% ERCOT requirement.

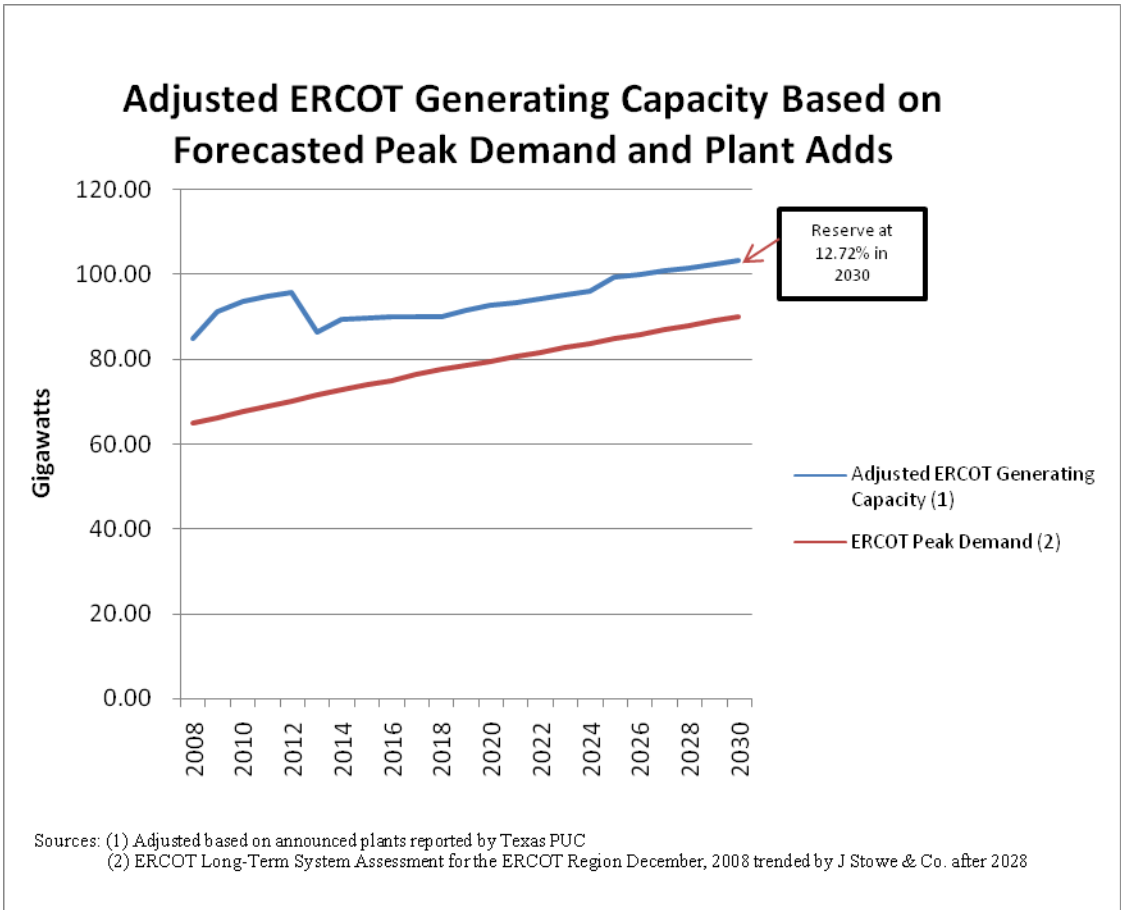
c. **Public Utility Commission of Texas' Listing of Announced Generation**

A listing developed by the PUCT was reviewed, which includes plants that are under construction as well as those announced, but not yet in the construction phase. It was confirmed that the AEO2009 Reference case includes the major plant additions that are on the PUCT's "construction" listing in order to ensure that that generation was already included in that pricing model. The first generation added was the larger base load gas fired units listed, and we conducted a general internet research of articles concerning those announced facilities to gauge the related possibility of construction. Our analysis showed these two large gas filed facilities have received some of the required regulatory approvals. These facilities are listed as a 1,750 megawatt unit in Greenville and a 1,092 megawatt unit near Temple. Assuming a construction start at the end of 2009, a construction period of three years, and an operating factor of 90%, we added 2.56 Gigawatts in 2014.

Based on discussions with the EIA representative, the ERCOT representative, and the PUCT representative, the addition of nuclear facilities will depend largely on the political environment. In Texas, there are five nuclear plants that already have applications filed at the Nuclear Regulatory Commission. These include two more reactors at the Comanche Peak facility, two at the South Texas Project facility and one near Victoria. Only two nuclear facilities have been added to the generation capacity in our analysis. The added nuclear plants were included at 90% of the nameplate capacity for one additional reactor at Comanche Peak in 2019, and one additional reactor at the South Texas Project in 2020. These plants are listed on the PUCT announced listing with an in-service date of 2015. However, in our interviews, no one believed that that date could be met.

The final addition to generating capacity includes four announced, moderately sized coal fired plants that have in-service dates of 2012. It is assumed that the "Cap and Trade" requirements will come to fruition during the near term (as also assumed by the AEO2009 case) and make coal a less economically viable choice until additional technological improvements can be made to coal generation. The added coal plants (totally additional capacity of 2.28 Gigawatts) are estimated to be on line in 2025.

The following chart shows the comparison of the EIA trended generation adjusted for the plant additions described above. These adjusted capacities allow for the required reserve when compared to ERCOT's projected increases in demand.



d. **EIA and ERCOT Pricing Information**

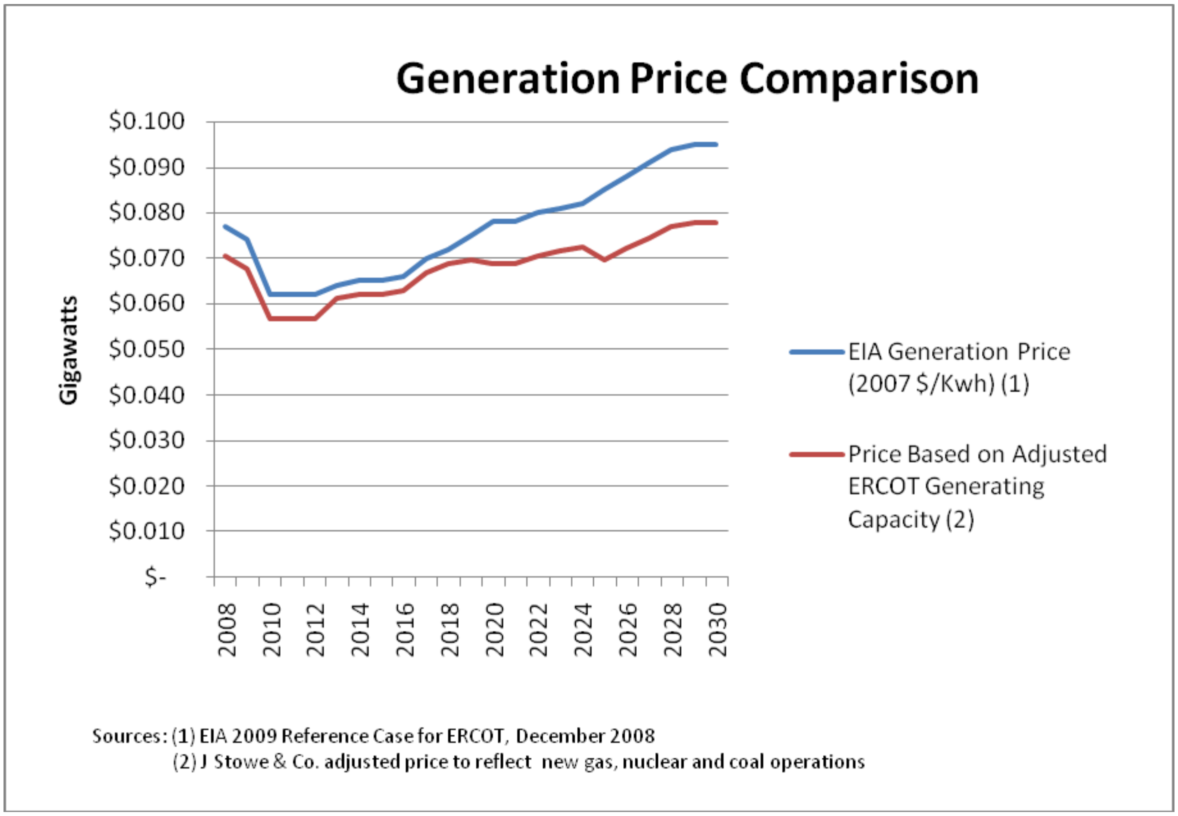
Next, the actual generation pricing information trended by EIA in the AEO2009 case was reviewed and analyzed. According to the EIA representative the energy pricing model was run with the following assumptions:

- Inflation CPI – 3.31%
- Inflation CPI-Energy – 3.88%
- Inflation WPI –Fuel and Power – 3.46%
- Fuel Prices ($ per MMBtu):
  - Coal - $1.72 to $2.01
  - Natural Gas - $8.77 to $8.52 (drops in 2009 and trends upward after)
  - Fuel Oil - $13.13 to $26.97

Additionally, the actual 15 minute interval prices were reviewed for each zone within ERCOT to develop the average total ERCOT price for the 2008 calendar year. The result of this analysis showed a 2008 average ERCOT price of $.070 per kilowatt hour for all zones. This compares to the 2008 AEO2009 reported price for ERCOT of $.077. Using the AEO2009 annual trends, we trended the actual 2008 price of $.070 through 2012. In 2013, the price was adjusted in order to take into account the two projected new gas fired plants. The EIA trends increase prices from 2012 to 2013 by approximately 3.22%. However, because we have added gas fired generation (at the EIA projected natural gas costs) we increased the price between 2012 and 2013 by 7.01%. But, due to the fact that our starting price of $.07 is less than EIA's $.077, we remain with an adjusted 2013 price that is $.003 lower.

Annually trending continued with the same percentage as EIA until the nuclear plants are added in 2019 and 2020. Inclusion of these plants allows for a lower to static price over the next three years with modest increases thereafter until 2025. These increases are due to continued increases in gas costs. As with nuclear, additional coal plants also allow for a slight drop in the annual price due to the price of coal being less than natural gas per MMBtu. This is seen in our additions for coal in 2025.

The following chart compares the price per kilowatt hours included in the AEO2009 Reference Case model and our adjusted starting price for the actual 2008 ERCOT average price and projected plant additions. The AEO2009 price information is still slightly higher, primarily due to a lower starting price and our estimated impacts of new plant with average pricing less than natural gas.



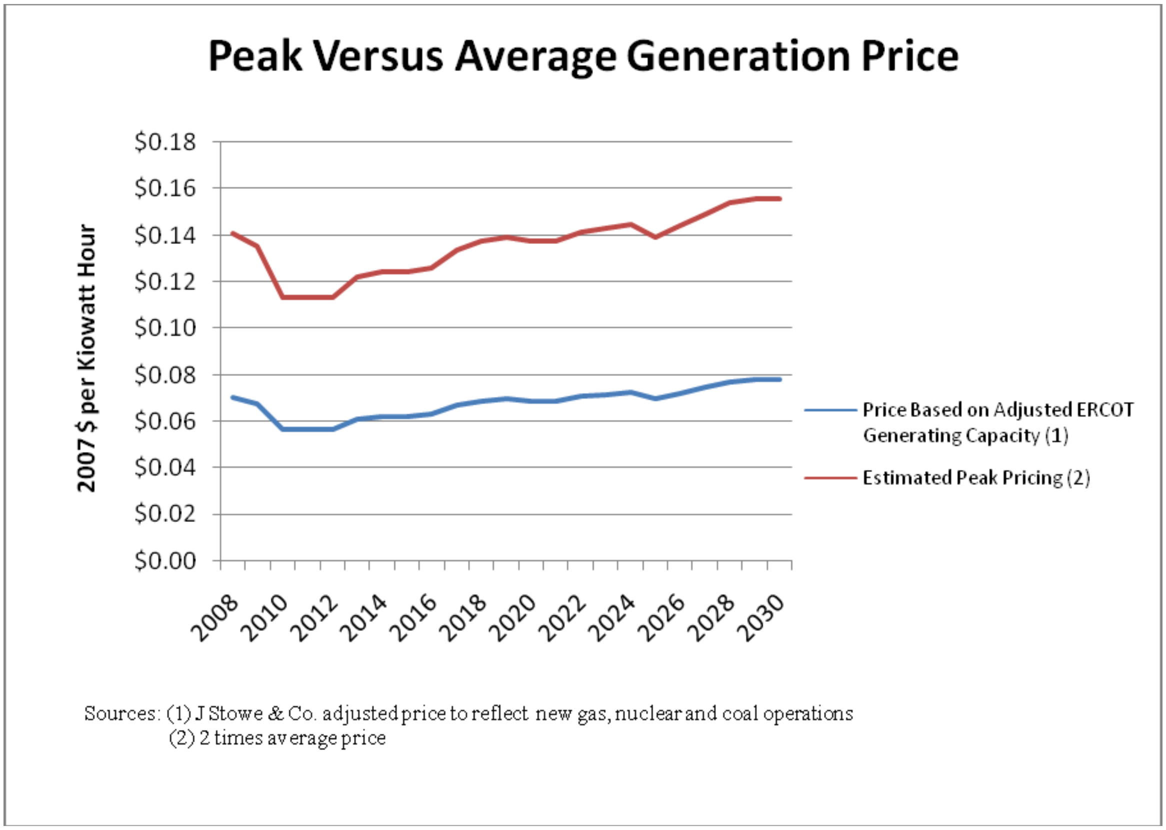
B. <u>ERCOT Peak, Average and Zonal Pricing Differences</u>

In order to better plan for the operation of the integrated pipeline project, variations were reviewed between the actual average ERCOT generation price and the peak price for the 2007 and 2008 calendar years. Peak and average pricing information for each of the current zones within ERCOT were also evaluated.

a. Peak v. Average Price

For the entire ERCOT region and based on the 15 minute interval pricing information, the peak price is approximately 2 times the average price for the two years reviewed.[2] Assuming that this relationship remains, our forecasted pricing would be as follows for ERCOT as a region:

[2] We note that for 2008, we removed the month of May as it reflected what appeared to be a one month anomaly in the peak pricing for the entire 24 months reviewed.



b. Zonal Pricing Differences

In reviewing the outlines of each of the ERCOT zones, it appears that the vast majority of the integrated pipeline project would be within the North Zone and have generation supplied easily from this area. It is anticipated that once the nodal market is implemented, and the CREZ transmission lines are complete, the integrated pipeline project area will have greater opportunity to receive benefits from the wind generation in the west. However, based on our conversations with a PUCT representative, the nodal market is several years from completion and the CREZ Transmission projects have just been awarded. Therefore, we have made no adjustments to the pricing to reflect what, in our opinion, may provide for lower pricing options with less reliability.

Reviewing the North Zone average prices for the 2007 and 2008 calendar years, it was noted that this area has average and peak prices that are approximately 99% of the total ERCOT region's average and peak pricing. Both the Houston and South zonal areas show higher average and peak pricing than the North zonal area, but the West zones has prices that are less; which may be due in large part to the continued increase in wind generation. For purposes of the integrated pipeline project and in order to be conservative, it is recommended that the average prices for the entire ERCOT region be utilized rather than making a reduction to reflect the slightly lower pricing in the North Zone.

C. Transmission Pricing

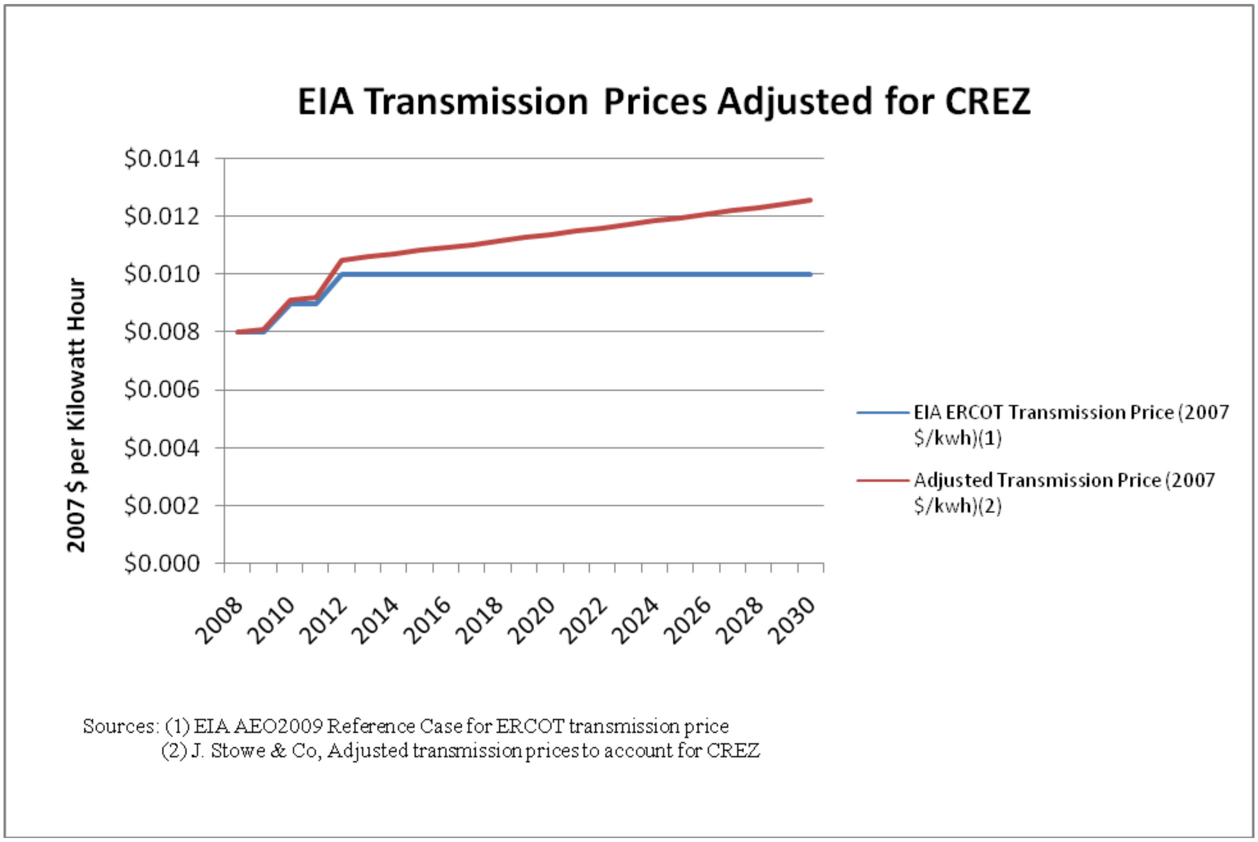
With respect to transmission pricing, the EIA AEO2009 Reference Case also includes a forecasted 2007 price per kilowatt hours for transmission costs. In order to verify the viability of using this information, we reviewed the following:

- Wholesale transmission matrix charges for ERCOT since 2004 to develop annual increases in postage stamp rates
- Selected billings from electric providers detailing the generation and transmission cost components to provide insight into estimating transmission costs as a percentage of generation costs

From this review, it is estimated that transmission costs range from approximately 7% to 11% of generation prices. The AEO2009 Reference Case shows transmission costs as a percentage of generation costs that range from 10% to 16%, with the higher percentages in those periods where the fuel costs trend downward while transmission costs continue a steady increase (2010 through 2016). The simple average percentage of transmission to generation for the period 2017 through 2030 is approximately 12% falling to 10.5% by 2030.

A review of the average annual increase in postage stamp rates demonstrated that from 2004 through 2007, the rates increased annual by approximately 3% including inflationary pressures. Excluding inflation, it was assumed that transmission prices would increase by 1% annually with normal replacement and additions.

As with the generation trending, the EIA AEO2009 model does not include transmission plant that is not already under construction. Therefore, an adjustment to the cost of transmission to account for the CREZ projects was made. Based on information from Docket No. 35665, the CREZ project will cost approximately $4.9 billion, will add approximately 18,000 MW to the ERCOT system and will be constructed by 2012. Computing an average change to the postage stamp rate of 2007 to take into account the additional investment costs and return beginning in 2012 increases the EIA AEO2009 Reference Case. In addition the costs beyond 2012 have been trended based on a 1% annual increase. The following chart depicts the comparison of our adjusted trend in transmission prices to those of EIA.



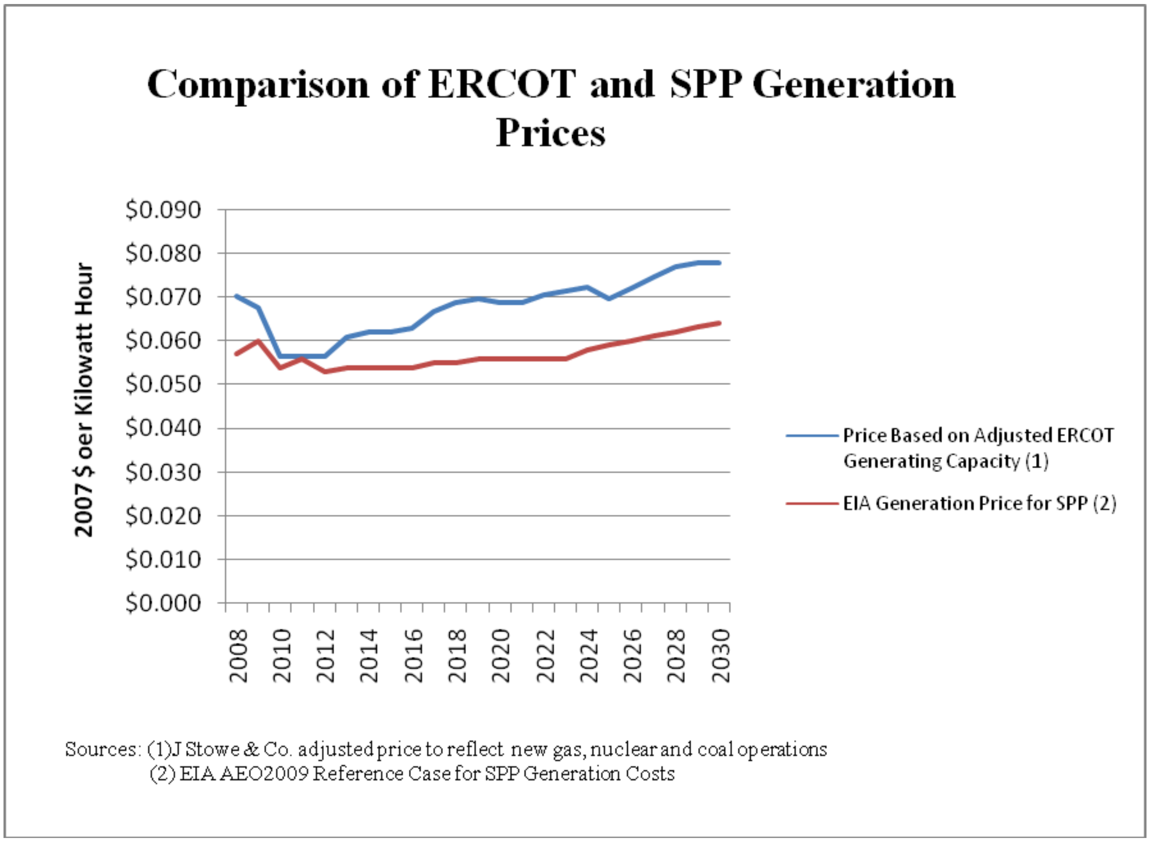
SOUTHWEST POWER POOL REGION ANALYSIS

Based on a limited review of the Southwest Power Pool ("SPP") generation and transmission prices, it appears that there may be limited opportunity to obtain power from this region. However, according to the CEO of Rayburn Country Electric Cooperative, the G&T cooperative owns transmission facilities at Lake Palestine. These transmission facilities are connected to the Southwest Power Pool. Therefore, it is our opinion that the planning for the integrated pipeline project should include a review of possibly contracting with Rayburn Country Electric Cooperative to supply the power to a pump station located at are near Lake Palestine if such supply would be obtained from the SPP with adequate reliability.

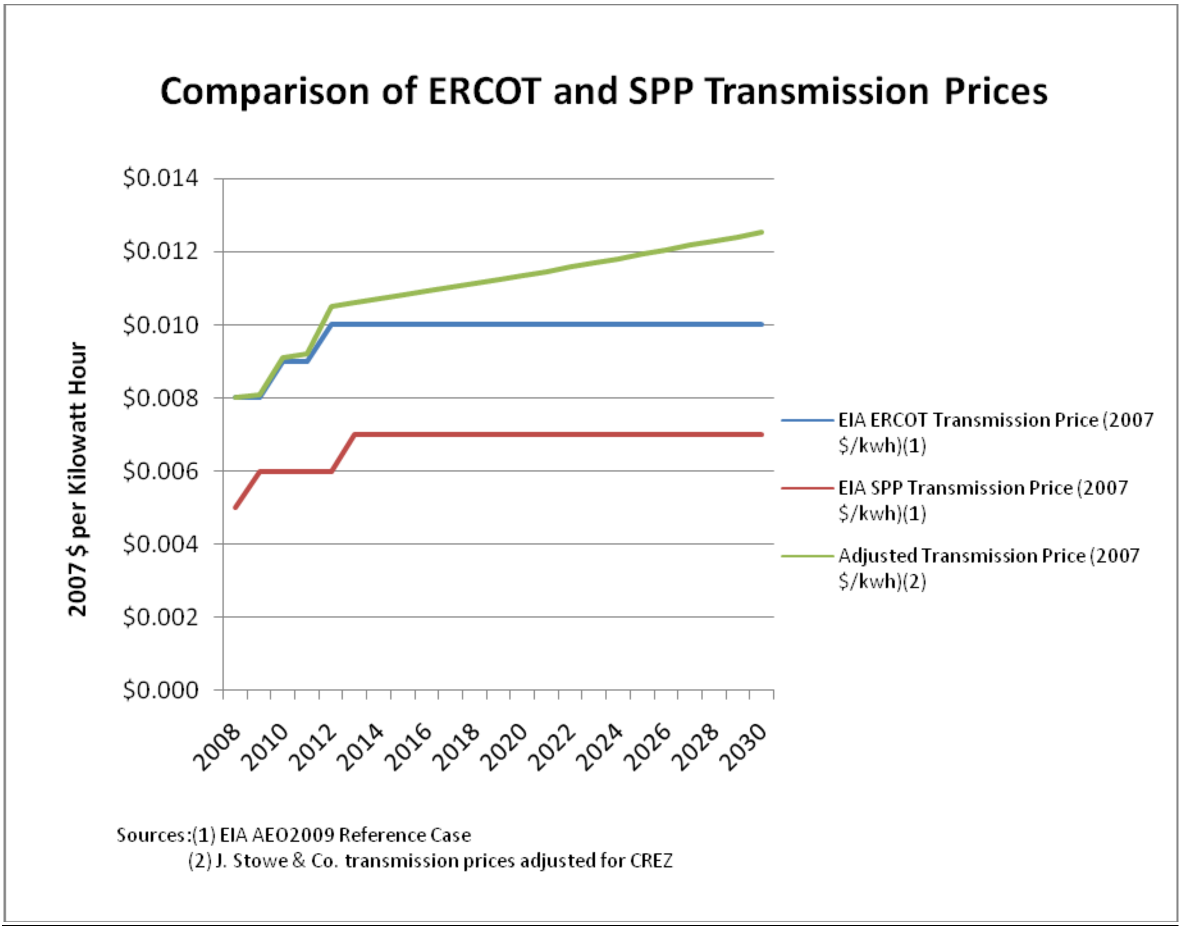
A. <u>EIA Pricing Model</u>

As with the ERCOT region, the EIA AEO2009 Reference Case also includes the trended capacity, pricing and usage information for the Southwest Power Pool. Although ERCOT has a significantly larger total generating capacity, the SPP has a much higher percentage of coal fired generation. Therefore the average $/kilowatt hour for generation costs is significantly less than ERCOT, with its large percentage of gas fired units.

The following chart compares the AEO2009 Reference Case results for generation prices for ERCOT and SPP. As shown, SPP has lower average generation costs for the entire trended period.



Transmission prices for the SPP are also provided by the AEO2009 Reference Case. These projections show a slower upward trend as well as lower prices than ERCOT transmission prices. The following chart provides the comparison of SPP transmission prices with both the EIA and our adjusted transmission prices:



B. SPP Reported Costs

SPP reported 2007 prices in its *2007 State of the Market Report, Southwest Power Pool, Inc.* Within the report were various comparisons with ERCOT pricing for the 2007 calendar year. The monthly hourly average prices showed that ERCOT prices were higher on average, with the greatest differential in the month of September. The months of July, August, and October through February showed lower variations between the two power grids.[3]

[3] January 2007 data was not included in the analysis.

SUMMARY

As described above, the analysis for both generation and transmission pricing begins with the forecasted pricing model developed by the Energy Information Administration in its annual energy outlooks. As the AEO2009 Reference Case was available, this model was used as a starting point. Through a series of interviews with a representative from EIA, ERCOT and the PUCT, it was determined that certain adjustments were necessary to more specifically reflect the possible generation pricing for the area in which the vast majority of the integrated pipeline project will be located.

With respect to the SPP region, there appears to be an opportunity to use Rayburn County Electric Cooperative at or near Lake Palestine. If the EIA trended generation and transmission costs for the SPP are enjoyed by Rayburn Country Electric Cooperative, the integrated pipeline project could enjoy cost savings over the projected prices on the ERCOT grid and those included in our forecast.

Based on an interview with the Chief Executive Office of Rayburn Country Electric, the G&T cooperative develops its forecasts solely based on the future price of gas as reported in NYMEX. Since natural gas costs are higher per MMBTU that other fossil fuels, these forecasts likely result in significantly higher generation prices. It is our opinion, that the approach described herein yields a more reasonable mix of possible plants used in determining future generation costs.

The following chart provides our recommended generation and transmission price in 2007 dollars. These will be adjusted in the model for inflation.

Recommended Generation and Transmission Prices
(2007 $/kwh)

Year	Generation	Transmission
2008	$0.070	$0.008
2009	$0.068	$0.008
2010	$0.057	$0.009
2011	$0.057	$0.009
2012	$0.057	$0.010
2013	$0.061	$0.011
2014	$0.062	$0.011
2015	$0.062	$0.011
2016	$0.063	$0.011
2017	$0.067	$0.011
2018	$0.069	$0.011
2019	$0.070	$0.011
2020	$0.069	$0.011

2021	$0.069	$0.011
2022	$0.071	$0.012
2023	$0.071	$0.012
2024	$0.072	$0.012
2025	$0.070	$0.012
2026	$0.072	$0.012
2027	$0.075	$0.012
2028	$0.077	$0.012
2029	$0.078	$0.012
2030	$0.078	$0.013

PROJECTED ENERGY RATES

Tarrant Regional Water District / City of Dallas
Raw Water Transmission Integration Study
Amendment 3, Phase 1

	Dallas			TRWD		
Year	Generation per $/kWh	Transmission $/kWh	Total Gen. & Trans.	Generation per $/kWh	Transmission $/kWh	Total Gen. & Trans.
2008	$0.048	$0.008	$0.056	$0.053	$0.008	$0.061
2009	$0.049	$0.009	$0.057	$0.054	$0.009	$0.062
2010	$0.040	$0.009	$0.050	$0.045	$0.009	$0.054
2011	$0.041	$0.010	$0.051	$0.046	$0.010	$0.055
2012	$0.042	$0.011	$0.053	$0.046	$0.011	$0.057
2013	$0.046	$0.012	$0.058	$0.051	$0.012	$0.063
2014	$0.048	$0.012	$0.060	$0.053	$0.012	$0.065
2015	$0.049	$0.013	$0.062	$0.055	$0.013	$0.067
2016	$0.051	$0.013	$0.063	$0.056	$0.013	$0.069
2017	$0.056	$0.013	$0.069	$0.061	$0.013	$0.075
2018	$0.058	$0.014	$0.072	$0.064	$0.014	$0.078
2019	$0.060	$0.014	$0.075	$0.067	$0.014	$0.081
2020	$0.060	$0.015	$0.075	$0.067	$0.015	$0.081
2021	$0.061	$0.015	$0.076	$0.068	$0.015	$0.083
2022	$0.065	$0.016	$0.080	$0.071	$0.016	$0.087
2023	$0.066	$0.016	$0.082	$0.073	$0.016	$0.089
2024	$0.067	$0.016	$0.083	$0.074	$0.016	$0.090
2025	$0.066	$0.015	$0.081	$0.073	$0.017	$0.089
2026	$0.068	$0.017	$0.085	$0.076	$0.017	$0.092
2027	$0.071	$0.017	$0.088	$0.079	$0.017	$0.096
2028	$0.074	$0.017	$0.092	$0.082	$0.017	$0.100
2029	$0.076	$0.018	$0.094	$0.084	$0.018	$0.102
2030	$0.077	$0.018	$0.095	$0.085	$0.018	$0.103
2031	$0.078	$0.019	$0.097	$0.086	$0.019	$0.105
2032	$0.079	$0.019	$0.098	$0.088	$0.019	$0.107
2033	$0.081	$0.019	$0.100	$0.089	$0.019	$0.109
2034	$0.082	$0.020	$0.102	$0.090	$0.020	$0.110
2035	$0.083	$0.020	$0.104	$0.092	$0.020	$0.112
2036	$0.084	$0.021	$0.105	$0.093	$0.021	$0.114
2037	$0.086	$0.021	$0.107	$0.095	$0.021	$0.116
2038	$0.087	$0.022	$0.109	$0.096	$0.022	$0.118
2039	$0.088	$0.022	$0.110	$0.097	$0.022	$0.120
2040	$0.089	$0.023	$0.112	$0.099	$0.023	$0.121
2041	$0.091	$0.023	$0.114	$0.100	$0.023	$0.123
2042	$0.092	$0.023	$0.115	$0.102	$0.023	$0.125
2043	$0.093	$0.024	$0.117	$0.103	$0.024	$0.127
2044	$0.094	$0.024	$0.119	$0.104	$0.024	$0.129
2045	$0.096	$0.025	$0.121	$0.106	$0.025	$0.130
2046	$0.097	$0.025	$0.122	$0.107	$0.025	$0.132
2047	$0.098	$0.026	$0.124	$0.108	$0.026	$0.134
2048	$0.099	$0.026	$0.126	$0.110	$0.026	$0.136
2049	$0.101	$0.027	$0.127	$0.111	$0.027	$0.138
2050	$0.102	$0.027	$0.129	$0.113	$0.027	$0.140
2051	$0.103	$0.027	$0.131	$0.114	$0.027	$0.141
2052	$0.105	$0.028	$0.132	$0.115	$0.028	$0.143
2053	$0.106	$0.028	$0.134	$0.117	$0.028	$0.145
2054	$0.107	$0.029	$0.136	$0.118	$0.029	$0.147
2055	$0.108	$0.029	$0.137	$0.120	$0.029	$0.149
2056	$0.110	$0.030	$0.139	$0.121	$0.030	$0.151
2057	$0.111	$0.030	$0.141	$0.122	$0.030	$0.152
2058	$0.112	$0.031	$0.143	$0.124	$0.031	$0.154
2059	$0.113	$0.031	$0.144	$0.125	$0.031	$0.156
2060	$0.115	$0.031	$0.146	$0.126	$0.031	$0.158
2061	$0.116	$0.032	$0.148	$0.128	$0.032	$0.160
2062	$0.117	$0.032	$0.149	$0.129	$0.032	$0.162
2063	$0.118	$0.033	$0.151	$0.131	$0.033	$0.163
2064	$0.120	$0.033	$0.153	$0.132	$0.033	$0.165
2065	$0.121	$0.034	$0.154	$0.133	$0.034	$0.167
2066	$0.122	$0.034	$0.156	$0.135	$0.034	$0.169
2067	$0.123	$0.034	$0.158	$0.136	$0.034	$0.171

Appendix I
Reservoir Firm Yields

Tarrant Regional Water District

Tarrant Regional Water District Reservoir Firm Yields

Accounting for Sedimentation

Donna Stephens
8/7/2013

Contents

trwd
Tarrant Regional Water District

1. Introduction

Firm (dependable) yield of a reservoir is typically defined as the maximum yield that could have been delivered without failure during the historical drought of record. In order to determine a reservoirs firm yield, several parameters are defined, and used to analyze the reservoir over a distinct period of time. To be effective, the period used includes a variety of wet and dry periods as well as the drought of record for the area being evaluated. Parameters incorporated are the reservoir characteristics, basin hydrology, in-stream flow requirements, and permit constraints.

Reservoir characteristics include capacity, or volume, area, and elevation of the water at said volume. Tables are developed, showing the relationship of these three parameters, from the lake at full capacity, to the lake nearly empty. Over the lifespan of the reservoir, sedimentation builds, as runoff deposits its silt into the lake. Therefore, the lakes original elevation-area-capacity (EAC) tables must be adjusted periodically to account for the sedimentation buildup.

Parameters also include the hydrology of the basin contributing flow. Rain gauges, or stream gauges are positioned along the contributing streams or rivers, to record the rainfall and streamflow. In some cases, no gauge is present, and other methods must be applied to determine the inflow into the reservoir. The most common of these methods is the basin-ratio method, where a neighboring basin's gauge is used for the rainfall and runoff parameters. The neighboring gauged flows are expected to be similar to the basin being evaluated. The amount of runoff is adjusted using a ratio of the known gauge basin to the basin where no gauge exists. The resulting adjusted runoff can then be used to account for the hydrologic inflow into the reservoir.

In-stream flow (also referred to as environmental flow) requirements are another parameter important in the development of yield. In-stream flow can be described by the quantity of water required to support the habitat in and around the stream. The Texas Water Development Board (TWDB) defines in-stream flows.

The Texas Commission on Environmental Quality (TCEQ) permit defines the amount, and availability, of water a reservoir owner is allowed to store and divert. In addition to in-stream flows, availability is determined by the rainfall and runoff into the stream, and the water diverted from the streams by other users. In Texas, permits are granted based on prior appropriation, where each permit granted is subordinate to previously granted permits.

TRWD, like other raw water providers, develops yield in order to determine how much water is available for its customers for the years to come. This is critical to know, should a drought tax the surface water supply.

Surface water models are used to develop yields. TCEQ has adopted the Water Availability Model (WAM) for this purpose, and for regional water planning in north Texas, Region C uses this model to plan for the future of North Texas water supply.

TRWD owns and operates four reservoirs in north Texas- Lakes Bridgeport and Eagle Mountain (north-west of the metroplex) and Cedar Creek and Richland-Chambers Reservoirs (to the south-east). Additionally, TRWD uses Lake Benbrook (owned by the U.S. Army Corp of Engineers) for terminal storage. The two western reservoirs, typically referred to as the West-Fork, operate as a system, in terms of yield analysis. The eastern reservoirs operate individually, but each has the addition of wetlands to supplement their yields.

This analysis is an exercise in the development of TRWD firm yields, and their comparison to the Region C yields, determined by the WAM, run 3. The exercise begins with the adjustment of the EAC tables, to account for the most current sedimentation rates provided by the Texas Water Development Board Volumetric Surveys. Hydrologic parameters are then defined, in-stream flows and permit constraints are applied, and yield results are determined. A comparison is then prepared, between the TRWD results and those published by Region C, where differences are discussed.

2. Sedimentation rates

To develop yields, one must know the elevation, area, and capacity of the reservoir (EAC). Over time, the capacity of the reservoir changes as a result of sedimentation. The Texas Water Development Board (TWDB) periodically conducts sedimentation surveys to determine the extent the lakes capacity has been reduced do to the deposition of sediment. Since 2010 the TWDB has improved methods of estimating sedimentation rates. This analysis uses the most current rates available to date.

2.1 Benbrook

Historic sedimentation rates are taken from the 2003 TWDB Volumetric survey (TWDB BB p. 13). According to the 2003 Survey, Benbrook Reservoir capacity, in 1998, is 85,650 acre-feet, with a surface area of 3,635 acres at an elevation of 694.0 feet above mean sea level (msl), capacity decreases 57.82 acre-feet per year due to sedimentation. Accordingly 57.82 acre-feet are subtracted from subsequent years, to develop EAC tables for a decadal analysis from 2010 to 2060.

2.2 Bridgeport

Historic sedimentation rates are taken from the 2010 TWDB Volumetric survey (TWDB BP executive summary), where according to new, improved methods of estimating sedimentation rates, using data previous to the 2010 Survey is not recommended. According to the 2010 Survey, Bridgeport Reservoir capacity is 361,875 acre-feet, with a surface area of 11,712 acres at an elevation of 836.0 feet above mean sea level (msl), and decreases between 321 and 772 acre-feet per year due to sedimentation. The average rate of loss is 546.5 acre-feet per year. Accordingly 546.5 acre-feet are subtracted from subsequent years, to develop EAC tables for a decadal analysis from 2010 to 2060.

2.3 Cedar Creek

The comparisons of Cedar Creek 1995 and 2005 TWDB Volumetric surveys imply that historic sedimentation rates increase the volume of the reservoir. Intuitively, sedimentation would cause a reduction in volume, therefore volumes compared in this study, are from the 1960 (TWDB Rpt. 26) and 2005 Surveys. Capacities are 679,200 acre-feet and 644,785 acre-feet respectively. The difference equates to 768.01 acre-feet per year. Accordingly 768.01 acre-feet are subtracted from subsequent years, to develop EAC tables for a decadal analysis from 2010 to 2060.

2.4 Eagle Mountain

Historic sedimentation rates are taken from the 2008 TWDB Volumetric survey (TWDB EM executive summary), where according to new, improved methods of estimating sedimentation rates, using data previous to the 2008 Survey is not recommended. According to the 2008 Survey, Eagle Mountain Reservoir capacity is 179,880 acre-feet, with a surface area of 8,694 acres at an elevation of 649.1 feet above msl, and decreases 210 acre-feet per year due to sedimentation. Accordingly 210 acre-feet are subtracted from subsequent years, to develop EAC tables for a decadal analysis from 2010 to 2060.

2.5 Richland Chambers

Historic sedimentation rates are taken from the 2007 TWDB Volumetric survey (TWDB RC executive summary), where according to new, improved methods of estimating sedimentation rates, using data previous to the 2007 Survey is not recommended. According to the 2007 Survey, Richland-Chambers Reservoir capacity decreases 2,065 acre-feet per year due to sedimentation. Accordingly 2,065 acre-feet are subtracted from subsequent years, to develop EAC tables for a decadal analysis from 2010 to 2060.

3. Hydrology

Firm (dependable) yield of a reservoir is defined as the maximum yield that could have been delivered without failure during the historical drought of record. It is therefore critical for hydrologic data to include this known period, along with fluctuations of wet and dry periods. Hydrology is developed by TRWD and Region C.

Hydrology relevant to yield analysis includes hydrologic inflow (acre-feet per month) and evaporation rates (feet per month). The TRWD historical hydrologic inflows and evaporation, from 1941 through 1980 is taken from the 2002 System Reliability and Enhancement Study (Appendix D). Methodology for the collection of this data, in general uses the basin-ratio method, and is explained in detail in the 1957 *Report on Water Supply for Fort Worth and Tarrant County.* The remaining Hydrology (1981 through 2008) is determined by TRWD through a mass balance for each of the reservoirs. The mass balance includes pumpage, precipitation, evaporation, customer use, discharge, storage, and surface area. In the mass balance, TRWD customers provide respective usage, pumpage is from the TRWD SCADA system historic records, precipitation is from TRWD gauge stations, the evaporation rates and pan-to-lake monthly evaporation coefficients are provided by the TWDB and NOAA's National Weather Service (NWS) methodologies. In developing the hydrology, it is critical to include drought of record. The 67 year period of record, for this analysis (1941-2008), includes the (1950-1956) critical drought of record for the region.

For water availability, Region C has adopted the Trinity River Basin Water Availability Model (WAM), run 3, required by the TCEQ. According to the Fundamentals of Water Availability Modeling with WRAP, "The River basin hydrology is represented by naturalized hydrologic inflows (acre-feet per month), and net evaporation less precipitation depths for each month (1940-2007). A typical hydrologic period-of-analysis used for studies in Texas is 1940 to near the present. This period includes the 1950-1956 most severe drought-of-record as well as a full range of fluctuating wet and dry periods."(TWRI)

4. In-stream Flow Requirements

In-stream flow, also known as environmental flow, is defined by the TWDB as, "…a salinity, nutrient, and sediment loading regime adequate to maintain an ecologically sound environment in the receiving bay and estuary system that is necessary for the maintenance and productivity of economically important and ecologically characteristic sport or commercial fish and shellfish species and estuarine life upon which such fish and shellfish are dependent." (TWDB)

Currently, the Trinity River basin environmental standards are in draft form, and include subsistence, base and pulse flows. Pulse flows are defined in terms of peak flow triggers, volumes and duration. Table 3 of the *Trinity and San Jacinto and Galveston Bay Basin and Bay Area Stakeholder Committee with support of the Basin and Bay Expert Science Team- Draft Work Plan Report*, provides hydrologic indicators of each flow category.(BBEST)

Table 3. Hydrologic Indicators

Indicators		
Category	*Indicator*	*Explanation*
Flow regime components	**Overbank flows** (frequency, timing, duration, rate of change, and magnitude)	Infrequent, high magnitude flow events that enter the floodplain * Maintenance of riparian areas * Transport of sediment and nutrients * Allow fish and other biota to utilize floodplain habitat during and after floods * Riparian and floodplain connectivity to the river channel * The National Weather Service provides flood impact summaries for most USGS streamflow gage sites, based on water surface elevation or "stage." These summaries provide an estimate of negative impacts of overbank flows.
	High pulse flows (frequency, timing, duration, rate of change, and magnitude)	Short duration, high magnitude, within channel, rainfall derived flow events * Maintain physical habitat features along the river channel * Provide longitudinal connectivity along the river corridor for many species (e.g. migratory fish) * Provide lateral connectivity (e.g., connections to oxbow lakes)
	Base flows (frequency, timing, duration, rate of change, and magnitude)	Range of average or "normal" flow conditions * Provide instream habitat quantity and quality needed to maintain the diversity of biological communities * Maintain water quality conditions * Recharge groundwater * Provides for recreational or other uses
	Subsistence flows (frequency, timing, duration, rate of change, and magnitude)	Low flows maintained during times of very dry conditions * Maintain water quality standards * Prevent increased loss of aquatic organisms
Natural variability	Natural	Determination of the natural variability of the above indicators, based on the older portions of gage records, presumably less impacted by human activity. The exact time period may vary by gage site.
	Current	Variability of the above indicators based on the last 20-25 years of gage records.
Losses/gains	Gain or loss in section of river	Difference in the amount of water entering and leaving a specific section of the river channel. Sources of gains include inflow from tributaries, alluvial and deeper aquifers, and discharges to the river. Sources of losses include evaporation, evapo-transpiration from riparian areas, diversions, and recharge of alluvial and deeper aquifers. Indicator may be influenced by shallow groundwater surface elevation and hydraulic head of deeper aquifers where present.

Since TWDB environmental flow requirements are in draft, the TRWD analysis incorporates other sources. The reservoir permit lends assistance to this determination. Benbrook reservoir is one of those cases. Permit 5157 states Benbrook in-stream flow requirements as follows;

Table 4.1 – Benbrook Environmental Flows

In-stream flow requirement (cubic feet per second)	In-stream flow requirement (acre-feet per day)	Reservoir Elevation (feet msl)	Period (months)
=> 1	1.78	< 690	All Months
=> 8	14.23	> 690	May
=> 5	8.90	> 690	June
=> 2	3.56	> 690	April, July and August

Cedar Creek has no in-stream flow requirement. In the TRWD Richland Chambers analysis, 5cfs (9.92 acre-feet per day) are applied, to meet in-stream flow requirements. No in-stream flows are required for the west-fork system according to the permits.

5. Permit Constraints

TRWD reservoir permits provide diversion, storage, and release volume constraints, as well as return flow constraints.

5.1 Benbrook

The Benbrook permit allows TRWD to use up to 72,500 acre-feet for storage, and 6,833 acre-feet of water per year (569.42 acre-feet per month), when Benbrook's elevation is between 665 and 694 ft msl. No local use is applied.

5.2 Cedar Creek

TRWD decadal analysis for 2010 and 2020 apply a maximum diversion of 175,000 acre-feet to Cedar Creek Reservoir. Beginning in 2030, when the wetlands is expected to go online, Cedar Creek is permitted for 227,500 acre-feet per year, of which a maximum of 52,500 acre-feet of return flows are from the wetlands. No local use is applied.

5.3 Richland Chambers

According to permit 05-5035C, the maximum Richland Chambers diversion is 273,000 acre-feet per year, where a maximum of 63,000 acre-feet of return flows are from the Wetlands to Richland Chambers. This constraint is applied to the TRWD model for all decades. No local uses are applied to Richland Chambers.

5.4 West-Fork System

Bridgeport and Eagle Mountain are modeled as system. In the TRWD analysis, Bridgeport local use is 15,000 acre-feet per year. Pursuant to permit 08-3809, Bridgeport is permitted to release 78,000 acre-feet per year to Eagle Mountain.

Eagle Mountain maximum diversion is 159,600 acre-feet per year. In the TRWD analysis, Eagle Mountain local use is 49,101 acre-feet per year.

According to the 2011 Region C Water Plan, Appendix I, Water Availability Model (WAM) Run 3, the version used for planning, assumes full permitted diversions by all water rights and no return flows, unless return flows are specifically required in the water right. TCEQ's run 3 does not account for reductions in reservoir capacities due to sediment accumulation. For Region C planning purposes, adjustments were made to the WAM to better reflect current and future surface water conditions in the region. Generally, changes to the WAM include

- Assessment of reservoir sedimentation rates and calculation of area-capacity conditions for 2000 and 2060 conditions
- Inclusion of subordination agreements
- Inclusion of system operations - The Trinity River Basin WAM model is modified to include Bridgeport, Eagle Mountain, and Lake Worth as the West Fork Water Supply System.
- Other corrections

6. Firm Yield

Firm, or dependable, yield of a reservoir is typically defined as the maximum yield that could have been delivered without failure during the historic drought of record.

6.1 TRWD Modeling Results

The TRWD firm yield analysis takes a monthly time-step of the parameters listed above, and determines the maximum available water. Decadal adjustments are made to the capacity of the reservoir, based on sedimentation accumulation. Table 6.1 shows the results of each reservoir, or system, and totals all reservoirs to provide TRWD surface water supply for each decade.

Table 6.1 – Surface Water Supply

TRWD Analysis of Available Water Supply
(Acre-Feet per Year)

	2010	2020	2030	2040	2050	2060
WFork Sys	116,797	114,606	112,421	110,238	109,318	107,119
CC	224,026	222,124	282,938	281,310	279,680	279,680
RC	329,412	326,935	324,455	321,965	319,472	316,974
BB	10,616	10,525	10,434	10,343	10,253	10,163
TOTAL	680,851	674,190	730,248	723,856	718,723	713,936

Total supply for 2020 is 674,190 acre feet per year, increasing to 730,248 acre-feet per year as the Cedar Creek Wetlands reuse facility will be online as of 2030. Surface water supply, in acre-feet per year, is graphed for further inspection.

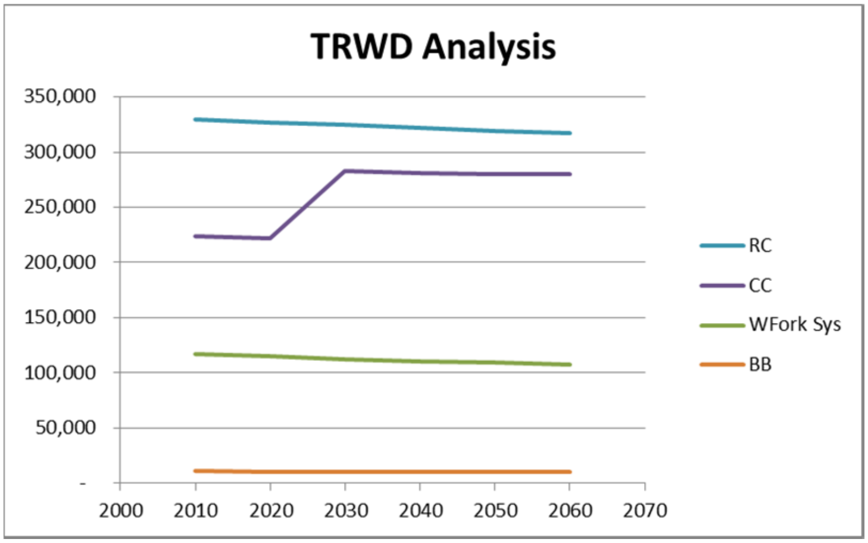


Figure 6.1 – Surface Water Supply

In the TRWD analysis, dependable yields are in excess of permitted amounts for all reservoirs, with the exception of the West Fork System. Cedar Creek and Richland Chambers decadal additional yields, above permitted values of 227,500 and 273,000 respectively, are shown below.

Table 6.2 – Supply Available above Firm Yields

CC			55,438	53,810	52,180	52,180
RC	56,412	53,935	51,455	48,965	46,472	43,974

6.2 Region C Modeling Results

From the 2011 Region C Water Plan, the following is a table of TRWD Reservoir Firm Yields.

Table 6.3 – Region C Yields

	2011 Region C Water Plan (Acre-Feet per Year)					
	2010	2020	2030	2040	2050	2060
WFork Sys	109,833	109,167	108,500	107,833	107,167	106,500
CC	211,900	210,783	208,550	207,433	206,317	205,200
RC	228,300	225,383	219,550	216,633	213,717	210,800
BB	7,206	7,131	7,057	6,982	6,908	6,833
TOTAL	557,239	552,464	543,657	538,881	534,109	529,333

Region C's calculated Surface water supply, for TRWD reservoirs (in acre-feet per year), is graphed for further inspection.

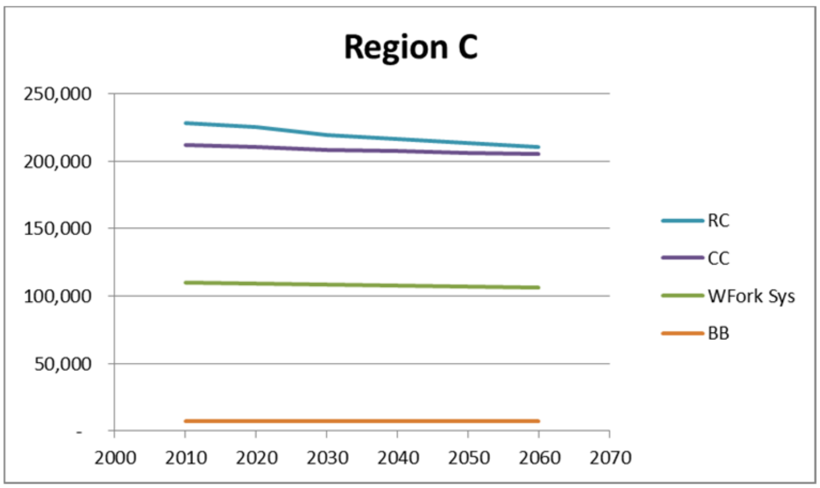


Figure 6.2 – Region C Yields

The 2020 Region C calculation of firm yield of Cedar Creek Reservoir is 210,783, decreasing to 208,550 acre-feet per year by 2030. The available supply from Cedar Creek is limited to 175,000 acre-feet per year for all decades, and does not take into account the addition of wetlands return flows reflected in the permit.

According to Region C, the firm yield of Richland Chambers is 228,300 acre-feet per year in 2010, decreasing to 210,800 acre-feet per year by 2060. The available supply to TRWD from Richland-Chambers is limited to 210,000 acre-feet per year, and does not take into account the addition of wetlands return flows reflected in the permit.

Lake Benbrook is operated by the U.S. Army Corps of Engineers, and used by TRWD for (terminal) storage of water pumped from Cedar Creek and Richland Chambers Reservoirs. The available supply does not include water from these sources. According to Region C, the firm yield of Lake Benbrook is 7,206 acre-feet per year in 2010, decreasing to 6,833 acre-feet per year by 2060. The available supply from Lake Benbrook is limited to the permitted amount of 6,833 acre-feet per year.

Two TRWD reservoirs have firm yields that exceed the permitted diversion amounts. Cedar Creek and Richland Chambers unpermitted yields, calculated by the Region C WAM, are listed in Table I.4.

Table I.4- Unpermitted Yields in TRWD Reservoirs

	Revised Surface Water Availability						
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Cedar Creek	36,900	35,783	34,667	33,550	32,433	31,317	30,200
Richland-Chambers	18,300	15,383	12,467	9,550	6,633	3,717	800
TOTAL	55,200	51,166	47,134	43,100	39,066	35,034	31,000

6.3 Firm Yield Comparison

Region C and TRWD dependable yields differ substantially.

Table 6.4 – Firm Yield Comparison

Total TRWD Surface Water Availability TRWD Analysis v Region C (Acre-Feet per Year)						
	2010	2020	2030	2040	2050	2060
TRWD Analysis	680,851	674,190	730,248	723,856	718,723	713,936
Region C	557,239	552,464	543,657	538,881	534,109	529,333
DIFFERENCE	123,612	121,726	186,591	184,975	184,614	184,603

Region C Firm Yields are 121,726 acre-feet per year lower than the TRWD analysis. The difference is magnified in 2030, where differences increase to 186,591 acre-feet per year. The increase is a result of return flows, explained in further detail below. Overall, the difference of estimates can be accounted for based on the following;

- Hydrology
- Period of Record
- Return flows
- Subordination agreements
- West Fork System includes Lake Worth

- Other Corrections

6.3.1 Hydrology

From 1941 to 1979, both TRWD and Region C WAM hydrology is derived from the basin-ratio method, for records where no gauge is present. Although it is unclear whether the two hydrologic datasets are derived from the same basins, the methodology of both is sound, and differences are insignificant.

6.3.2 Period of Record

In 1981, TRWD methodology deviates from the basin-ratio method to the use of mass balance to determine hydrology for the reservoirs. Additionally, TRWD's analysis extends the period of record to 2008, where the Region C WAM's period of record ends in 1996.

6.3.3 Return Flows

On February 8, 2005, the TRWD received amendments to its water rights in Richland-Chambers and Cedar Creek Reservoirs. The amended certificates allow the District to divert, from the Trinity River, a portion of the historic and future return flow, that originate from water stored in District reservoirs. The return flows will be diverted into off-channel, wetlands impoundment to improve water quality and then delivered into the Reservoir for storage and future diversion.

Table I.5- Water Right Amendments Involving Reuse

Flow Description	Certification of Adjudication/ Permit Number	Additional Annual Diversion for Water Supply (ac-ft/year)
Multiple WWTPs to Wetland/Cedar Creek Reservoir	08-4976C	52,500
Multiple WWTPs to Wetland/Richland-Chambers Reservoir	08-5035C	63,000

The maximum annual diversion from the wetlands reuse, to Cedar Creek Reservoir, is 52,500 acre-feet per year, increasing Cedar Creek's maximum to 227,500 acre-feet per year.

The maximum annual diversion from the wetlands reuse, to Richland-Chambers Reservoir, is 63,000 acre-feet per year, increasing Richland Chambers maximum to 273,000 acre-feet per year.

The difference in unpermitted Firm yield, for these two reuse projects is tabulated below.

Table 6.6- Unpermitted Comparison

Unpermitted Firm Yield Comparison (Acre-feet per year)	2010	2020	2030	2040	2050	2060
TRWD Analysis	105,438	101,059	106,893	102,775	98,652	96,154
Region C	51,166	47,134	43,100	39,066	35,034	31,000
DIFFERENCE	54,272	53,925	63,793	63,709	63,618	65,154

6.3.4 Subordination agreements

Region C WAM flows are reduced by senior water rights holders. Downstream of TRWD, Lake Livingston holds a Senior Water right to the TRWD system, which is taken into consideration in the WAM analysis.

6.3.5 The West Fork System

The Region C WAM models the West Fork System including Lake Worth, where TRWD's analysis models Bridgeport and Eagle Mountain only.

An excerpt from the Region C Water Plan (Appendix A, table I.3) provides TRWD Reservoir results, where the supply available is limited to the lesser of the firm yield or the permit amount.

Table I.3- Currently Available TRWD Water Supplies

	Revised Surface Water Availability (Acre-Feet per Year)						
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
West Fork (includes Bridgeport Local)	110,500	109,833	109,167	108,500	107,833	107,167	106,500
Cedar Creek	175,000	175,000	175,000	175,000	175,000	175,000	175,000
Richland-Chambers	210,000	210,000	210,000	210,000	210,000	210,000	210,000
Benbrook	6,833	6,833	6,833	6,833	6,833	6,833	6,833
TOTAL	502,333	501,666	501,000	500,333	499,666	499,000	498,333

Region C revised firm yields are displayed along with Region C original firm yields and TRWD model results.

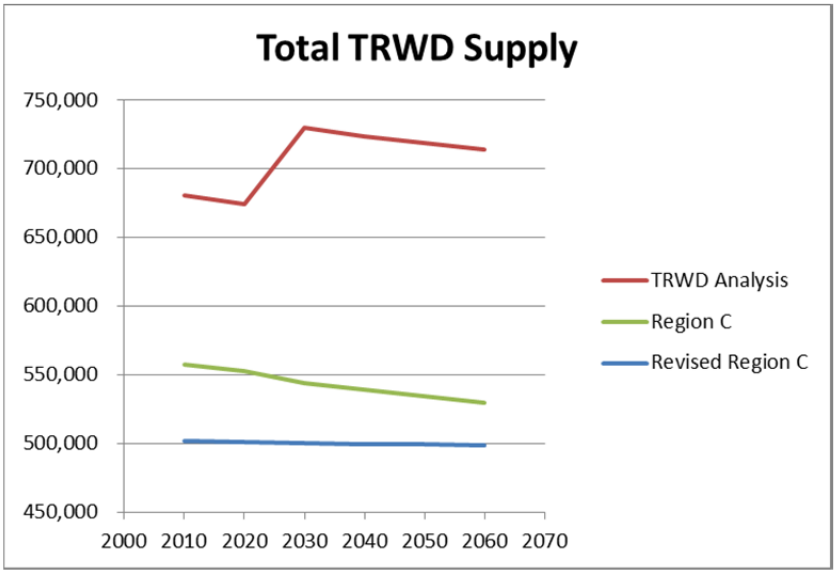


Figure 6.3- Total Supply Comparison

According to the revised Region C model, TRWD total surface water available was 501,666 acre-feet per year in 2010, decreasing to 498,333 acre-feet per year by 2060. Both Region C estimates do not take into account the wetlands reuse permitted volumes available to Cedar Creek and Richland Chambers Reservoirs, totaling a permitted 115,500 acre feet per year.

7. Conclusion

Four reservoirs were analyzed- Lake Bridgeport, Eagle Mountain Lake, Cedar Creek and Richland-Chambers Reservoirs. Lake Benbrook (owned by the U.S. Army Corp of Engineers) was included for purposes of TRWD total yield, but generally its impacts are valuable for terminal storage only. Bridgeport and Eagle Mountain Lakes, typically referred to as the West-Fork, are operated as a system, in terms of yield analysis. The eastern reservoirs operate individually, but each has permitted wetlands reuse to supplement their supply.

In this analysis, TRWD reservoirs are defined by each reservoir's characteristics, adjusted for sedimentation, and Firm (dependable) yields are determined. Hydrologic parameters did not change from past TRWD studies, and environmental flows were dictated by permit constraints.

Results of the TRWD analysis indicate total surface water available ranging from 674,190 acre-feet per year in 2020 to 713,936 acre-feet per year in 2060. Yields would generally decrease from sedimentation over time, but instead increase, as a result of the wetlands reuse project at Cedar Creek (online in 2030).

In a comparison with Region C, WAM run 3, TRWD modeled dependable yields are substantially higher as a result of reuse, not included in the Region C model. Other factors likely play a part, as Firm yield disparities range from 121,726 acre-feet per year in 2020 to 184,603 in 2060. Possibilities include hydrology, period of record, subordination agreements, or other corrections made to the Region C model.

References

Benbrook E Flows <\\trwd.com\fw\EngDept\TRWD - Tarrant Regional Water District\Water Operations\Water Supply\MasterSAA\SAAupdate\Contracts (Laura)\Permit 5157 (Benbrook).pdf>

Cedar Creek Reservoir and Wetlands Yield Analysis. October 2012. <X:\RES\RESCC\STRC\6416 WET\PRELIM STUDY\Cedar Creek Reservoir and Wetlands Yield Analysis.pdf>

Freese and Nichols. Report on Water Supply for Fort Worth and Tarrant County. City of Fort Worth. Tarrant County Water Control and Improvement District Number One. May 1957.

SDI et., al. Cedar Creek Reservoir Sediment Density and Channel Erosion Study. April 2006. <http://dp/Docs/ADM/ADMENV/WQ/WTRSHED%20PLG/CC/2008%20CC%20Res%20Sediment%20Density%20and%20Chnnl%20Erosion%20Study.pdf>

SRE. System Reliability and Enhancement Study. 2002 <http://dp/Docs/ADM/ADMENG/WTR OPS/WTR SUPL//WTR PLAN/SRE/20050515 SRE Final Report Appendices.pdf>

BBEST. Trinity and San Jacinto and Galveston Bay Basin and Bay Area Stakeholder Committee with support of the Basin and Bay Expert Science Team. Draft Work Plan Report. Dec 2010 Retrieved from the World Wide Web 5 Aug 2013. <http://www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/eflows/20110803tsjbbasc_draftwp.pdf>

TWDB. Surface Water. Environmental Flows. Retrieved from the World Wide Web 5 August 2013. < http://www.twdb.texas.gov/surfacewater/flows/freshwater/index.asp>

TWDB BB. TWDB Volumetric and Sedimentation Survey for Benbrook Lake 1998 . Retrieved 07May2013. < http://www.twdb.texas.gov/hydro_survey/Benbrook/1998-01/Benbrook1998_FinalReport.pdf>

TWDB BP. TWDB Volumetric and Sedimentation Survey for Lake Bridgeport Oct-December 2010. Retrieved 06May2013. <http://www.twdb.texas.gov/hydro_survey/Bridgeport/2010-12/Bridgeport2010_FinalReport.pdf>

TWDB CC. TWDB Volumetric and Sedimentation Survey for Cedar Creek Reservoir July 2005. Retrieved 06May2013. < http://www.twdb.texas.gov/hydro_survey/CedarCreek/2005-07/CedarCreek2005_FinalReport.pdf>

TWDB EM. TWDB Volumetric and Sedimentation Survey for Eagle Mountain Lake February 2008. Retrieved 06May2013. < http://www.twdb.texas.gov/hydro_survey/EagleMountain/2008-02/EagleMountain2008_FinalReport.pdf>

TWDB RC. TWDB Volumetric and Sedimentation Survey for Richland Chambers Reservoir October 2007. Retrieved 06May2013. <http://www.twdb.texas.gov/hydro_survey/RichlandChambers/2007-10/RichlandChambers2007_FinalReport.pdf>

TWDB Report No. 126. Engineering Data on Dams and Reservoirs in Texas- Part II. November 1973. <docs:\ADM\ADMENG\WTR OPS\WTR SUPL\WTR PLAN\YIELD STDY\19601231 Cedar Creek Volumetric Survey>

TWRI. Fundamentals of Water Availability Modeling with WRAP. By Ralph A. Wurbs Texas A&M University. TR-283 Texas Water Resources Institute College Station, Texas. March 2008. Retrieved 1 Aug 2013 from the World Wide Web. <http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/0704830755_WRAP/Fundamentals.pdf>

Wetlands. Tarrant Regional Water District. Retreived 10 Aug 2009. <http://www.trwd.com/prod/aboutus_wetlands.asp>

Wetlands Dependable Yield Study. TRWD. <F:\TRWD - Tarrant Regional Water District\RES - Reservoir System\RESRC - Richland Chambers\RESRCSTR - Structures\4334 - Wetlands\20081229 - wetlands dependable yield.xls>

Yield Analysis of Trinity River Project. June 1998.<X:\RES\RESRC\STRC\4334 WET\19980601 yield analysis of Trinity River – wetland Brandes.pdf>