Study 1
Updated Drought of Record and Water Quality Implications for Reservoirs Upstream of Possum Kingdom Reservoir

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WATER PLANNING GROUP

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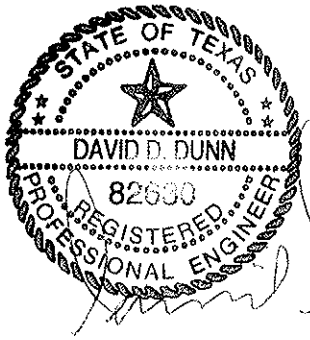

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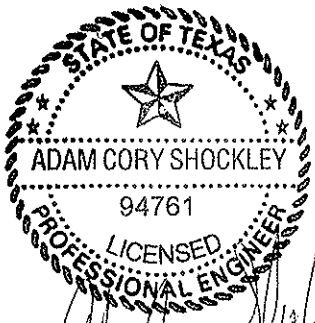

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A. Cory Shockley, P.E.

Table of Contents

Section			Page
	Executive Summary		ES-1
1.0	Background		1
2.0	Hydrology and Naturalized Flow Update		2
	2.1	Historical Streamflow Data	3
	2.2	Historical Water Use Data	5
	2.3	Historical Return Flow Data	6
	2.4	Historical Reservoir Contents	7
	2.5	Historical Evaporation and Precipitation	9
		2.5.1 January 2003 – December 2004	9
		2.5.2 January 2005 – June 2008	10
	2.6	Naturalized Flow Calculation Methodology	12
		2.6.1 Filling Data	12
3.0	Brazos Mini-WAM Update		14
	3.1	INF File – Naturalized Flows	15
	3.2	EVA File – Evaporation Data	15
	3.3	Simulation Assumptions	15
4.0	Safe Yield Estimates		16
5.0	Water Quality Impacts of Low Reservoir Levels		20
	5.1	Methodology	20
	5.2	Impacts of Low Reservoir Levels on Water Quality	20
		5.2.1 Fort Phantom Hill Reservoir	21
		5.2.2 Lake Stamford	21
		5.2.3 Lake Graham	24
	5.3	Water Treatment Cost Considerations	24
6.0	Summary		29
7.0	Recommendations		30

Appendices

A	Historical Streamflows, Diversions, Return Flows, and Naturalized Flows for Updated Control Points in the Brazos Mini-WAM
B	Simulated Reservoir Storages under Safe Yield Operations
C	Updated Model Hydrologic Data, Newly-Developed Naturalized Flows and Evaporation Rates, January 1998 – June, 2008
D	Comments from the Texas Water Development Board Regarding Phase I Reports and Responses from the Brazos G Regional Water Planning Group

List of Figures

Figure		Page
1-1	Comparison of Cumulative Streamflows for Two Drought Periods for the Clear Fork at Nugent, TX Streamgage (08084000)	2
2-1	Control Points in the Upper Brazos WAM	4
2-2	Annual Historical Streamflows for the Clear Fork Brazos River at Nugent, 2003 – 2008	5
2-3	Annual Diversions Upstream from the Clear Fork Brazos River at Nugent, 2003 – 2008	6
2-4	Annual Return Flows Discharged Upstream from the Clear Fork Brazos River at Fort Griffin, 2003 – 2008	7
2-5	Hubbard Creek Reservoir Storage, January 2002 – June 2008	9
2-6	Gross Evaporation for Lake Proctor and Quadrangle 509, 1977 – 2004	11
2-7	Gross Evaporation for Quadrangles 507 and 509, 1940 – 2004	11
2-8	Annual Naturalized Streamflow for Two Drought Periods for the Brazos River near Palo Pinto	14
4-1	Hubbard Creek Reservoir without Possum Kingdom Subordination Safe Yield Storage Trace, 2000 Sediment Conditions	19
5-1	Relationship between Chloride Concentration and Reservoir Storage, Fort Phantom Hill Reservoir	22
5-2	Relationship between TDS Concentration and Reservoir Storage, Fort Phantom Hill Reservoir	22
5-3	Relationship between Chloride Concentration and Reservoir Storage, Lake Stamford	23
5-4	Relationship between TDS Concentration and Reservoir Storage, Lake Stamford	23
5-5	Relationship between Chloride Concentration and Reservoir Storage, Lake Graham	25
5-6	Relationship between TDS Concentration and Reservoir Storage, Lake Graham	25
5-7	Projected Chloride Concentration vs. Reservoir Storage, Lake Stamford	27
5-8	Projected TDS Concentration vs. Reservoir Storage, Lake Stamford	27

List of Tables

Table		Page
2-1	Methodology Used to Determine Changes in Reservoir Contents.....	8
2-2	Methods Used to Develop Naturalized Flows.....	13
4-1	Summary of Safe and Firm Yield Analyses Using Brazos Mini-WAM.....	18
4-2	Safe and Firm Yield Estimates for Millers Creek Reservoir.....	19
5-1	Desalination Process Flow Summary for 1,500 mg/L TDS Raw Water.....	28
5-2	Estimated Desalination Costs for Raw Water with 1,500 mg/L (2Q 2007 Prices).....	28

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Executive Summary

The Brazos G Regional Water Planning Group (Brazos G) is in the process of developing the 2011 Brazos G Regional Water Plan. The 2011 Plan will be an update of the current 2006 Plan. As part of the process for developing the 2011 Plan, the Texas Water Development Board (TWDB) has provided funding to Brazos G to perform an investigation of the impacts the ongoing drought might have on water supplies in the upper portion of the Brazos G Area, specifically in the area upstream of Possum Kingdom Reservoir. The impacts of the drought on reservoir safe yields were determined, and a preliminary investigation of the impacts of low reservoir levels on water quality that might be experienced during drought was completed.

During development of the 2006 Plan, a subset of the Brazos Basin Water Availability Model (Brazos WAM) was developed that includes the Clear Fork watershed, and the area contributing flows from the Brazos River Basin downstream of the confluence of the Clear Fork with the main stem of the Brazos River to just below Possum Kingdom Reservoir. This model is referred to as the "Brazos Mini-WAM." Hydrologic data in the Brazos Mini-WAM were updated to reflect the ongoing drought through June 2004, and reservoir yields for water supply reservoirs were computed to determine supply available to water user groups and wholesale water suppliers in the area.

The drought has continued since June 2004 and likely has further reduced estimates of reservoir yield. For this study, hydrology data (naturalized streamflows and evaporation) in the Brazos Mini-WAM were extended through June 2008, and reservoir one-year safe yields were computed for 18 water supply reservoirs. For seven of the reservoirs, the critical drought period remains the drought of the 1950s, generally accepted as the "drought of record" in the Brazos River Basin and much of Texas. For the remaining reservoirs, the ongoing drought is more critical than the 1950s drought.

A separate analysis was completed for Millers Creek Reservoir because it is located outside of the area included in the Brazos Mini-WAM. Hydrology data were updated for the Millers Creek watershed, and an analysis outside the Brazos Mini-WAM was used to estimate the reservoir's safe yield. The analysis indicates that the current drought is also more severe than the 1950s drought, and that the large rainfall event in 2007 that provided some temporary relief from the drought conditions did not benefit Millers Creek Reservoir significantly.

As a reservoir's level lowers during extended drought periods, concentrations of various water quality constituents increase as water is evaporated from the reservoir pool and is not replenished with inflows. During extreme drought periods, under use levels approximating the yield of the reservoir, water quality can be expected to degrade considerably. A preliminary analysis of chloride and total dissolved solids concentrations in three reservoirs – Fort Phantom Hill Reservoir, Lake Graham and Lake Stamford – indicates that treatment costs will be much greater during critical drought periods under use levels that closer approximate reservoir yields.

The updated Brazos Mini-WAM should be used for developing estimates of water supply available in the Brazos Basin upstream of Possum Kingdom Reservoir during the development of the 2011 Brazos G Regional Water Plan. Consideration should also be given to the impacts of degraded water quality on treatment costs when reservoir levels are low during extended drought periods.

1.0 Background

The Brazos G Regional Water Planning Group (Brazos G) is in the process of developing the 2011 Brazos G Regional Water Plan. The 2011 Plan will be an update of the current 2006 Plan. As part of the process for developing the 2011 Plan, the Texas Water Development Board (TWDB) has provided funding to Brazos G to update drought-of-record analyses for reservoirs in the upper portion of the Brazos G Area (upstream of Possum Kingdom Reservoir), and to evaluate the impacts of drought on the quality of reservoir water supplies.

The ongoing drought has significantly reduced supplies from reservoirs in the upper Brazos G Area. An updated drought–of-record analysis was completed for the 2006 Plan utilizing data available only through June 2004. Continuation of the drought since 2004 has likely resulted in further reduction in supplies. Figure 1-1 presents cumulative streamflows recorded by the Clear Fork at Nugent, TX streamgage (08084000) during the first 13 years (1943 to 1956) of the 1950s drought (largely considered to be the "drought of record") and since the start of the ongoing drought (1993 to July 2008). The cumulative flows for the 1993 to 2008 period are significantly less than those of the 1943 to 1956 timeframe. This is a strong indicator that the current drought is more severe than the drought of the 1950s.

The Brazos Water Availability Model (BWAM) includes data through 1997, which does not include a substantial portion of the current drought. During the development of the 2006 Plan, a portion of the hydrology data were updated through 2004 for a portion of the Brazos WAM, specifically the Clear Fork watershed and the drainage area entering the main steam from the Clear Fork confluence down to Possum Kingdom Reservoir. This formed a model identified as the "Brazos Mini-WAM." As the period of record for the Brazos Mini-WAM was only updated through June 2004, a significant portion of the current drought is still excluded from the model analysis. This report describes the extension through June 2008 of the naturalized streamflow record for the applicable upper basin control points in the Brazos Mini-WAM. This hydrology update was used to evaluate if supplies have been further reduced since the June 2004 update.

Safe yields (one-year basis) were determined using the updated model for several water supply reservoirs in the area. The safe yield (one-year basis) of a reservoir is defined as the maximum amount of annual diversions that can be withdrawn from the reservoir with the minimum storage of the reservoir throughout the simulation period being approximately equal to

the annual diversion amount. This methodology is commonly utilized by reservoir owners in west Texas to estimate water supplies from reservoirs.

During the recent drought, many reservoirs in the upper Brazos G Area experienced extremely low levels. During periods of low water levels, reservoir water quality tends to degrade as concentrations of water quality constituents increase. In order to determine how water quality degrades at lower reservoir levels, correlations between water quality constituents and reservoir level were developed for three reservoirs for which sufficient data were available. The implications of water quality degradation during drought with regards to the usability of the water and the resulting costs associated with treating water from drought-stricken reservoirs are discussed.

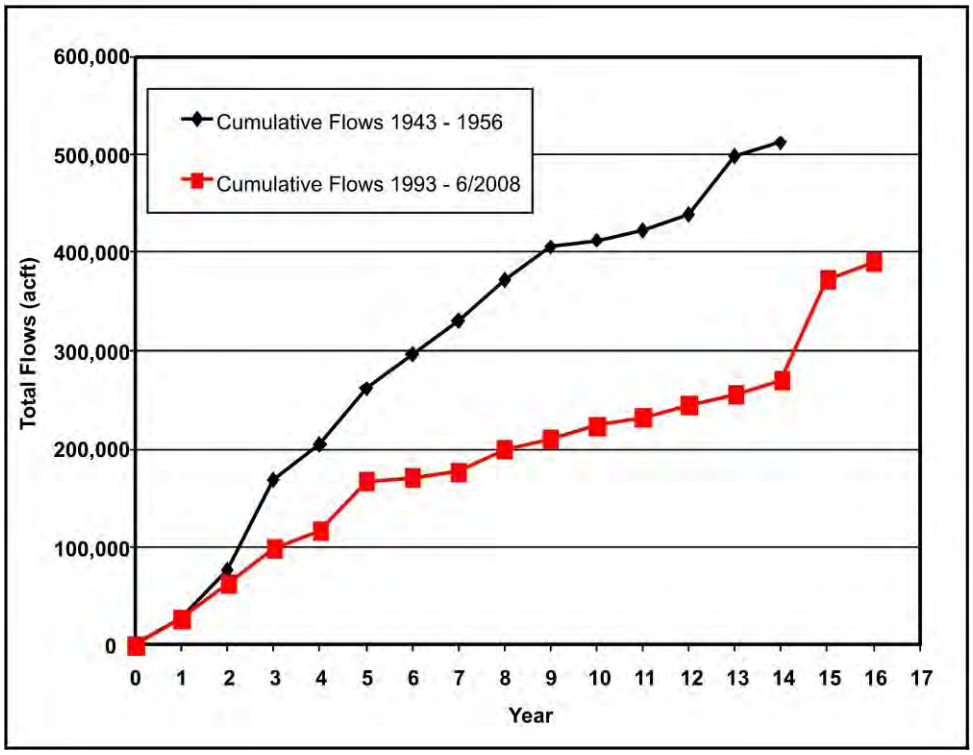


Figure 1-1. Comparison of Cumulative Streamflows for Two Drought Periods for the Clear Fork at Nugent, TX Streamgage (08084000)

2.0 Hydrology and Naturalized Flow Update

The drought update completed for the 2006 Plan utilized data available through June 2004. The West Central Texas region has continued to experience the drought that prompted the

June 2004 update. Consequently, reservoir yield estimates, which are based on drought-of-record analysis, would likely be reduced using data extended through June 2008.

Stream flow, water use, and return flow (wastewater effluent discharges) data were collected for the time period ending in June 2008 for pertinent locations in the upper portion of the Brazos River Basin. As most water supply reservoirs in the upper portion of the Brazos G Area are located in the Clear Fork watershed of the Brazos River Basin, this update focuses on the Clear Fork watershed and the drainage area entering the main steam from the Clear Fork confluence down to Possum Kingdom Reservoir. This is the area represented in the Brazos Mini-WAM. Figure 2-1 presents a map of the upper Brazos Basin control points included in the Brazos WAM, and identifies the updated control points in red that are utilized to form the Brazos Mini-WAM.

Naturalized streamflows were updated for the period January 2003 through June 2008. Data for the time period of January 2003 through June 2004, included in the previous update, were revised during this analysis to refine some minor differences in data that were not available during the previous update.

2.1 Historical Streamflow Data

Historical streamflow data were obtained from the U.S. Geological Survey (USGS) website for 2003 through June 2008. The streamflow data serve as the basis for determining the naturalized flows for each primary control point included in the Brazos Mini-WAM. The following USGS gages were used in the flow naturalization process.

- Brazos River at Seymour, TX (08082500);
- Clear Fork Brazos River near Roby, TX (8083100);
- Clear Fork Brazos River at Nugent, TX (08084000);
- California Creek near Stamford, TX (8084800);
- Clear Fork Brazos River at Fort Griffin, TX (8085500);
- Hubbard Creek below Albany, TX (8086212);
- Big Sandy Creek above Breckenridge, TX (8086290);
- Brazos River near South Bend, TX (8088000); and
- Brazos River near Palo Pinto, TX (8089000).

Annual streamflow data for the Clear Fork at Nugent, TX gage (08084000) are shown in Figure 2-2.

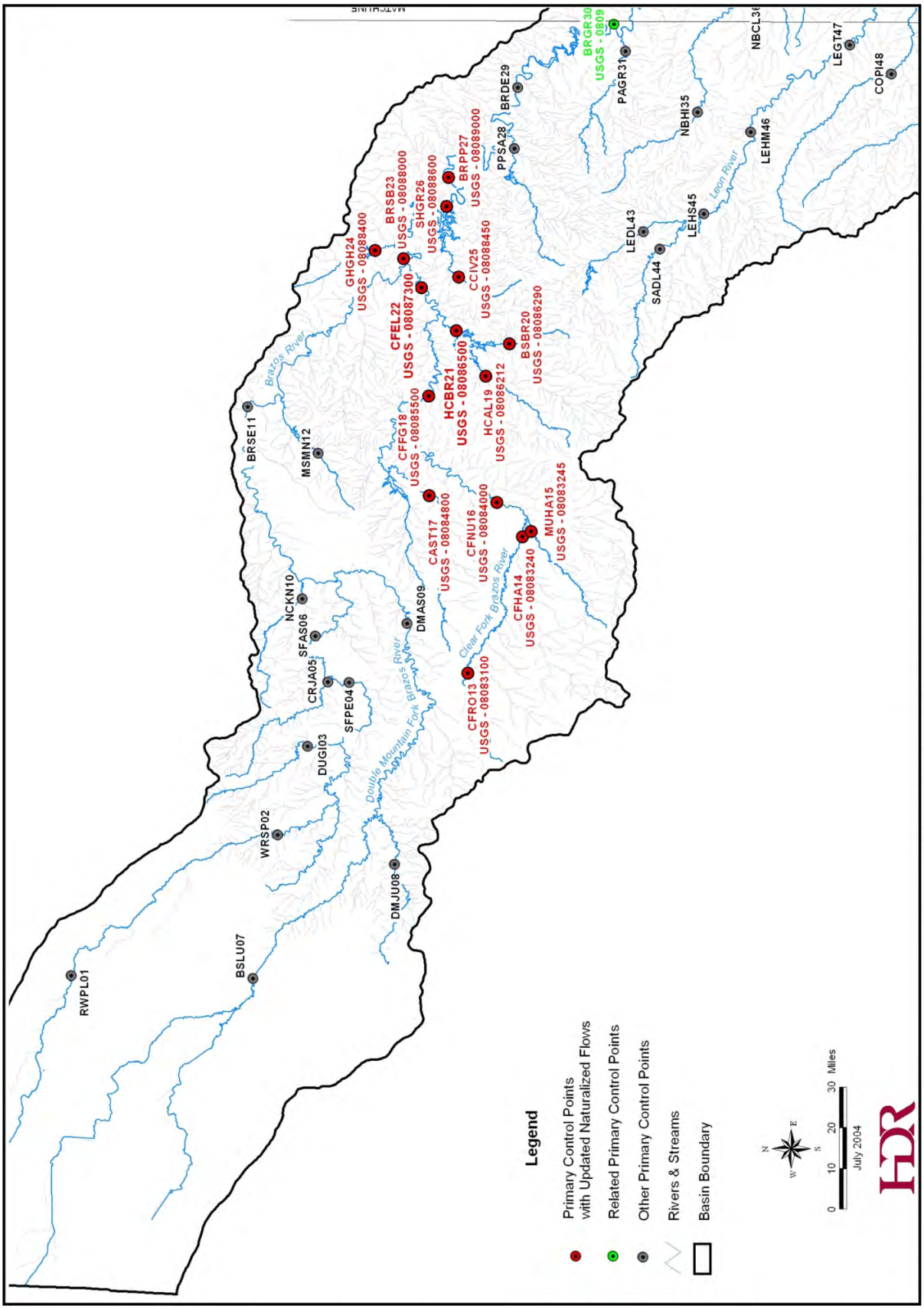


Figure 2-1. Control Points in the Upper Brazos WAM

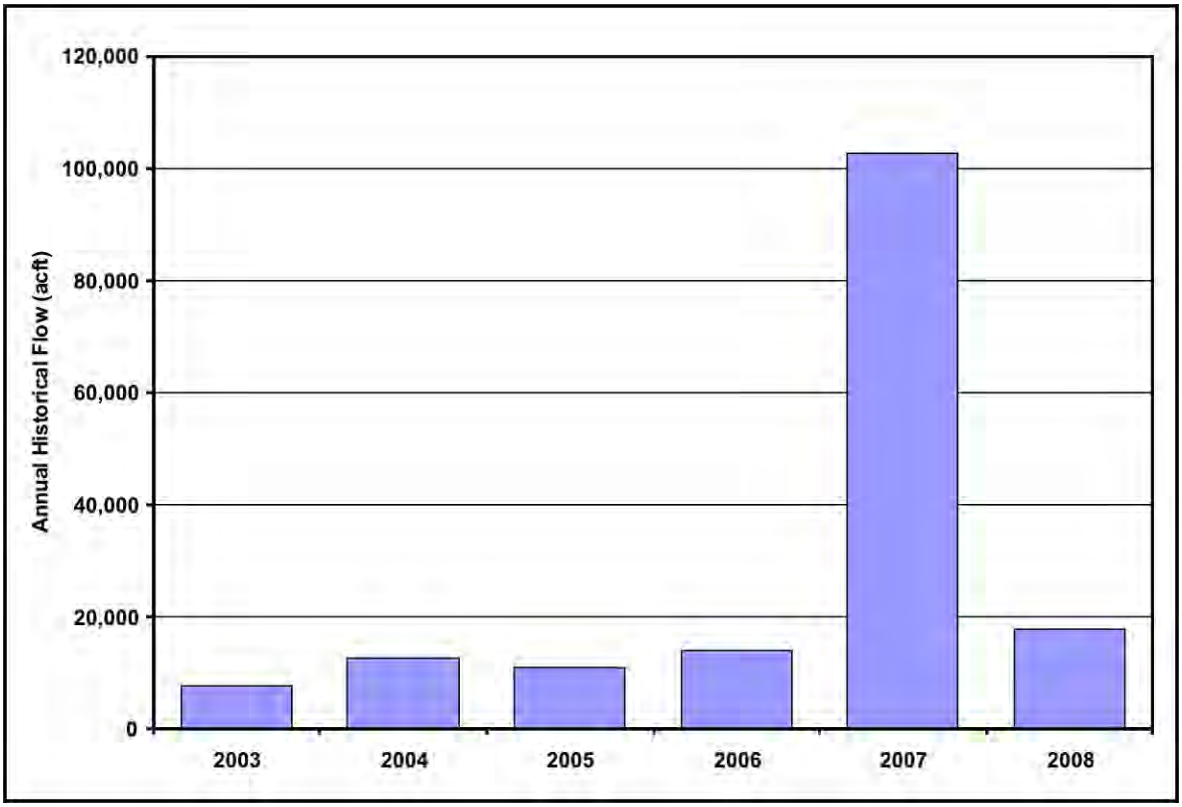


Figure 2-2. Annual Historical Streamflows for the Clear Fork Brazos River at Nugent, 2003 – 2008. (Note: 2008 represents only half of a year)

2.2 Historical Water Use Data

Updated water right usage data were obtained through 2006 from the Texas Commission on Environmental Quality (TCEQ). Water use data for 2007 and 2008 were not available, and water use for these years was estimated by averaging the water use data from 2000-2006 for each water right with reported use. The water right use data from the previous update was checked against these latest data from TCEQ, and those years (2003 – 2004) that were estimated in the previous model update were corrected with the actual reported values from TCEQ.

Specific water right usage data were obtained from the City of Abilene, Texas, for 2007 and 2008. These water rights include the following:

- Certificate of Adjudication 4139 (Scalping into Fort Phantom Hill Reservoir),
- Certificate of Adjudication 4150 (Lake Kirby),
- Certificate of Adjudication 4161 (Fort Phantom Hill Reservoir),
- Certificate of Adjudication 4165 (Deadman Creek), and

- Permit 4266 (Application Number 4589- Reuse Right).

The annual diversions recorded upstream of the Clear Fork Brazos River at Nugent control point are presented in Figure 2-3. Actual reported diversions are shown in the graph for 2003 through 2006. Diversions for 2007 and the first half of 2008 are based on averages of previous years, except where actual data from the City of Abilene were provided.

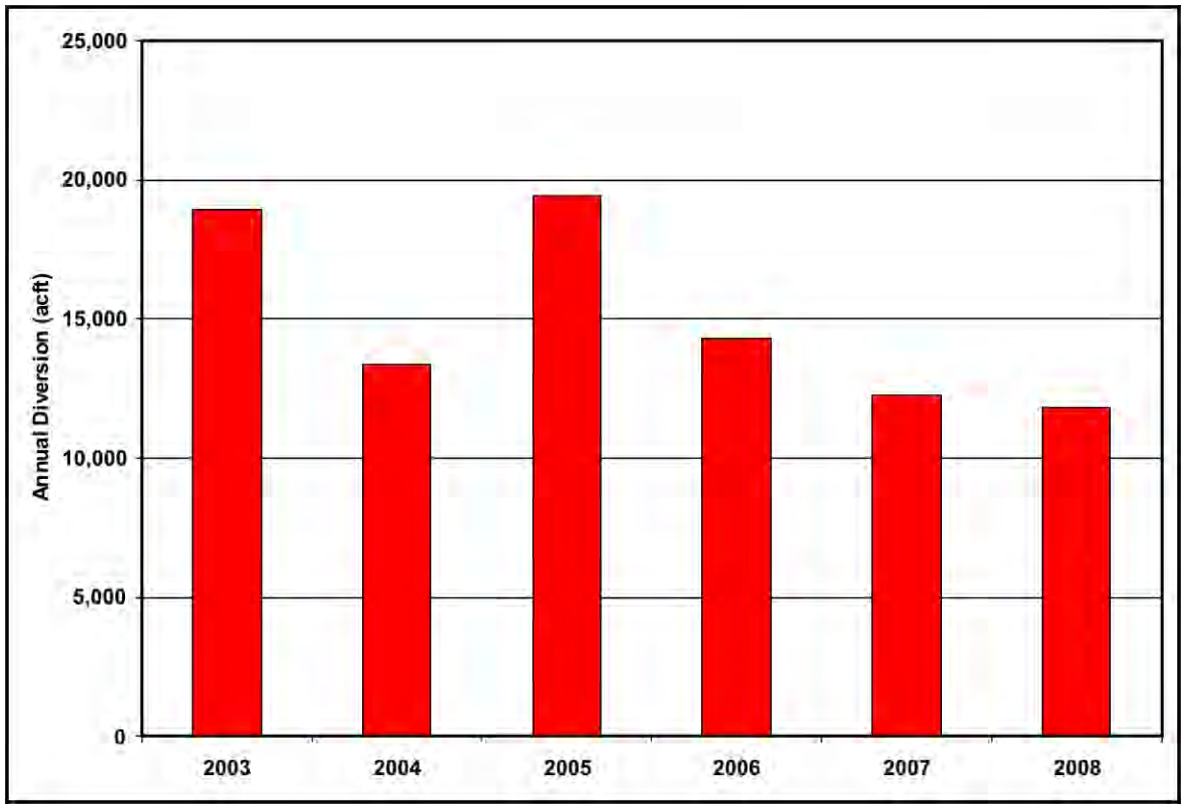


Figure 2-3. Annual Diversions Upstream from the Clear Fork Brazos River at Nugent, 2003 – 2008.

2.3 Historical Return Flow Data

Historical return flow data were estimated for certain entities to allow the model to be extended through 2008. Since there has been little growth recorded over the past decade, it was assumed that return flows from 1999 through 2008 could be estimated using historical data from 1994 through 1998.

The City of Abilene also provided wastewater discharges for TPDES Permit 10334 (May and June 2008) and Fort Phantom Hill Reservoir operations (reservoir spills from January 2007 – June 2008). The City of Abilene return flows are the largest return flows in the Clear Fork watershed that could significantly impact the calculation of naturalized flows. These actual data were incorporated into the flow naturalization process.

Annual return flows discharged upstream from the Clear Fork Brazos River at Fort Griffin control point are shown in Figure 2-4. This control point is located downstream of the City of Abilene's discharge.

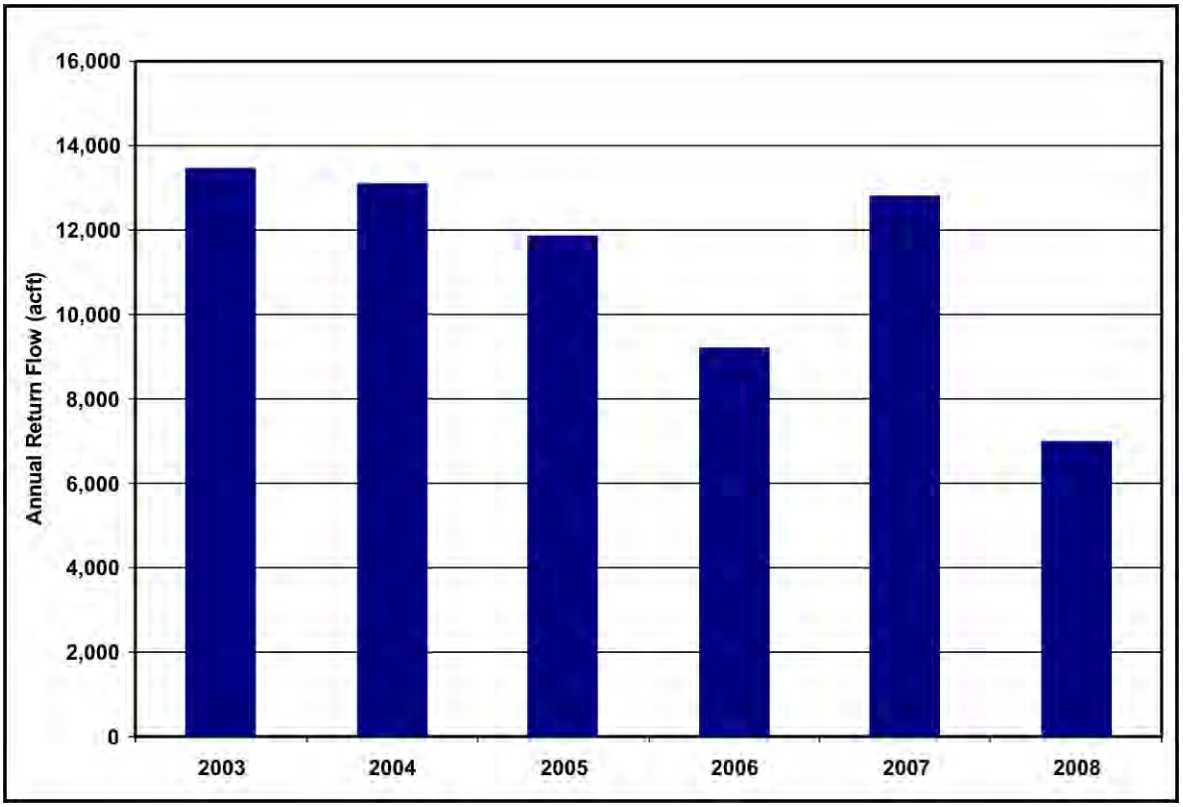


Figure 2-4. Annual Return Flows Discharged Upstream from the Clear Fork Brazos River at Fort Griffin, 2003 – 2008

2.4 Historical Reservoir Contents

Content changes for 13 large reservoirs were utilized in the flow naturalization process. Historical reservoir content records were assembled and incorporated by control point. End-of-month reservoir content data were updated using daily USGS water surface-elevation data and the most recent available reservoir elevation-area-capacity relations. Reservoir elevation-area-

capacity relations were obtained from data used to develop the original Brazos WAM, and were updated to reflect the most recent bathymetric survey by the Texas Water Development Board. Beginning- and end-of-month reservoir surface areas were estimated from the elevation-area-capacity relations to estimate an average monthly surface area for use in calculating net evaporation losses. A water balance calculation was performed for reservoirs for which elevation data were not available. Daily runoff, releases, evaporation, diversions, and spills were incorporated into the water balance calculations to produce an estimate of daily content and surface area for the reservoirs. These methodologies are consistent with those used to develop the original Brazos WAM.

Table 2-1 identifies the methodology used to estimate storage for each large reservoir considered during the flow naturalization process. Reservoir content change data were used only for naturalized flow estimates and were not entered directly into the Mini-WAM.

Table 2-1.
Methodology Used to Determine Changes in Reservoir Contents

Reservoir	*USGS Elevation Data*	*Water Balance*
Abilene	✓	
Cisco	✓	
Clyde		✓
Daniel	✓	
Davis		✓
Graham	✓	
Hubbard Creek	✓	
Kirby		✓
Millers Creek	✓	
Fort Phantom Hill	✓	
Possum Kingdom	✓	
Stamford	✓	
Sweetwater	✓	

Monthly contents for Hubbard Creek Reservoir for the period January 2002 through June 2008 are shown in Figure 2-5. The figure shows the low reservoir contents during the drought period of 2003 through 2007, and subsequent refilling of the reservoir during 2007. The other major reservoirs within the study area also follow the same trend of refilling during 2007.

2.5 Historical Evaporation and Precipitation

Evaporation data are used during the flow naturalization process, and are also entered directly into the WAM model for control point locations containing reservoirs. These data were obtained from a variety of sources, as described below.

2.5.1 January 2003 – December 2004

Monthly precipitation and gross evaporation data for January 2003 through December 2004 were provided by the TWDB on a 1-degree quadrangle basis for the portion of the study area containing reservoirs. Gross evaporation and precipitation values for each reservoir were estimated by taking a weighted average using distances from the reservoir to the center of the four surrounding quadrangles. Net evaporation depths were calculated and monthly net evaporation volumes were estimated using an average of beginning- and end-of-month reservoir surface areas.

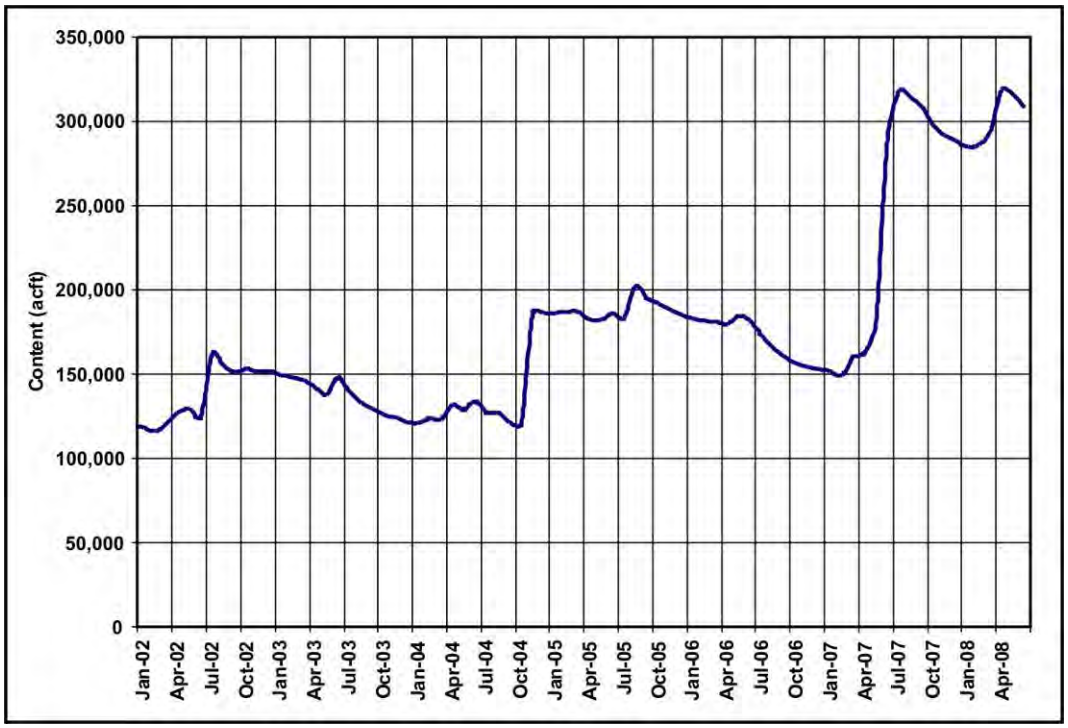


Figure 2-5. Hubbard Creek Reservoir Storage, January 2002 – June 2008.

2.5.2 January 2005 – June 2008

Quadrangle precipitation and evaporation depths are not available from the TWDB for January 2005 through June 2008, and an alternative method was used to estimate monthly precipitation and evaporation depths. Monthly pan evaporation depths measured at Lake Proctor from January 1977 through June 2008 were obtained from the U.S. Army Corps of Engineers. These pan evaporation depths were adjusted with monthly pan coefficients to more accurately estimate gross evaporation depths. A linear regression analysis from 1977 to 2004 was performed using the TWDB Quadrangle 509 monthly gross evaporation data and the Lake Proctor monthly gross evaporation data to create a linear relationship between the two data sets. This regression relationship was then used to estimate Quadrangle 509 monthly gross evaporation depths from January 2005 through June 2008, based on the Lake Proctor evaporation depth for corresponding months. Similar linear regression relationships between Quadrangle 509 gross evaporation values and other quadrangle gross evaporation data sets relevant to reservoir locations were created to update values through June 2008. Figures 2-6 and 2-7 show scatter plots and regression statistics used to estimate linear relationships between Lake Proctor, Quadrangle 509, and Quadrangle 507 monthly gross evaporation depths.

Monthly PRISM (http://www.prism.oregonstate.edu/) precipitation data at each reservoir from January 2005 through June 2008 were acquired for use in net evaporation estimates. Net evaporation depths for each large reservoir were then estimated by subtracting the PRISM precipitation depths from the gross evaporation data.

Runoff adjustments were made to the reservoir-specific net evaporation depths to account for the effects of precipitation on the surface area of the reservoirs. The runoff adjustments consist of the addition of a monthly unit depth of runoff to the net evaporation. These monthly unit runoff depths were developed using USGS streamflows and the corresponding gage drainage areas. It should be noted that runoff adjustments were only made to the net evaporation estimates used in the naturalized flow calculations. Net evaporation data included in the WAM data files were not adjusted because the WAM performs the adjustments automatically within the simulations.

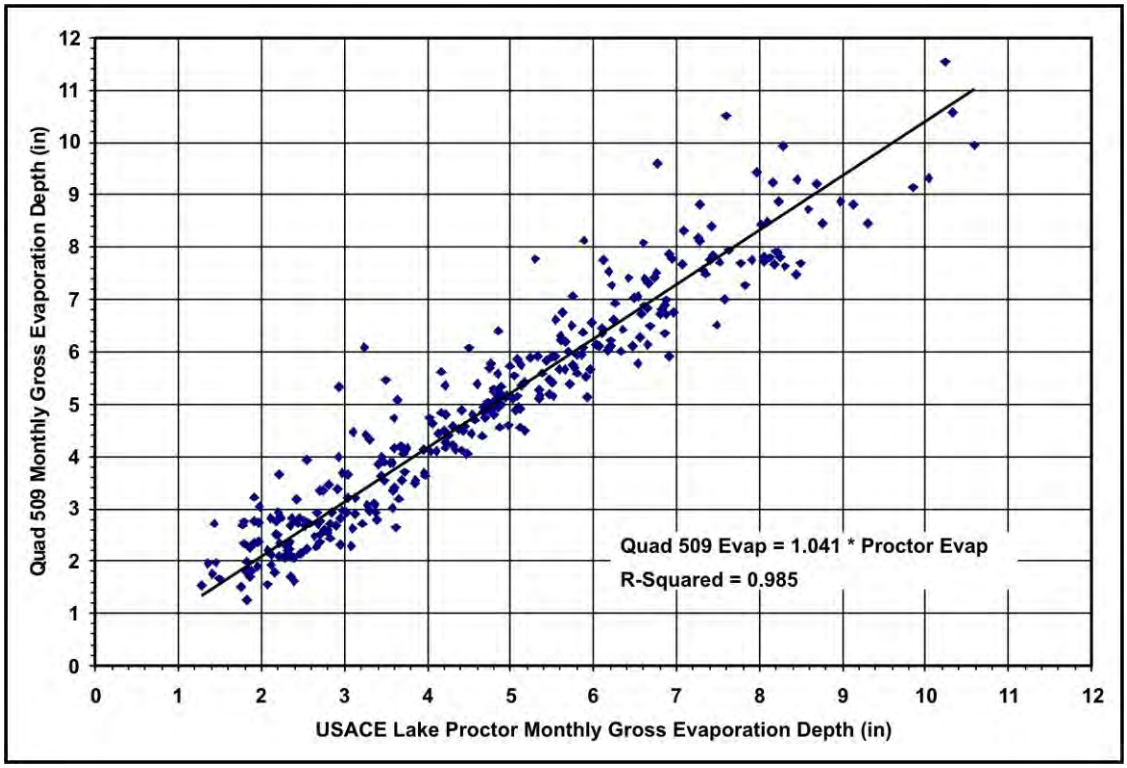


Figure 2-6. Gross Evaporation for Lake Proctor and Quadrangle 509, 1977 – 2004

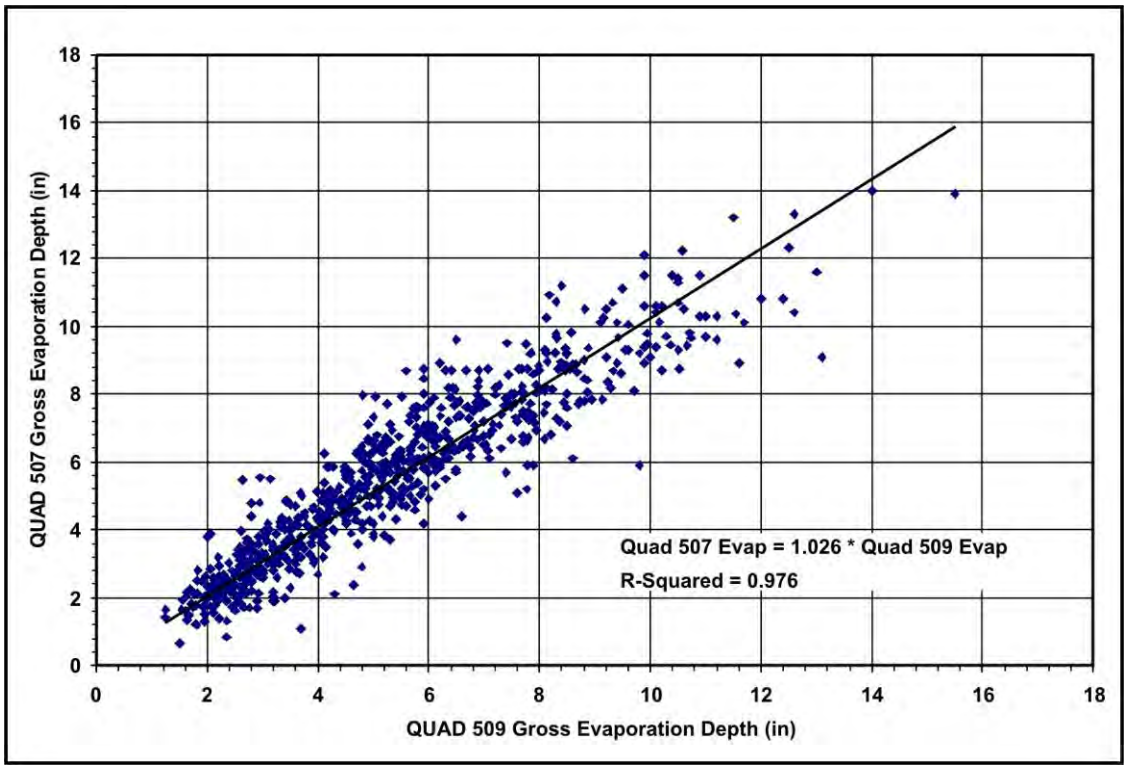


Figure 2-7. Gross Evaporation for Quadrangles 507 and 509, 1940 – 2004

2.6 Naturalized Flow Calculation Methodology

The methodology used to create the naturalized flows for the original Brazos WAM was updated for use in the Mini-WAM. Separate spreadsheet workbooks were created for the primary control points contained within the Mini-WAM that required updated naturalized flows. Each workbook includes separate worksheets that incorporate the gage flows, water use, return flows, reservoir contents, and net reservoir evaporation affecting the flows at the primary control point. Adjustments were made to the gage flows using these data to estimate naturalized flows, using the following general equation:

Naturalized flow = (gaged flow) + diversions – (return flows) + (changes in reservoir contents) – (reservoir evaporation)

2.6.1 Filling Data

For instances in which USGS streamflow data do not exist during the WAM simulation period of January 1940 through June 2008, naturalized flow data are filled using regression relations with one or more other "partner" control points. The fill relationships developed during the original Brazos WAM development were adopted for this update; the relationships were not revisited during this work effort. Table 2-2 lists the control points included in the Brazos Mini-WAM and summarizes the process used to develop the naturalized flows, whether through adjustment of gaged streamflows or through filling in flows using partner control points.

Figure 2-8 shows the annual naturalized flow estimates for the control point at the Brazos River at Palo Pinto. The years from 1958 to 1992 have been omitted from the figure to emphasize the comparison of the two critical drought periods. The separate colors of the annual bars distinguish the original Brazos WAM naturalized flows (1940 – 1997), the previous naturalized flow update for the 2006 Plan (1998 – 2002), and the current naturalized flow update (2003 – June 2008). Appendix A includes similar graphs for all control points in which naturalized flows were updated.

Table 2-2.
Methods Used to Develop Naturalized Flows

Primary Control Point	*Fill Period Needed from Partner Control Point*	*Partner Control Point(s) Used for Fill Period*	*Adjustments Included for:*			*Comments*
			WR Diversions	*Return Flows*	*Reservoirs*	
CFR013	None	None	None	None	None	Gaged equals Natural
CFHA14	1998 to 2008	CFNU16	✓	✓	Sweetwater	
MUHA15	1998 to 2008	CFNU16	None	None	None	
CFNU16	None	None	✓	✓	Fort Phantom Hill Lake Abilene & Kirby	
CAST17	None	None	✓	✓	None	
CFFG18	None	None	✓	✓	Lake Stamford	
HCAL19	None	None	✓	✓	None	
BSBR20	None	None	✓	✓	Lake Cisco	
HCBR21	None	None	✓	None	Hubbard Creek	Historical inflows developed from separate HCR model
CFEL22	1998 to 2008	CFFG18	✓	✓	Lake Daniel	
BRSB23	None	None	✓	✓	Millers Creek	
BRSE11	None	None	✓	None	Lake Davis	Included for naturalization purposes, but not included in Mini-WAM
MSMN12	None	None	None	None	None	Included for naturalization purposes, but not included in Mini-WAM
GHGH24	1998 to 2008	BRPP27 & BRSB23	✓	✓	Lake Eddleman/Graham	
CCIV25	1998 to 2008	BRPP27 & BRSB23	None	None	None	
SHGR26	1998 to 2008	BRPP27	✓	✓	Possum Kingdom	
BRPP27	None	None	None	✓	None	

Note: Abbreviations are from the Brazos WAM and indicate the following control point locations:

CFR013 – Clear Fork Brazos River near Roby
CFHA14 – Clear Fork Brazos River at Hawley
MUHA15 – Mulberry Creek near Hawley
CFNU16 – Clear Fork Brazos River at Nugent
CAST17 – California Creek near Stamford
CFFG18 – Clear Fork Brazos River at Fort Griffin
HCAL19 – Hubbard Creek below Albany
BSBR20 – Big Sandy Creek above Breckenridge
HCBR21 – Hubbard Creek near Breckenridge
CFEL22 – Clear Fork Brazos River at Eliasville
BRSB23 – Brazos River near South Bend
BRSE11 – Brazos River at Seymour
MSMN12 – Millers Creek near Munday
GHGH24 – Lake Graham near Graham
CCIV25 – Big Cedar Creek near Ivan
SHGR26 – Brazos River at Morris Shepherd Dam near Graford
BRPP27 – Brazos River near Palo Pinto

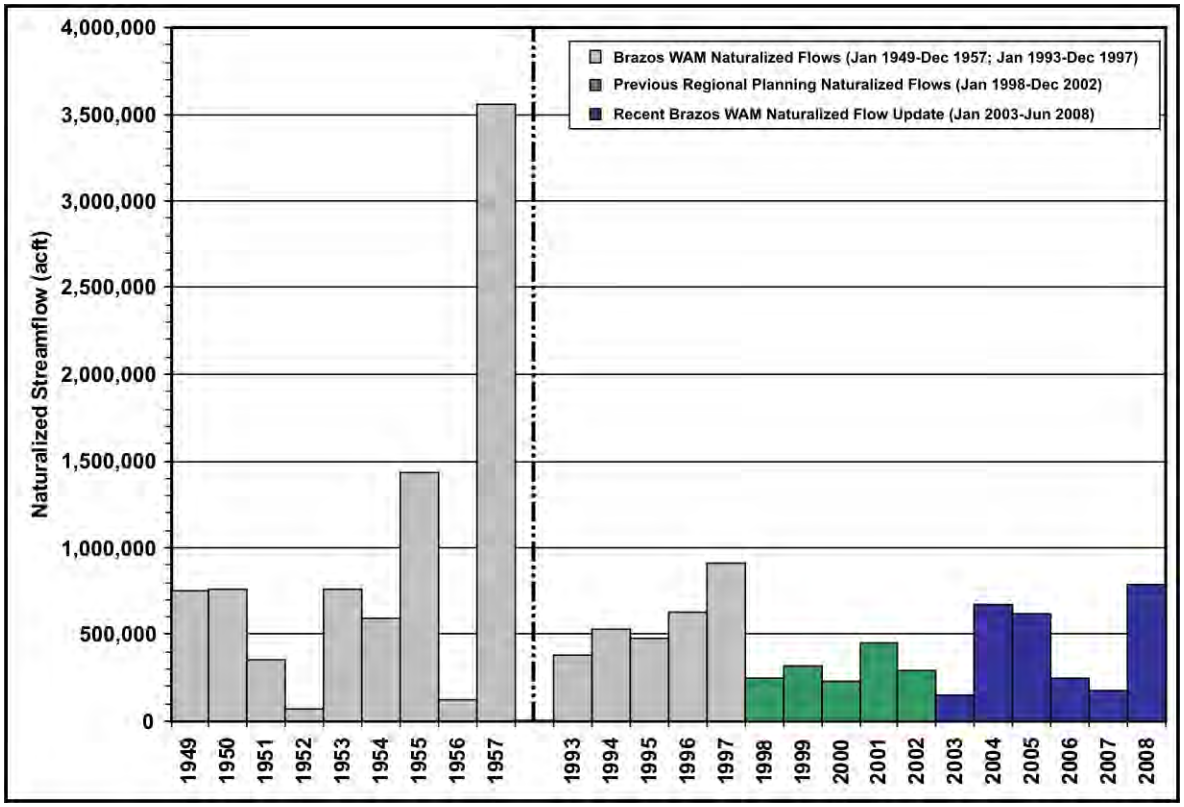


Figure 2-8. Annual Naturalized Streamflow for Two Drought Periods for the Brazos River near Palo Pinto

3.0 Brazos Mini-WAM Update

A subset of the Brazos WAM referred to as the Brazos Mini-WAM was developed for the 2006 Plan to facilitate an extended period of record needed to investigate the impacts of the ongoing drought on reservoir yields in the upper Brazos Basin. The Brazos Mini-WAM is an application of the Water Rights Analysis Package (WRAP) and simulates the Clear Fork watershed of the Brazos Basin and the main stem watershed from the confluence with the Clear Fork to just downstream of Possum Kingdom Reservoir at the primary control point Brazos River near Palo Pinto.

The WRAP model utilizes several text input files to describe the hydrology and other pertinent data included in a model simulation. The methodology for updating the necessary files for use in this analysis is described in this section.

3.1 INF File – Naturalized Flows

The extended naturalized flows were incorporated into the Brazos Mini-WAM by appending the monthly naturalized flow estimates for the 13 primary control points from January 2003 through June 2008 into the existing inflow file (.INF). The INF file is read by WRAP during the Mini-WAM simulations. All naturalized flows existing in the original Brazos Mini-WAM files prior to January 2003 were not altered for this analysis. As discussed in Section 2, the previous update covered hydrology through June 2004; however, the recent update allowed for the incorporation of more complete hydrologic data for 2003 and 2004, replacing some of the estimates from the 2006 Plan effort.

3.2 EVA File – Evaporation Data

Updated monthly net evaporation depths, without runoff adjustments, from January 2003 through June 2008 were incorporated into the existing evaporation (.EVA) file. This process consisted of appending the monthly net evaporation depths for the 13 control points corresponding to the major reservoirs and the 5 control points that WRAP uses to calculate evaporation for smaller reservoirs. All evaporation depths existing in the original Brazos Mini-WAM prior to January 2003 were not altered for this analysis.

3.3 Simulation Assumptions

The following assumptions were included in all simulation runs incorporating the updated naturalized flows and evaporation:

- Full authorized diversions for all water rights;
- Zero return flows;
- The proposed Cedar Ridge Reservoir was omitted;
- The City of Abilene's Clear Fork Scalping operation into Fort Phantom Hill Reservoir was included; and
- Priority calls agreements for Hubbard Creek Reservoir and the Clear Fork Scalping Operation into Fort Phantom Hill Reservoir associated with Possum Kingdom Reservoir were included in some of the simulations, as described in further detail in Section 4.

Safe yield simulations were completed using both 2000 and 2060 estimated sediment conditions for the major reservoirs within the Brazos Mini-WAM. The safe yield of a reservoir is defined as the maximum amount of annual diversions that can be withdrawn from the reservoir

with the minimum storage of the reservoir throughout the simulation period being approximately equal to the annual diversion amount. For smaller supply reservoirs less than 5,000 acre-feet (acft) storage capacity, safe yield simulations were performed for only the authorized storage amount of the reservoir. Year 2000 and 2060 sediment conditions were not estimated for these reservoirs. Reservoir sediment conditions in this analysis are identical to those used in development of the 2006 Plan. Note that reservoir sediment conditions will be updated during the development of the 2011 Plan to account for sedimentation data obtained since development of the 2006 Plan.

4.0 Safe Yield Estimates

Safe yield simulations using the Brazos Mini-WAM with naturalized flows and evaporation data extended through June 2008 were performed for the 18 reservoirs listed in Table 4-1. Simulation runs for Fort Phantom Hill Reservoir were made both with (4.1) and without (4.2) the priority calls agreement regarding the City of Abilene's Clear Fork Scalping into Fort Phantom Hill Reservoir and Possum Kingdom Reservoir. Hubbard Creek Reservoir was also simulated with (6.1) and without (6.2) the priority calls agreements regarding Possum Kingdom Reservoir. Table 4-1 also displays the year in which minimum storage occurs under the safe yield demands during the critical drought. For seven of the reservoirs, the drought of the 1950s remains the critical drought of record. For the remainder, the ongoing drought appears to more critical. Instituting the priority calls agreements regarding Possum Kingdom Reservoir for Hubbard Creek Reservoir and the City of Abilene's Clear Fork Scalping into Fort Phantom Hill Reservoir changes the timing of the critical drought for those two reservoirs. This indicates that the severity of a drought has much to do with how a reservoir relates to surrounding water rights in addition to hydrologic processes.

Table 4-1 also shows the safe yield estimates utilized in the 2006 Plan, which utilized hydrology updated through mid-2004. For the current analyses, some of the 2003 and 2004 data were updated to reflect refined estimates of diversions that occurred during those years. This accounts for some of the differences between the yield estimates when both have critical periods between 2000 and 2004. Firm yield estimates were also computed, to provide a consistent comparison with other reservoirs in the Brazos G Area where firm yield is used instead of safe yield as a basis for determining supply.

The storage trace of the safe yield simulation for Hubbard Creek Reservoir without the priority calls agreement is shown in Figure 4-1. Review of these data identifies two significant drought periods: (1) the drought of the 1950s and (2) the ongoing drought. The simulation results for each reservoir follow this pattern, with the two significant droughts causing nearly identical low reservoir storage amounts. Even though one drought period may result in a lower minimum storage than the other, the differences are minor. With the data available to date, the current drought and the 1950s drought appear to be roughly equivalent in terms of their impacts on reservoir operations. Storage traces and storage frequency plots for all reservoir simulations are included in Appendix B.

Note that Hubbard Creek Reservoir does not refill during the recent drought under a safe yield demand. While many of the reservoirs in the area did refill during 2007, most were operating under demands substantially less than safe yield, and would not have refilled if they had been operating under the larger safe yield demands simulated here. Until the reservoirs refill under a safe yield demand, the ongoing drought cannot be considered to have ended.

The North Central Texas Municipal Water Authority owns and operates Millers Creek Reservoir near Munday, Texas. The authority utilizes this reservoir for water supply for several municipal customers. Millers Creek Reservoir is located within the Brazos G Area proximate to the area for which the updated Brazos Mini-WAM analysis was completed. However, it is located outside the Clear Fork watershed and is tributary to the main stem of the Brazos River. The Brazos Mini-WAM does not include this part of the Brazos Basin, as it would have necessitated updating hydrology for all of the Brazos Basin upstream of Possum Kingdom Reservoir, and not just the Clear Fork to downstream. To estimate the safe yield supply from Millers Creek Reservoir subject to the ongoing drought, an analysis was completed outside of the Brazos Mini-WAM utilizing hydrology data updated specifically for the Millers Creek watershed. Millers Creek Reservoir was simulated for both 2000 and 2060 reservoir sedimentation conditions and also with and without a priority calls agreement with Possum Kingdom Reservoir. The safe yield and firm yield simulation results are shown in Table 4-2, along with the supply (safe yield) estimates utilized in the 2006 Plan.

Table 4-1.
Summary of Safe and Firm Yield Analyses using Brazos Mini-WAM

Reservoir Analysis	Priority Calls Agreement with Possum Kingdom Reservoir	Minimum Storage Year	Hydrology Updated through June 2008				2006 Plan Supply (2004 Hydrology)	
			Safe Yield[3,4]		Firm Yield[3,4]		Safe Yield[3,4]	
			2000 EAC	2060 EAC	2000 EAC	2060 EAC	2000 EAC	2060 EAC
1 Abilene	No	1953	1,255	570	2,200	1,300	1,200	525
2 Cisco	No	1981	1,140	1,130	1,304	1,294	1,340	1,340
3 Daniel	No	2004	235	205	260	205	650	550
4.1 Fort Phantom Hill	Yes[1]	2000	16,850	15,145	21,850	21,615	-	-
4.2 Fort Phantom Hill	No	2004	10,455	10,300	13,105	12,950	7,430	6,940
5 Graham	No	1953	3,935	3,215	5,335	4,815	4,650	3,700
6.1 Hubbard Creek	Yes[2]	1953	33,305	32,600	42,572	41,350	-	-
6.2 Hubbard Creek	No	2004	17,015	16,485	21,015	20,385	18,658	17,760
7 Kirby	No	1953	570	350	970	550	500	320
8 Stamford	No	1953	5,740	5,300	8,760	8,350	5,890	5,400
9 Sweetwater	No	1955	1,055	1,030	1,430	1,405	1,035	980
10 Lake Trammel (RC4128)[5]	No	1955	540		700		717	
11 Lytle Lake (RC4152)[5]	No	1978	230		750		230	
12 Lake Hamlin (RC4180)[5]	No	2004	80		109		300	
13 Anson North Lake (RC4181)[5]	No	2004	65		85		120	
14 Lake Woodson (RC4194)[5]	No	2004	30		38		60	
15 McCarty Lake (RC4208)[5]	No	2004	120		155		575	
16 Baird Lake (RC4202)[5]	No	2004	60		82		385	
17 Moran City Lake (RC4207)[5]	No	2000	70		165		90	
18 Bryson Lake (RC3462)[5]	No	2007	40		52		30	

Notes

[1] Possum Kingdom Reservoir subordinated to Abilene's Clear Fork Scalping operations.

[2] Possum Kingdom Reservoir subordinated to Hubbard Creek Reservoir.

[3] Safe and firm yield units are in acft/yr.

[4] Blank/shaded entries are smaller reservoirs for which 2060 sedimentation conditions were not determined.

[5] Parenthetical text following names of small reservoirs indicates reservoir identifier code used in Brazos WAM when reservoir is not specifically named in model data set.

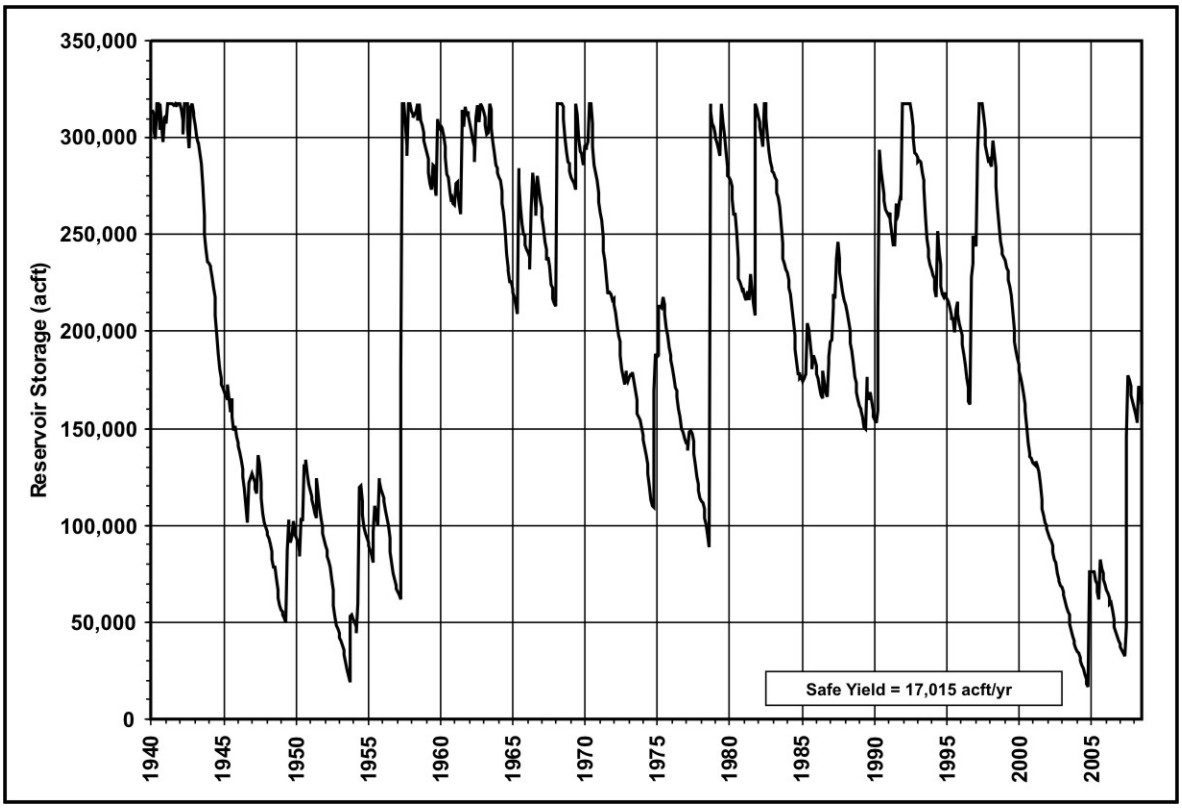


Figure 4-1. Hubbard Creek Reservoir without Possum Kingdom Subordination Safe Yield Storage Trace, 2000 Sediment Conditions

Table 4-2.
Safe and Firm Yield Estimates for Millers Creek Reservoir (acft/yr)

Run	Priority Calls Agreement with Possum Kingdom Reservoir[1]	Minimum Storage Year	Hydrology Updated through June 2008				2006 Plan Supply (2004 Hydrology)	
			Safe Yield		Firm Yield		Safe Yield	
			2000 EAC	2060 EAC	2000 EAC	2060 EAC	2000 EAC	2060 EAC
1	No	2008	90	0	100	0	900	700
2	Yes	2000	4,900	1,900	5,000[2]	4,015		

[1] No priority calls agreement exists between the BRA and the North Central Texas Municipal Water Authority. However, such an agreement is identified in the 2006 Plan as part of the recommended water management strategy for the district (Augmentation of Millers Creek Reservoir).

[2] Yield estimate capped at the annual authorized diversion.

5.0 Water Quality Impacts of Low Reservoir Levels

The ongoing drought has reduced storage in reservoirs in the upper Brazos G Area to levels not previously experienced by the water suppliers of the area. Before largely refilling in 2007, multiple reservoirs in the upper Brazos G Area experienced extremely low levels, which affected the water quality for the remaining supply. This section documents an investigation of the correlation between water quality constituent concentrations and reservoir levels for three reservoirs (Fort Phantom Hill Reservoir, Lake Graham, and Lake Stamford) in the western (upper) portion of the Brazos G Area. These reservoirs are a representative sample to determine the level of degradation in water quality that occurs at lower lake levels in this region.

5.1 Methodology

Water quality data were first collected for each of the three selected study reservoirs from TCEQ's water quality monitoring database (STORET). Using average monthly reservoir storage data from the USGS, the water quality data were analyzed for relationships between reservoir level and water quality. The water quality constituents analyzed were chlorides and total dissolved solids (TDS). TDS is not reported routinely, but specific conductance, which is routinely measured and related to TDS, can be utilized to estimate TDS. For this analysis, the TDS was assumed to equal the measured specific conductance divided by 1.9, which is a typical relationship between the two constituents in natural waters.

Once the data were collected, graphs plotting reservoir storage versus the water quality constituent were created, and a linear trend line was added to each graph to determine a basic relationship between that constituent and the reservoir storage level. Based upon these results, a general discussion of decreased water quality as it relates to treatment cost has been developed and is presented in the following sections.

5.2 Impacts of Low Reservoir Levels on Water Quality

The relationship between water quality and reservoir storage is discussed below for each of the three reservoirs. Following is a general discussion concerning the impacts that these results have on water supply planning and on treatment costs.

5.2.1 Fort Phantom Hill Reservoir

Figure 5.1 illustrates the relationship between chlorides and reservoir storage levels for Fort Phantom Hill Reservoir. As the reservoir storage level decreases, the chloride concentration tends to increase. Sampled chloride concentrations in the reservoir have been as small as 40 mg/L and as great as 172 mg/L. While there is a great amount of scatter around the trend line, the data support a conclusion that water quality generally degrades as the reservoir level drops.

Figure 5-2 illustrates the relationship between TDS and reservoir storage level for Fort Phantom Hill Reservoir. Similar to chlorides, as the reservoir storage level decreases, the TDS concentration tends to increase. Estimated TDS concentrations in water samples have been as small as 256 mg/L and as great as 553 mg/L. A similar conclusion can be drawn from the TDS data as from the chloride data.

5.2.2 Lake Stamford

Figure 5-3 illustrates the relationship between chlorides and reservoir storage levels for Lake Stamford. As the reservoir storage level decreases, the chloride concentration increases, similar to Fort Phantom Hill Reservoir. Sampled chloride concentrations have been as small as 42 mg/L and as great as 648 mg/L.

Figure 5-4 illustrates the relationship between TDS and reservoir storage levels for Lake Stamford. Similar to chlorides, as the reservoir storage level decreases, the TDS concentration increases. Estimated TDS concentrations in water samples have been as small as 233 mg/L and as great as 1,000 mg/L.

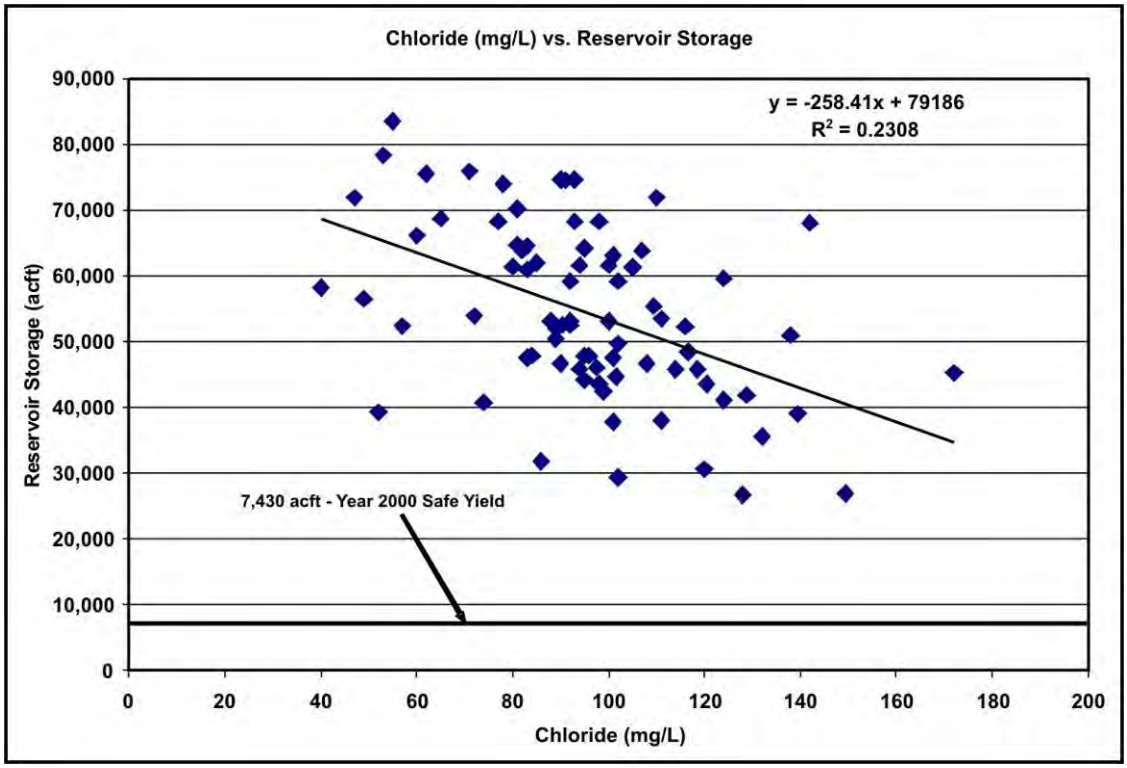


Figure 5-1. Relationship between Chloride Concentration and Reservoir Storage, Fort Phantom Hill Reservoir

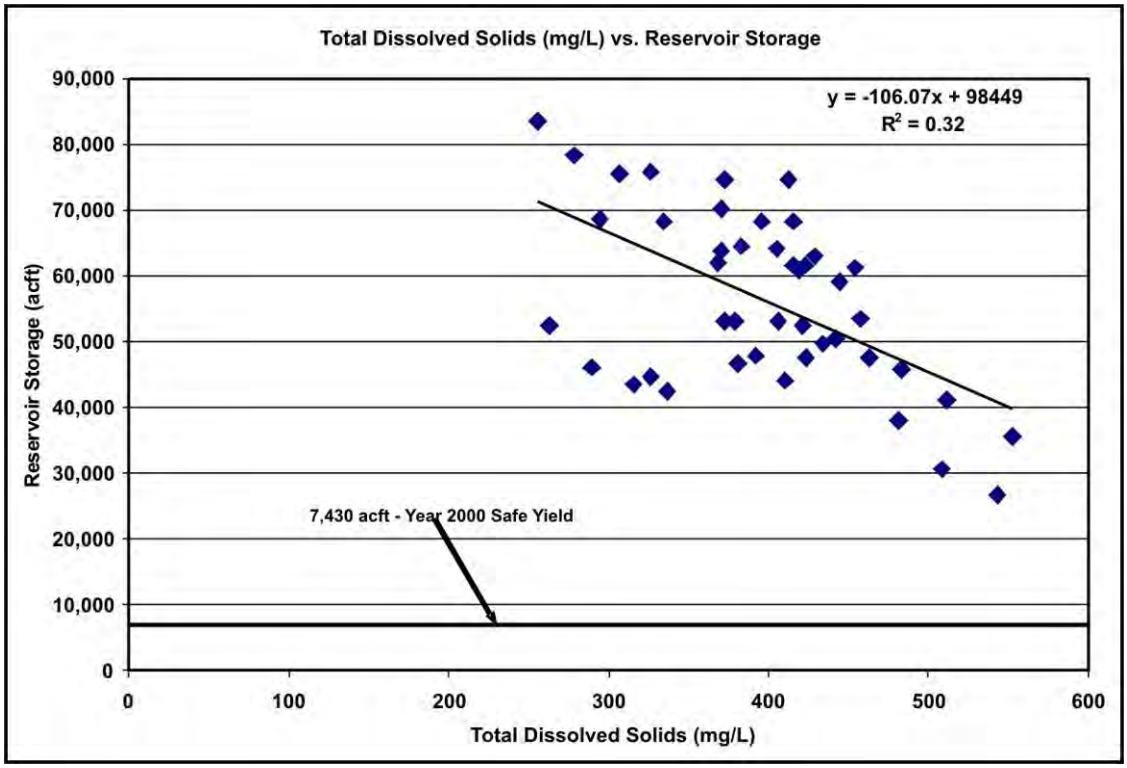


Figure 5-2. Relationship between TDS Concentration and Reservoir Storage, Fort Phantom Hill Reservoir

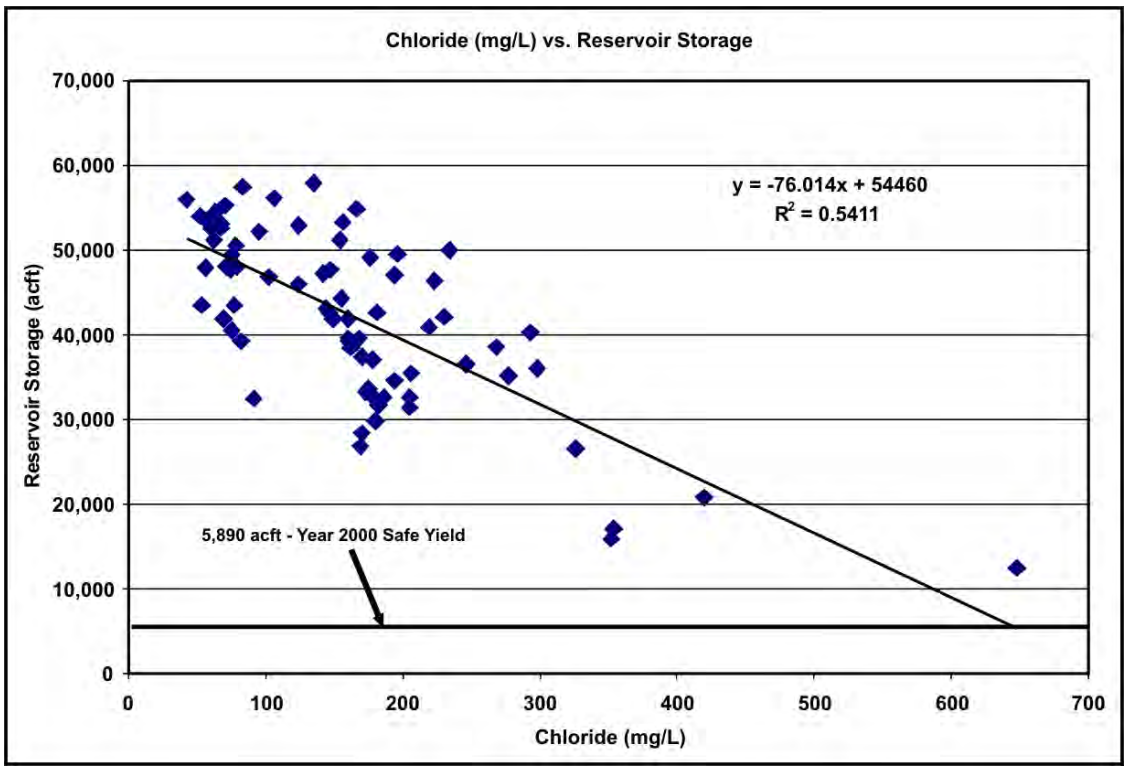


Figure 5-3. Relationship between Chloride Concentration and Reservoir Storage, Lake Stamford

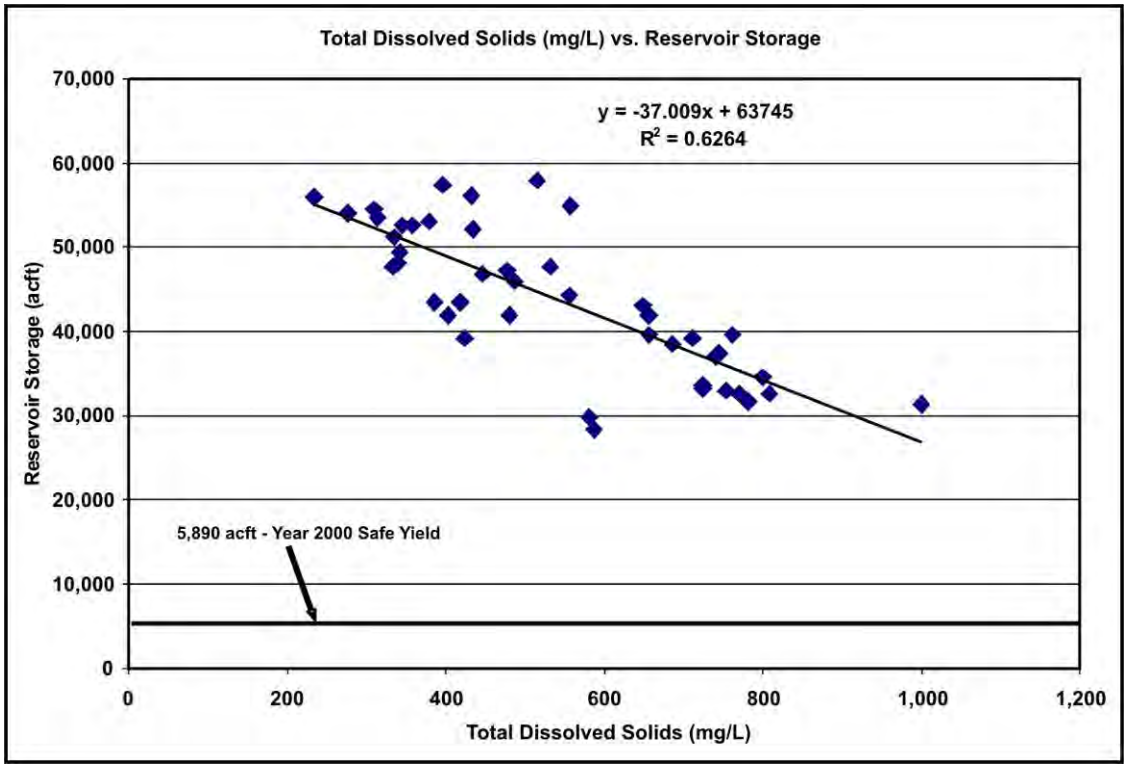


Figure 5-4. Relationship between TDS Concentration and Reservoir Storage, Lake Stamford

5.2.3 Lake Graham

Figure 5-5 illustrates the relationship between chlorides and reservoir storage levels in Lake Graham. As the reservoir storage level decreases, the chloride concentration increases, in similar fashion to Fort Phantom Hill Reservoir and Lake Stamford. Sampled chloride concentrations have been as small as 48 mg/L and as great as 223 mg/L.

Figure 5-6 illustrates the relationship between TDS and reservoir storage levels for Lake Graham. Similar to chlorides, as the reservoir storage level decreases, the TDS concentration increases. Estimated TDS concentrations in water samples have been as small as 212 mg/L and as great as 379 mg/L.

5.3 Water Treatment Cost Considerations

The primary constituents of concern that increase as a result of decreasing reservoir storage are dissolved constituents such as TDS and chlorides that are not removed by conventional treatment processes. Additional desalination treatment measures such as reverse osmosis would be required to remove these dissolved constituents. TDS and chloride are regulated as secondary contaminants with secondary maximum contaminant levels (SMCL) for TDS and chloride of 1,000 and 300 mg/l, respectively. SMCLs regulate contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water and are not as strictly regulated as primary contaminants. The compliance requirements for SMCLs are regulated by TCEQ under the Texas Administrative Code Rule §290.118 that states:

> "The requirements for secondary constituents apply to all public water systems. Water that does not meet the secondary constituent levels may not be used for public drinking water without written approval from the executive director. When drinking water that does not meet the secondary constituent levels is accepted for use by the executive director, such acceptance is valid only until such time as water of acceptable chemical quality can be made available at reasonable cost to the area(s) in question."

For a period of time during drought conditions, it may be possible to continue utilizing a water supply for public drinking water that exceeds the SMCL for TDS and/or chloride if approval is granted by TCEQ. If desalination treatment is necessary to remove dissolved constituents on an ongoing basis, additional treatment costs for reverse osmosis would be applicable.

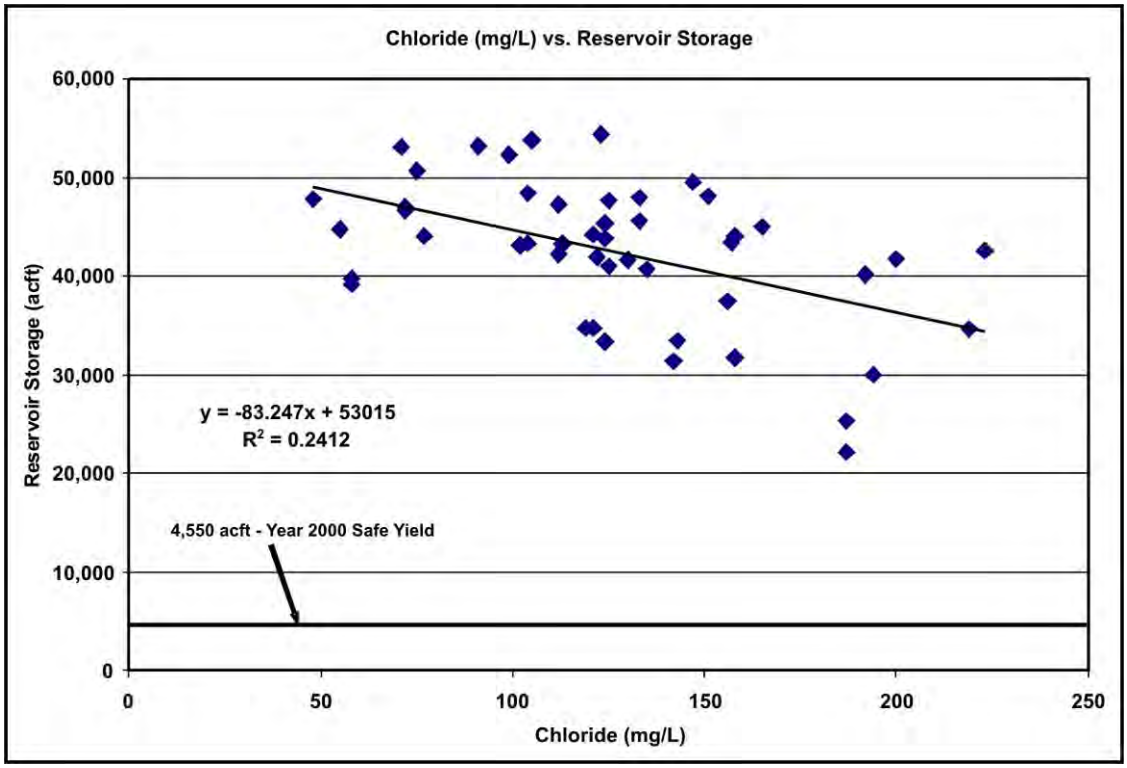


Figure 5-5. Relationship between Chloride Concentration and Reservoir Storage, Lake Graham

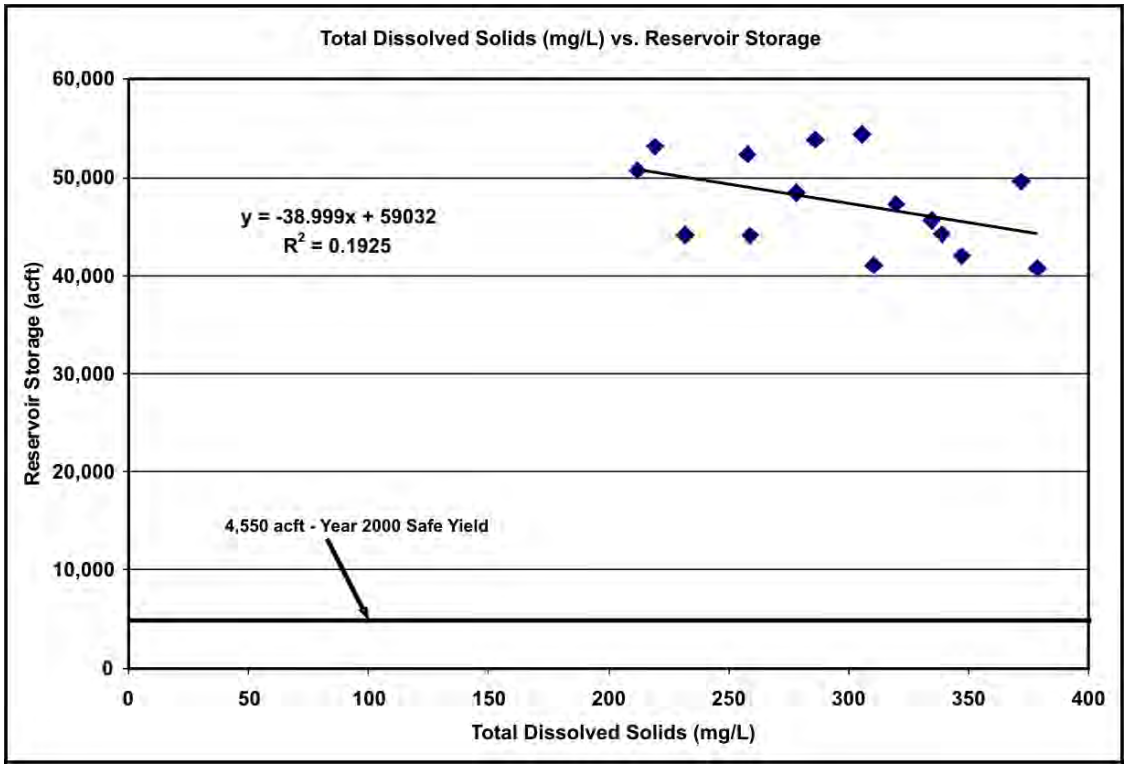


Figure 5-6. Relationship between TDS Concentration and Reservoir Storage, Lake Graham

The linear relationships developed from historical water quality and reservoir storage can be utilized to estimate the water quality anticipated at reservoir levels that are lower than historically observed. As an example, Figure 5-7 shows the projected chloride concentrations for Lake Stamford at decreasing reservoir storage levels. The chloride concentration in Lake Stamford is projected to exceed the SMCL at reservoir storage levels less than 31,656 acft. A similar relationship between TDS and reservoir storage level for Lake Stamford is shown in Figure 5-8 with the SCML for TDS exceeded when the reservoir storage level is less than 26,736 acft.

Desalination with reverse osmosis produces two streams: (1) permeate and (2) concentrate. Permeate is the desalinated product water that has passed through the membrane. Concentrate is the stream rejected by the membrane that contains the concentrated dissolved constituents. The quantity of each stream estimated to result from desalinating a raw water source with 1,500 mg/L of TDS is shown in Table 5-1. At relatively small TDS concentrations a quantity of raw water may be blended with desalted water to decrease the quantity of water requiring desalination treatment and increase the total quantity of product water.

Estimated costs for a desalination facility at the varying capacities shown in Table 5-1 are presented in Table 5-2. The estimated costs for the desalination facilities would be in addition to other existing facilities for the supply and treatment of potable surface water. Estimates include the cost of the reverse osmosis membrane system and standard pretreatment system consisting of cartridge filters and acid addition. Concentrate disposal costs are not included in the estimate, but the cost for disposal of the concentrate can vary widely from relatively low, if the concentrate can be discharged to surface water, to costs of over $500/acft for deep well injection of the concentrate.

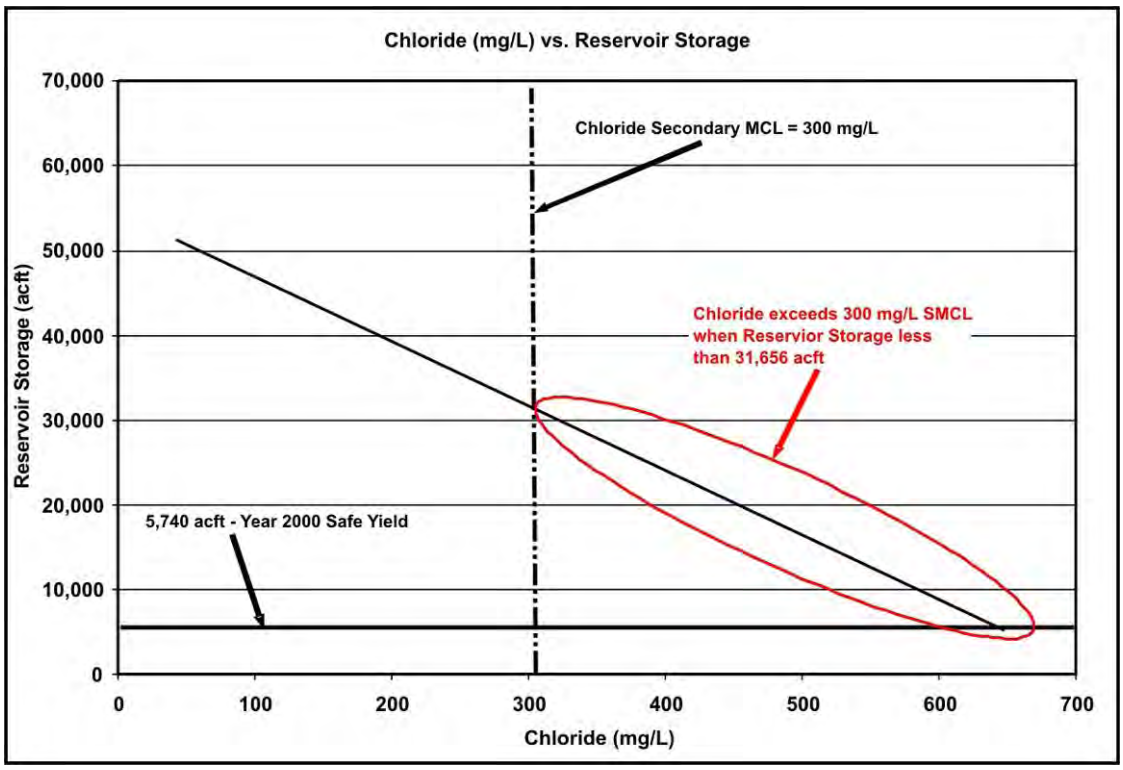


Figure 5-7. Projected Chloride Concentration vs. Reservoir Storage, Lake Stamford

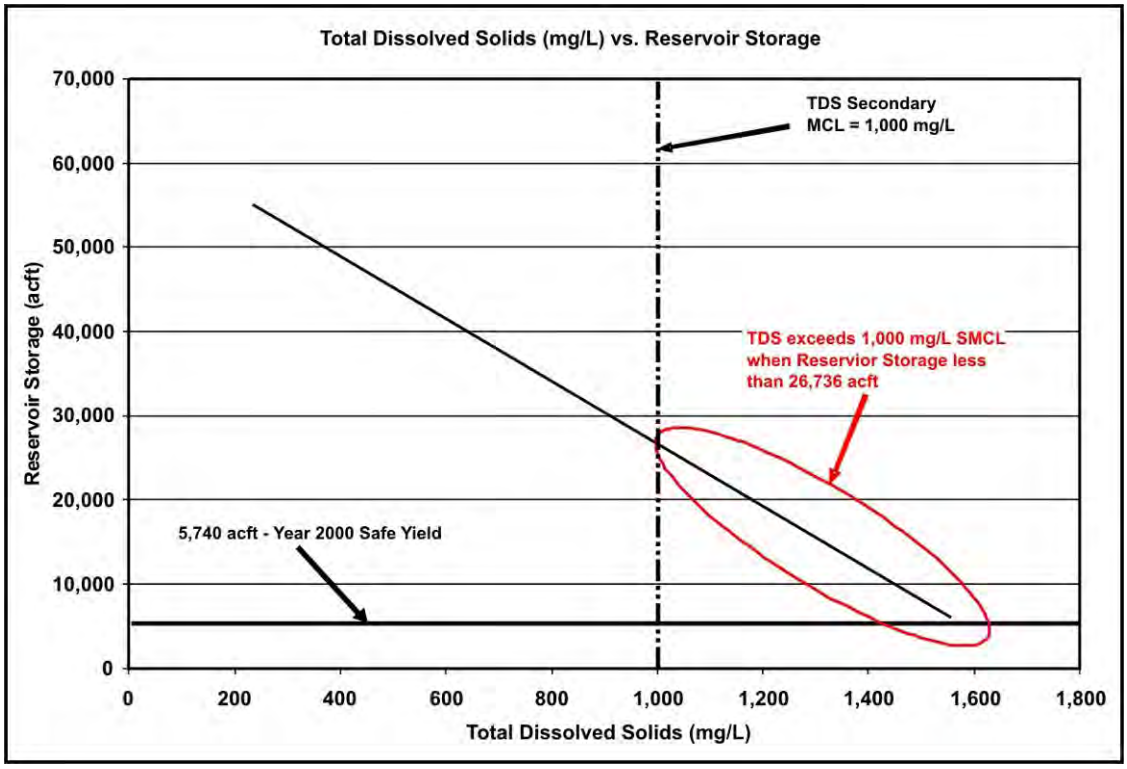


Figure 5-8. Projected TDS Concentration vs. Reservoir Storage, Lake Stamford

Table 5-1.
Desalination Process Flow Summary for 1,500 mg/L TDS Raw Water

Process Stream	*Water Quantity (MGD)*		
Raw Water Quantity	1.00	3.00	10.00
Concentrate	0.14	0.40	1.40
Desalinated Water	0.55	1.70	5.60
Total Blended Water Supply	0.86	2.60	8.60

Table 5-2.
Estimated Desalination Costs for Raw Water with 1,500 mg/L
(2Q 2007 Prices)

Item	*Raw Water Quantity*		
	1 MGD	*3 MGD*	*10 MGD*
Capital Costs			
Desalination Water Treatment Plant	$1,724,000	$3,592,000	$8,631,000
Total Capital Cost	**$1,724,000**	**$3,592,000**	**$8,631,000**
Engineering, Legal Costs and Contingencies	$603,000	$1,257,000	$3,021,000
Environmental & Archaeology Studies and Mitigation	$1,000	$3,000	$6,000
Land Acquisition and Surveying (6 acres)	$2,000	$3,000	$6,000
Interest During Construction (2 years)	$187,000	$389,000	$934,000
Total Project Cost	**$2,517,000**	**$5,244,000**	**$12,598,000**
Annual Costs			
Debt Service (6 percent, 30 years)	$183,000	$381,000	$915,000
Operation and Maintenance			
Ground Storage Tank	$0	$0	$0
Water Treatment Plants	$184,000	$459,000	$1,351,000
Total Annual Cost	**$367,000**	**$840,000**	**$2,266,000**
Available Project Yield (acft/yr)	964	2,899	9,664
Annual Cost of Water ($ per acft)	$381	$290	$234
Annual Cost of Water ($ per 1,000 gallons)	$1.17	$0.89	$0.72

As discussed by the preceding analysis, a general statement can be made that as reservoir storage declines, the water quality also declines due to increased concentrations of various constituents. This will likely result in a higher cost to treat the water. In fact, if any of these reservoirs were to be drawn down to their safe yield level, the water quality would be expected to deteriorate to the point where additional treatment measures, such as reverse osmosis, would need to be implemented to produce potable water of an acceptable quality. Utilization of safe yield versus firm yield is a common practice in West Texas where droughts are frequent and severe, and water managers are acutely aware that a drought more severe than the historical drought of record could occur. Water managers should be aware that if the "safe yield" level is reached, the water treatment costs associated with treating this water could be much greater than experienced under higher reservoir levels.

6.0 Summary

The Brazos G Regional Water Planning Group is in the process of developing the 2011 Brazos G Regional Water Plan. The 2011 Plan will be an update of the current 2006 Plan. As part of the process for developing the 2011 Plan, the Texas Water Development Board (TWDB) has provided funding to Brazos G to update drought-of-record analyses for reservoirs in the upper portion of the Brazos G Area (upstream of Possum Kingdom Reservoir), and to evaluate the impacts of drought on the quality of reservoir water supplies.

A subset of the Brazos WAM, identified as the Brazos Mini-WAM, was developed during the development of the 2006 Plan. This model included hydrologic data extended through June 2004 to estimate the effects of the ongoing drought on water supply reservoirs upstream of Possum Kingdom Reservoir. The Brazos Mini-WAM data have now been extended through June 2008, and were used to update safe yield estimates for 18 water supply reservoirs located upstream of Possum Kingdom Reservoir. The safe yield of Millers Creek Reservoir was updated through an analysis outside of the Brazos Mini-WAM. Safe yield estimates indicate that the current drought is more severe than the drought of the 1950s for 11 of the reservoirs included in the Brazos Mini-WAM and for Millers Creek Reservoir.

Water quality data from three reservoirs – Fort Phantom Hill Reservoir, Lake Graham and Lake Stamford – were analyzed to investigate the relationship between decreased storage levels during drought and degraded water quality. Data indicate that water quality will degrade

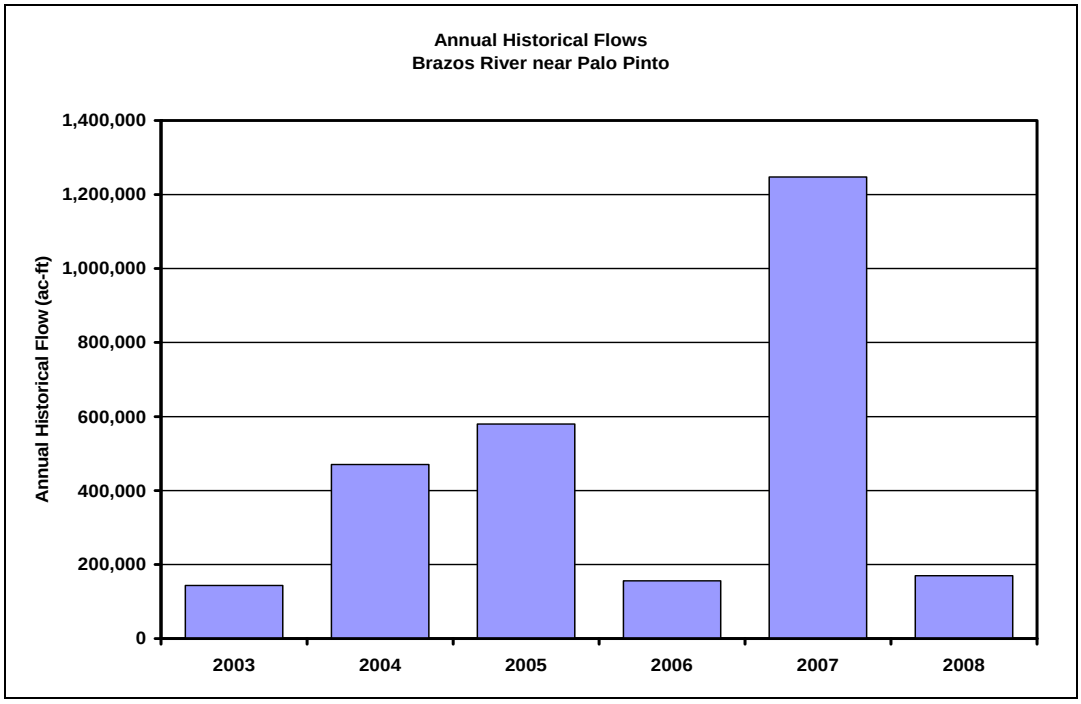
significantly during severe, extended drought periods, and will likely require expensive advanced treatment to be used as potable water supplies.

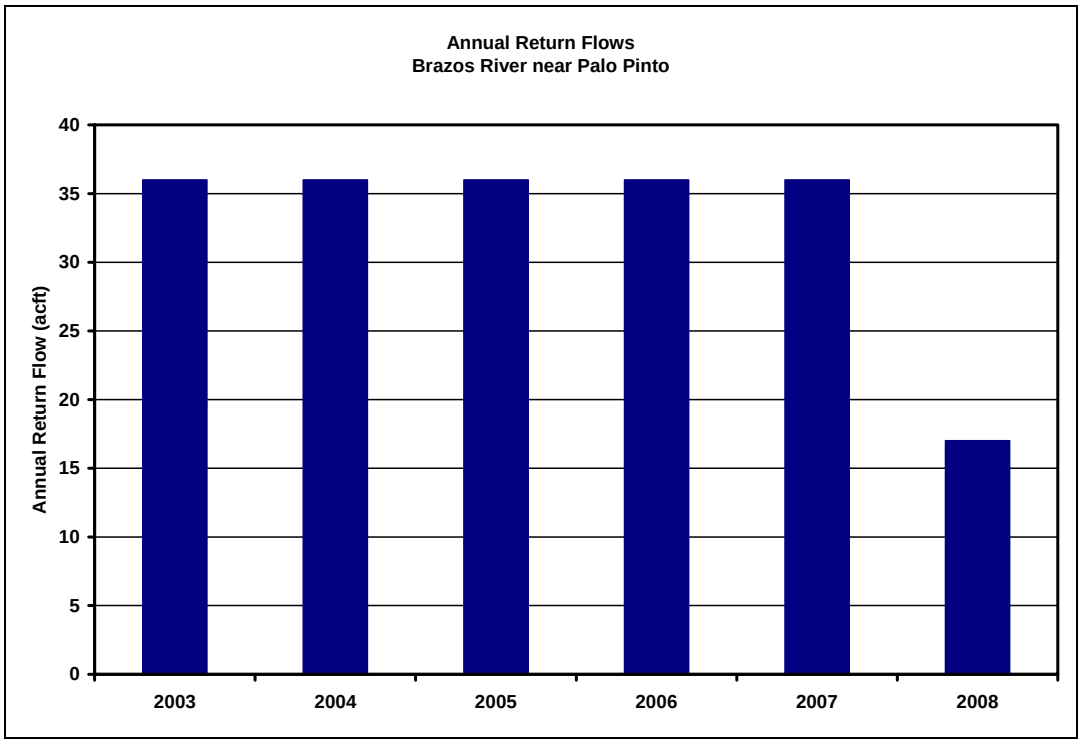
7.0 Recommendations

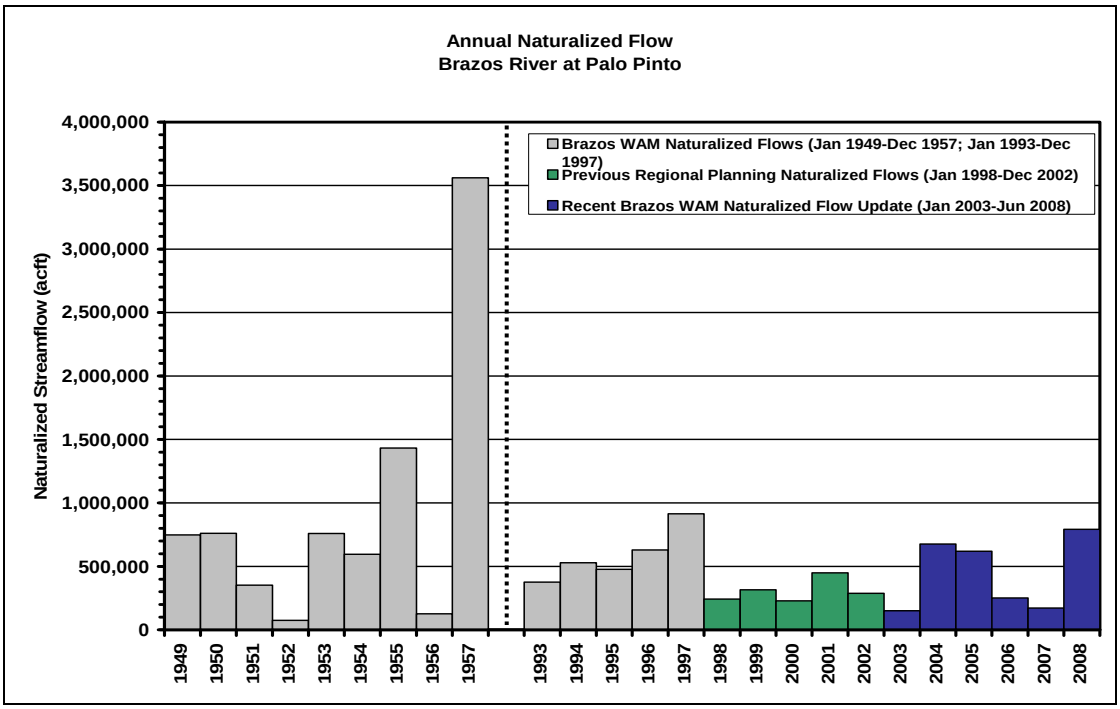
The Brazos Mini-WAM model updated and applied during this analysis should be utilized to estimate safe yield supplies for the reservoirs located upstream of Possum Kingdom Reservoir during the development of the 2011 Brazos G Regional Water Plan. Analyses based upon this model (with hydrology through June 2008) will account more accurately for the ongoing drought than would analyses based on the existing TCEQ Brazos WAM (with hydrology data through 1997) or the Brazos Mini-WAM model used during development of the 2006 Plan (with hydrology through June 2004). In addition, consideration should be given to extra treatment costs associated with utilizing supplies from reservoirs during severe drought periods. These costs result from degraded water quality at low reservoir levels, and should be recognized as a potential concern when evaluating long-term water supplies and developing drought contingency plans.

Appendix A
Historical Streamflows, Diversions, Return Flows, and Naturalized Flows for Updated Control Points in the Brazos Mini-WAM

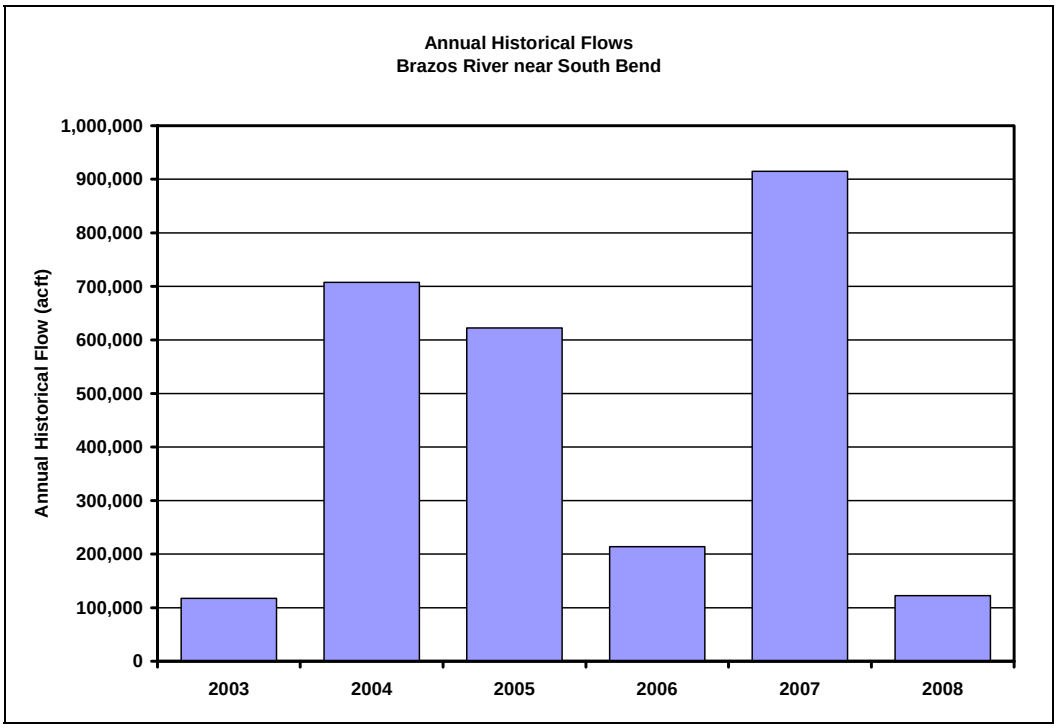
Brazos River near Palo Pinto

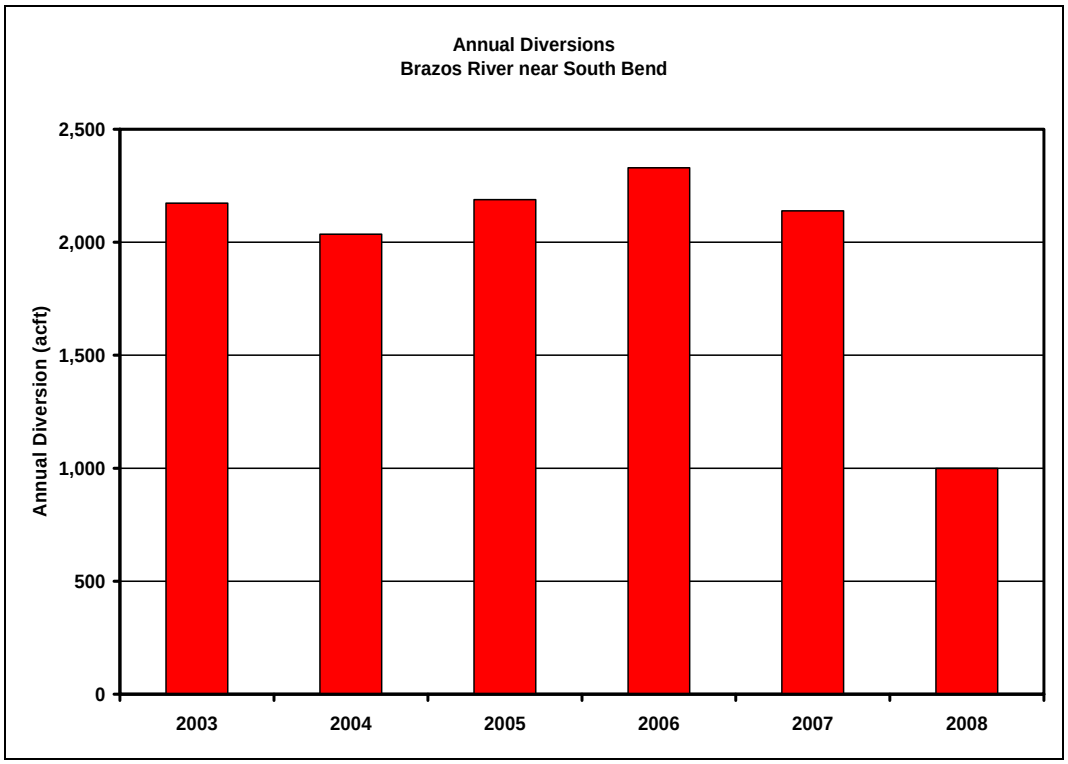


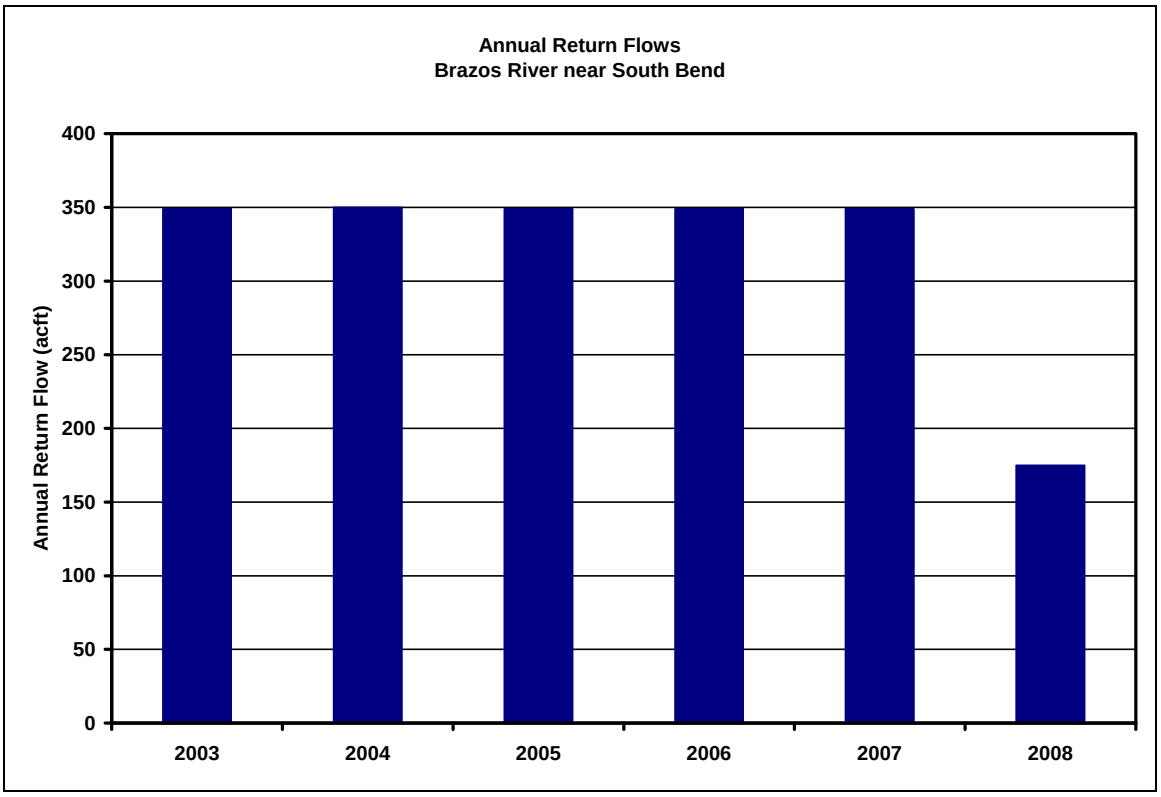


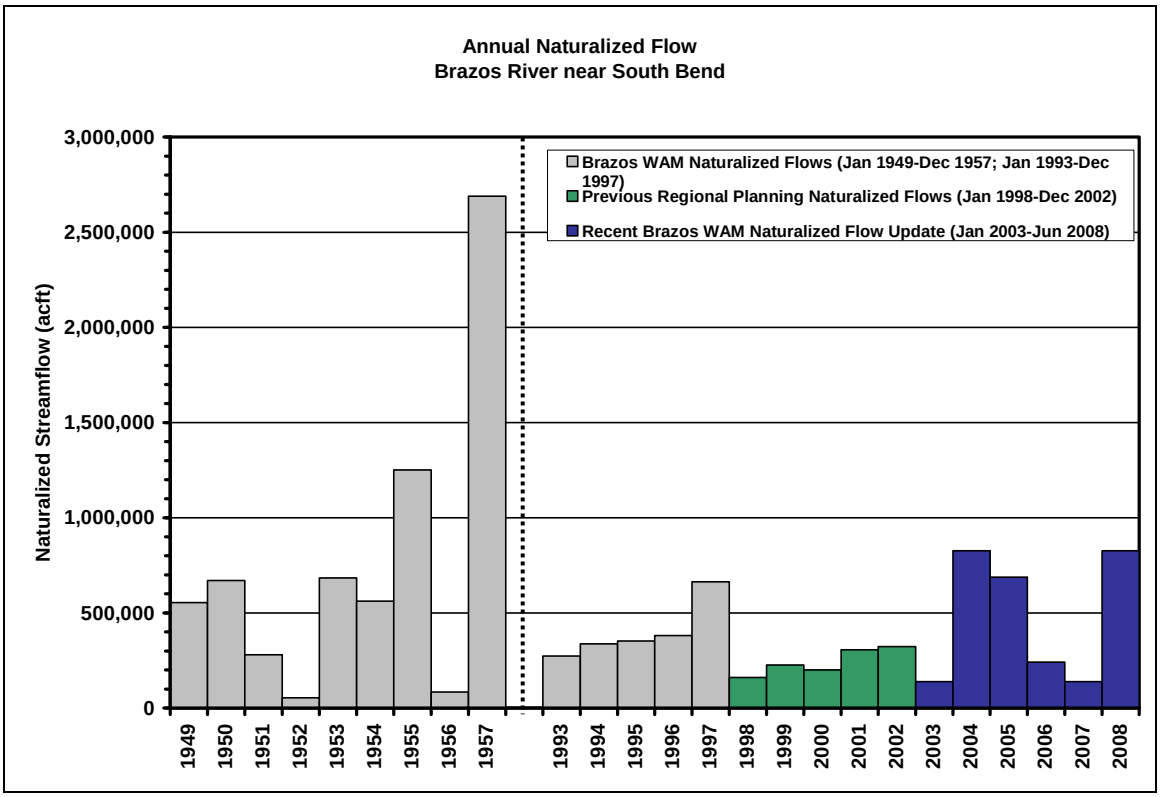

Annual Naturalized Flow
Brazos River at Palo Pinto
Naturalized Streamflow (acft)
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
1949
1950
1951
1952
1953
1954
1955
1956
1957
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

Brazos River near South Bend






Annual Return Flows
Brazos River near South Bend
Annual Return Flow (acft)
400
350
300
250
200
150
100
50
0
2003
2004
2005
2006
2007
2008


Annual Naturalized Flow
Brazos River near South Bend
Naturalized Streamflow (acft)
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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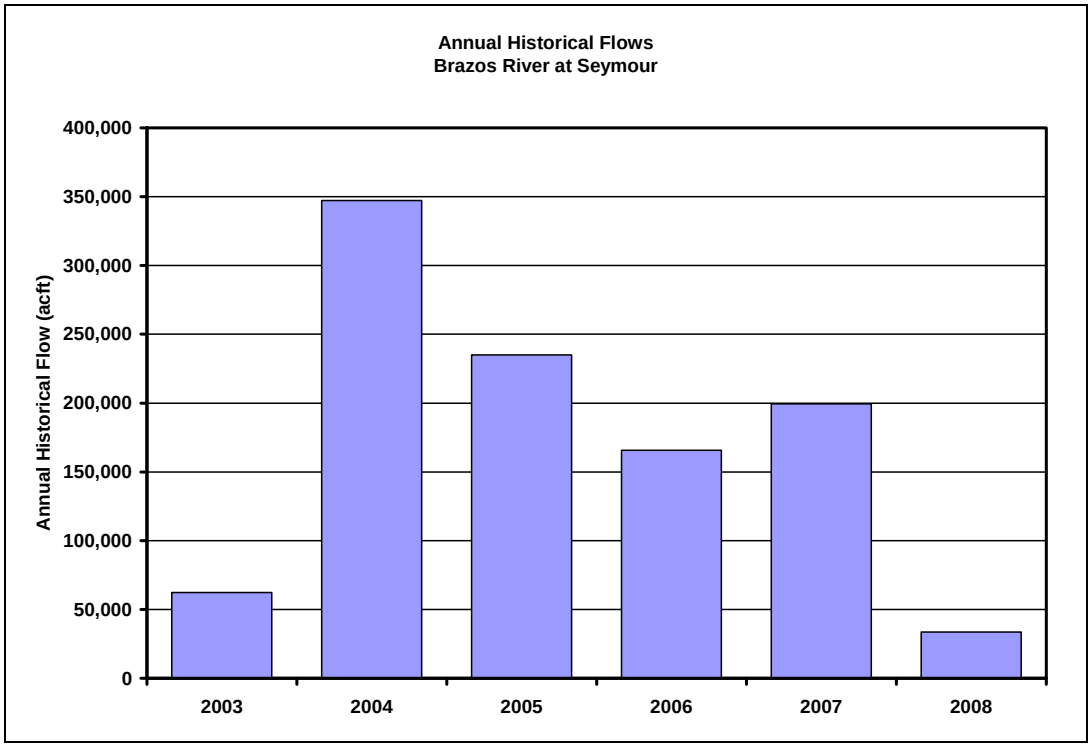
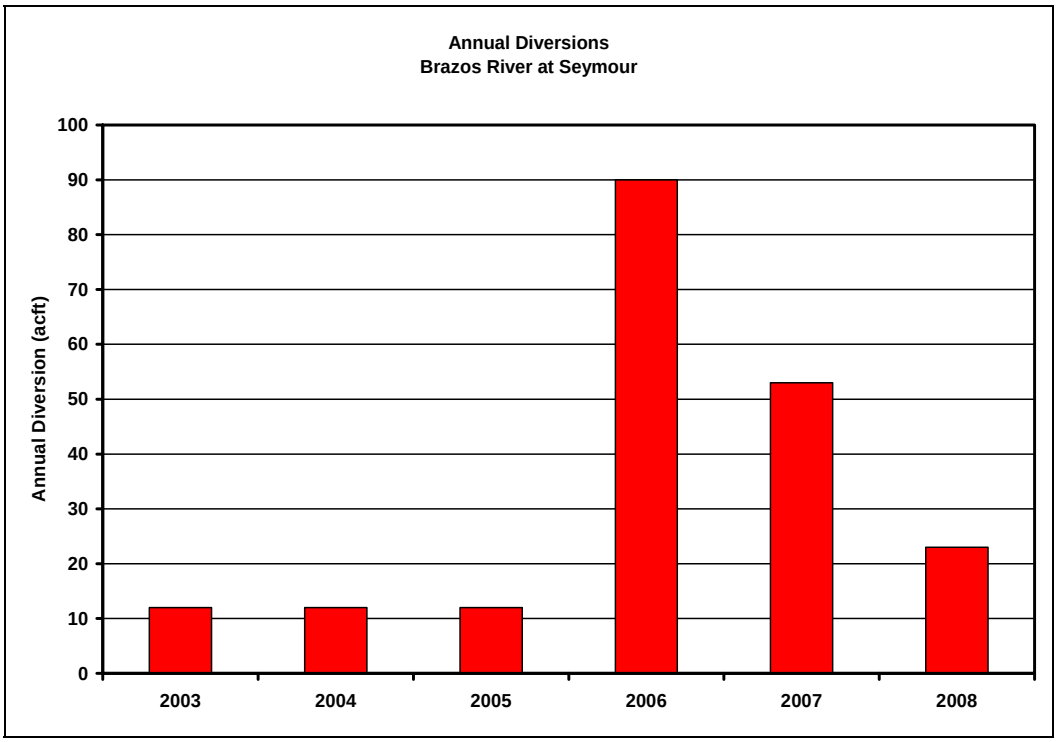
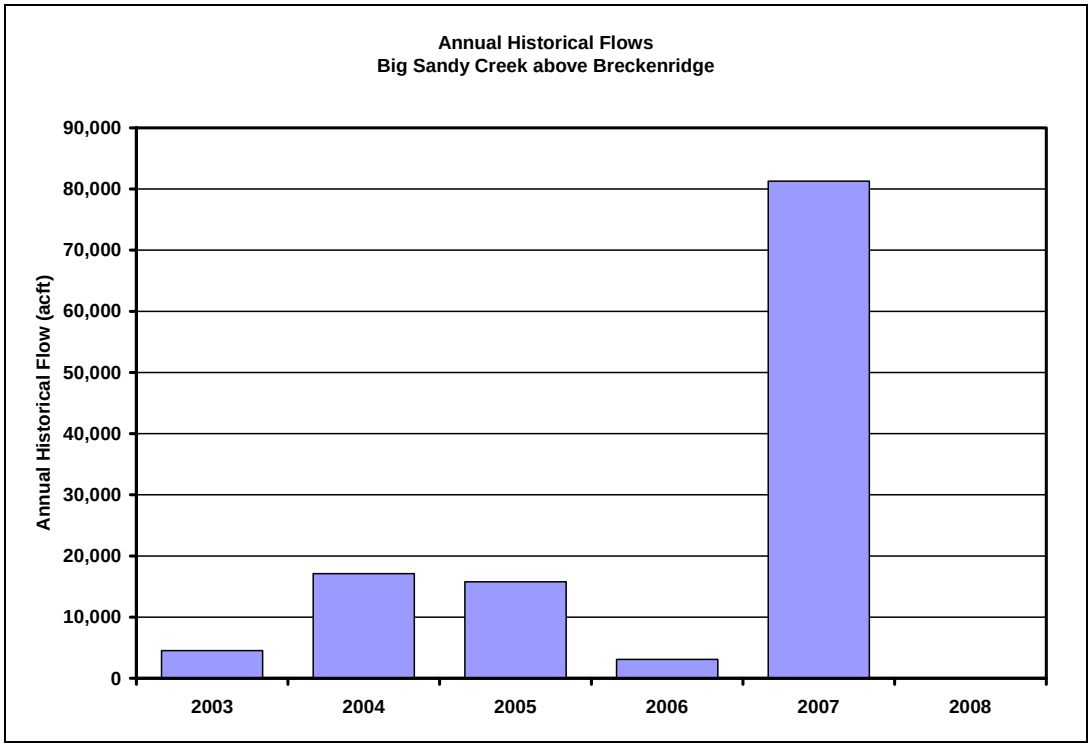
2007
2008

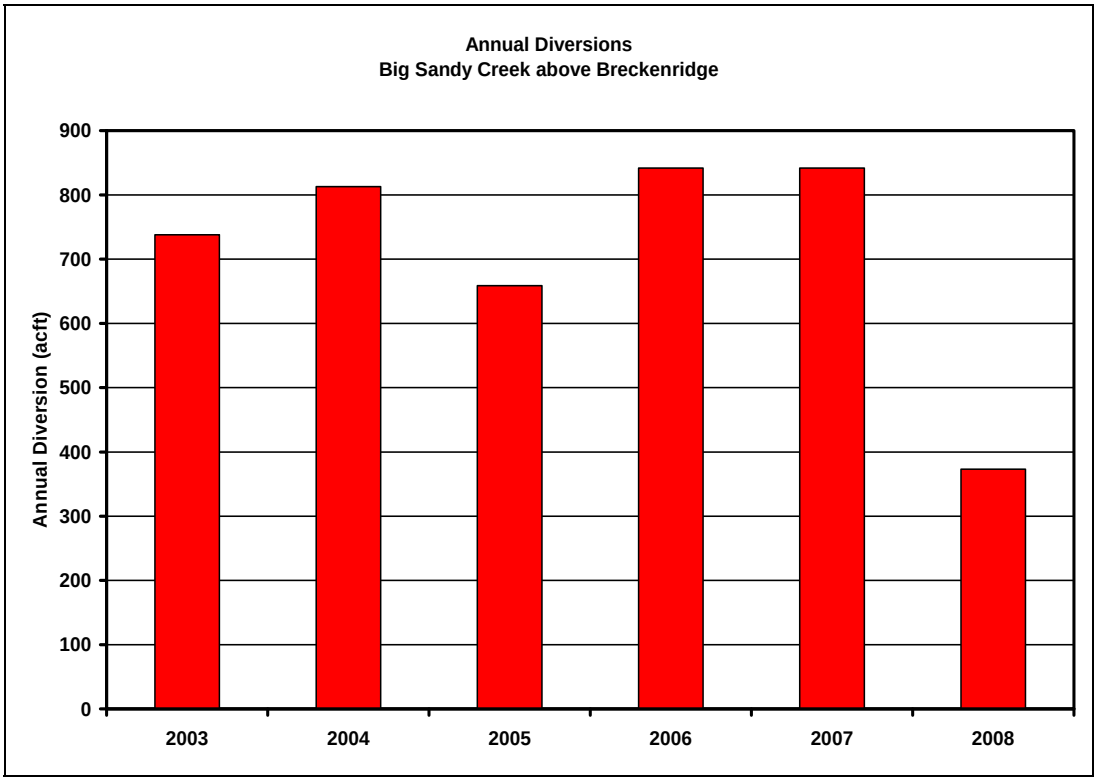
Brazos River at Seymour

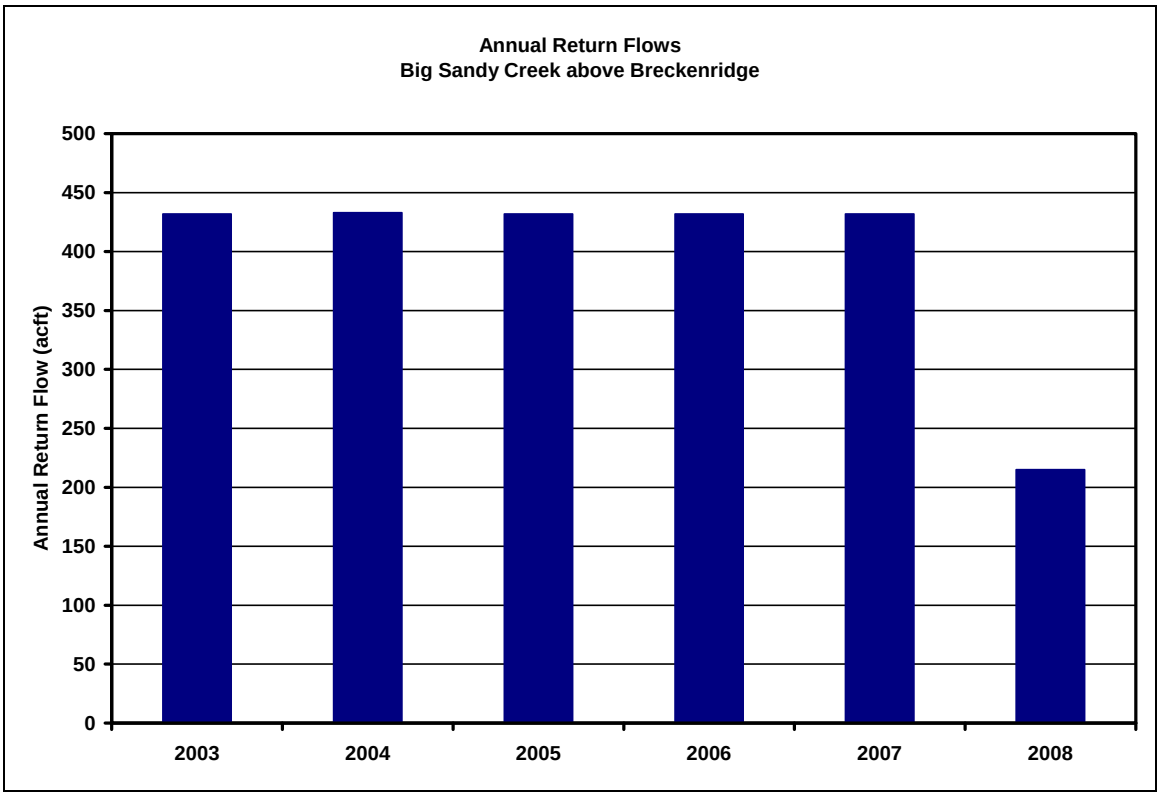


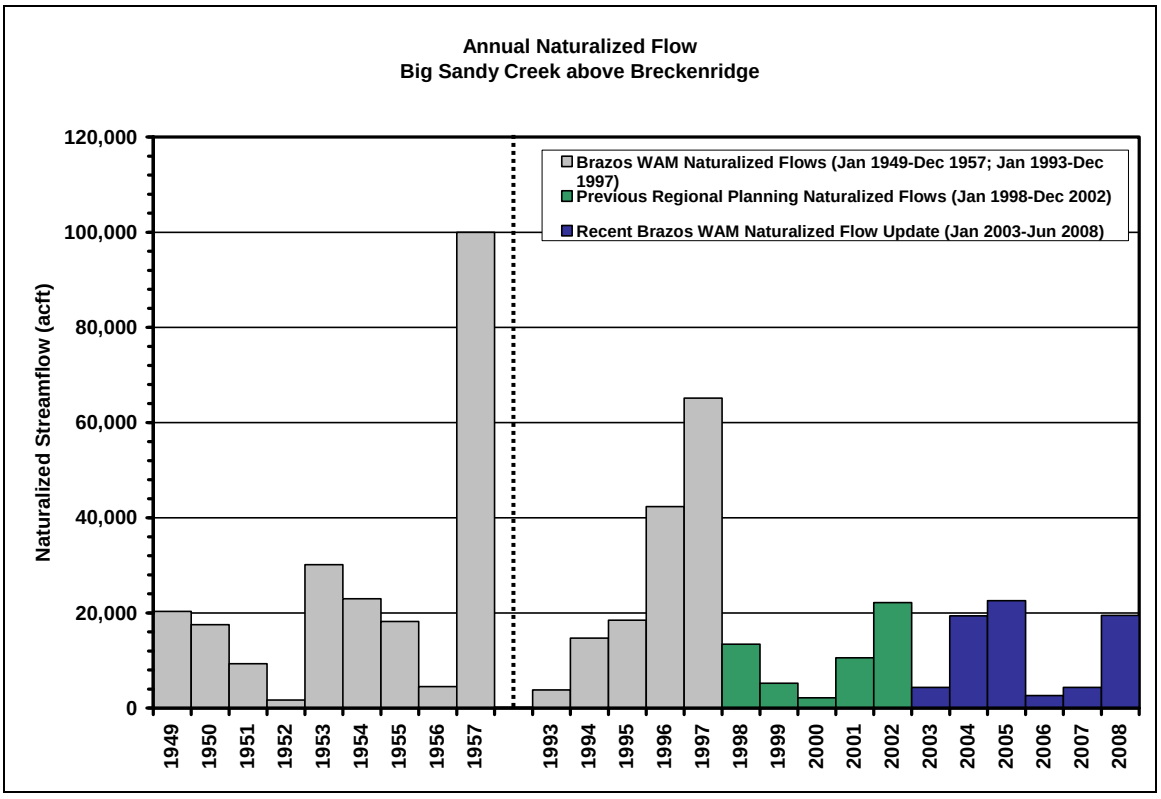


Big Sandy Creek above Breckenridge






Annual Return Flows
Big Sandy Creek above Breckenridge
Annual Return Flow (acft)
500
450
400
350
300
250
200
150
100
50
0
2003
2004
2005
2006
2007
2008


Annual Naturalized Flow
Big Sandy Creek above Breckenridge
Naturalized Streamflow (acft)
120,000
100,000
80,000
60,000
40,000
20,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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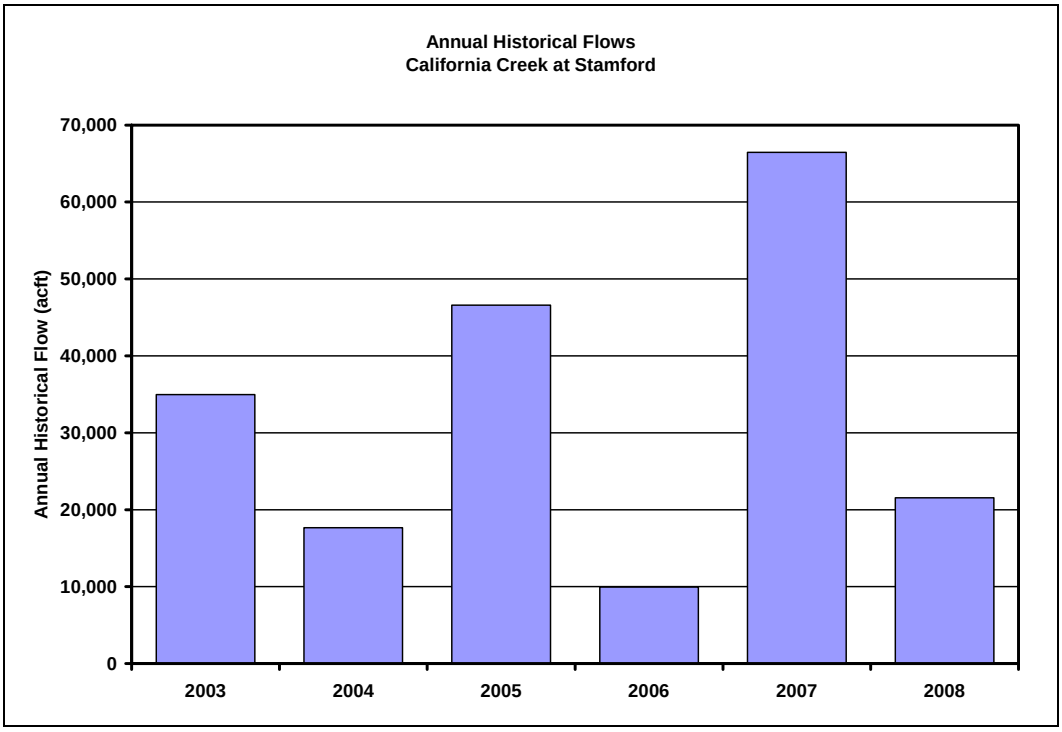
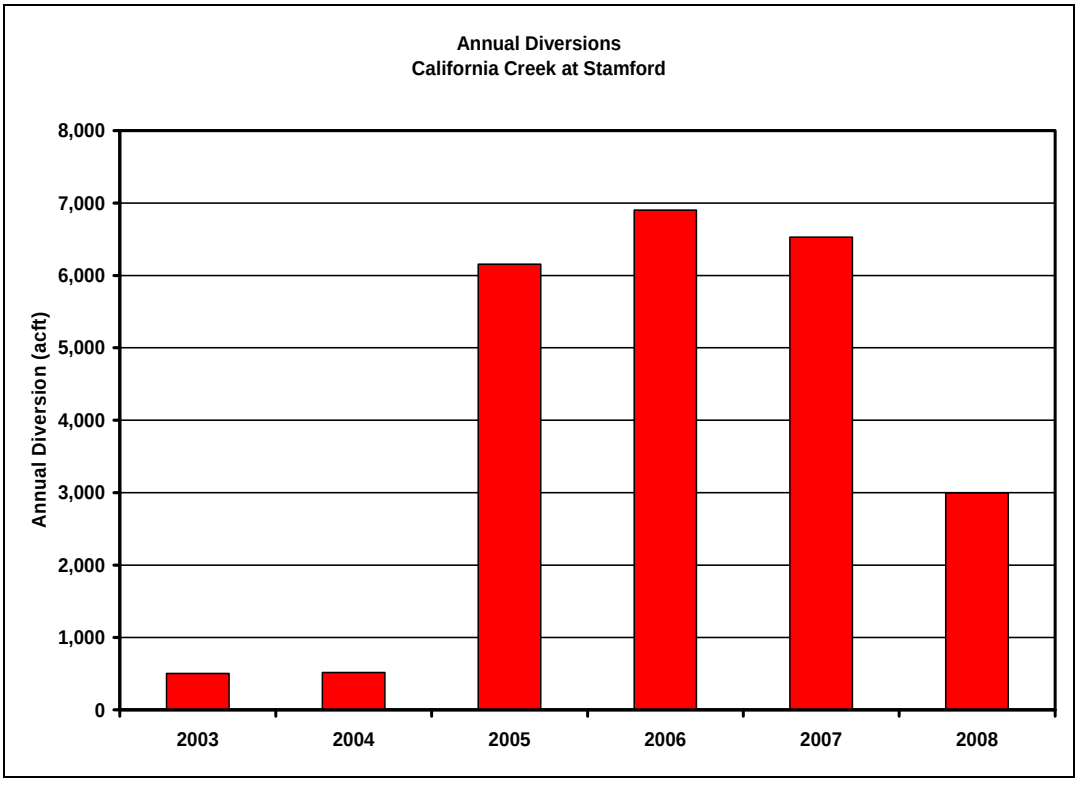
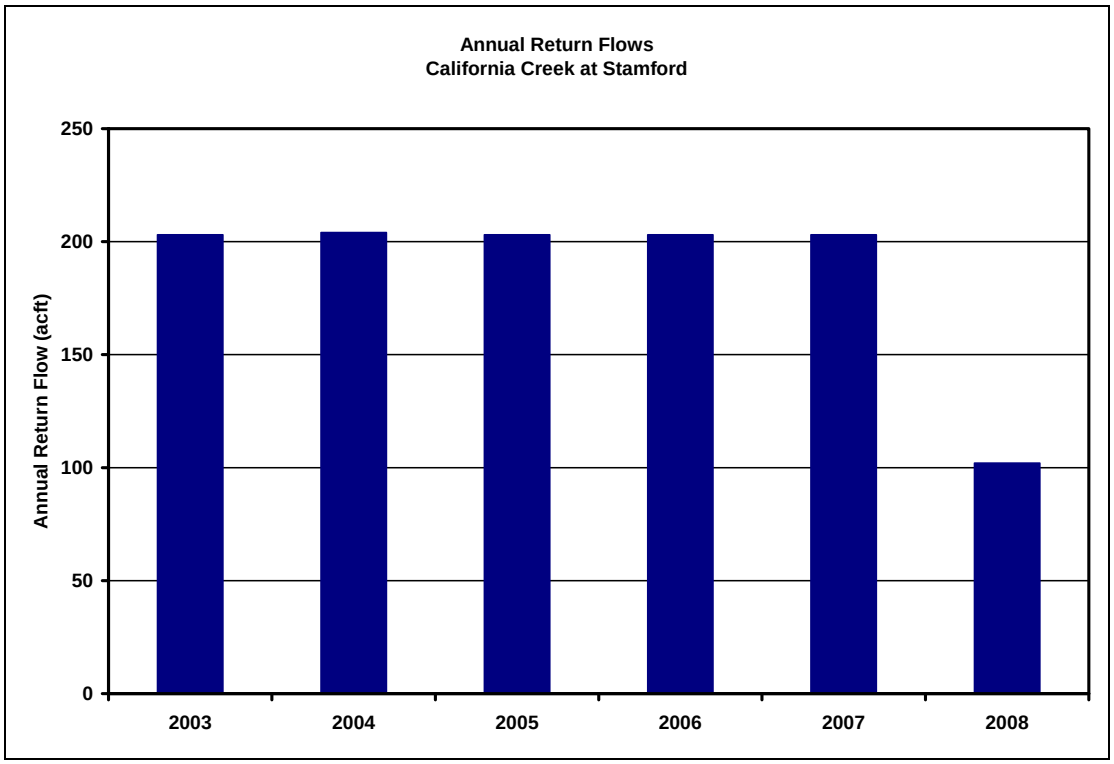
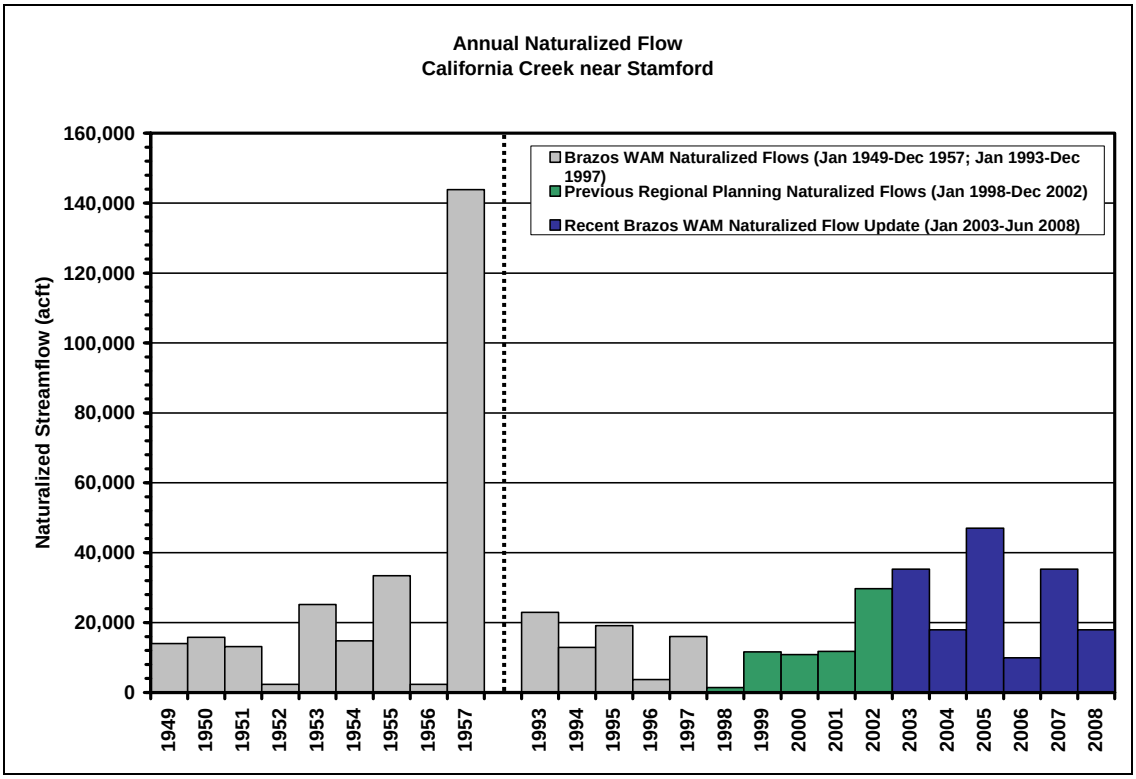
California Creek at Stamford






Annual Return Flows
California Creek at Stamford
Annual Return Flow (acft)
250
200
150
100
50
0
2003
2004
2005
2006
2007
2008


Annual Naturalized Flow
California Creek near Stamford
Naturalized Streamflow (acft)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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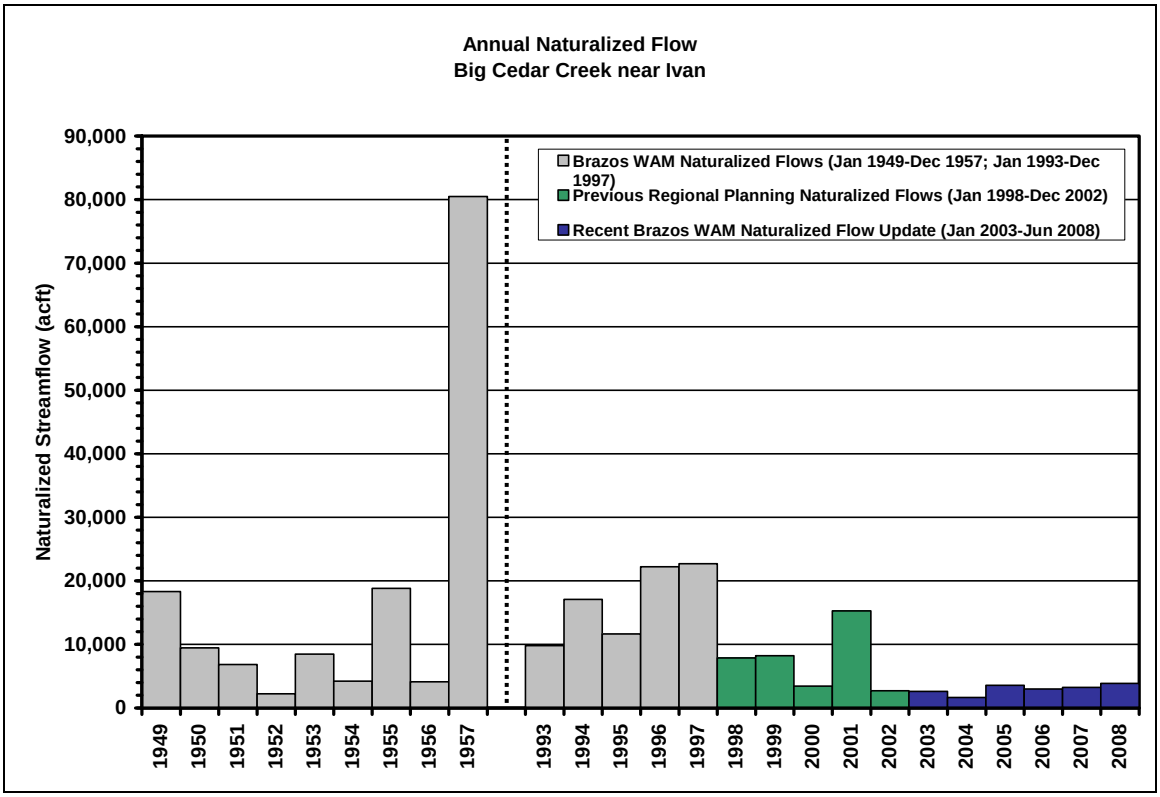
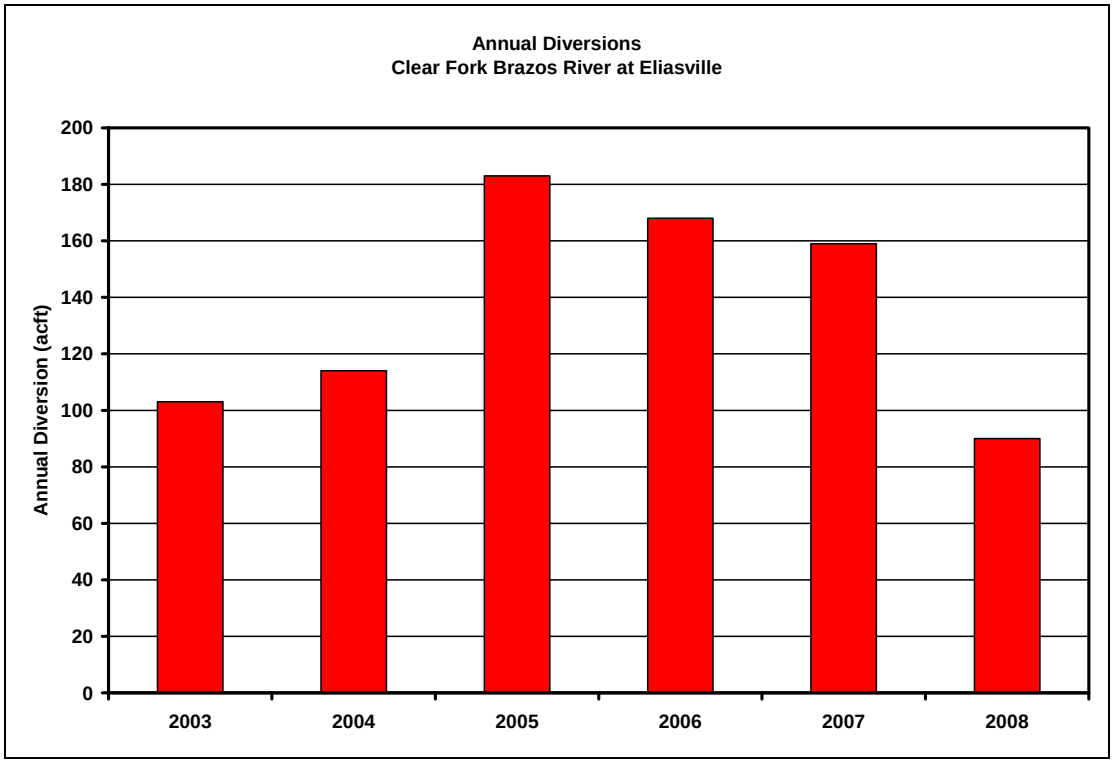
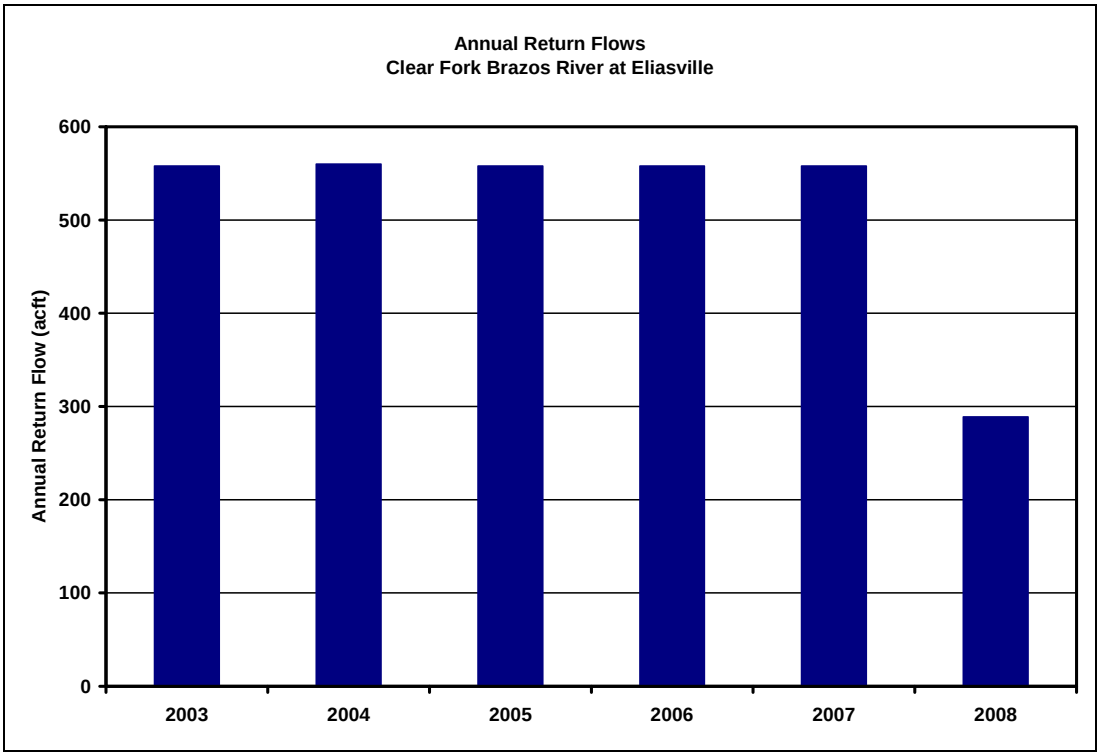
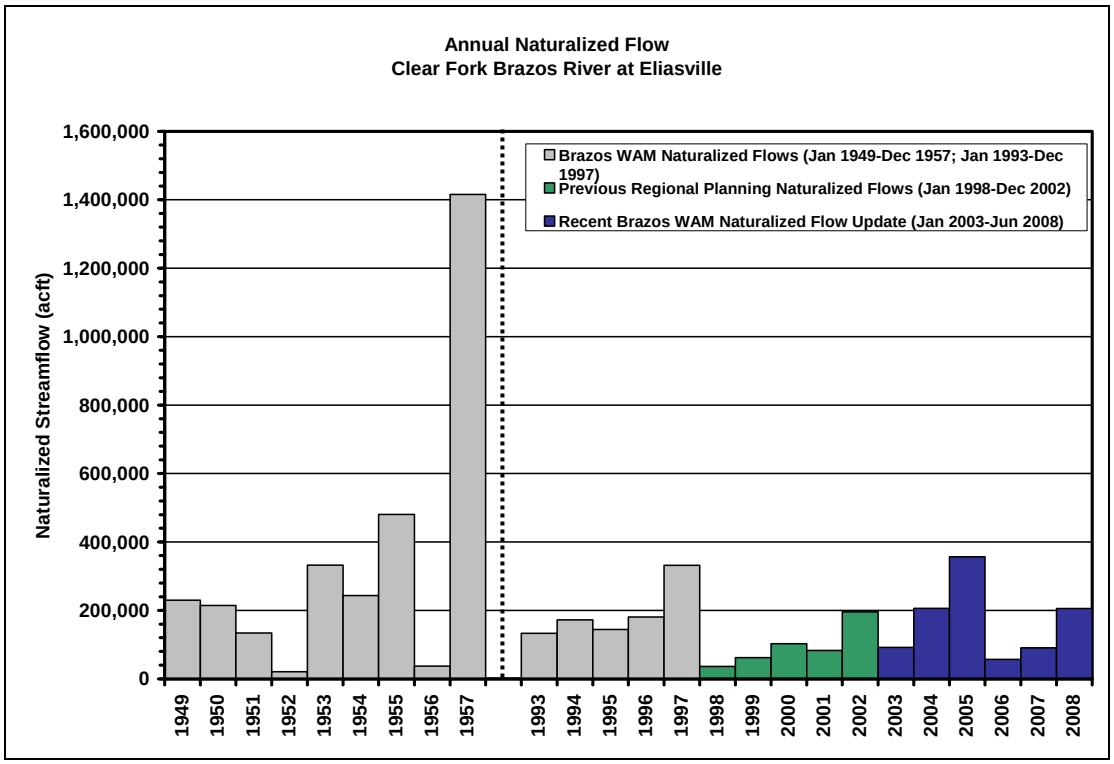
Big Cedar Creek near Ivan



Clear Fork Brazos River at Eliasville






Annual Naturalized Flow
Clear Fork Brazos River at Eliasville
Naturalized Streamflow (acft)
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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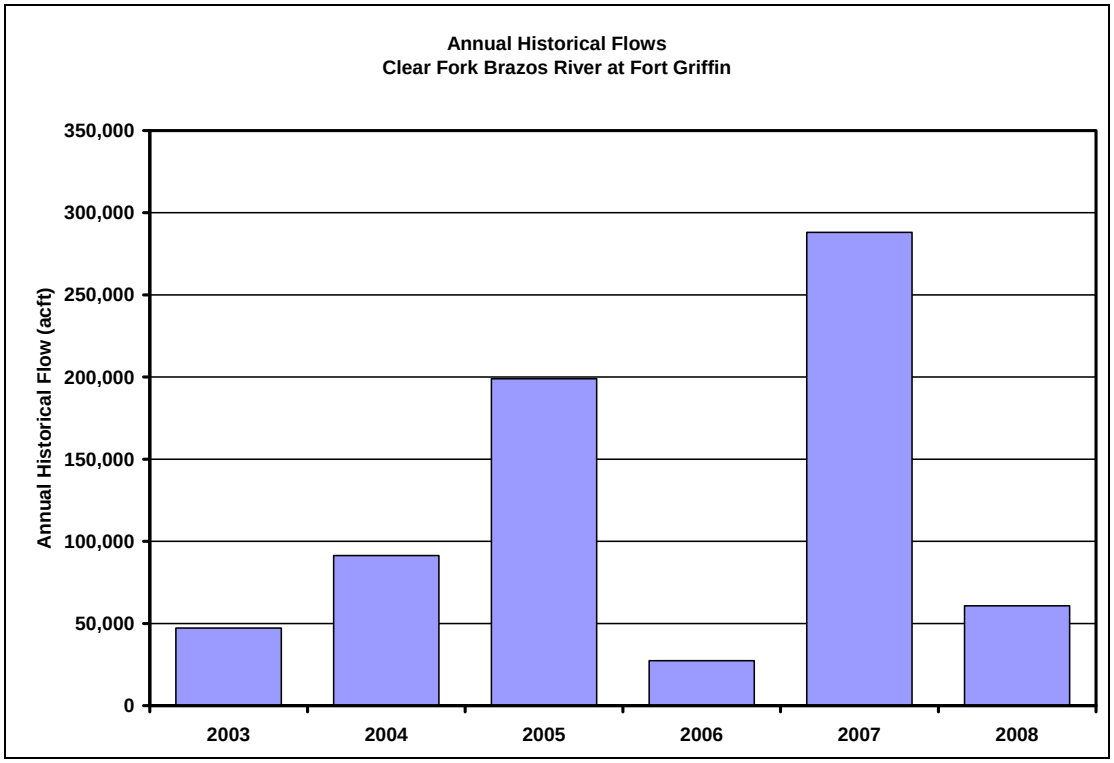
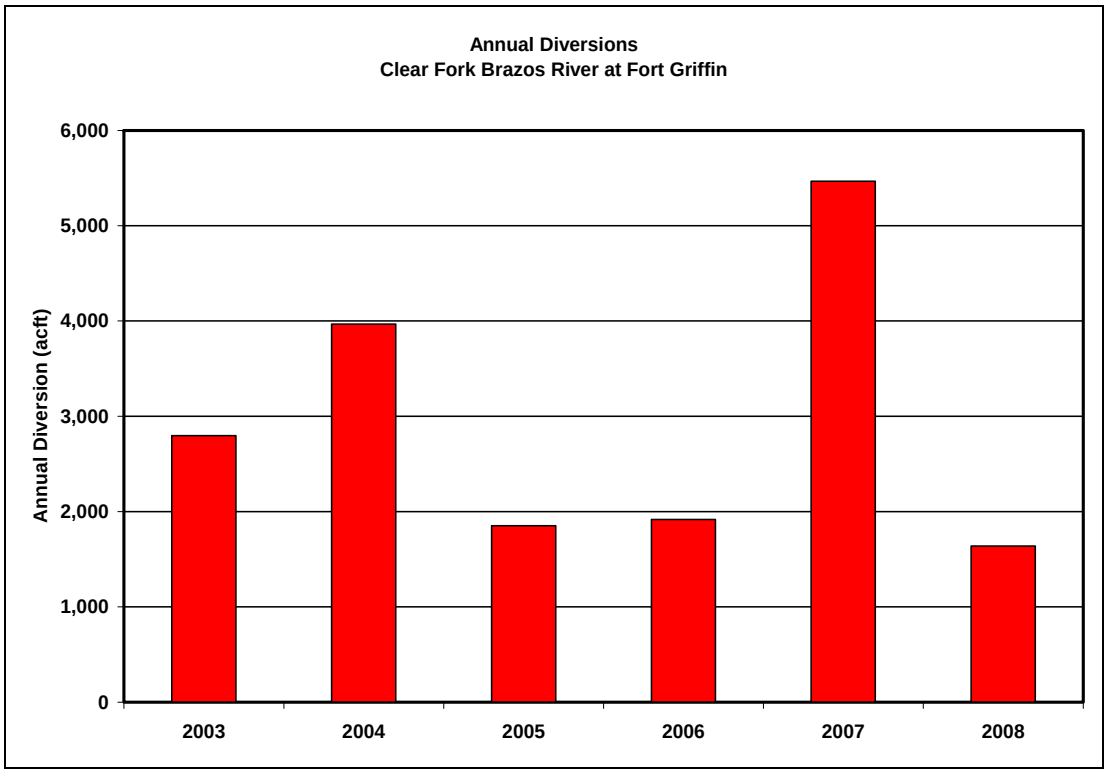
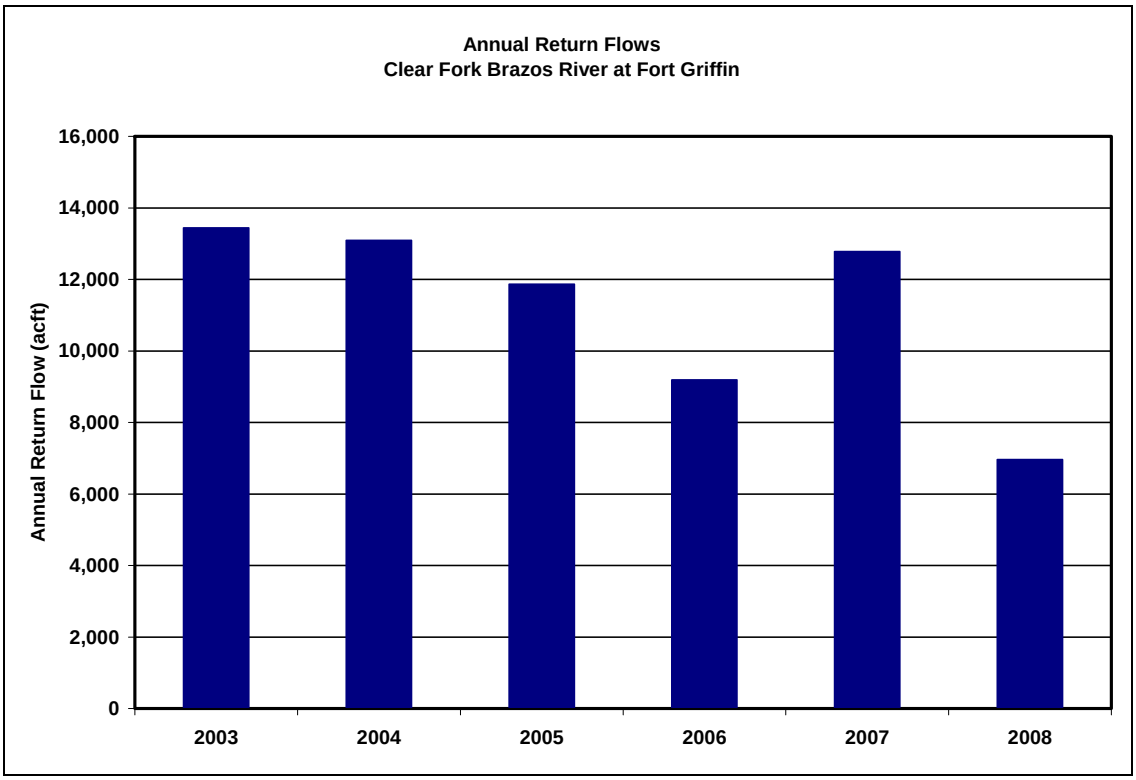
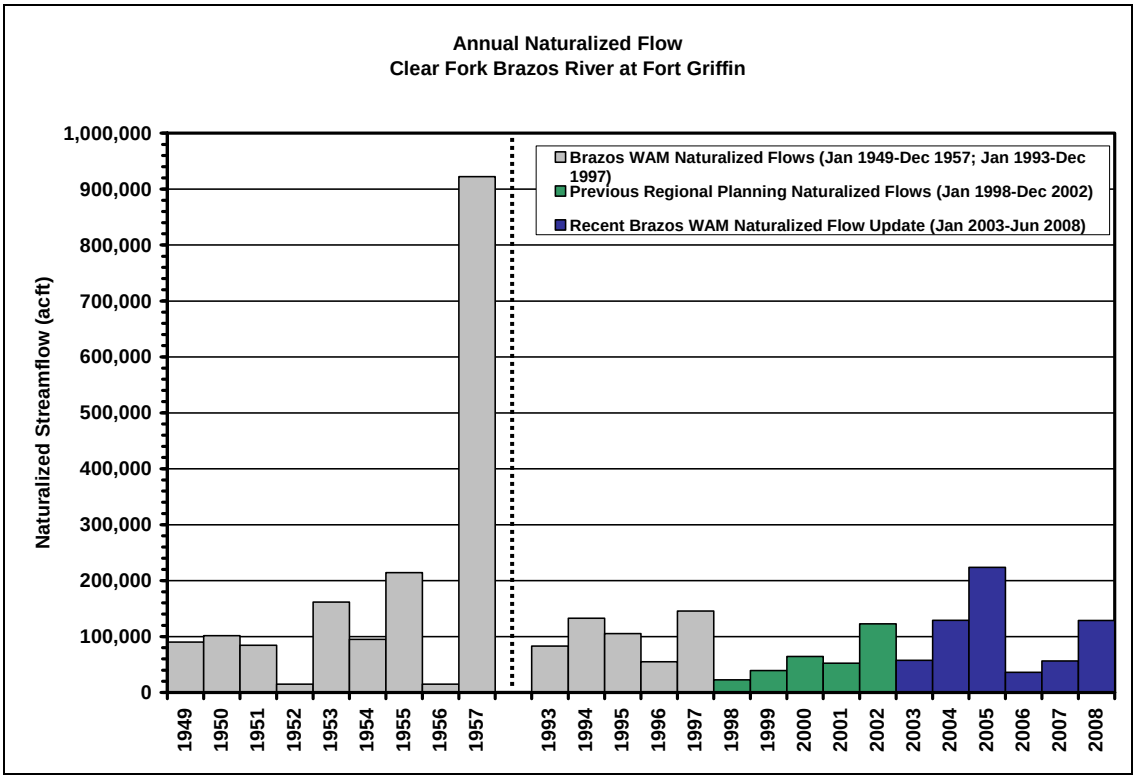
Clear Fork Brazos River at Fort Griffin






Annual Return Flows
Clear Fork Brazos River at Fort Griffin
Annual Return Flow (acft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2003
2004
2005
2006
2007
2008


Annual Naturalized Flow
Clear Fork Brazos River at Fort Griffin
Naturalized Streamflow (acft)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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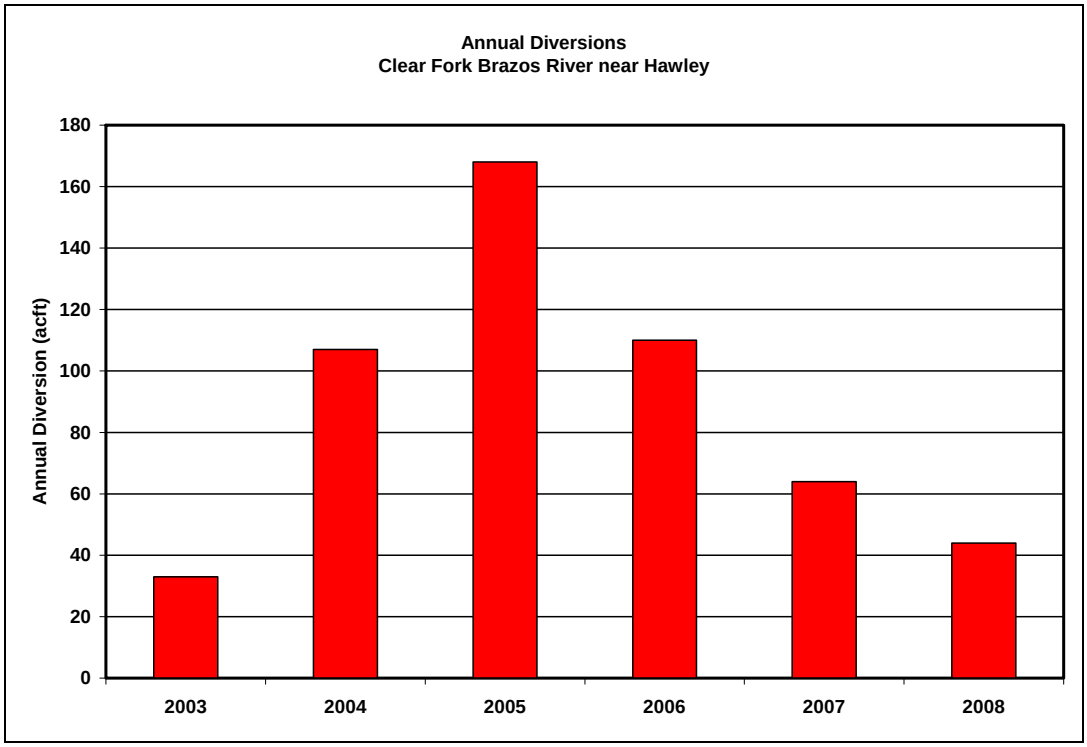
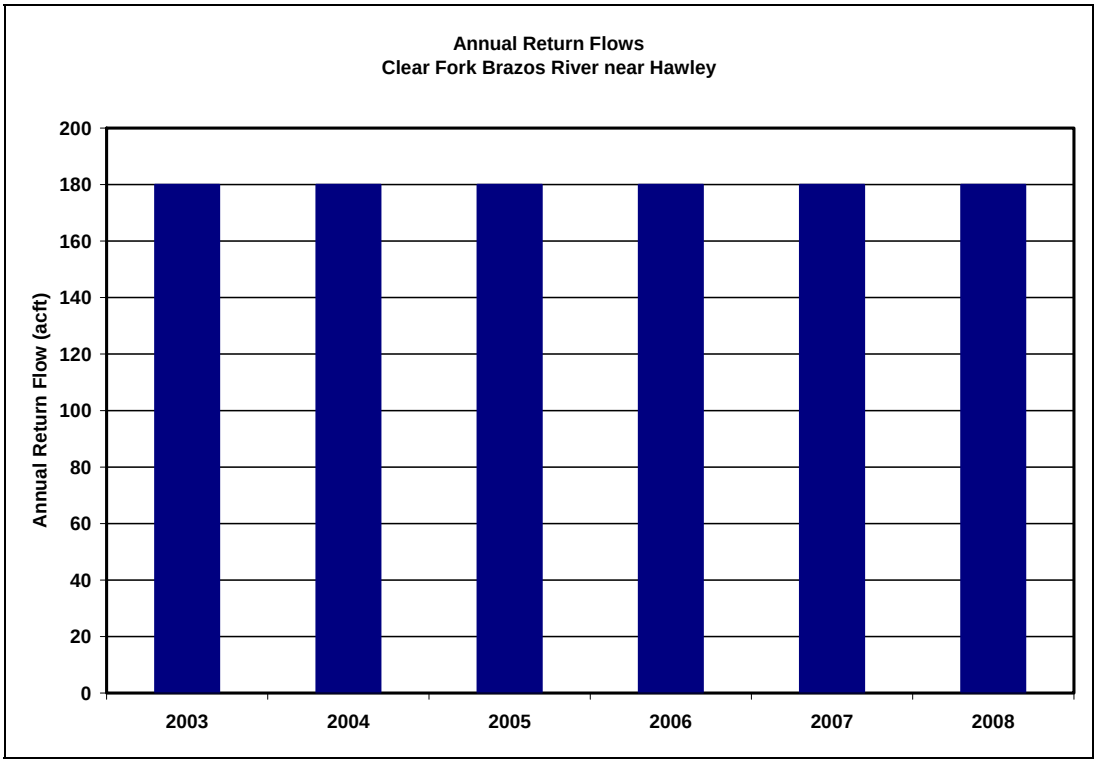
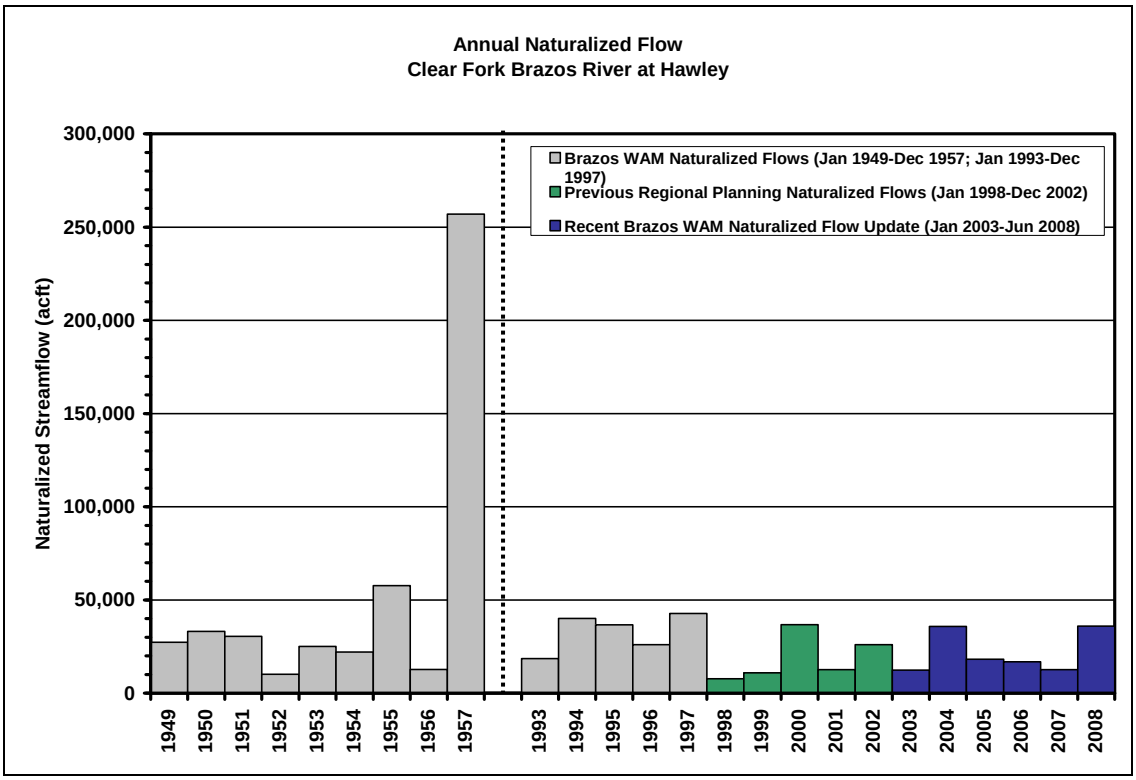
Clear Fork Brazos River near Hawley






Annual Naturalized Flow
Clear Fork Brazos River at Hawley
Naturalized Streamflow (acft)
300,000
250,000
200,000
150,000
100,000
50,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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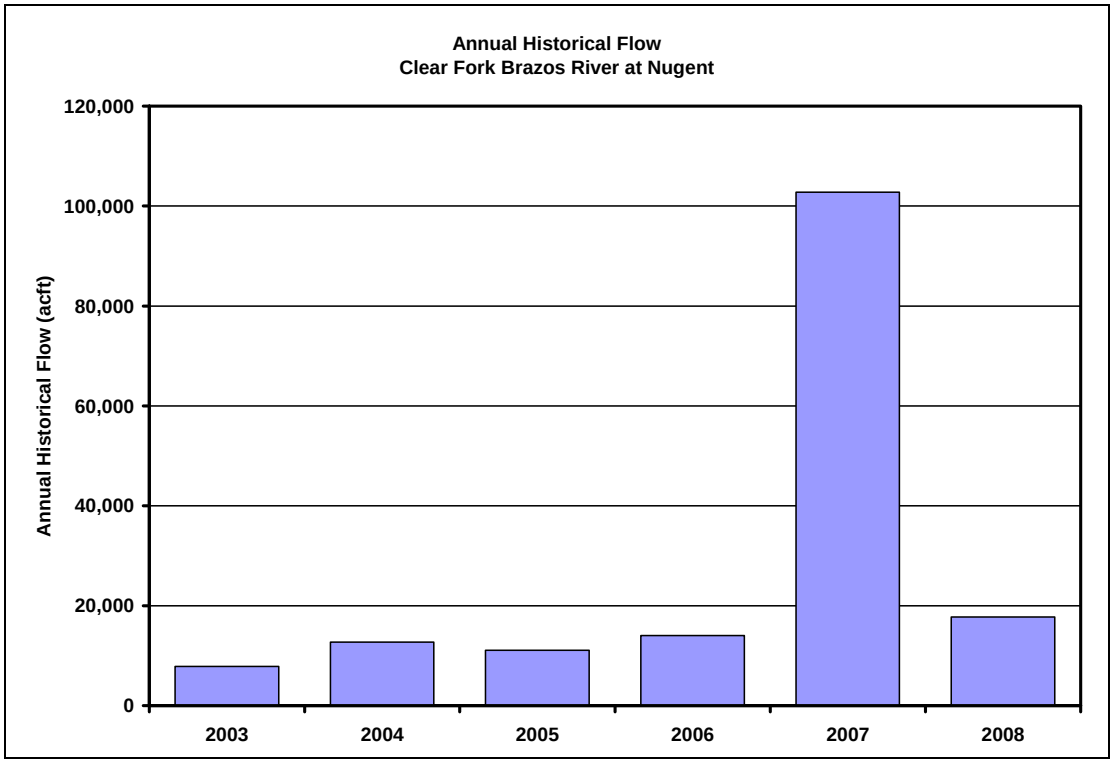
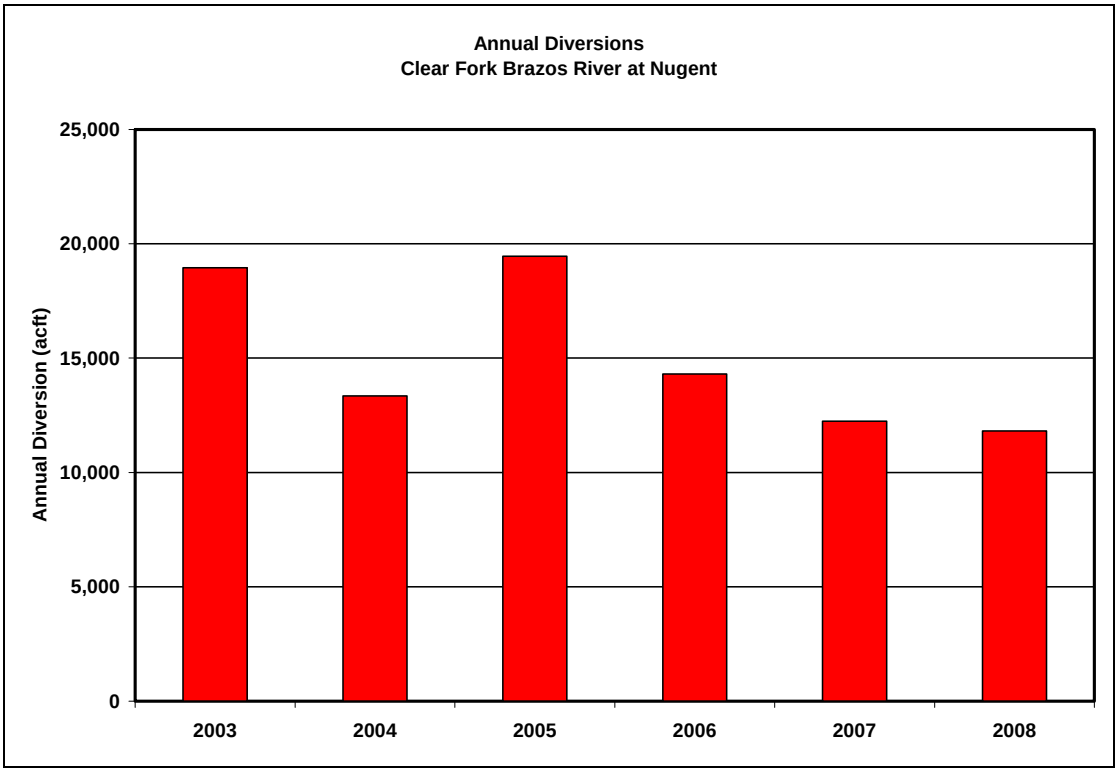
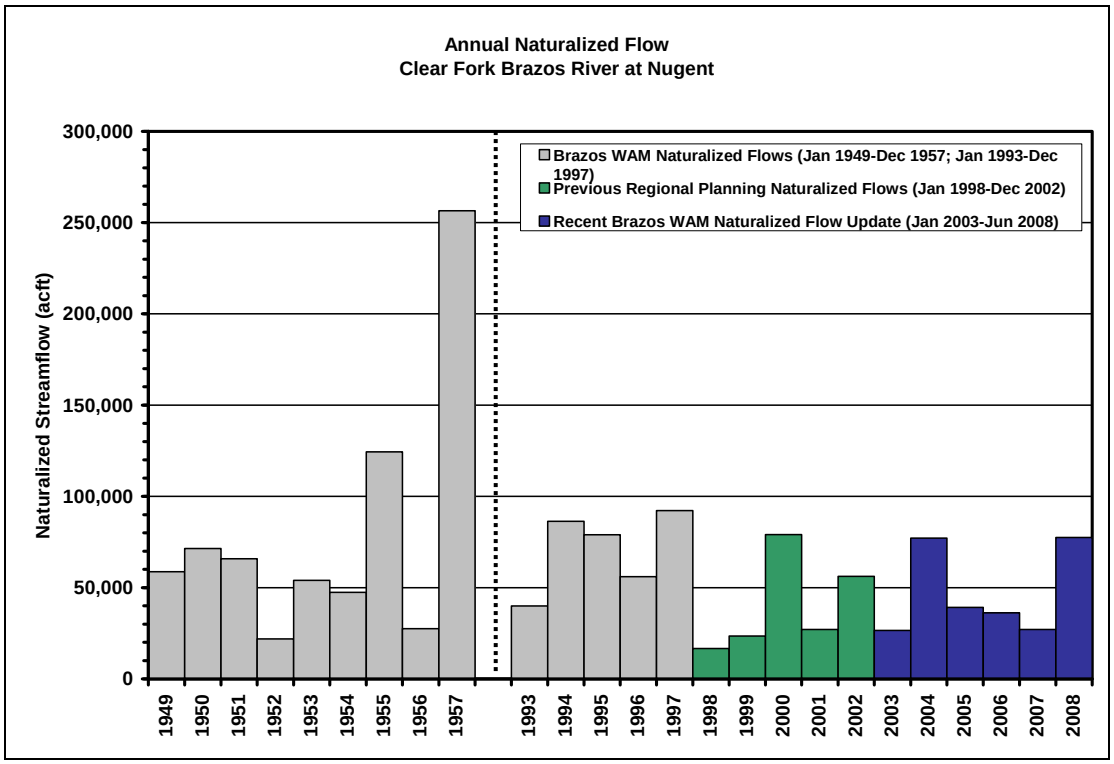
Clear Fork Brazos River at Nugent






Annual Naturalized Flow
Clear Fork Brazos River at Nugent
Naturalized Streamflow (acft)
300,000
250,000
200,000
150,000
100,000
50,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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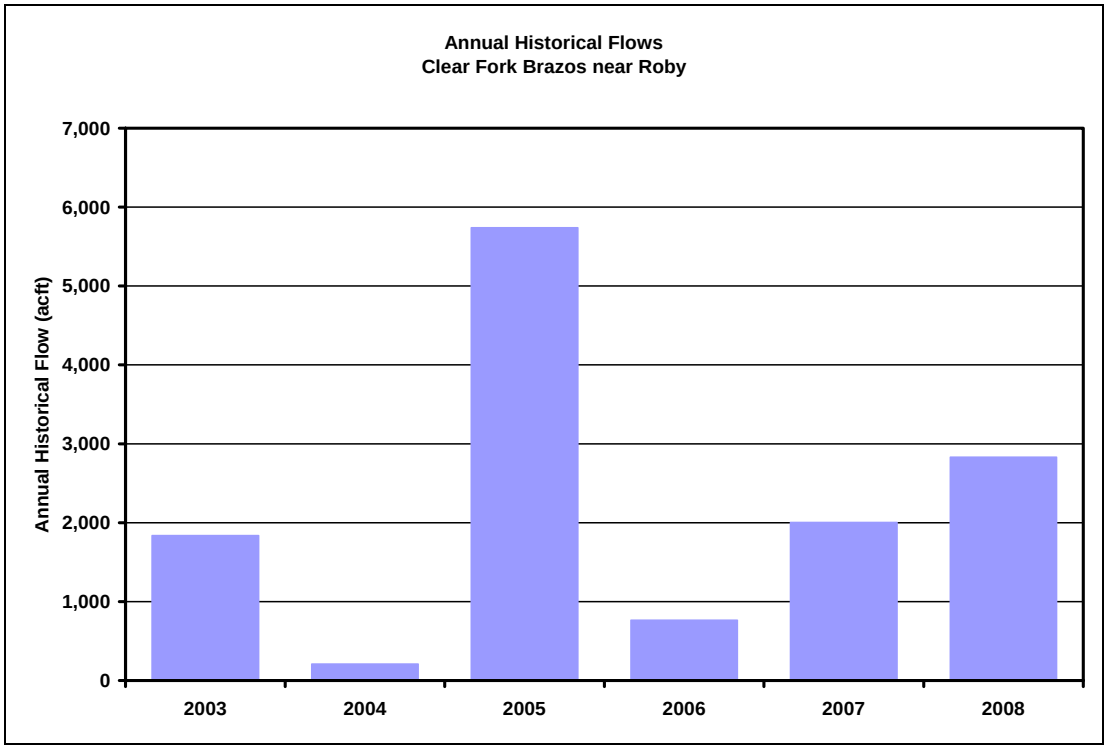
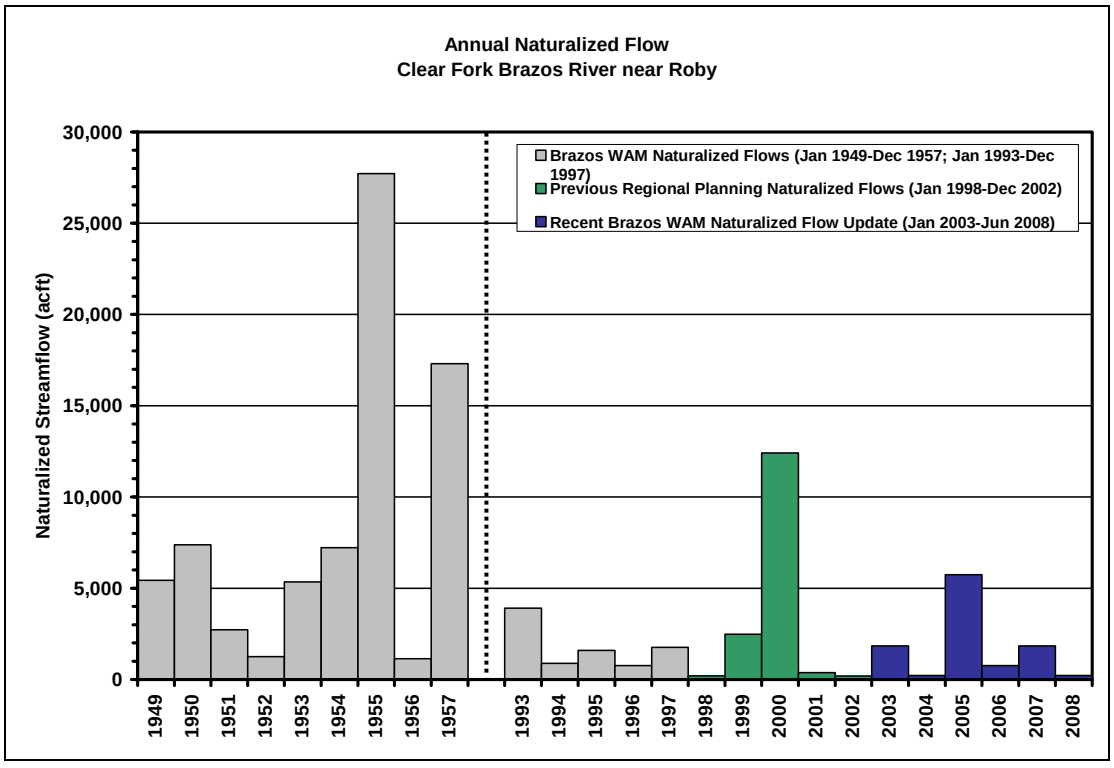
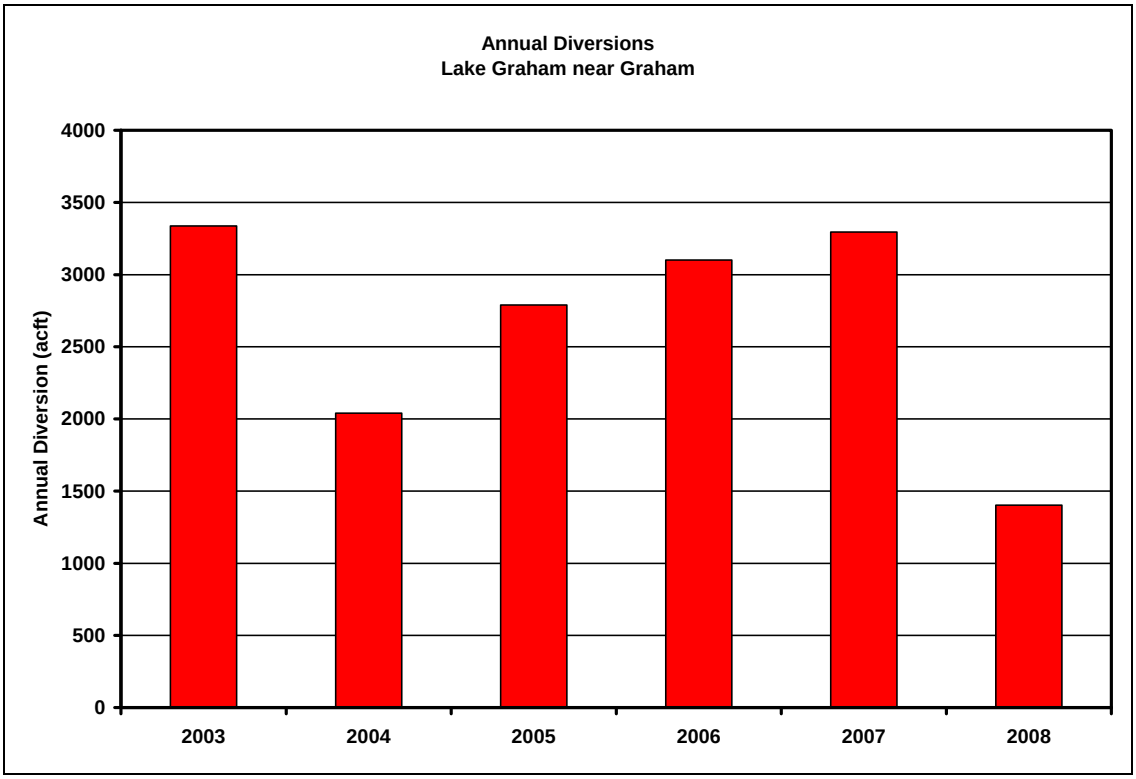
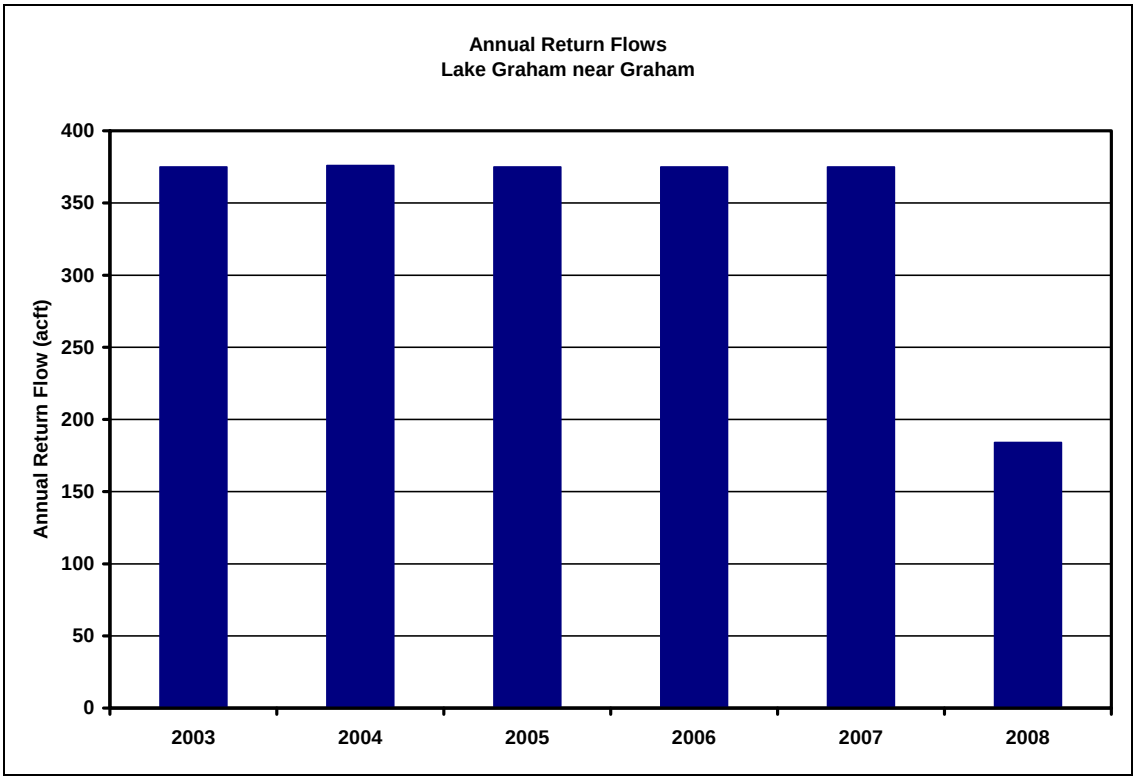
Clear Fork Brazos near Roby

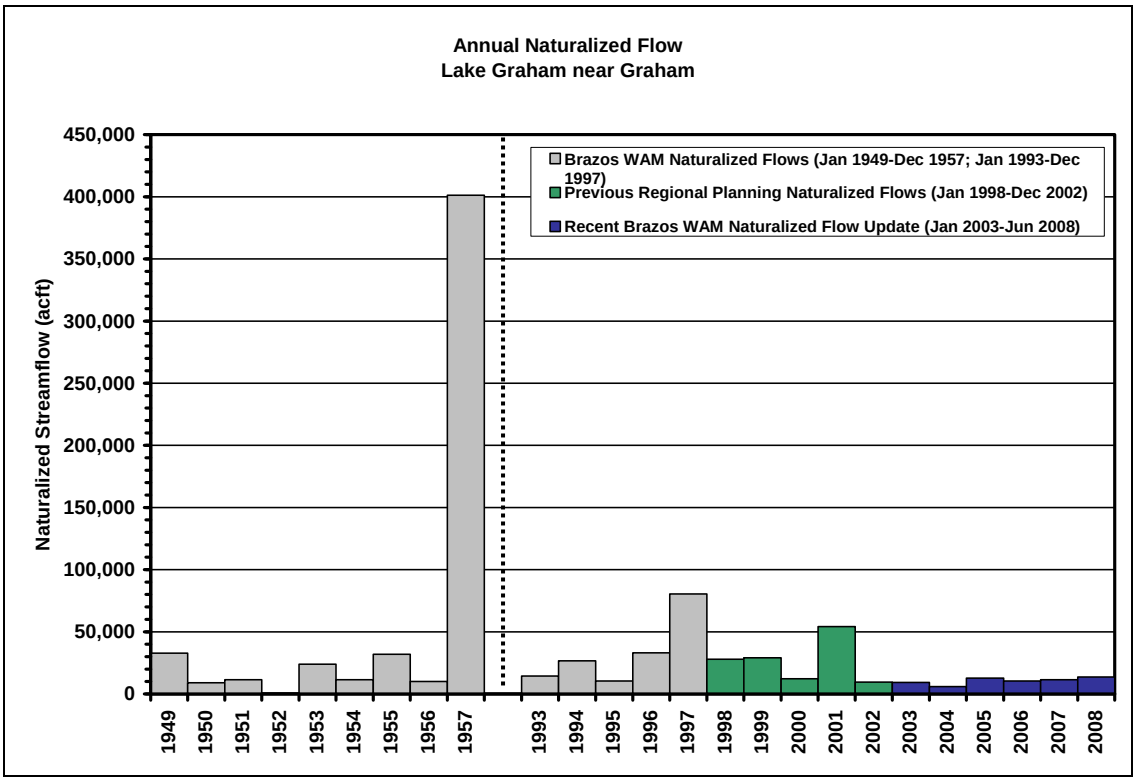




Lake Graham near Graham






Annual Naturalized Flow
Lake Graham near Graham
Naturalized Streamflow (acft)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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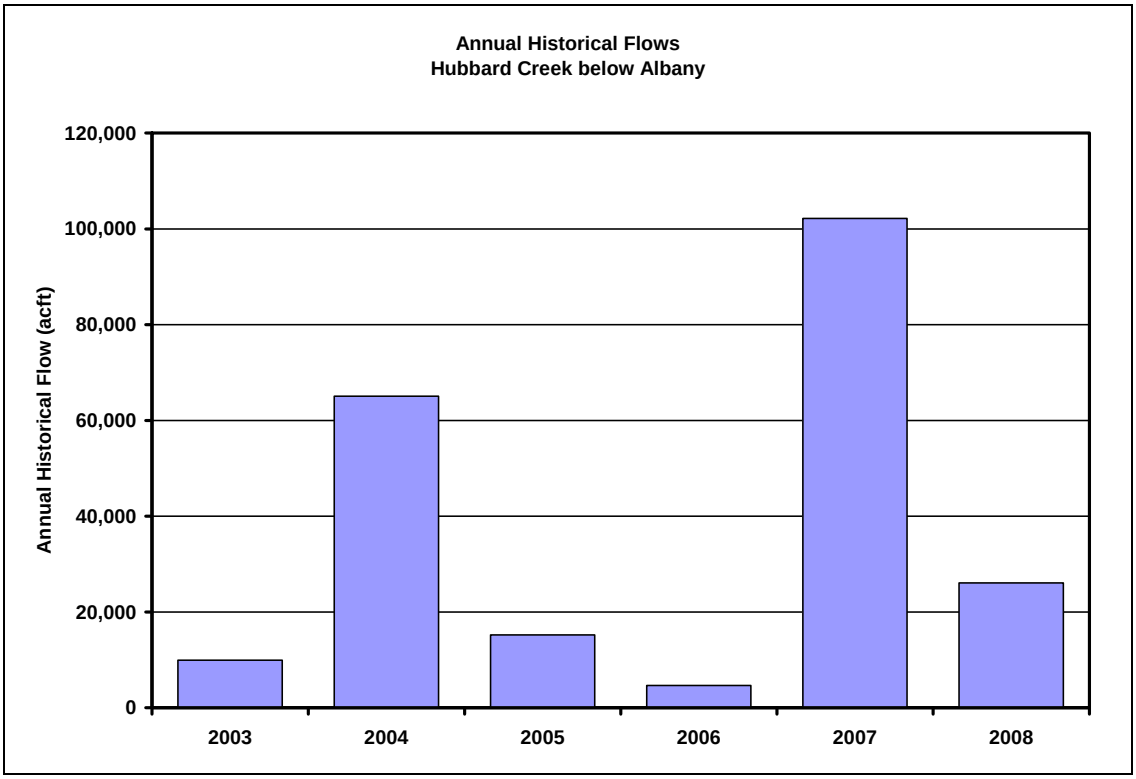
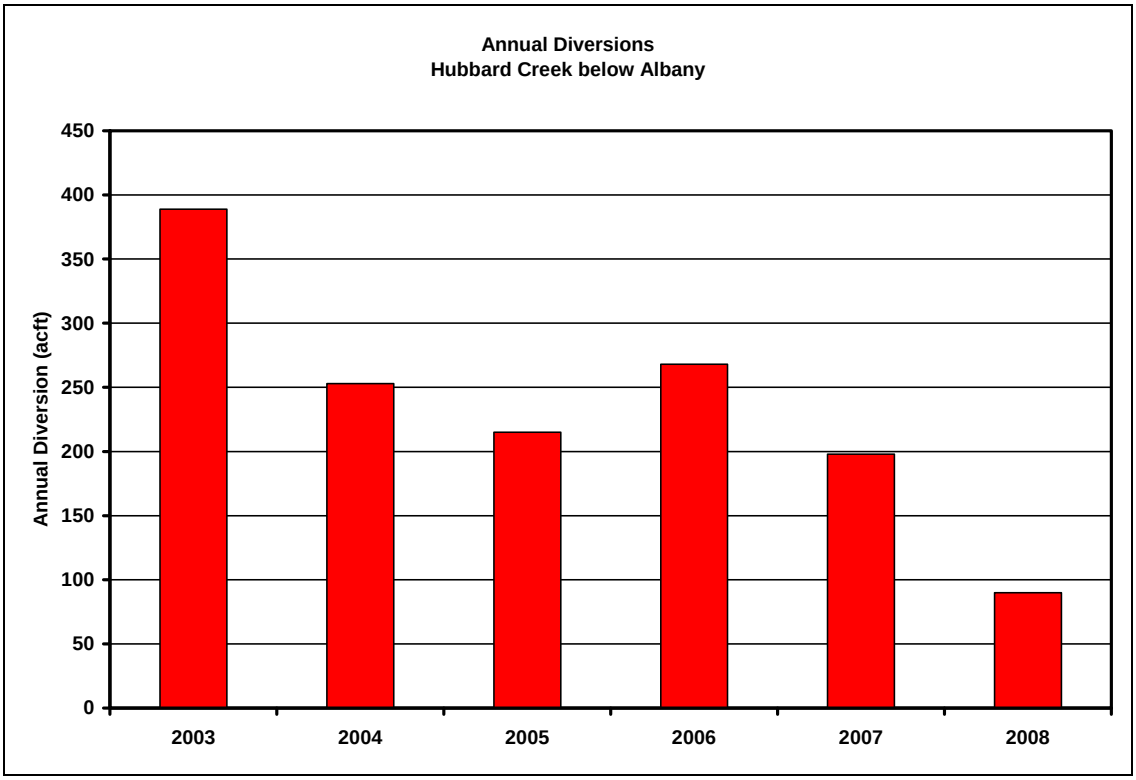
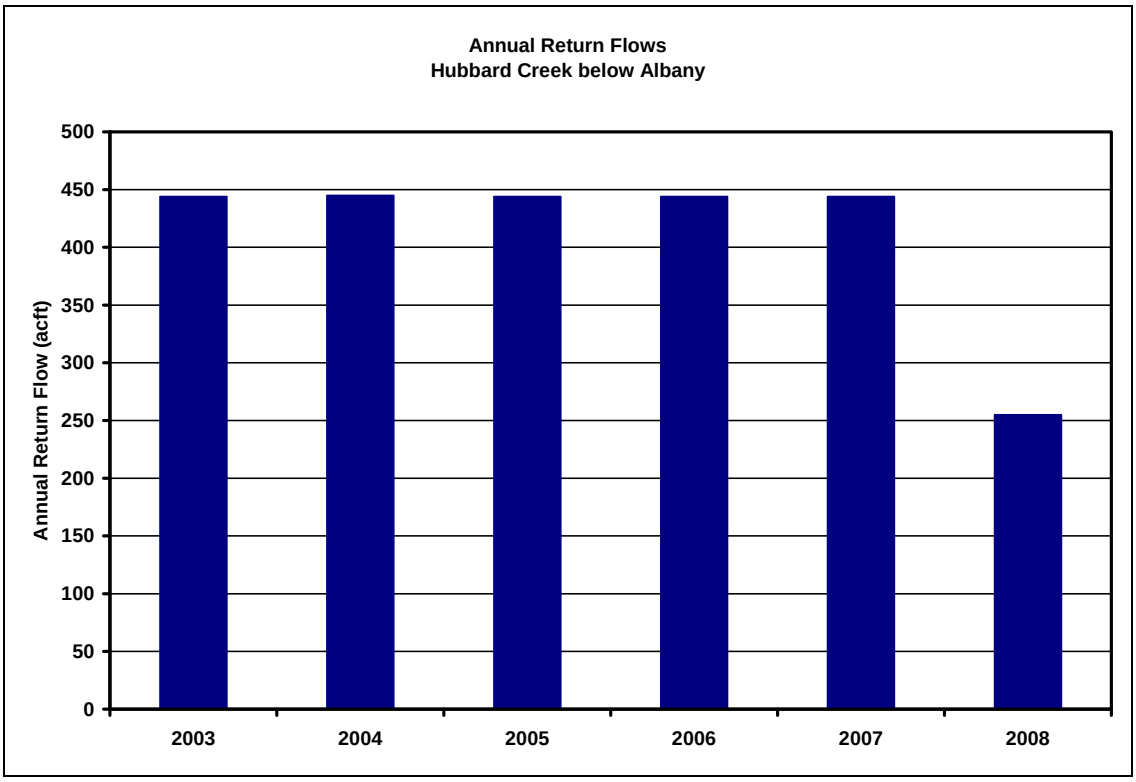
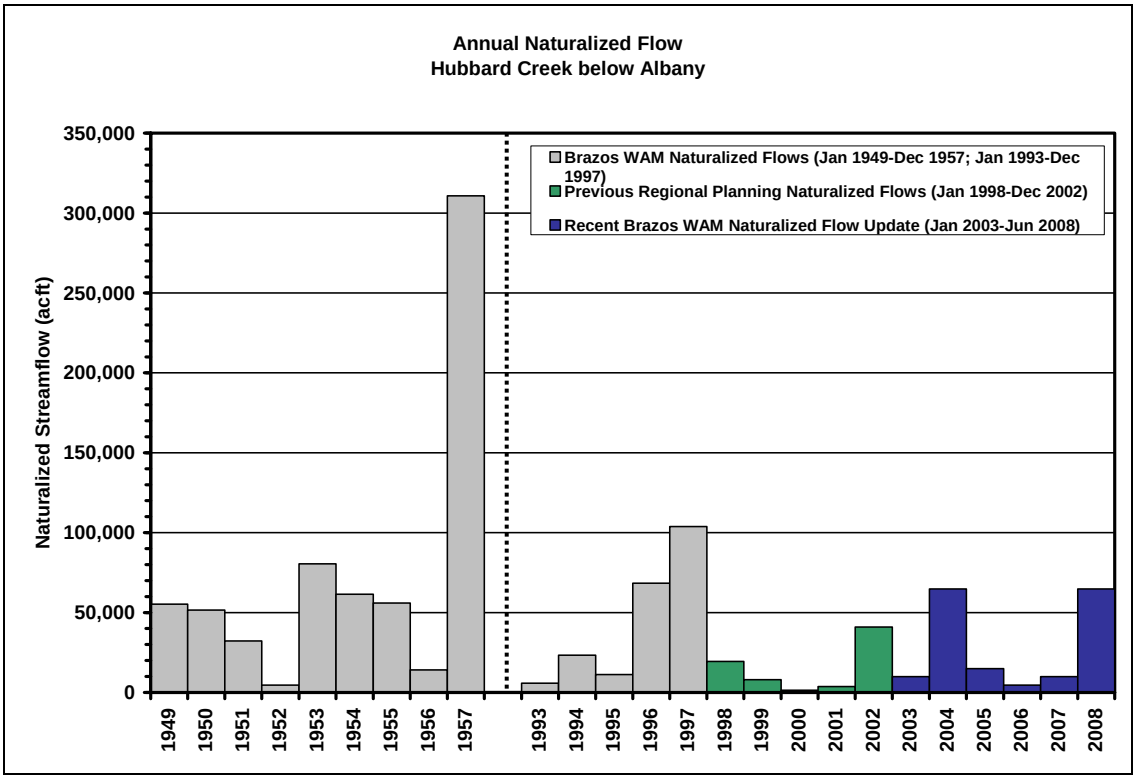
Hubbard Creek below Albany






Annual Return Flows
Hubbard Creek below Albany
Annual Return Flow (acft)
500
450
400
350
300
250
200
150
100
50
0
2003
2004
2005
2006
2007
2008


Annual Naturalized Flow
Hubbard Creek below Albany
Naturalized Streamflow (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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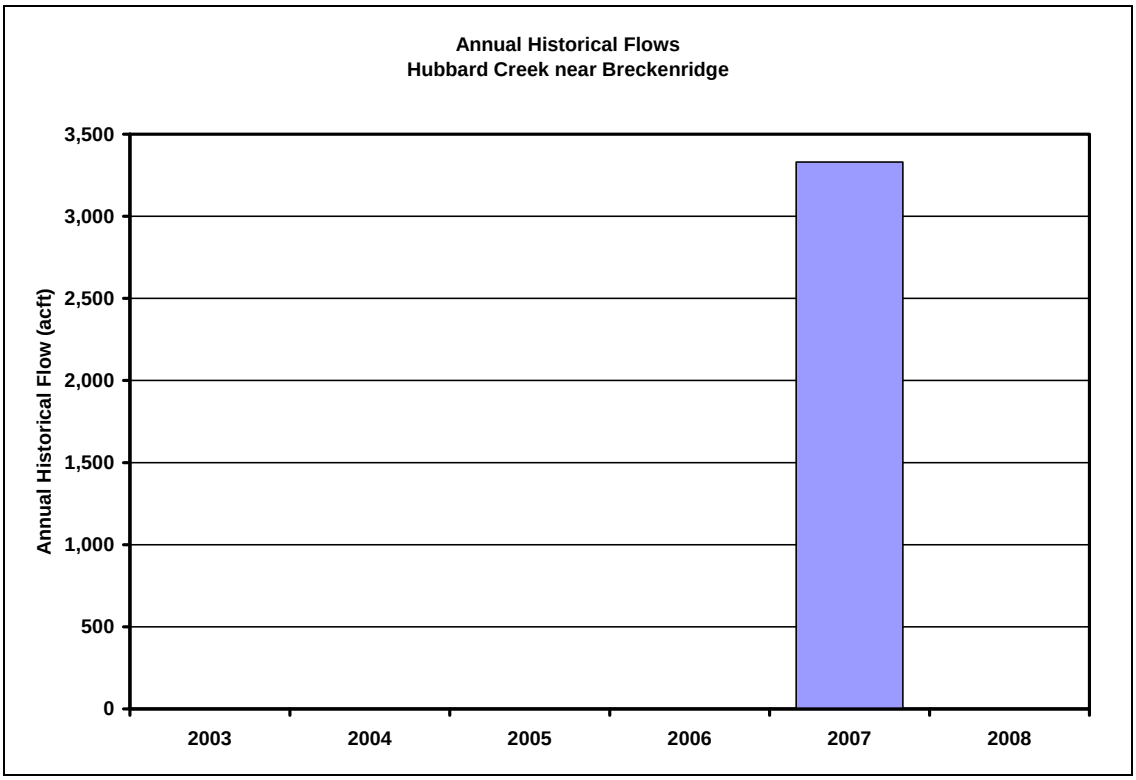
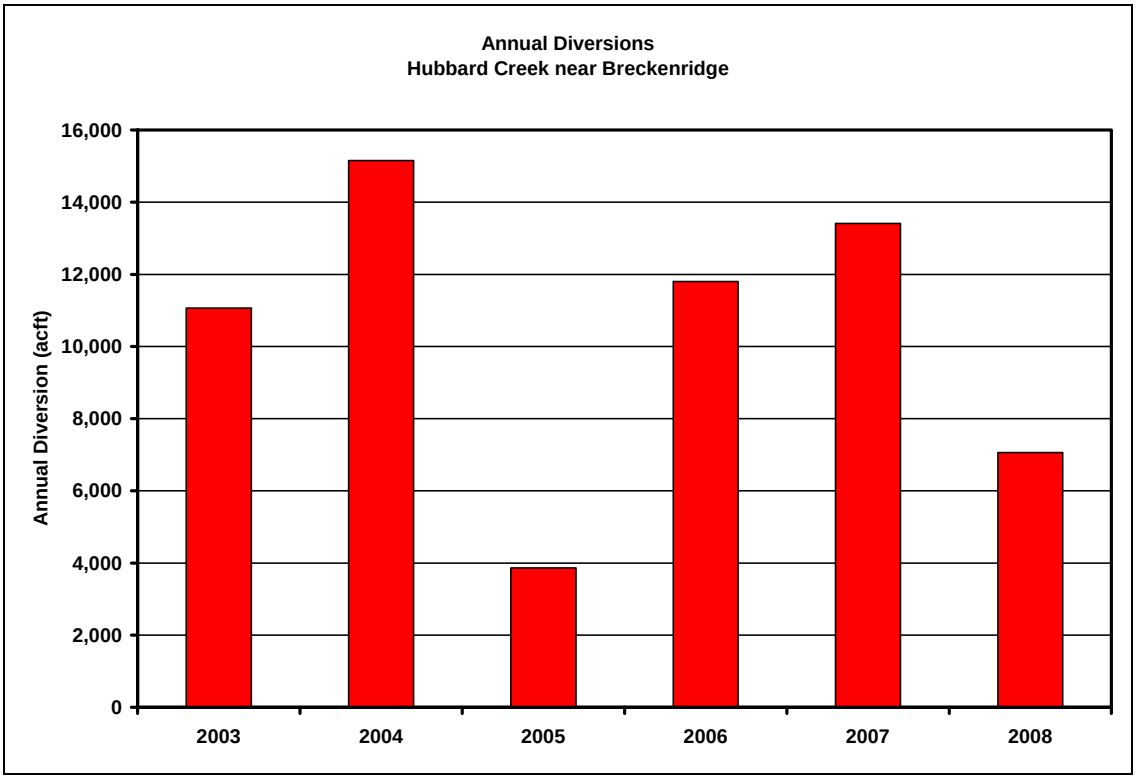
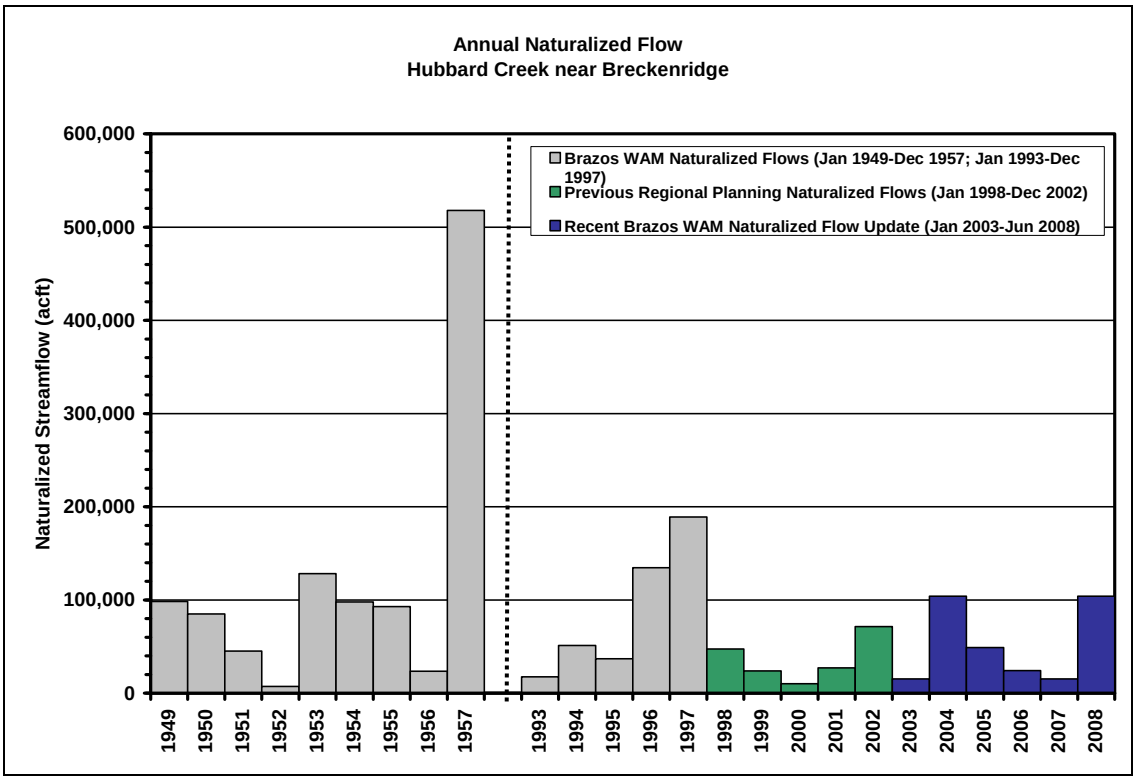
Hubbard Creek near Breckenridge






Annual Naturalized Flow
Hubbard Creek near Breckenridge
Naturalized Streamflow (acft)
600,000
500,000
400,000
300,000
200,000
100,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Jun 2008)
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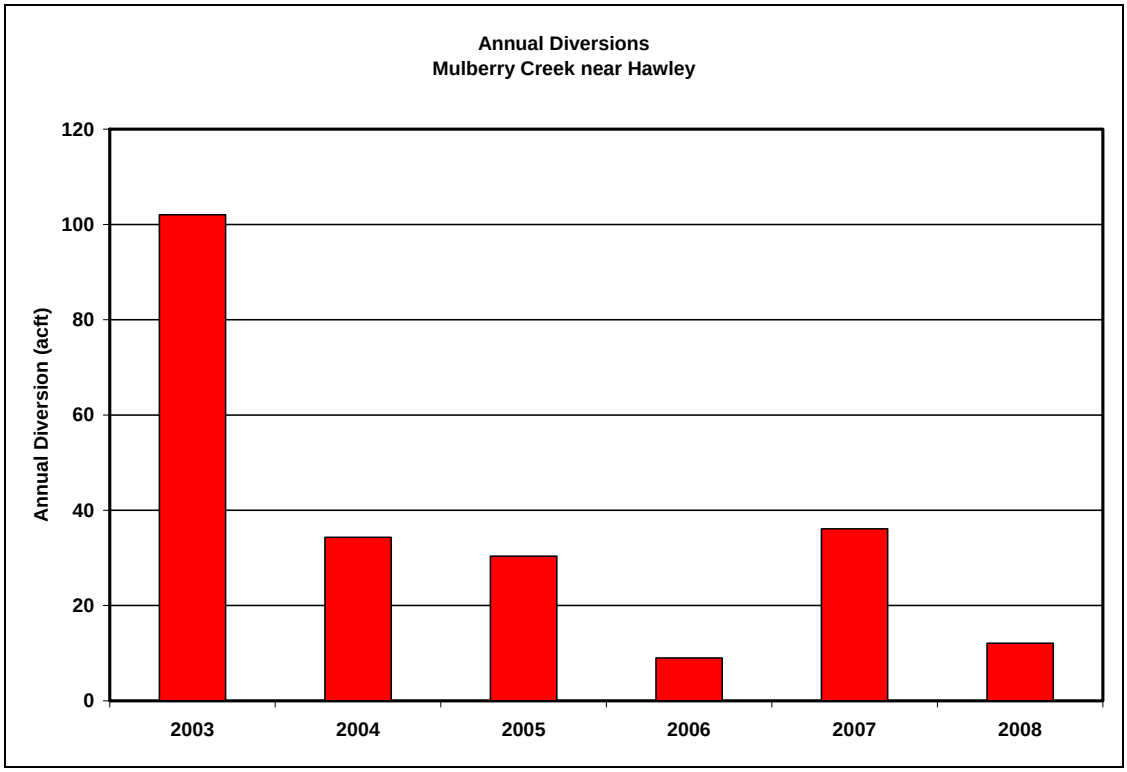
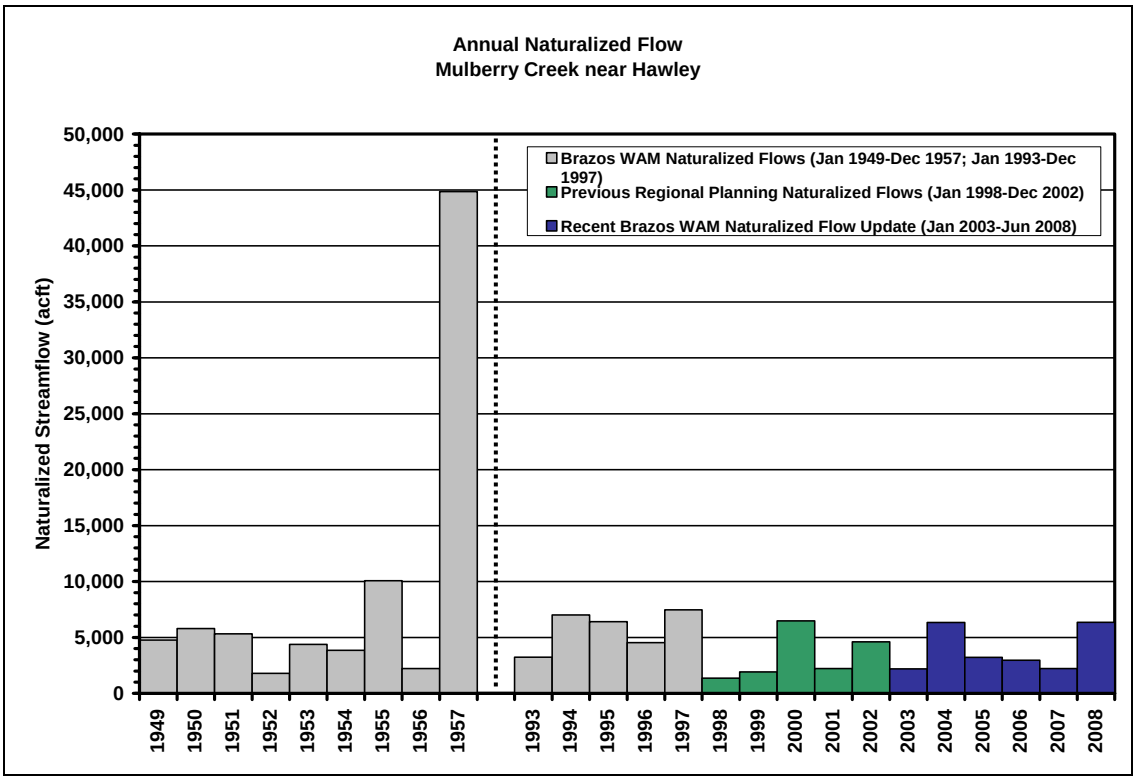
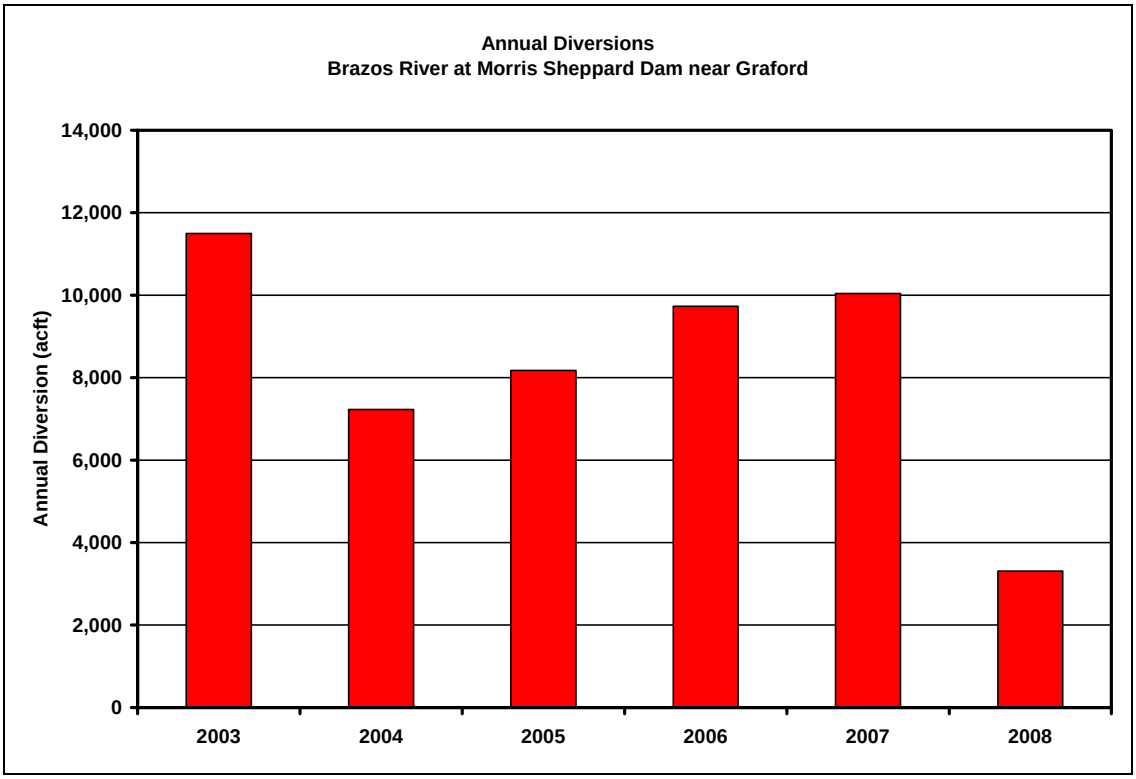
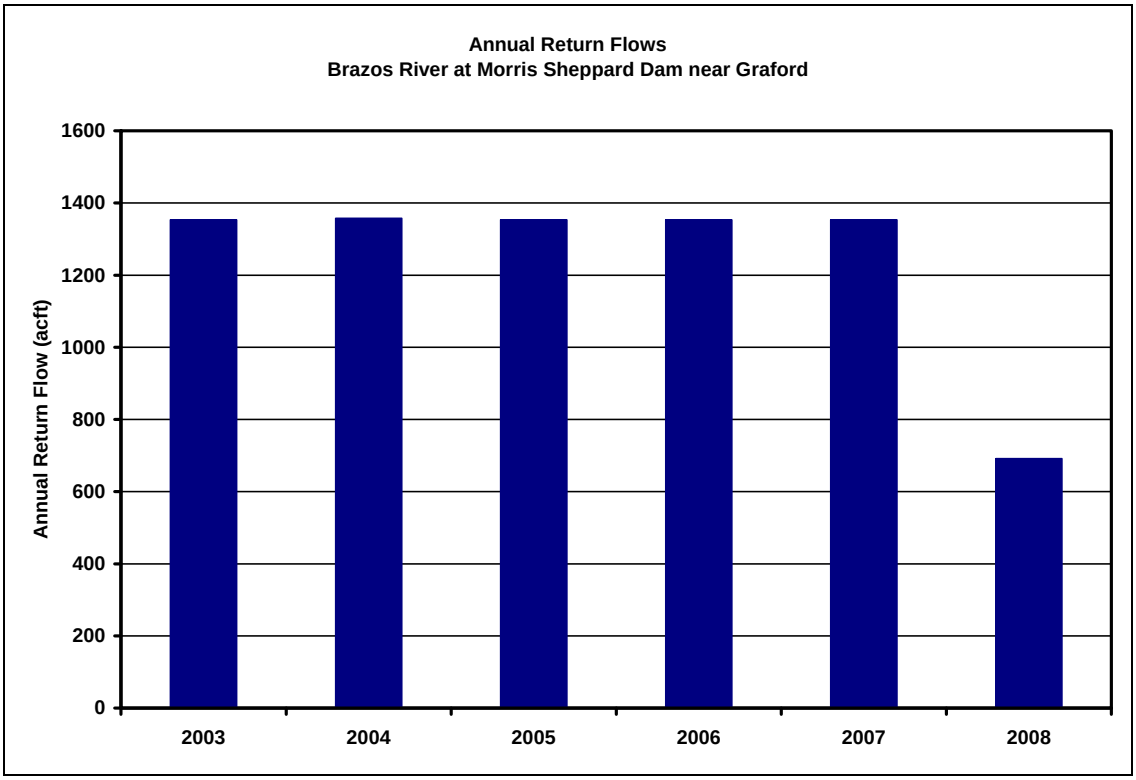
Mulberry Creek near Hawley

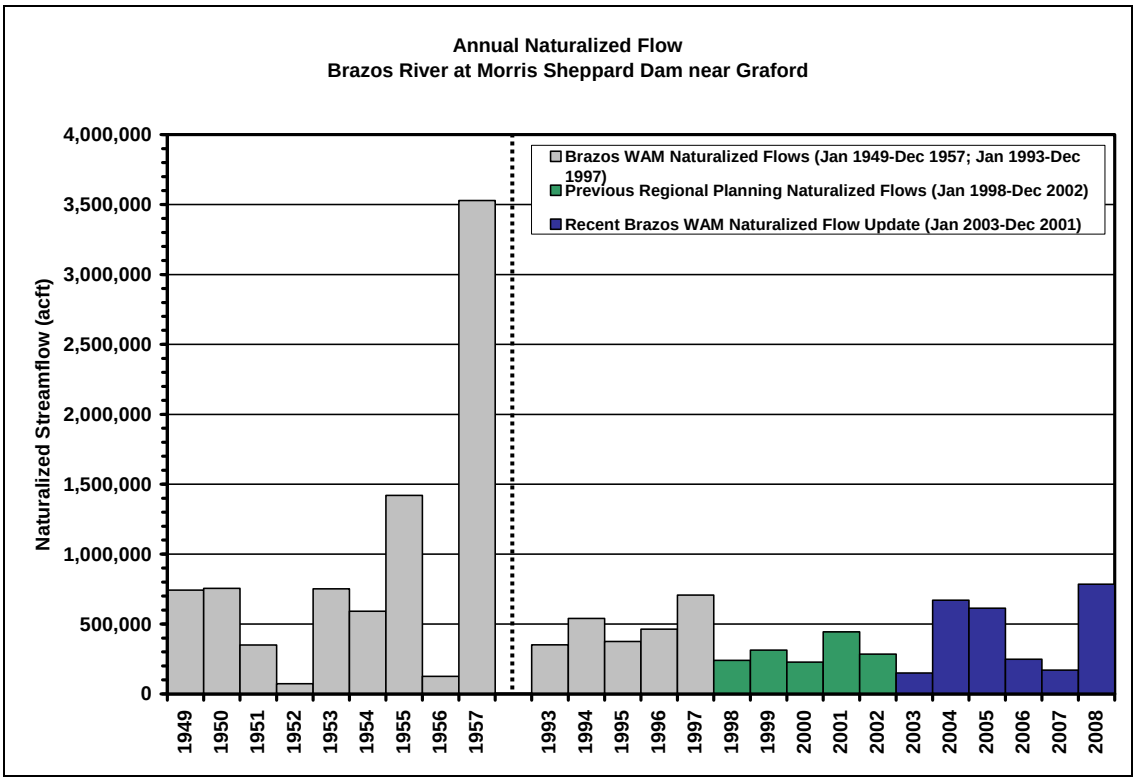




Brazos River at Morris Sheppard Dam near Graford






Annual Naturalized Flow
Brazos River at Morris Sheppard Dam near Graford
Naturalized Streamflow (acft)
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Brazos WAM Naturalized Flows (Jan 1949-Dec 1957; Jan 1993-Dec 1997)
Previous Regional Planning Naturalized Flows (Jan 1998-Dec 2002)
Recent Brazos WAM Naturalized Flow Update (Jan 2003-Dec 2001)
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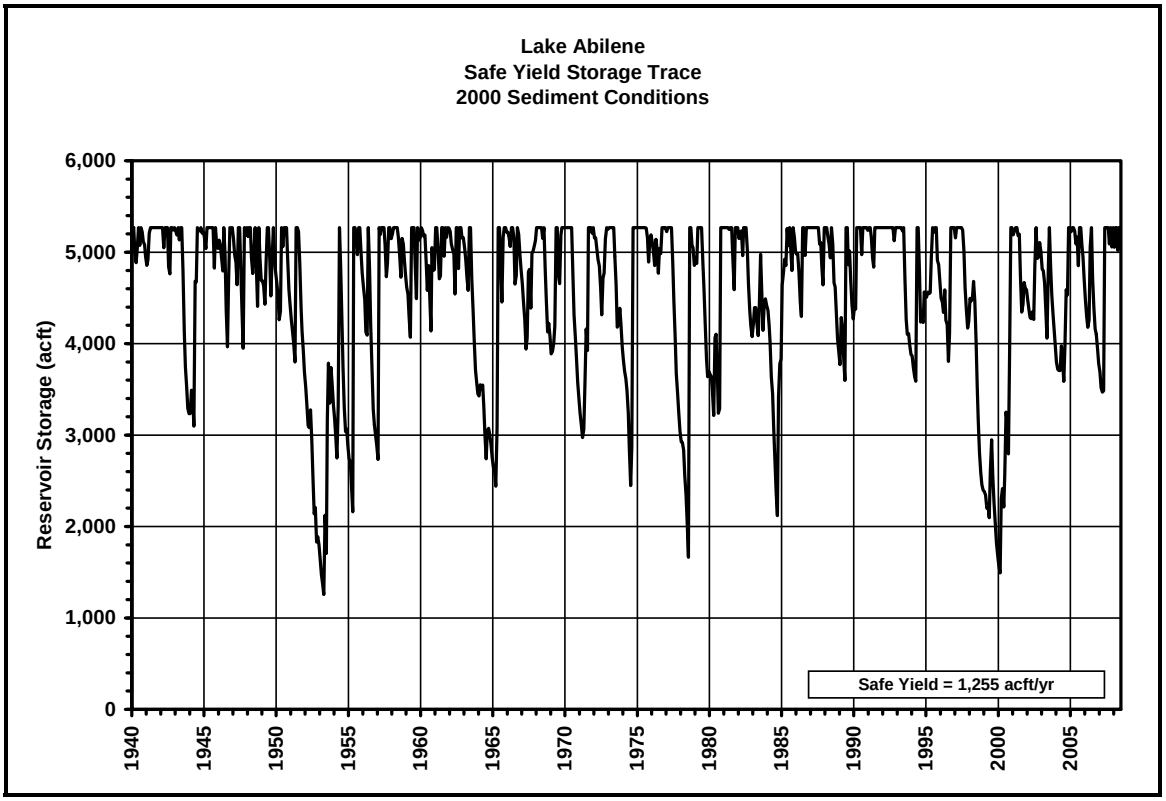
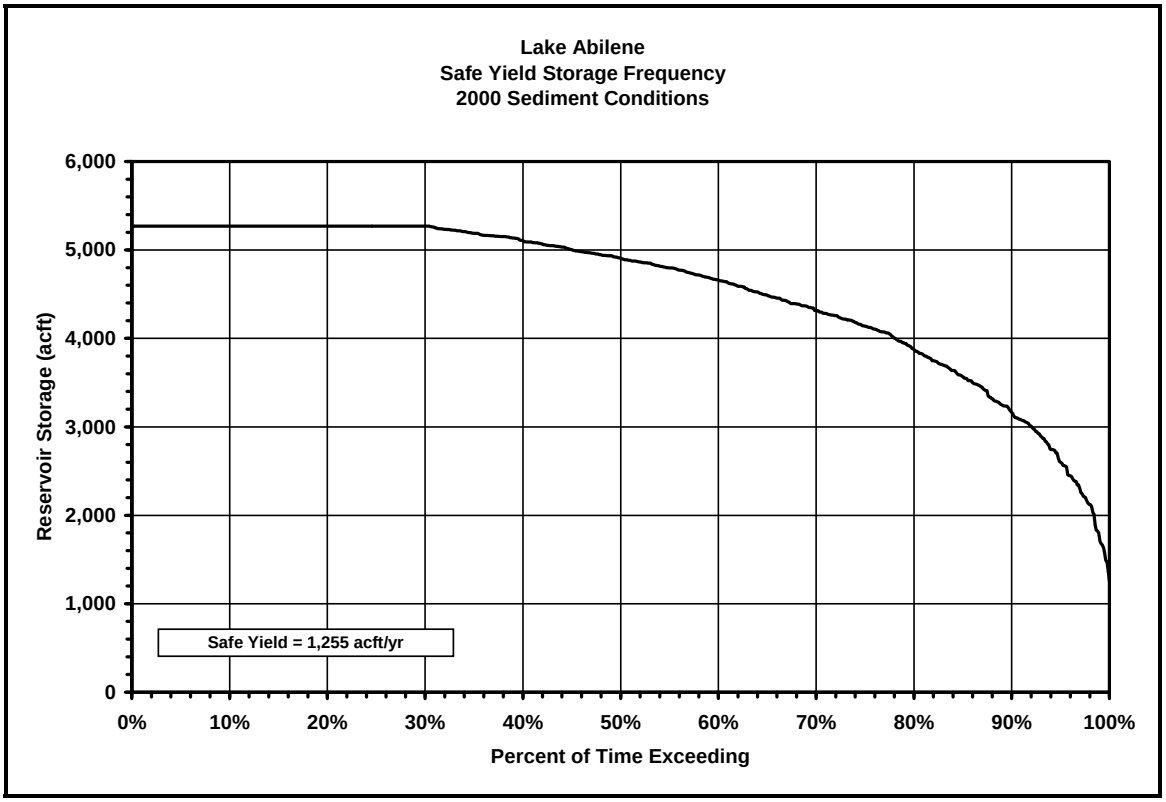
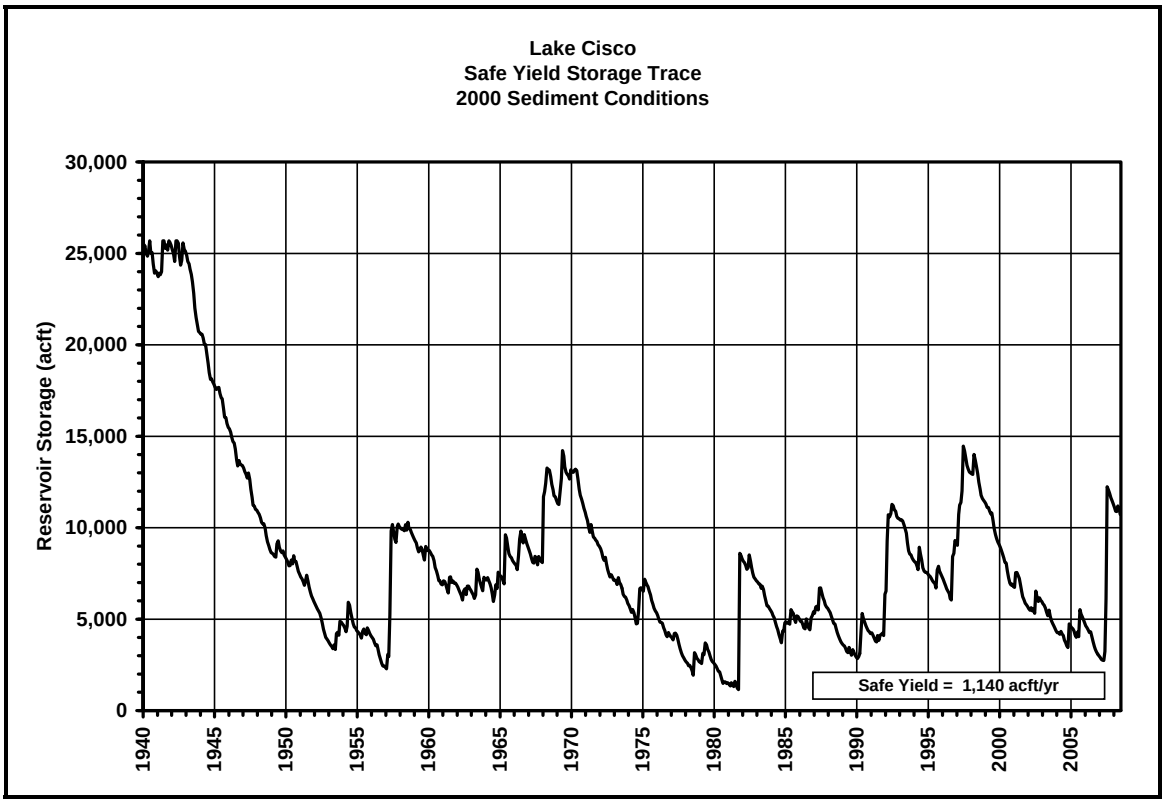
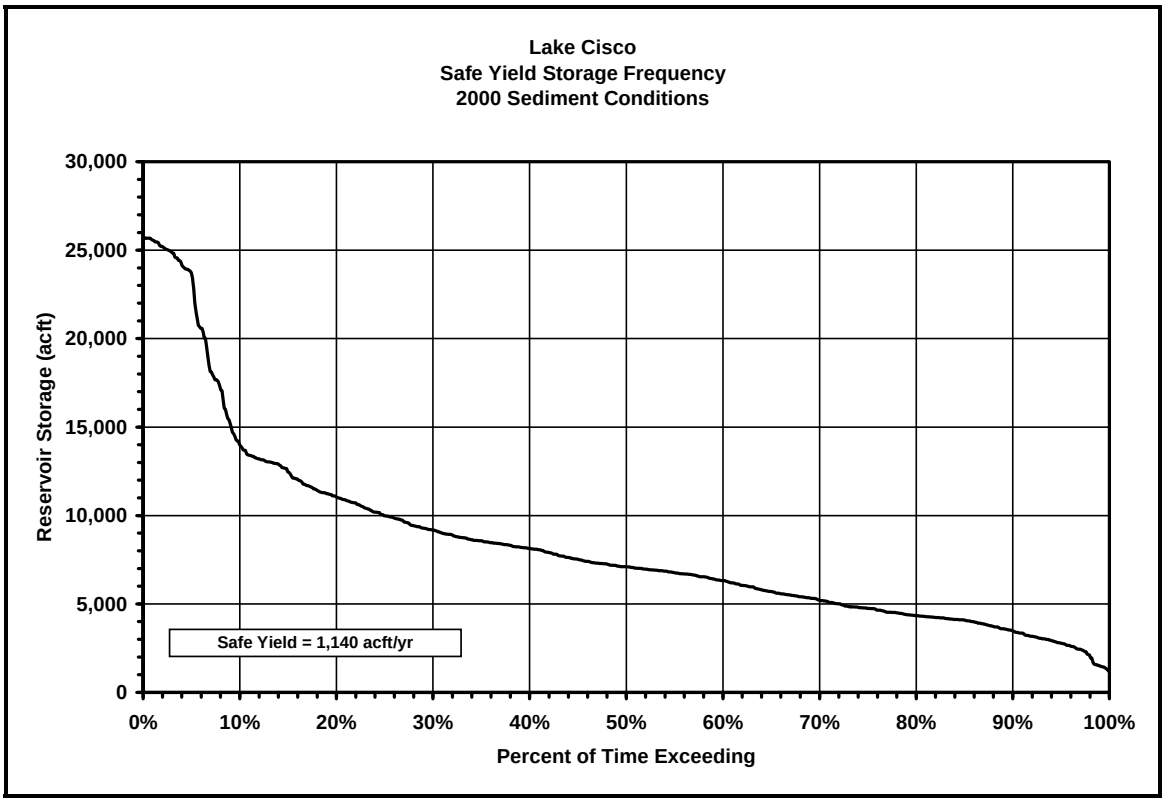
Appendix B
Simulated Reservoir Storages under Safe Yield Operations

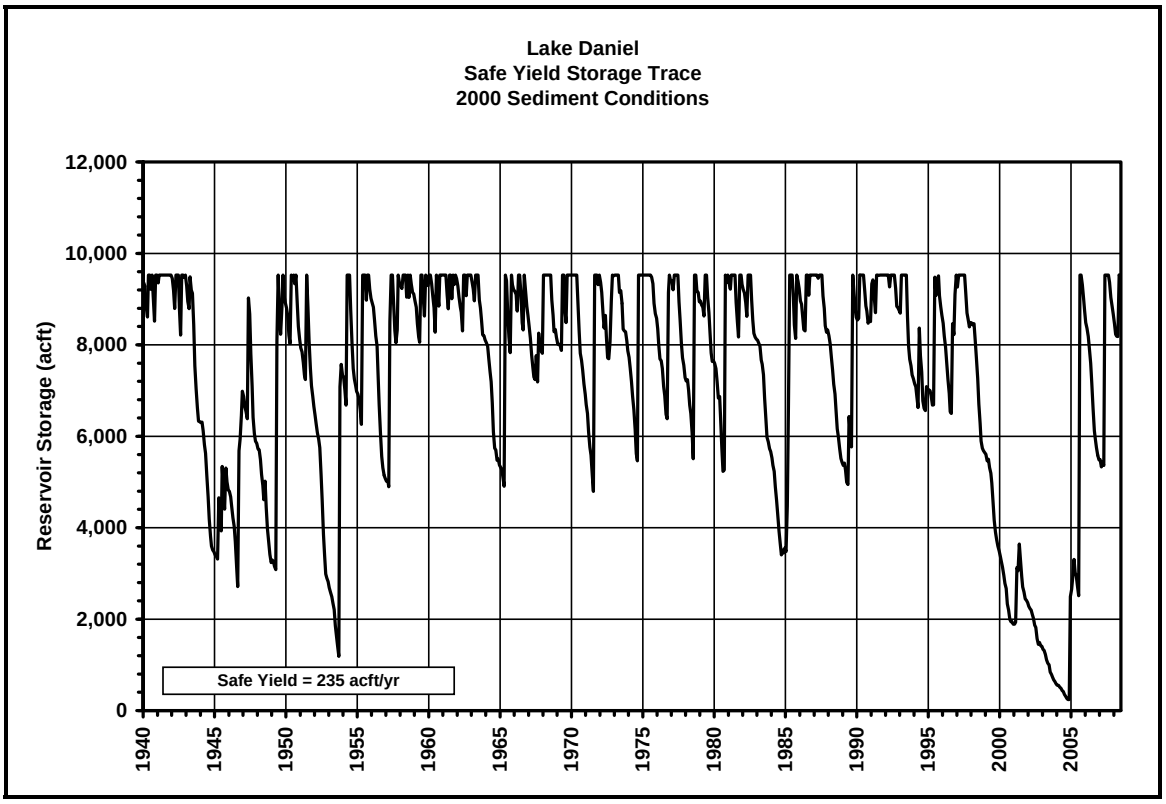
2000 Sediment Conditions

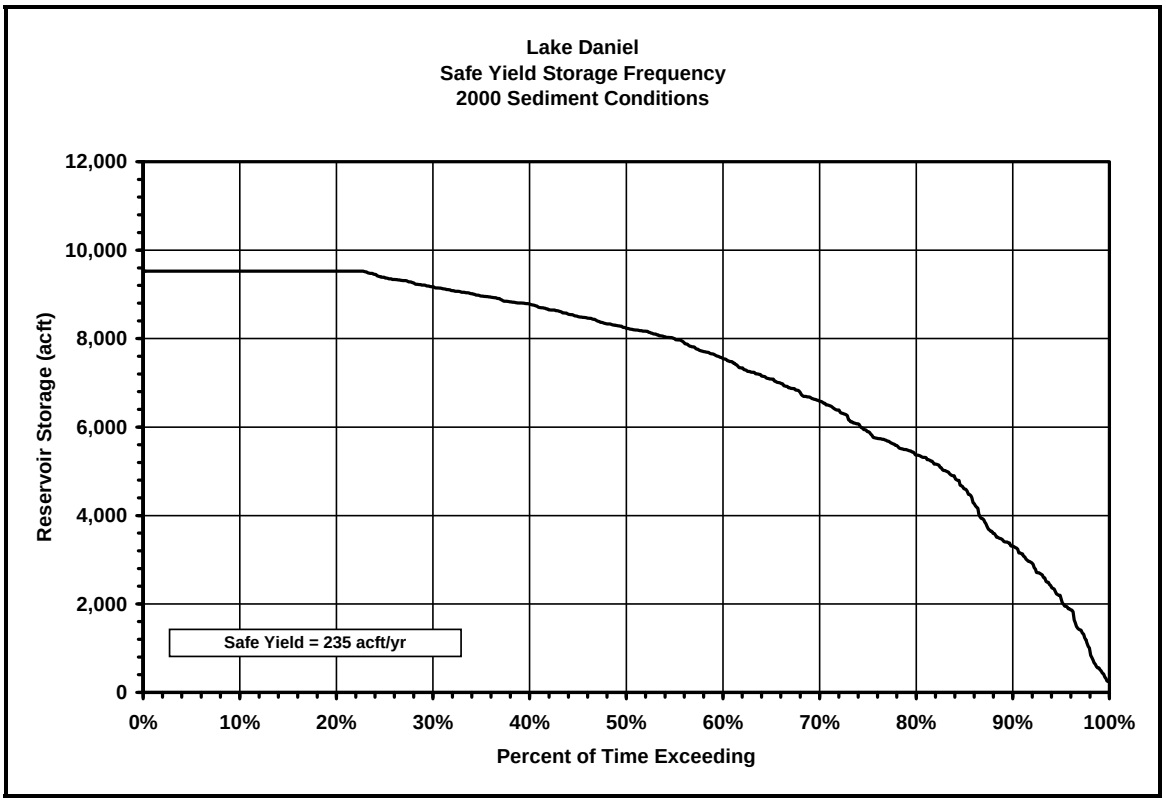


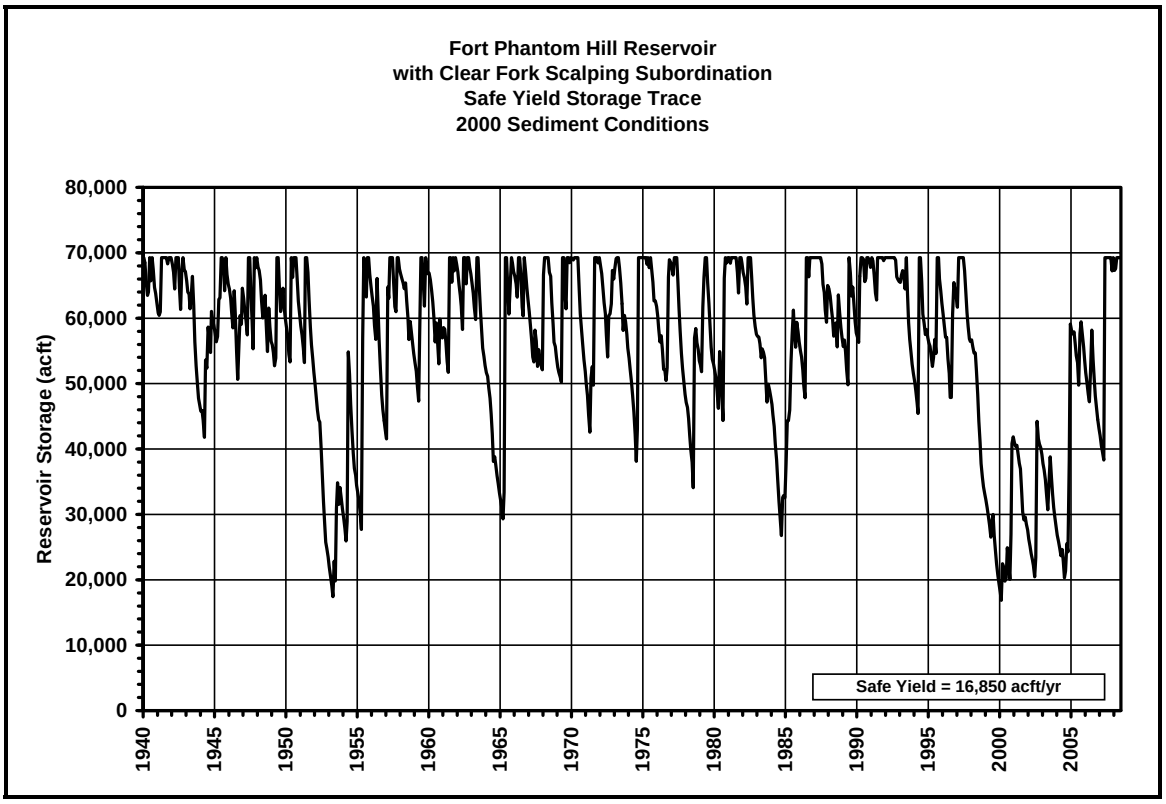


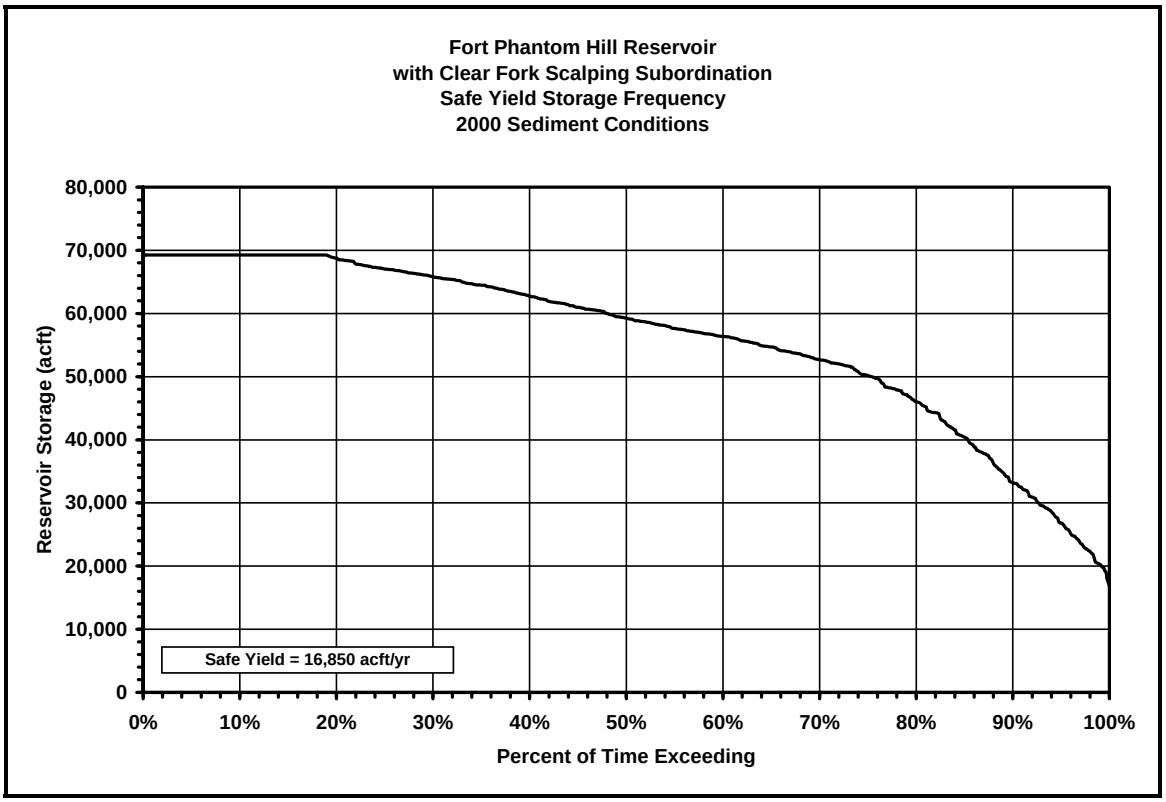

Lake Cisco
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
30,000
25,000
20,000
15,000
10,000
5,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 1,140 acft/yr

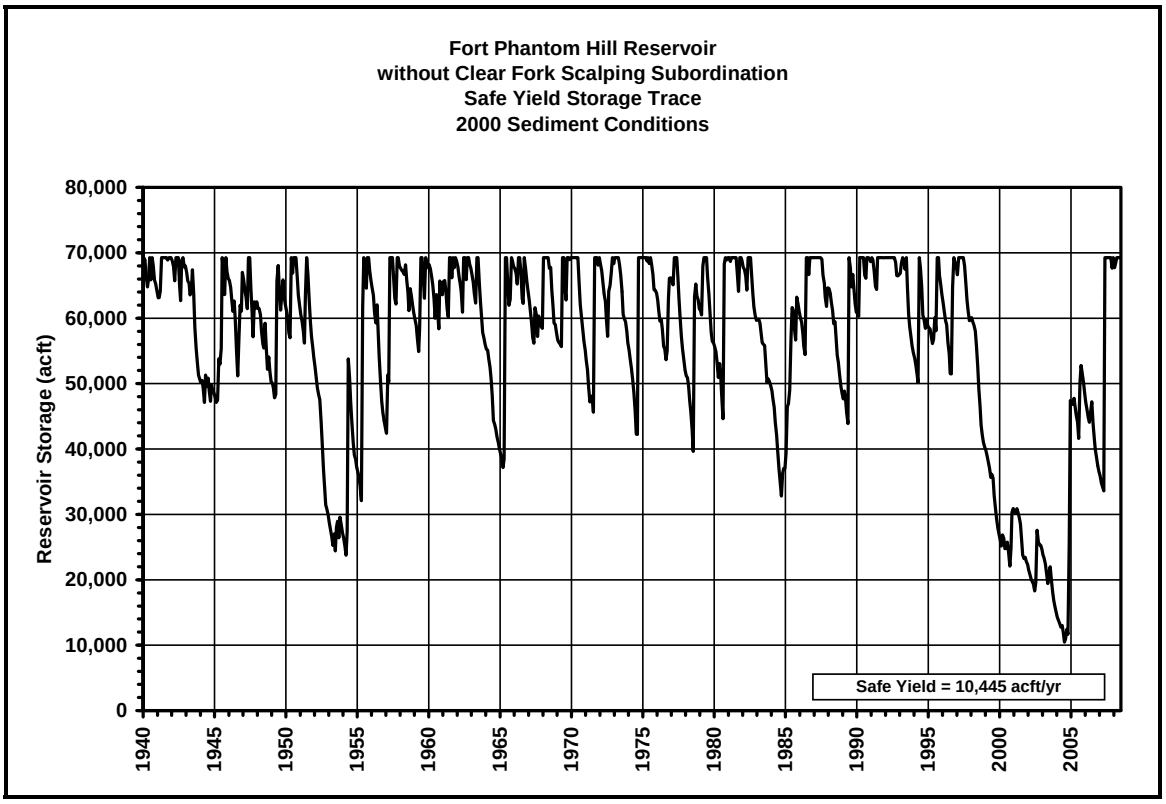

Lake Cisco
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
30,000
25,000
20,000
15,000
10,000
5,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 1,140 acft/yr

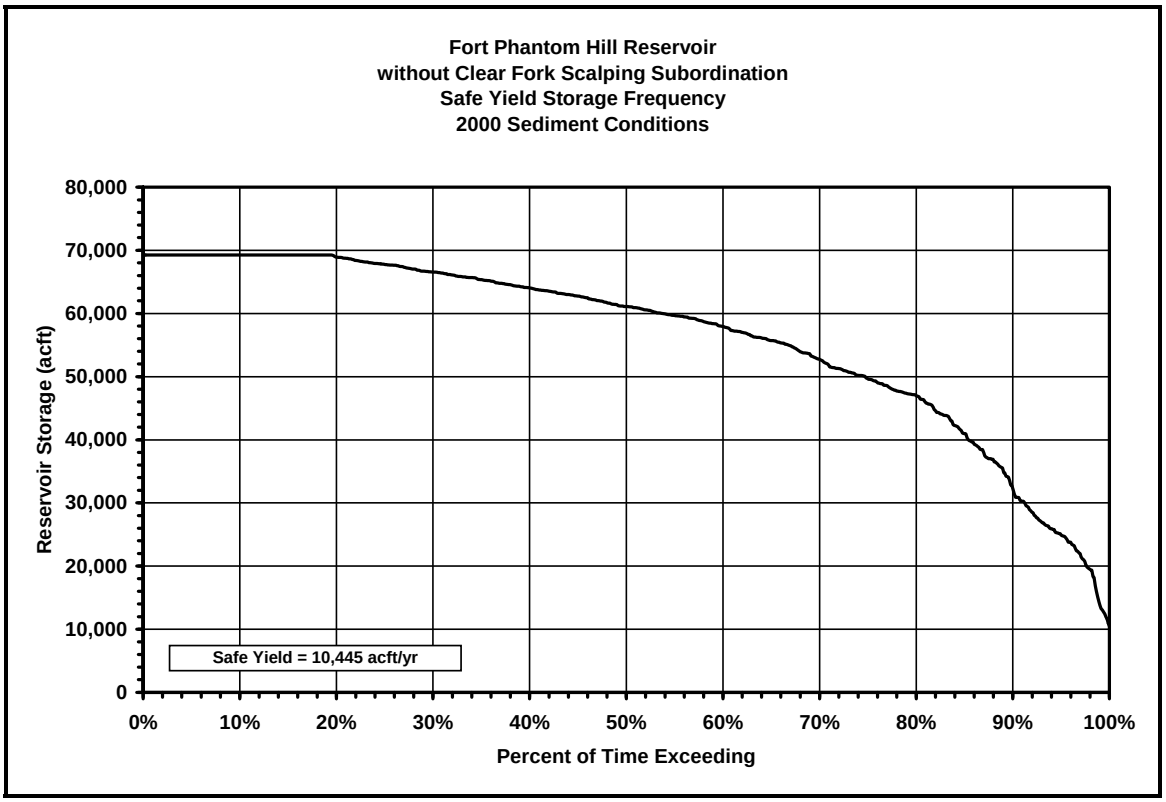

Lake Daniel
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
12,000
10,000
8,000
6,000
4,000
2,000
0
Safe Yield = 235 acft/yr
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

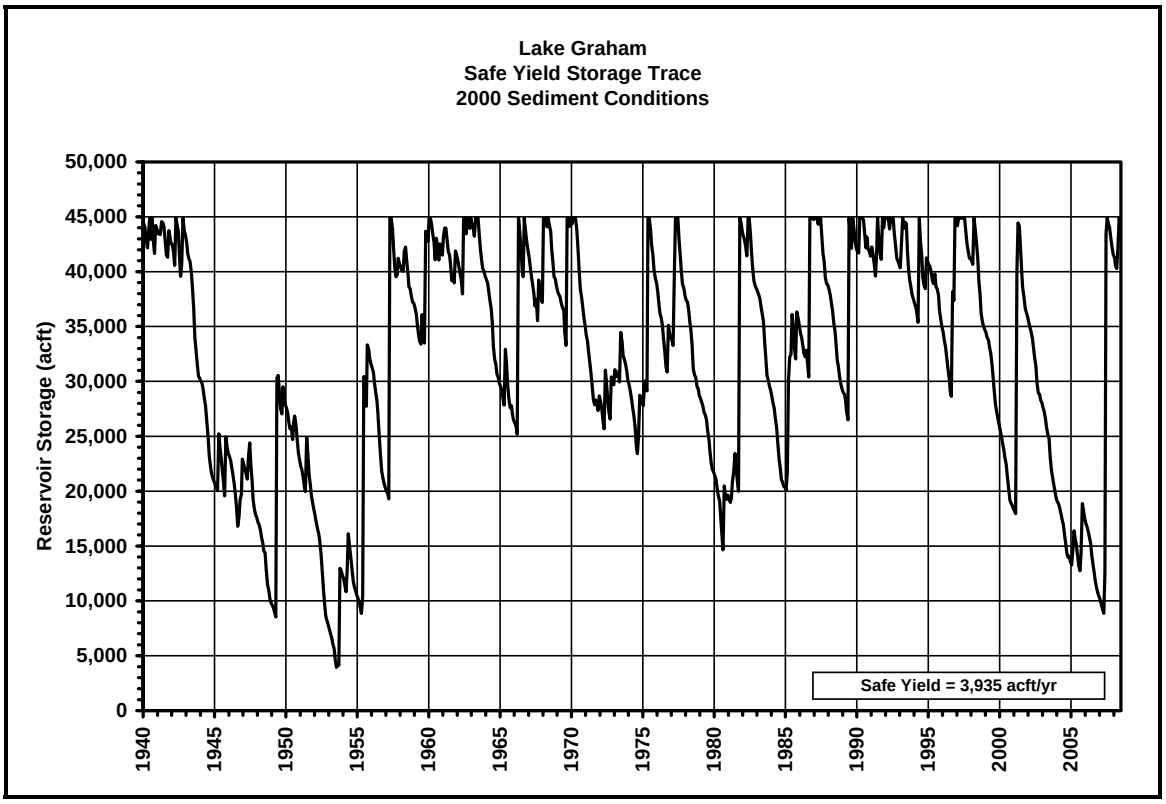

Lake Daniel
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
12,000
10,000
8,000
6,000
4,000
2,000
0
Safe Yield = 235 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding

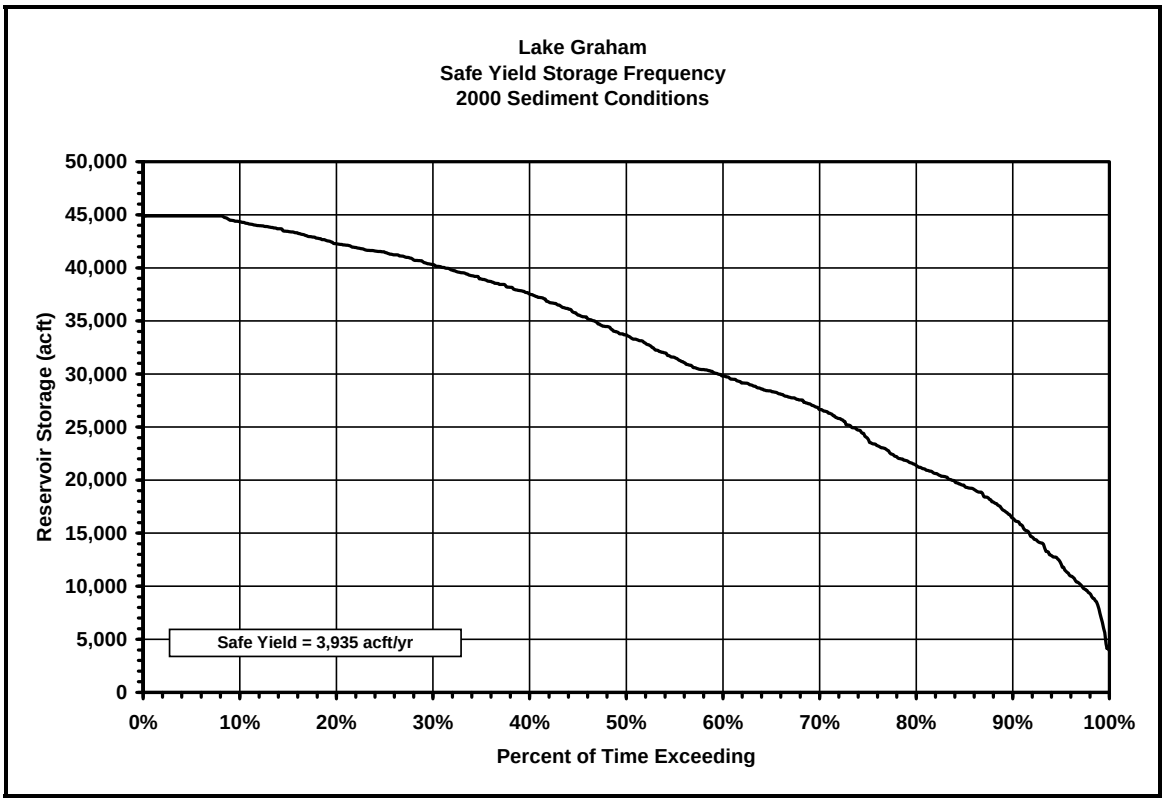

Fort Phantom Hill Reservoir
with Clear Fork Scalping Subordination
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 16,850 acft/yr

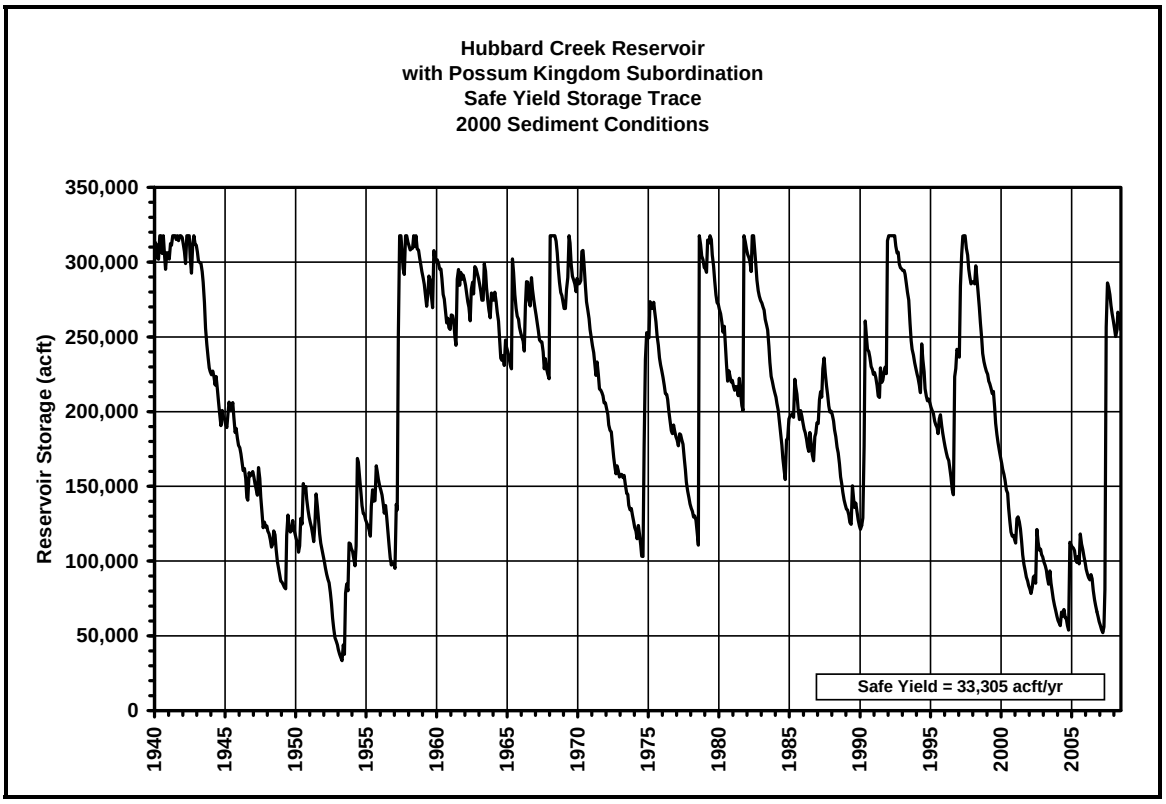

Fort Phantom Hill Reservoir
with Clear Fork Scalping Subordination
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Safe Yield = 16,850 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding

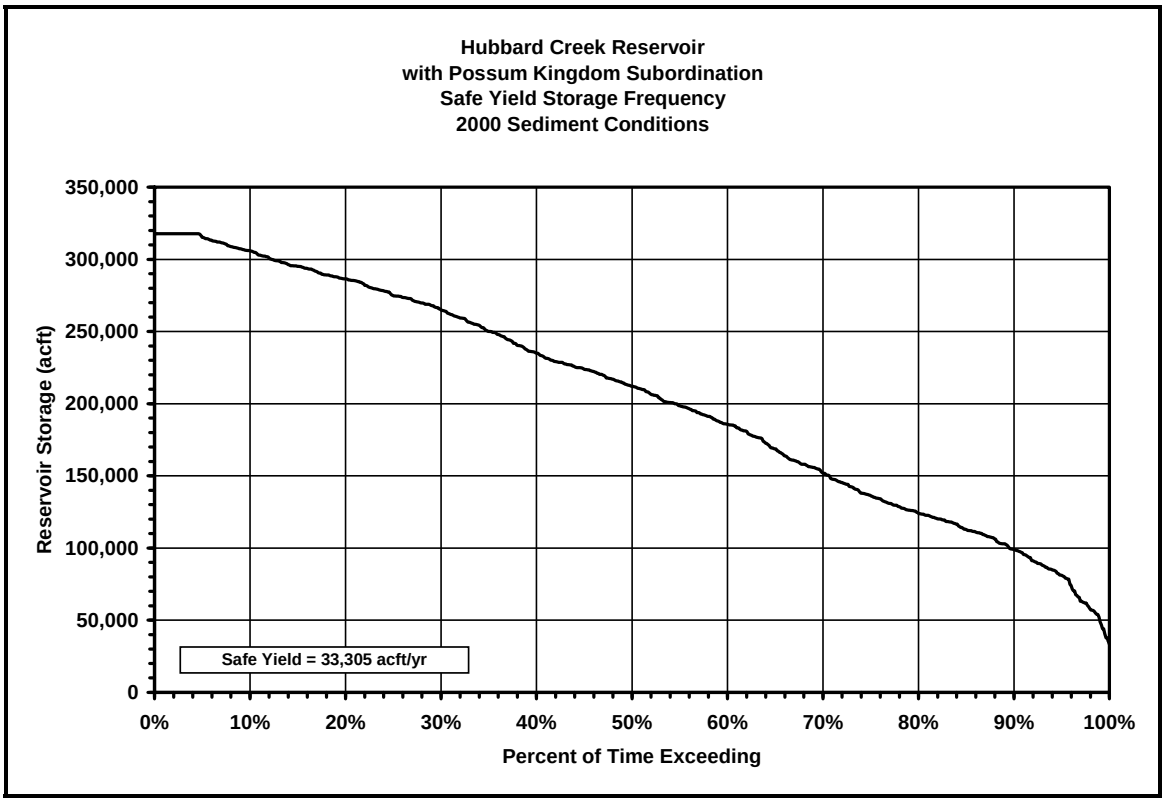

Fort Phantom Hill Reservoir
without Clear Fork Scalping Subordination
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 10,445 acft/yr

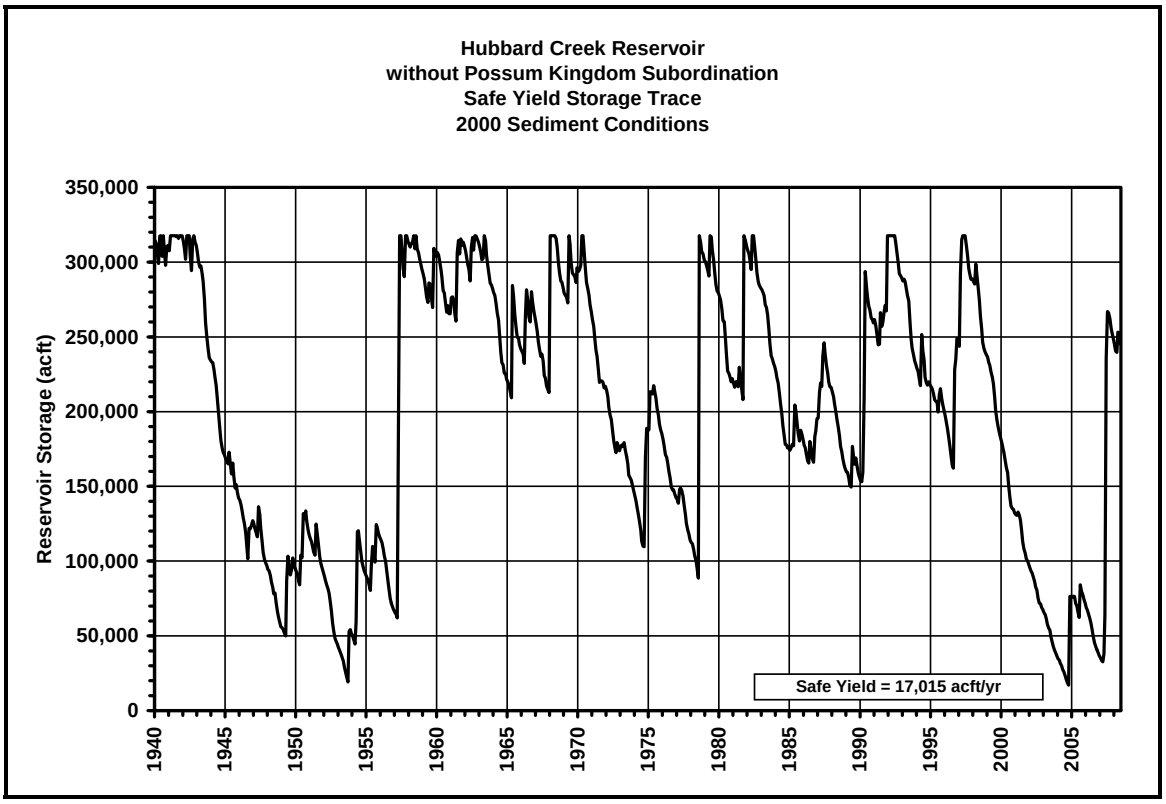

Fort Phantom Hill Reservoir
without Clear Fork Scalping Subordination
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Safe Yield = 10,445 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding

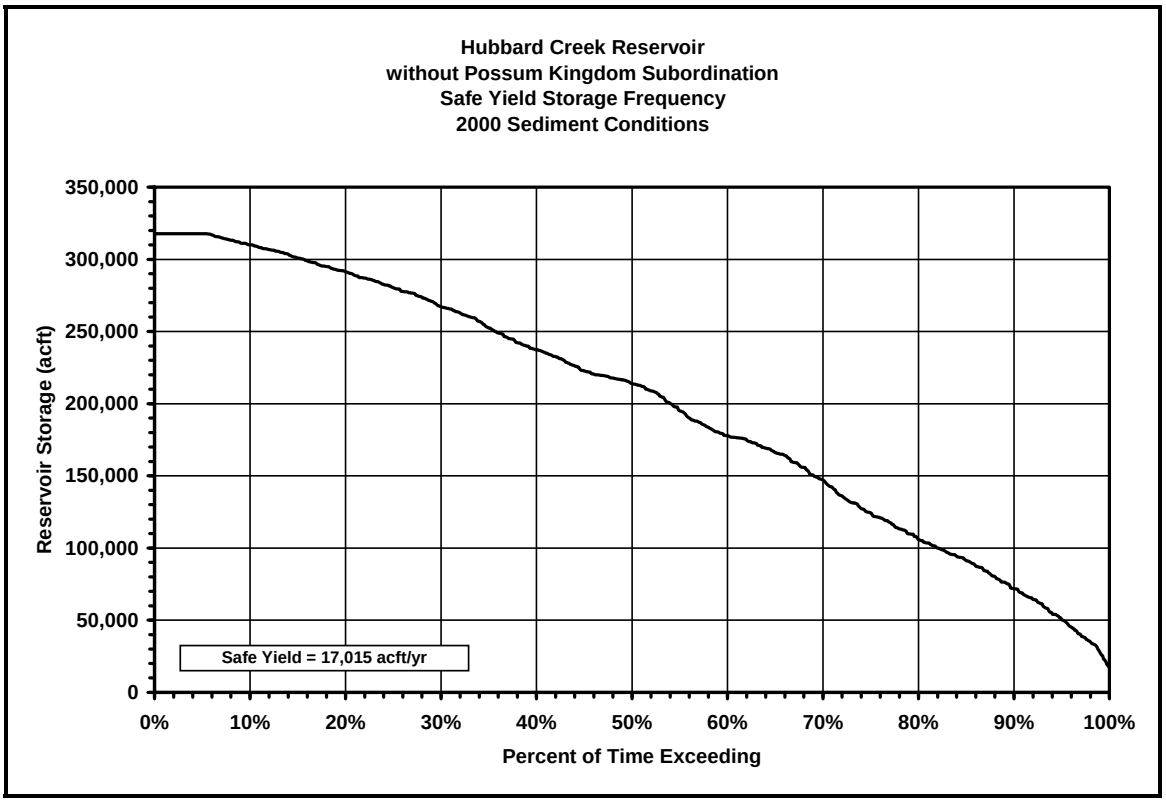

Lake Graham
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 3,935 acft/yr

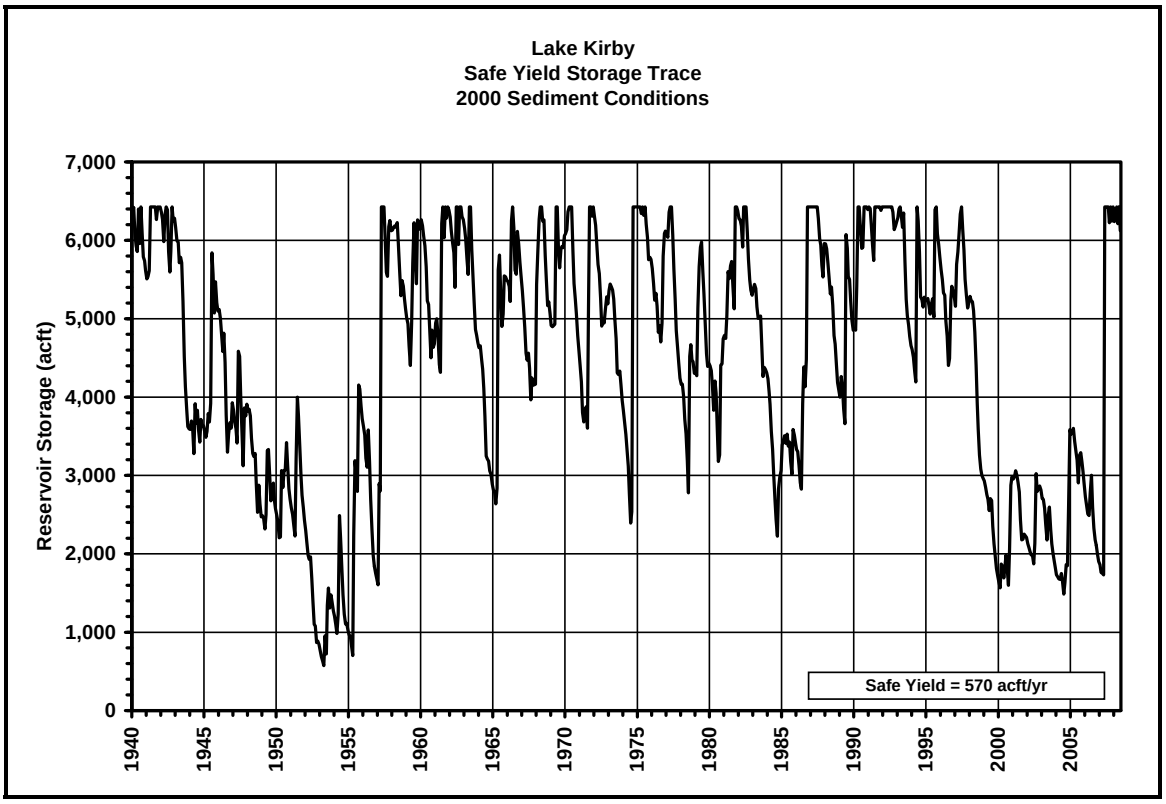

Lake Graham
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 3,935 acft/yr

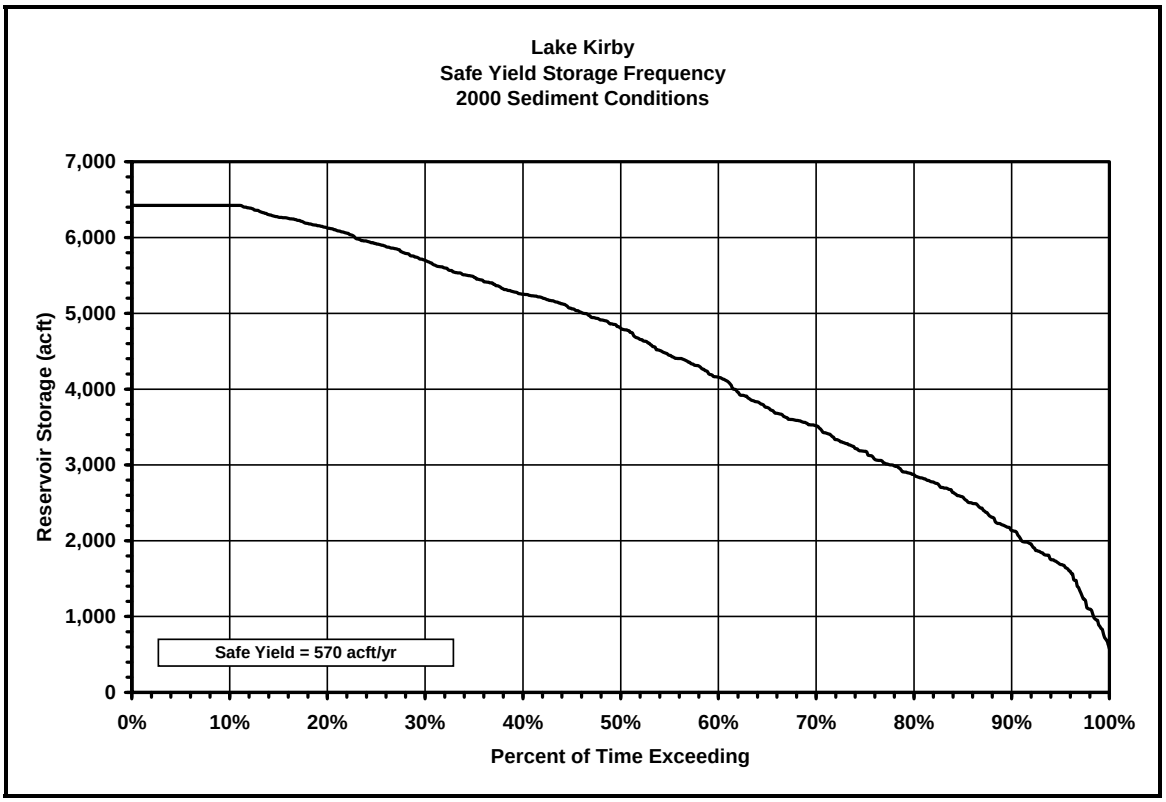

Hubbard Creek Reservoir
with Possum Kingdom Subordination
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 33,305 acft/yr

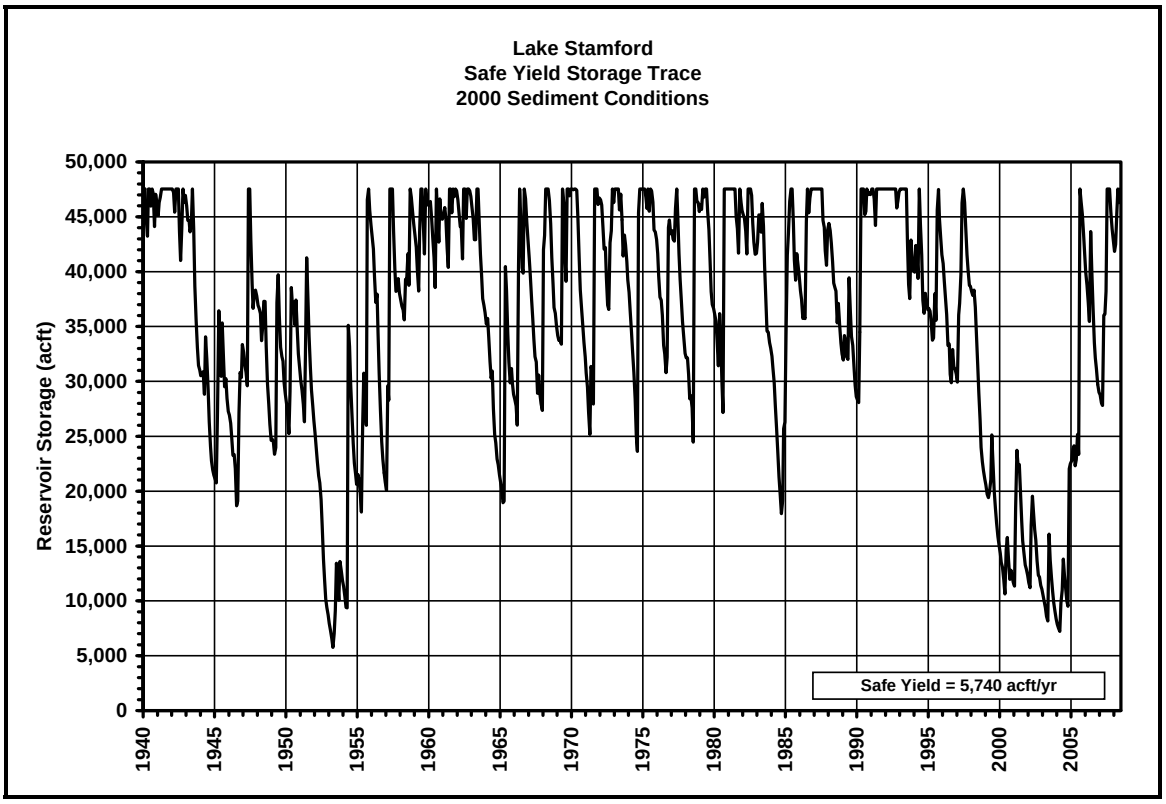

Hubbard Creek Reservoir
with Possum Kingdom Subordination
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 33,305 acft/yr

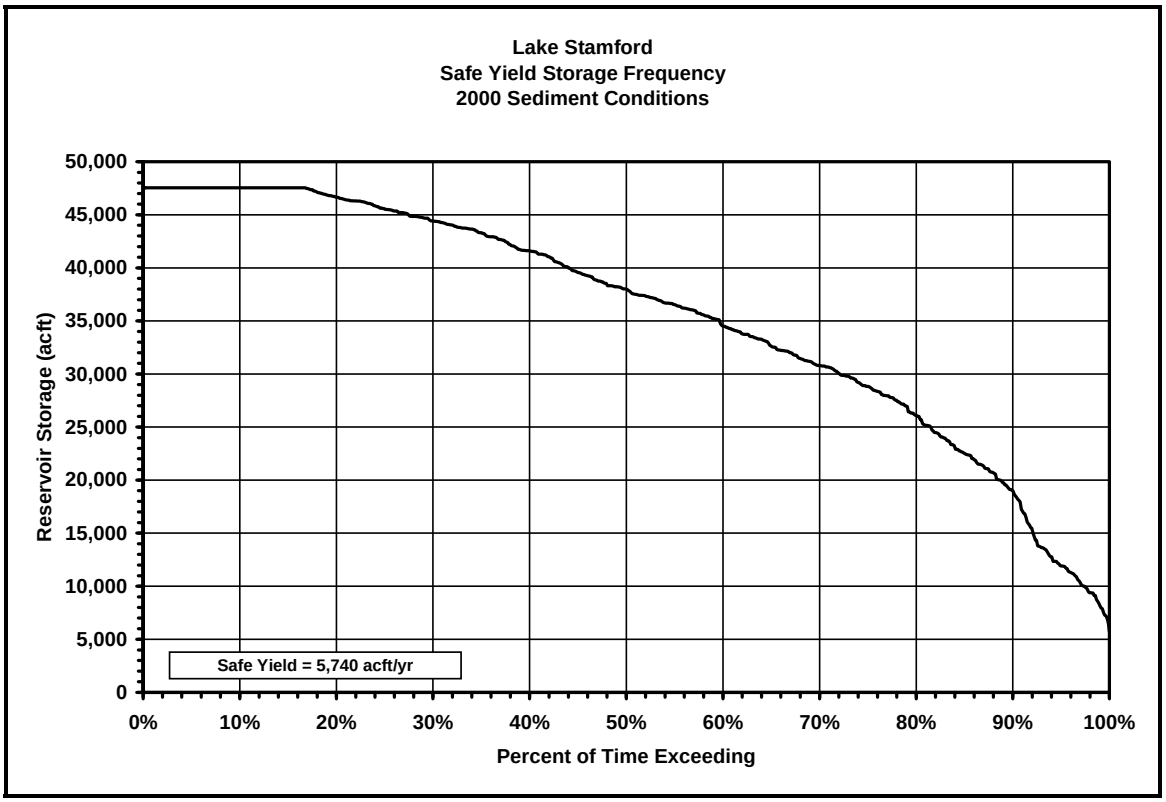

Hubbard Creek Reservoir
without Possum Kingdom Subordination
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 17,015 acft/yr

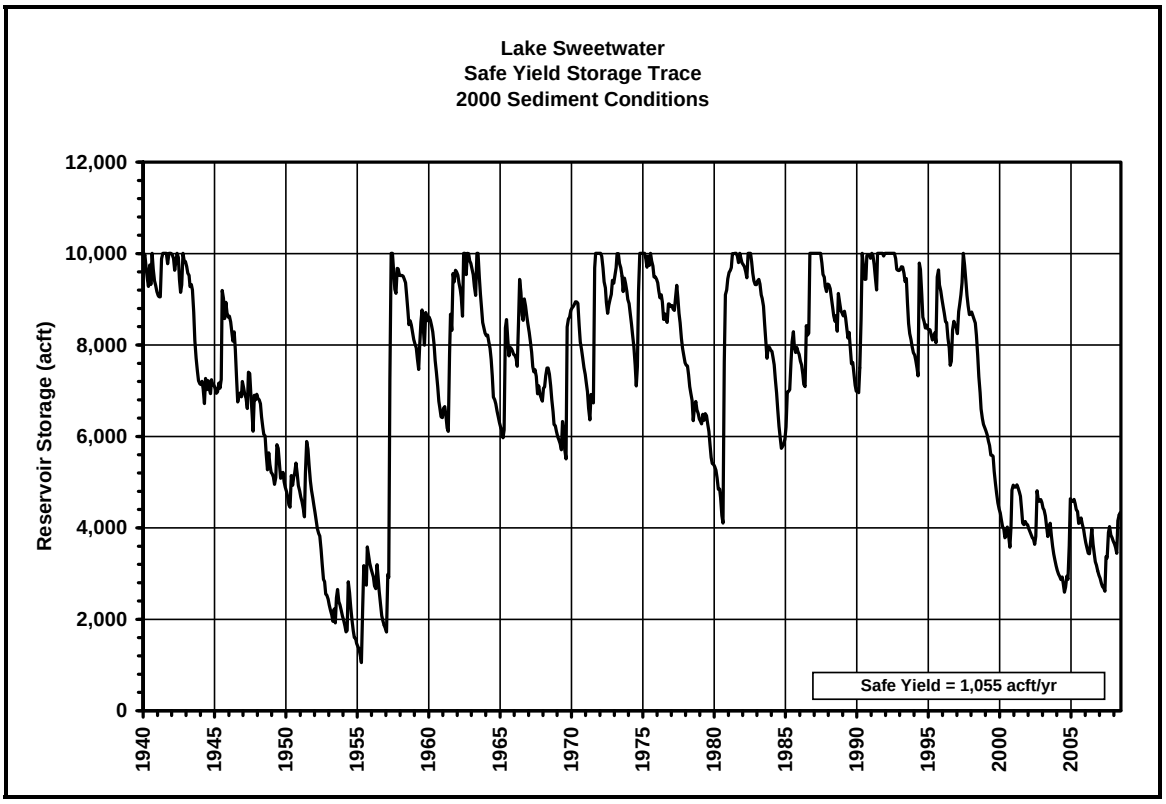

Hubbard Creek Reservoir
without Possum Kingdom Subordination
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Safe Yield = 17,015 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding

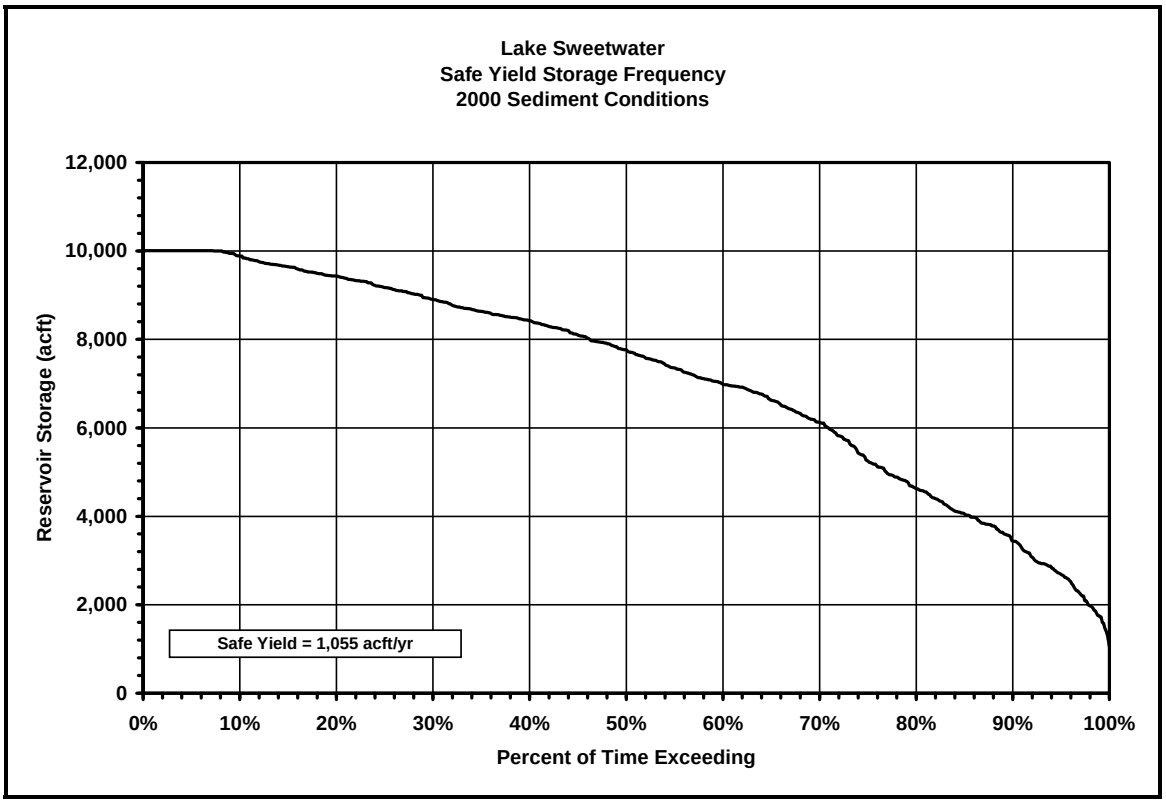

Lake Kirby
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 570 acft/yr

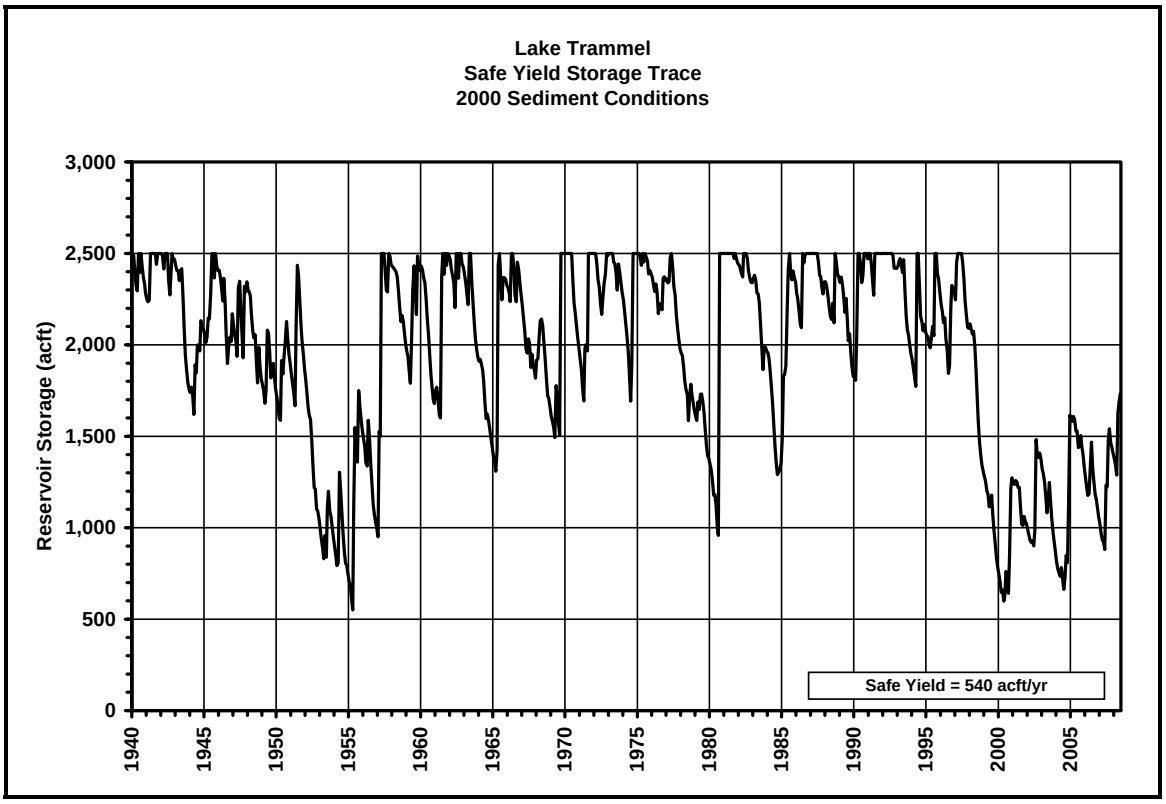

Lake Kirby
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Safe Yield = 570 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding

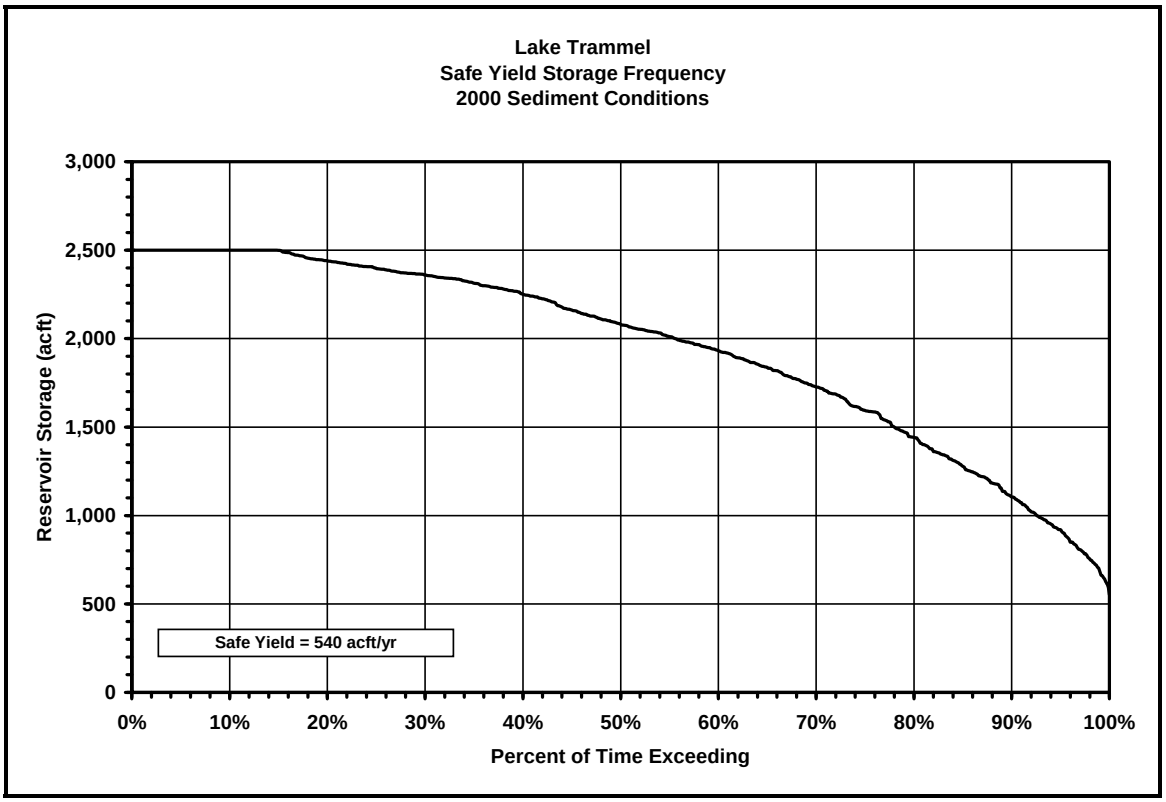

Lake Stamford
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 5,740 acft/yr

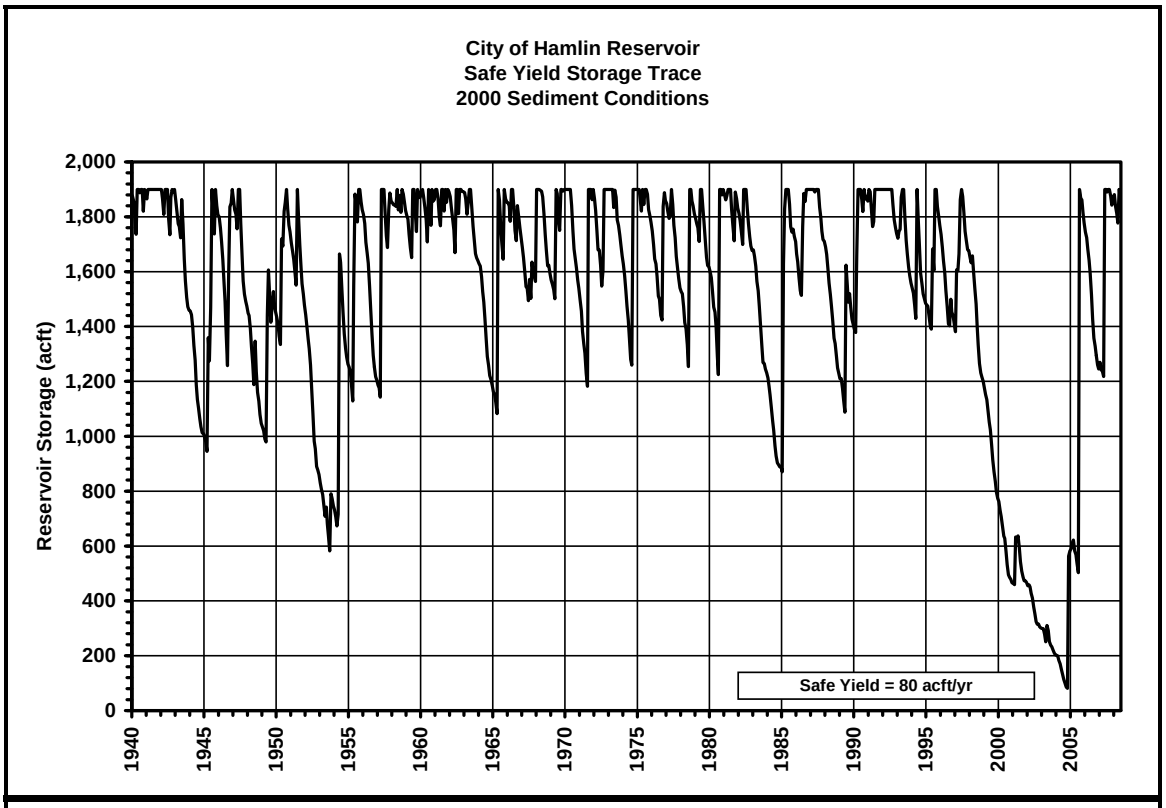

Lake Stamford
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Safe Yield = 5,740 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding

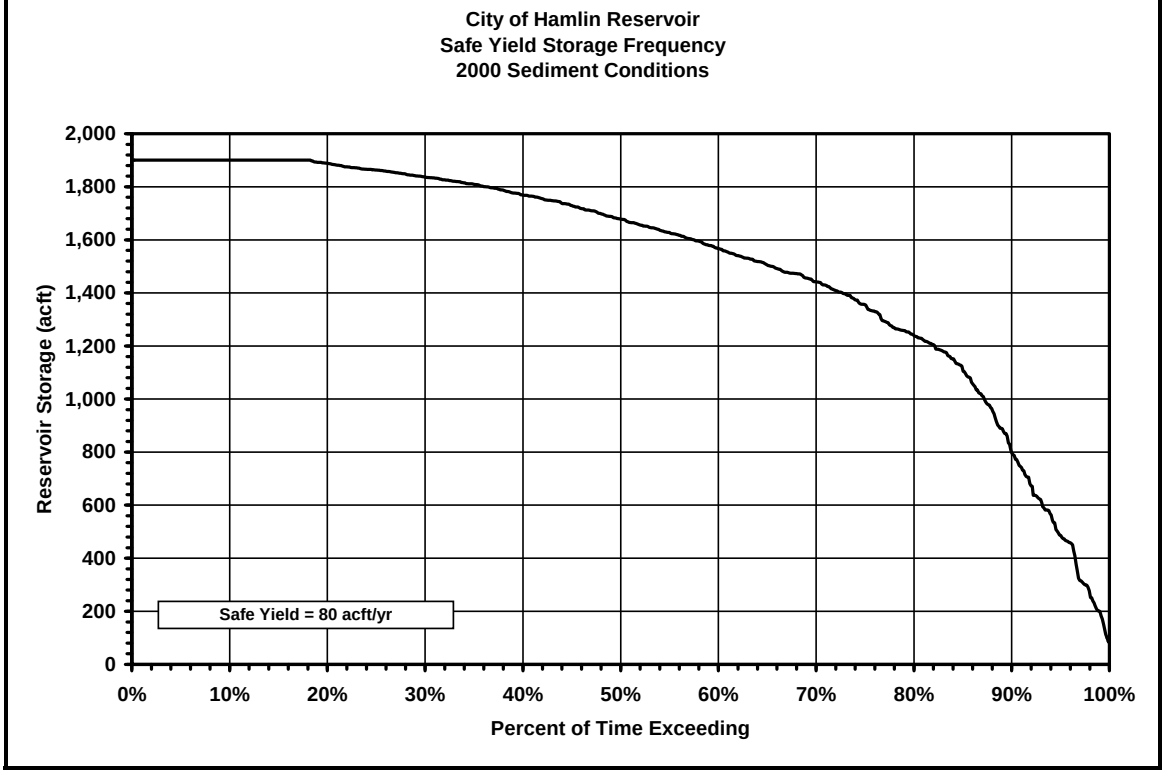

Lake Sweetwater
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 1,055 acft/yr

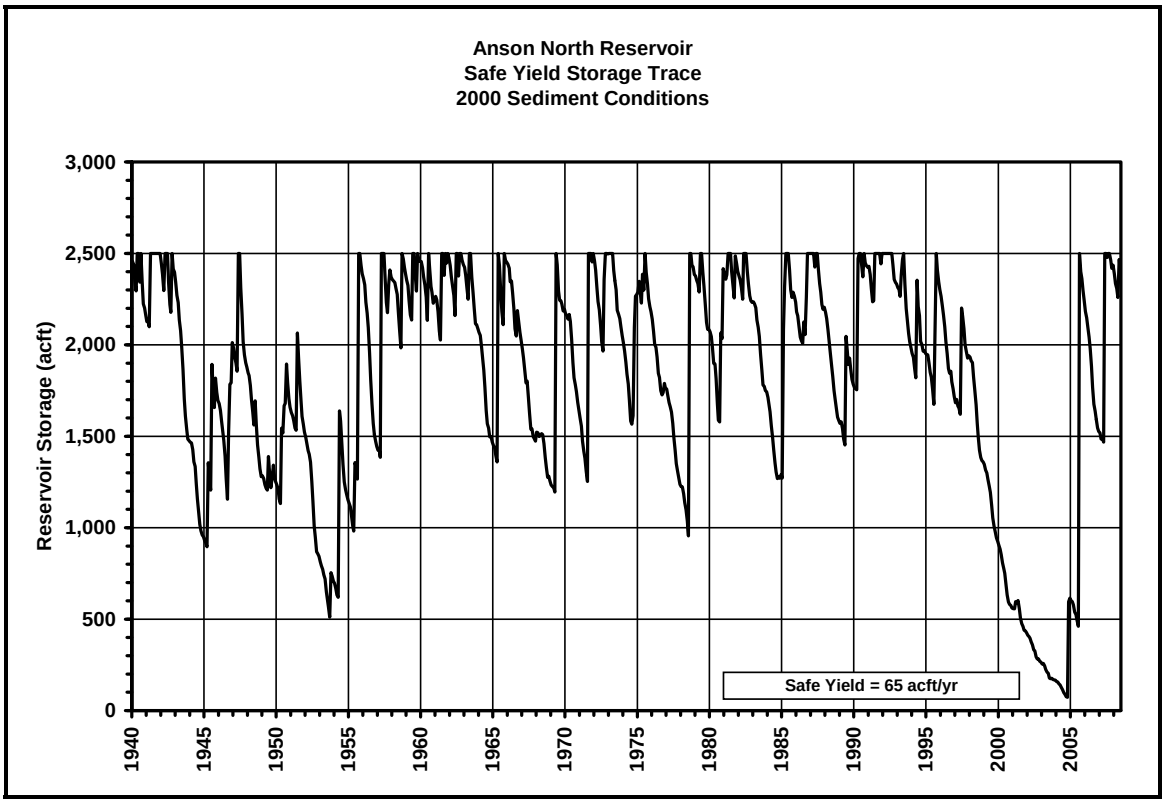

Lake Sweetwater
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
12,000
10,000
8,000
6,000
4,000
2,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 1,055 acft/yr

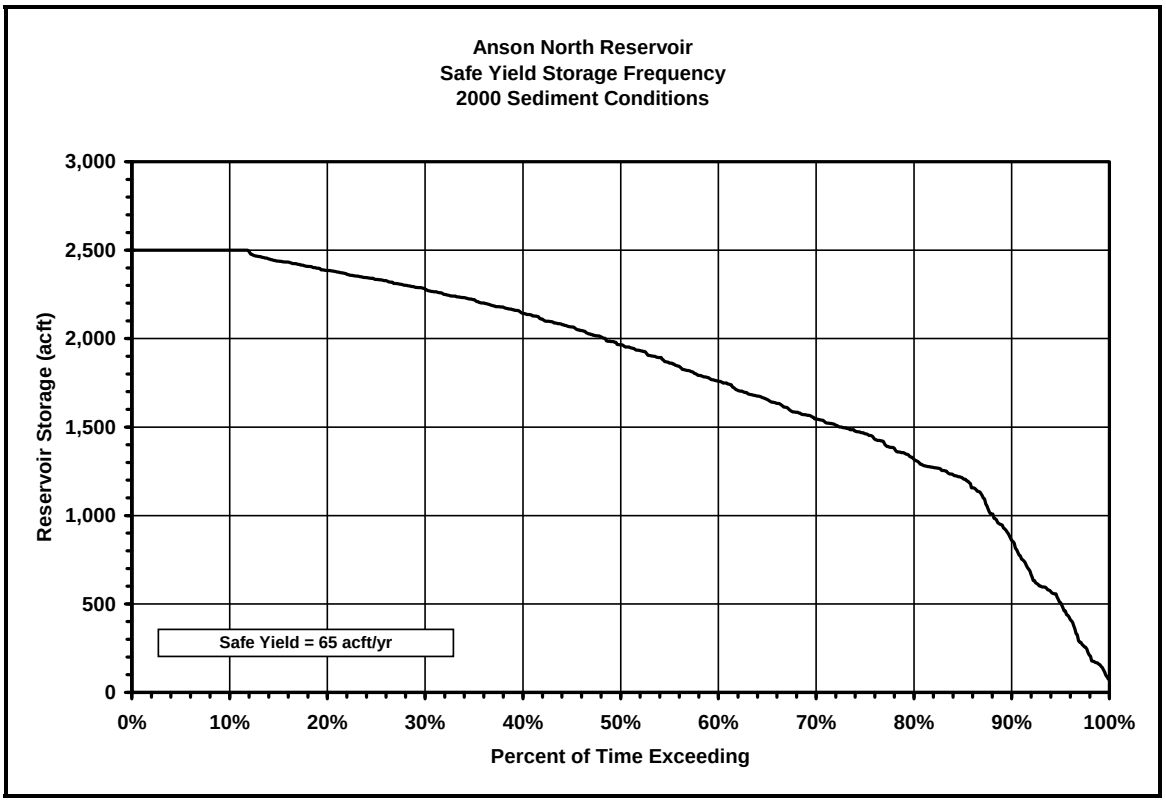

Lake Trammel
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
3,000
2,500
2,000
1,500
1,000
500
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 540 acft/yr

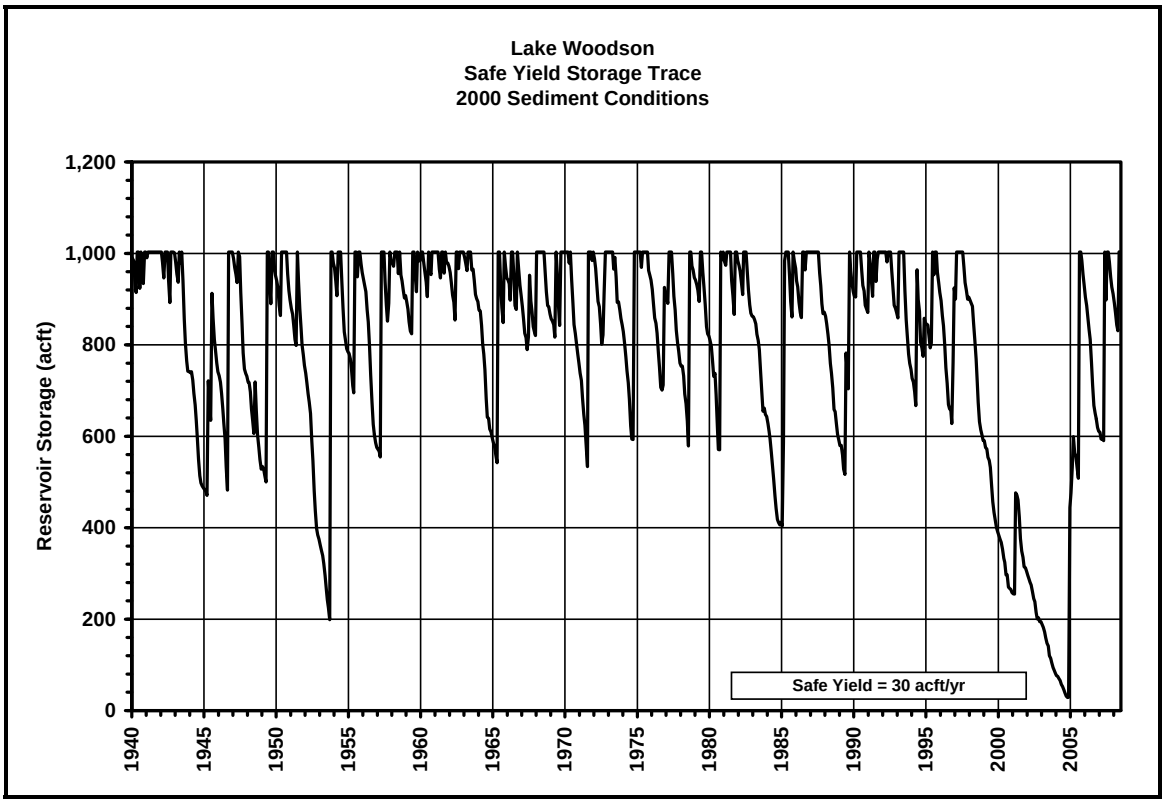

Lake Trammel
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
3,000
2,500
2,000
1,500
1,000
500
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 540 acft/yr

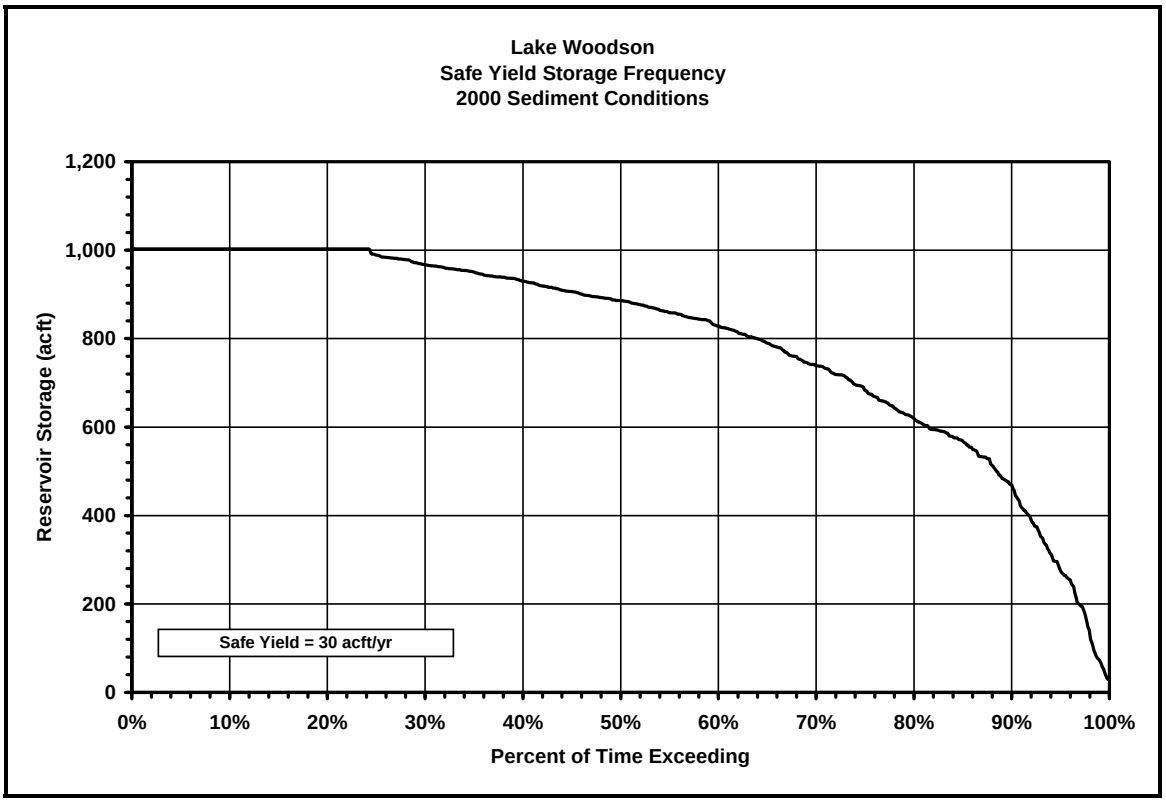

City of Hamlin Reservoir
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 80 acft/yr

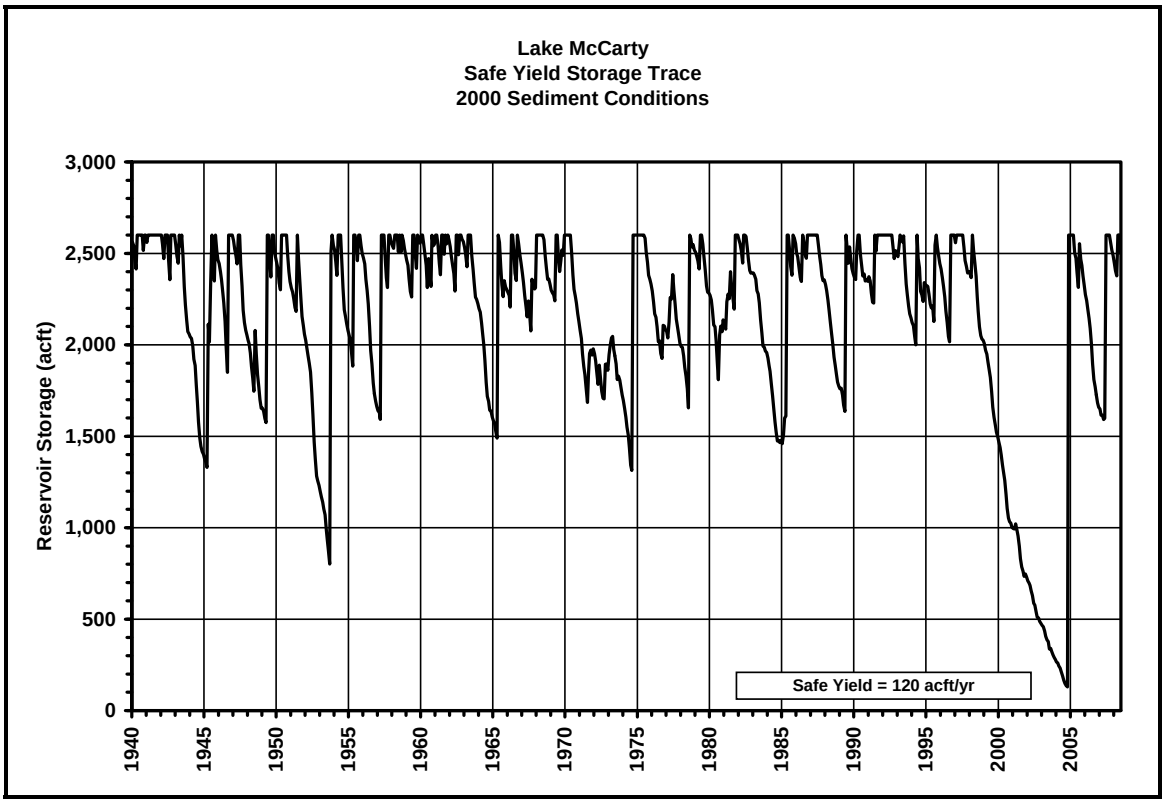

City of Hamlin Reservoir
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 80 acft/yr

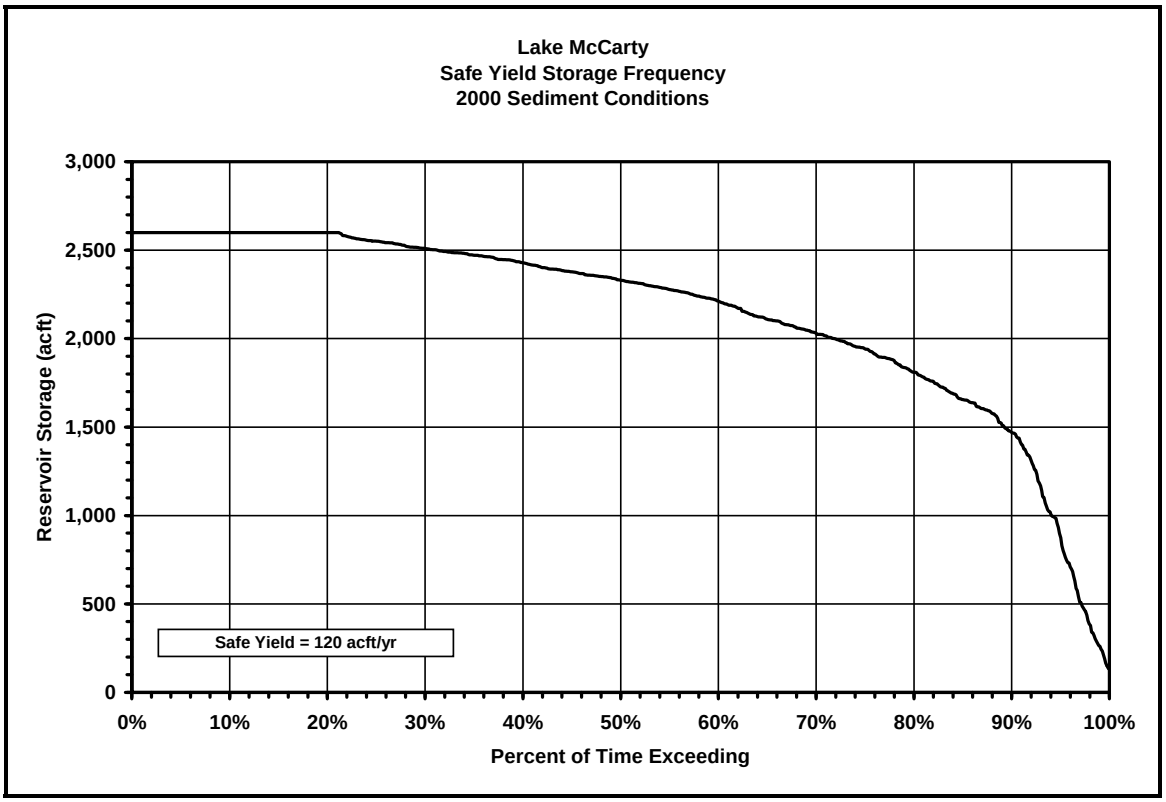

Anson North Reservoir
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
3,000
2,500
2,000
1,500
1,000
500
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 65 acft/yr

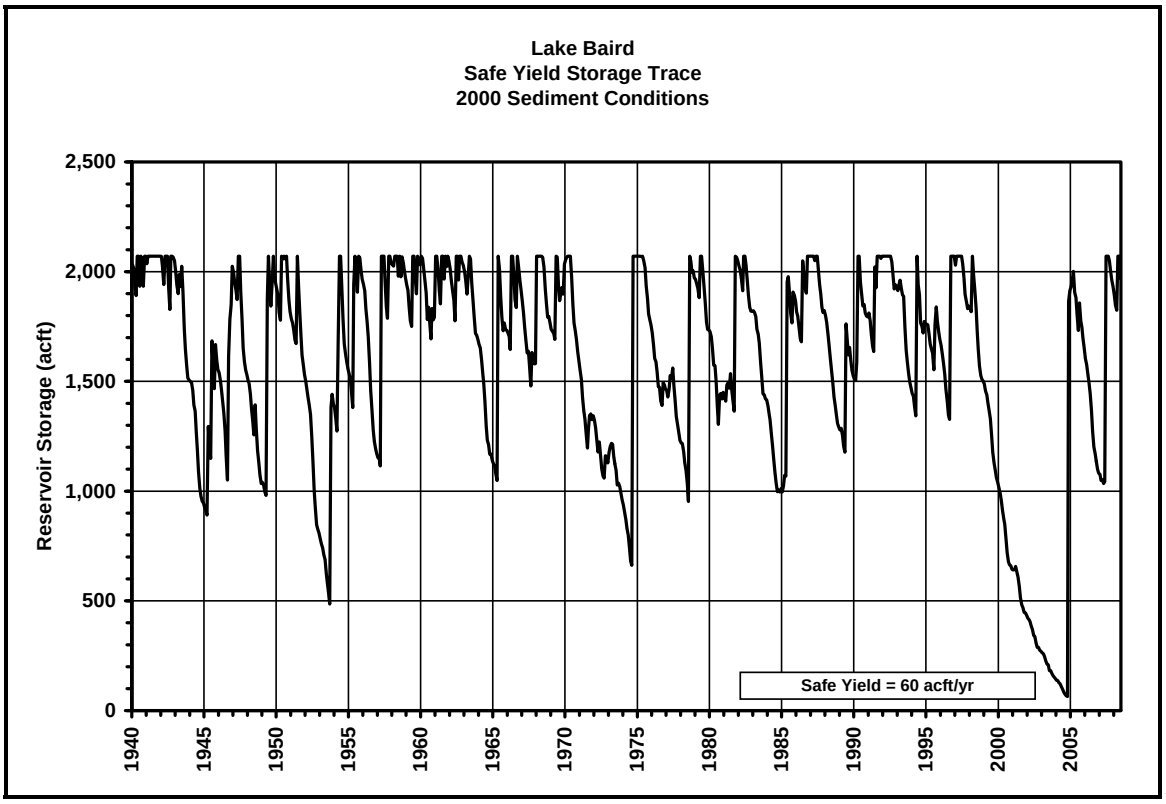

Anson North Reservoir
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
3,000
2,500
2,000
1,500
1,000
500
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 65 acft/yr

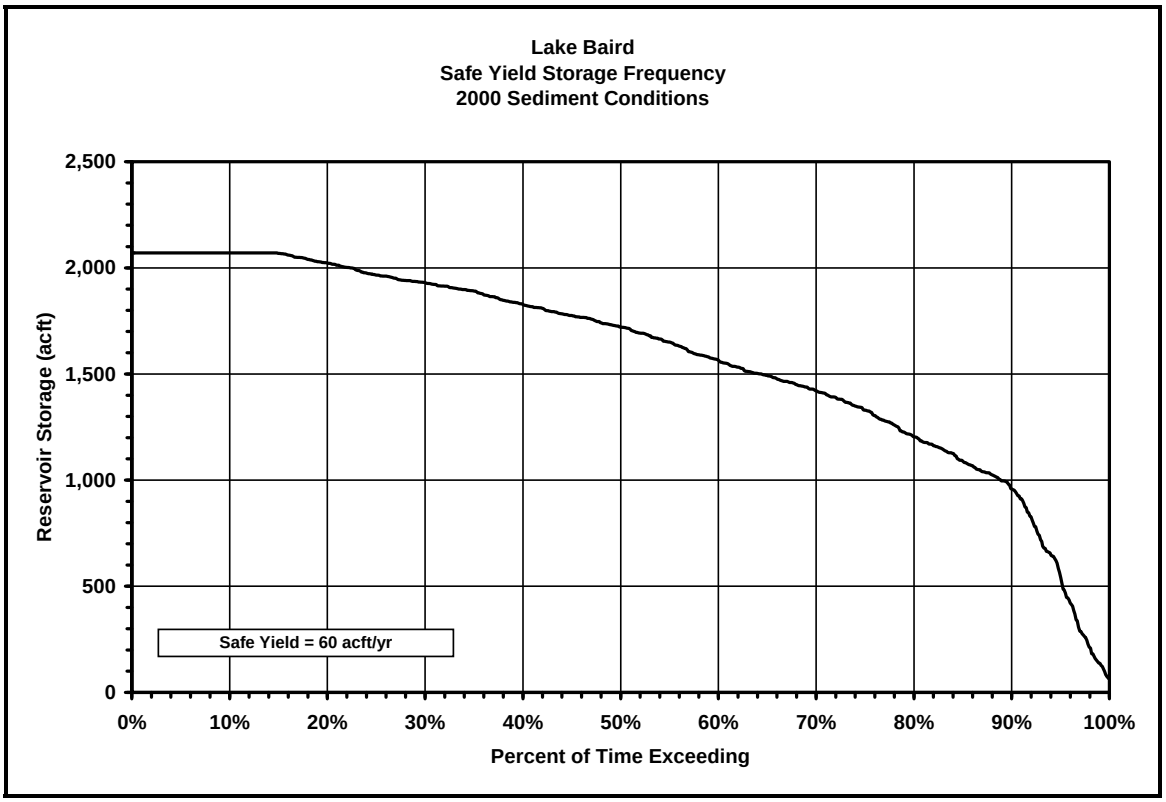

Lake Woodson
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
1,200
1,000
800
600
400
200
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 30 acft/yr

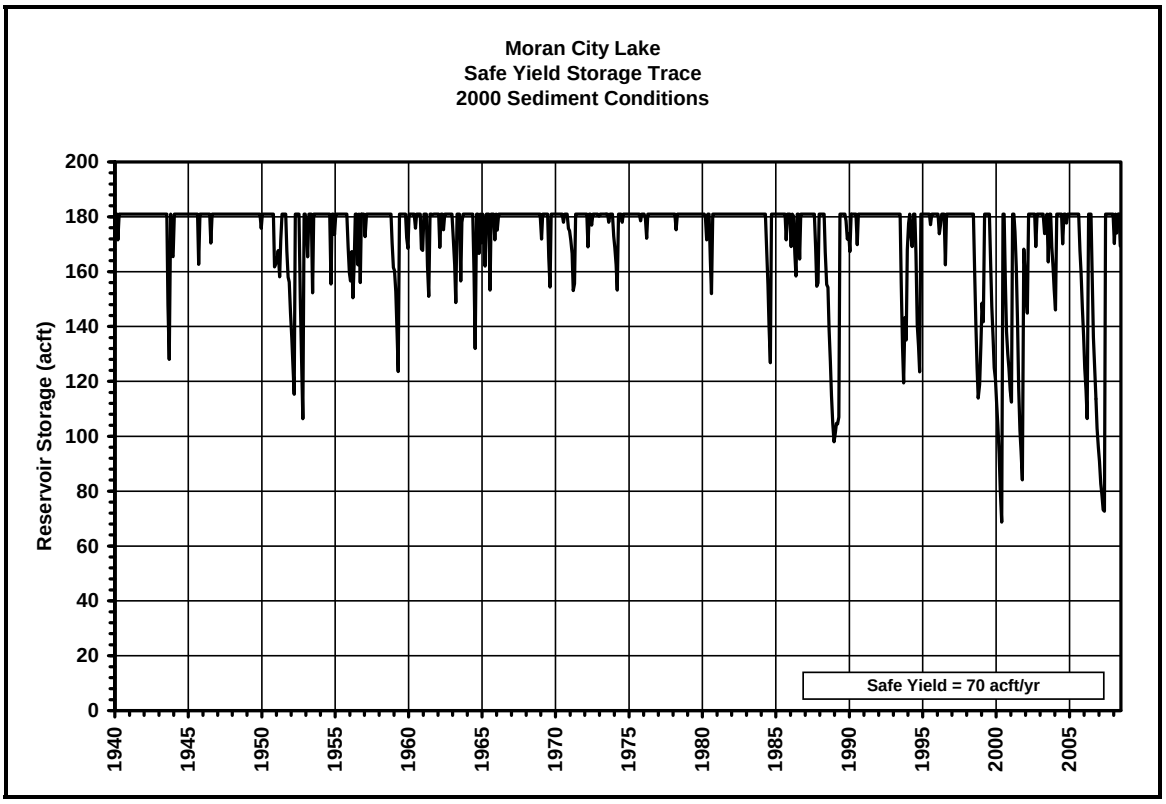

Lake Woodson
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
1,200
1,000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 30 acft/yr

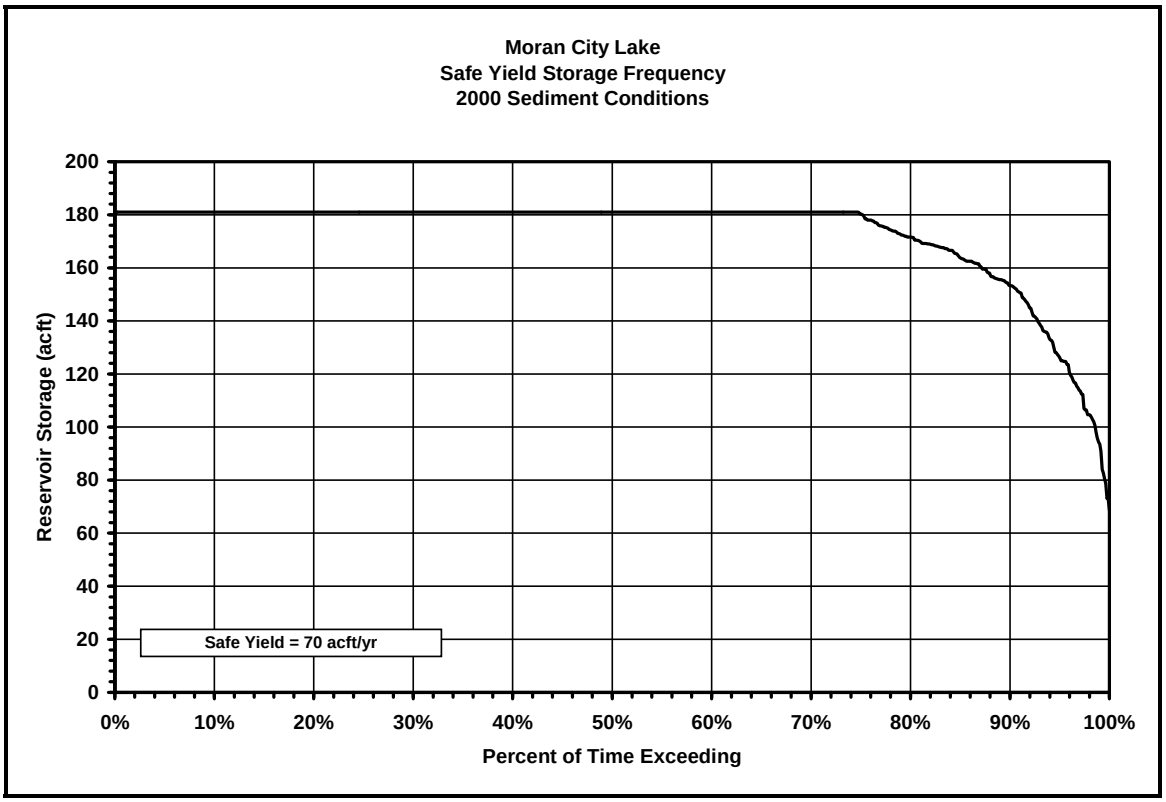

Lake McCarty
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
3,000
2,500
2,000
1,500
1,000
500
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 120 acft/yr

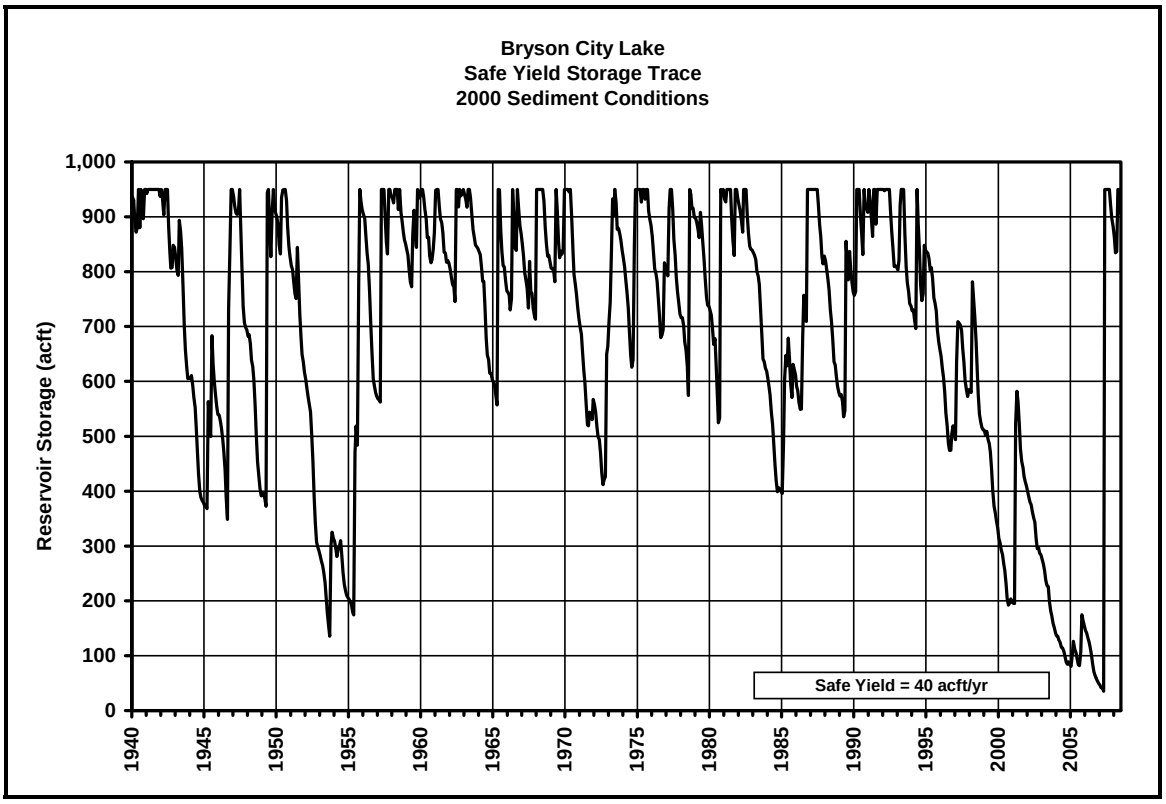

Lake McCarty
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
3,000
2,500
2,000
1,500
1,000
500
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 120 acft/yr

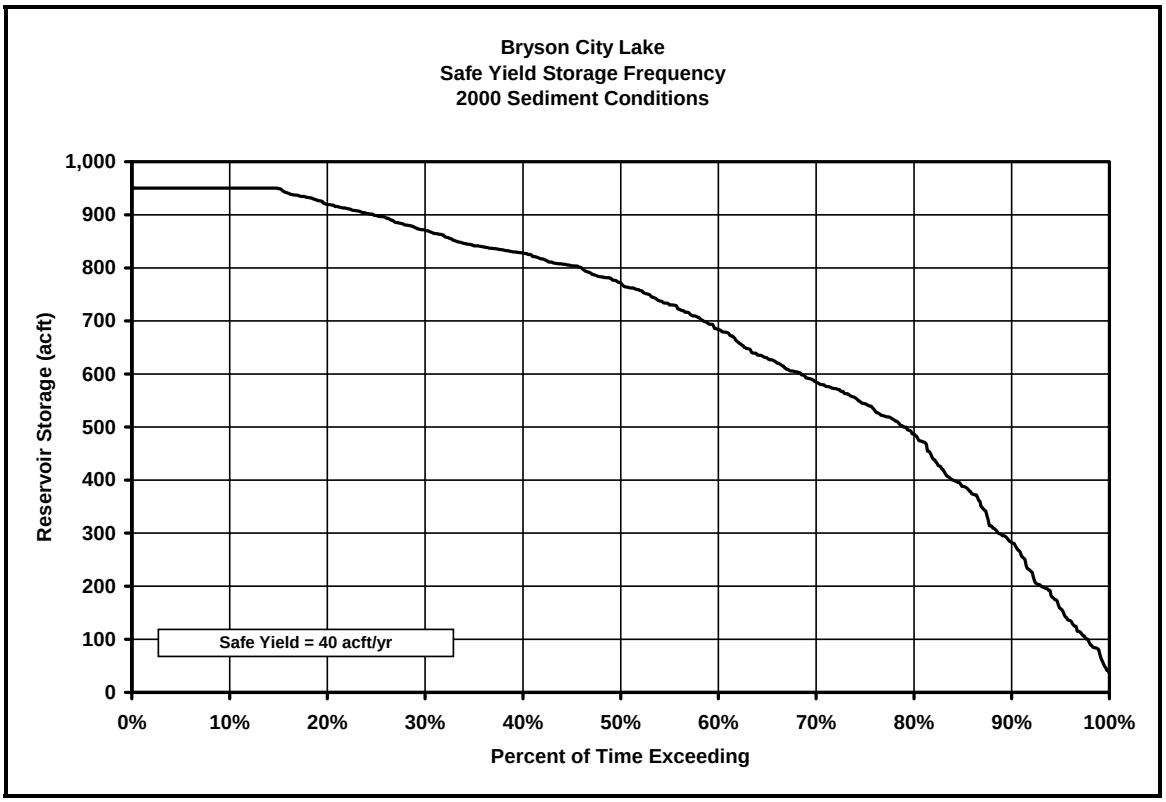

Lake Baird
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
2,500
2,000
1,500
1,000
500
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 60 acft/yr


Lake Baird
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
2,500
2,000
1,500
1,000
500
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 60 acft/yr

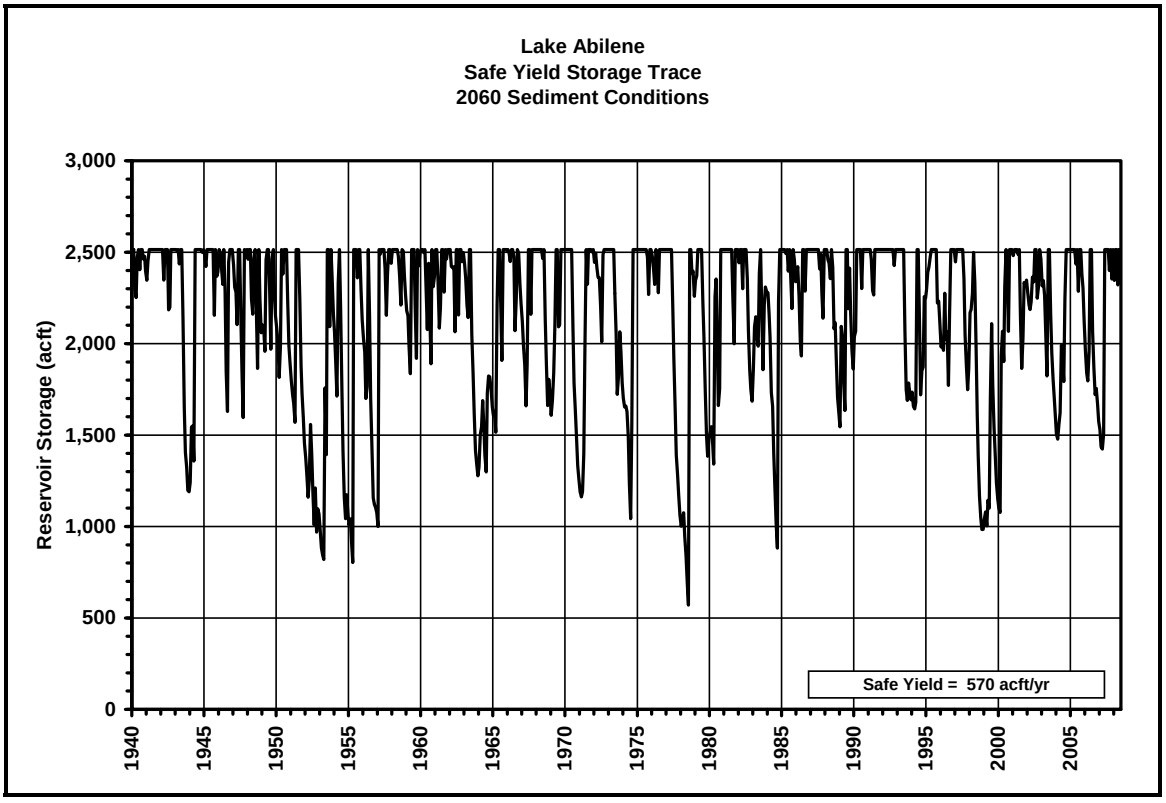

Moran City Lake
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
0
20
40
60
80
100
120
140
160
180
200
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 70 acft/yr

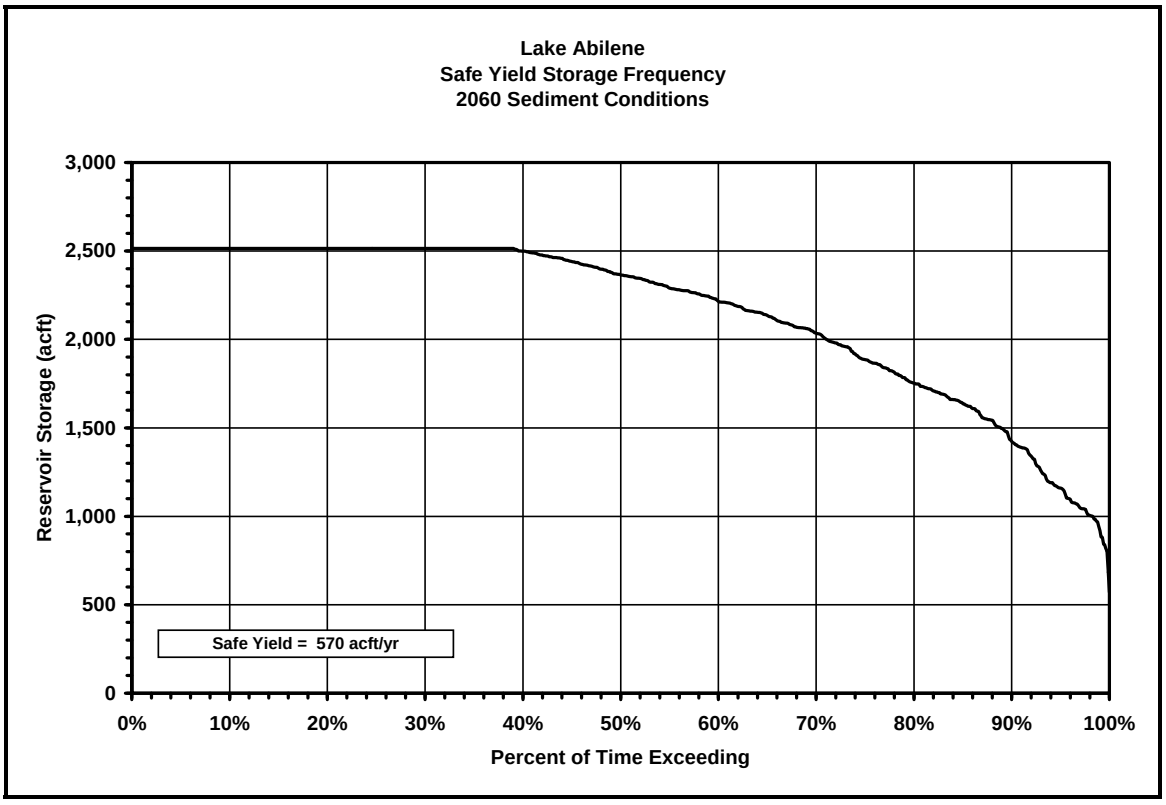

Moran City Lake
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
0
20
40
60
80
100
120
140
160
180
200
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 70 acft/yr

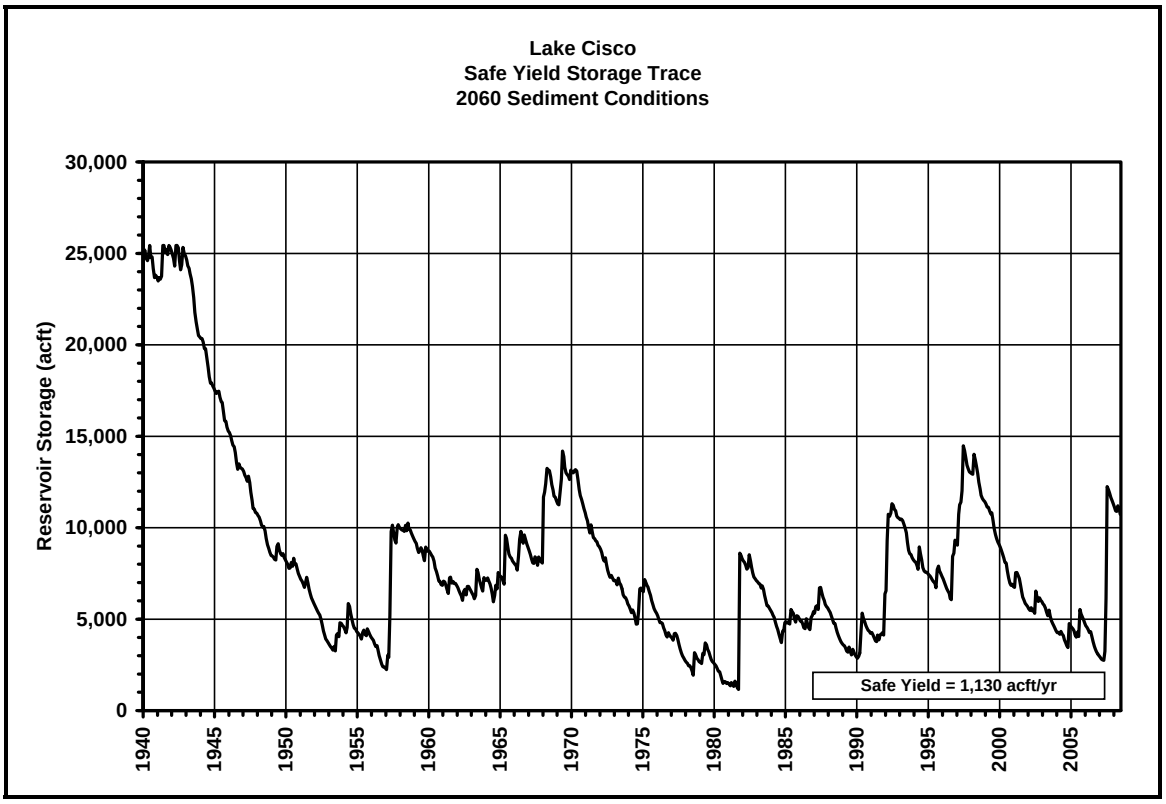

Bryson City Lake
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
1,000
900
800
700
600
500
400
300
200
100
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 40 acft/yr

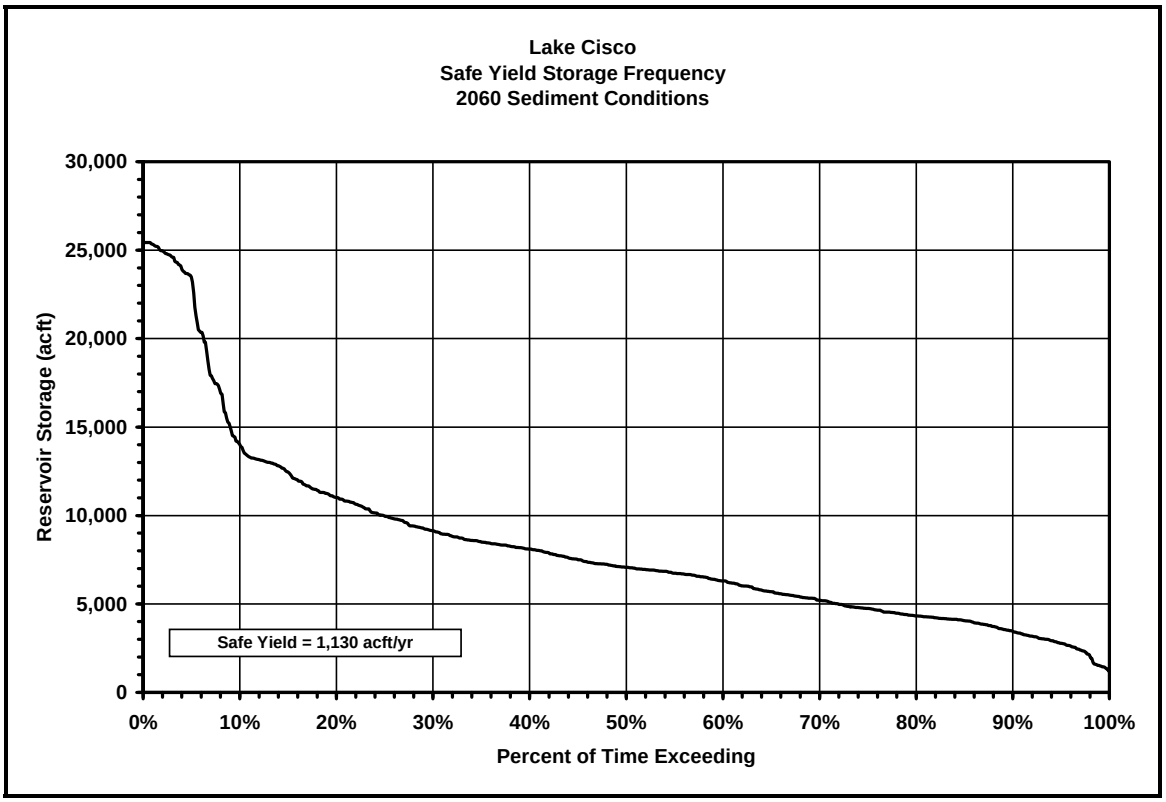

Bryson City Lake
Safe Yield Storage Frequency
2000 Sediment Conditions
Reservoir Storage (acft)
1,000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 40 acft/yr

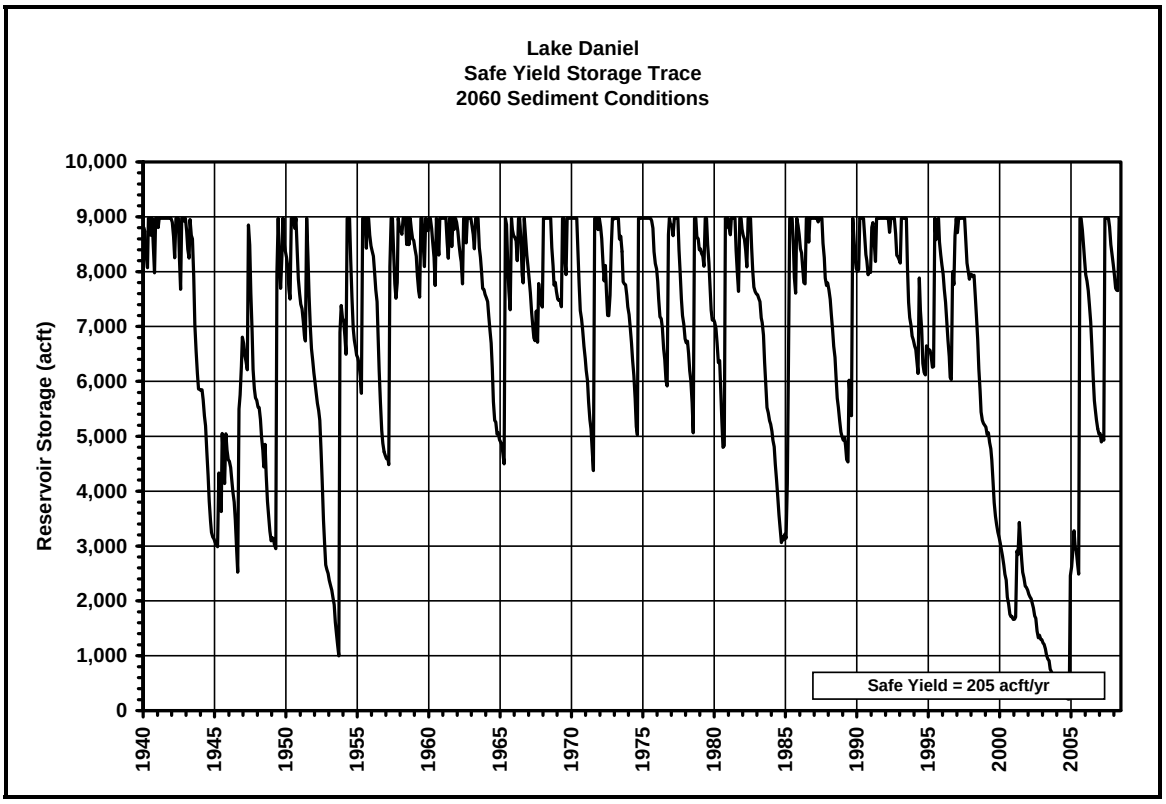
2060 Sediment Conditions

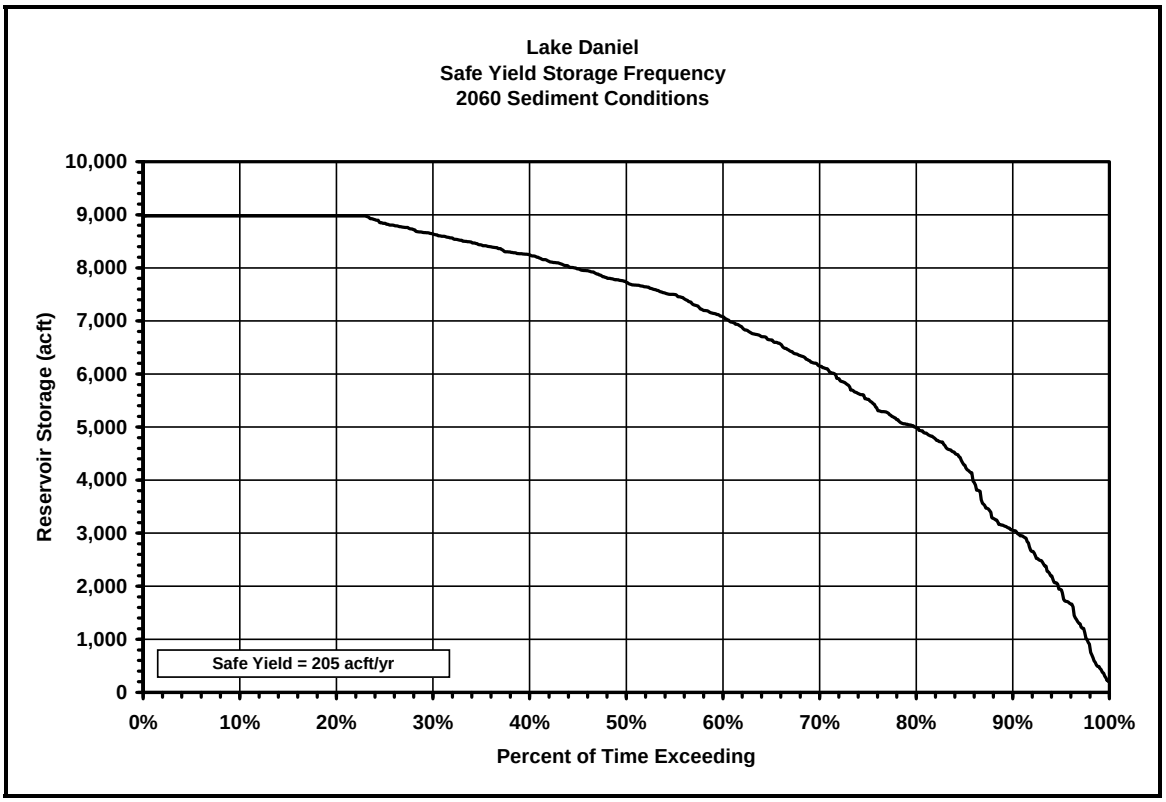


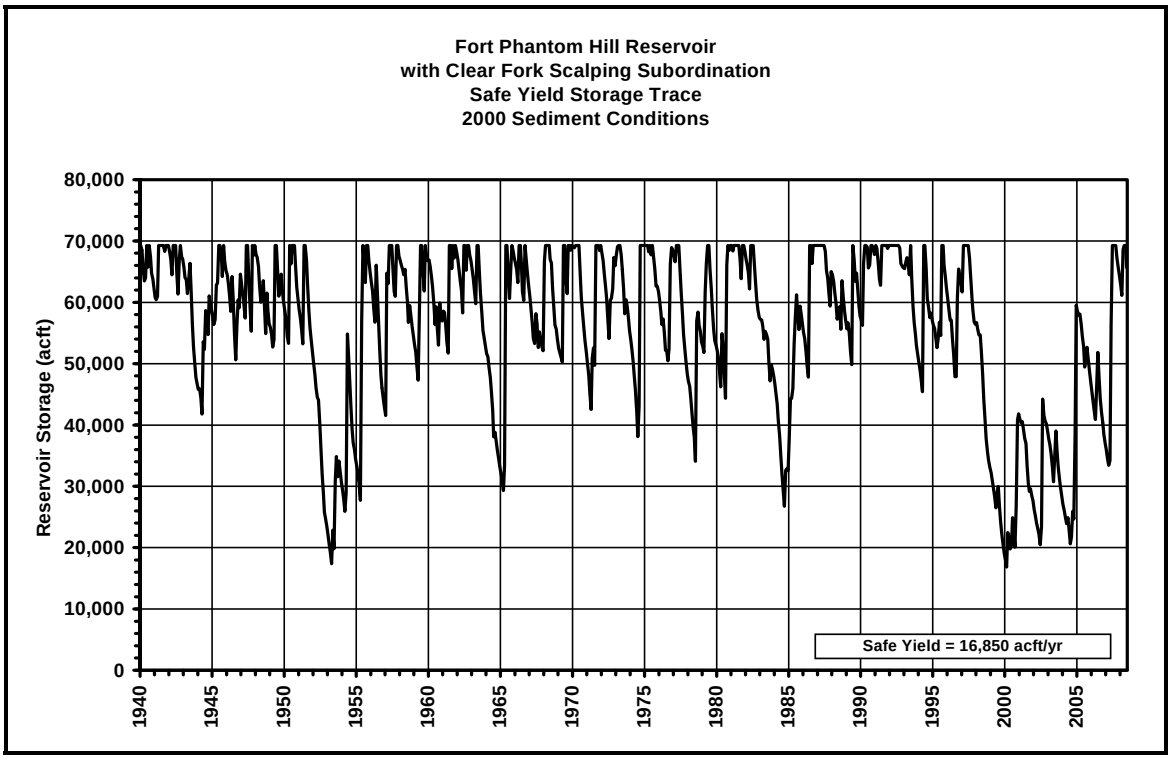


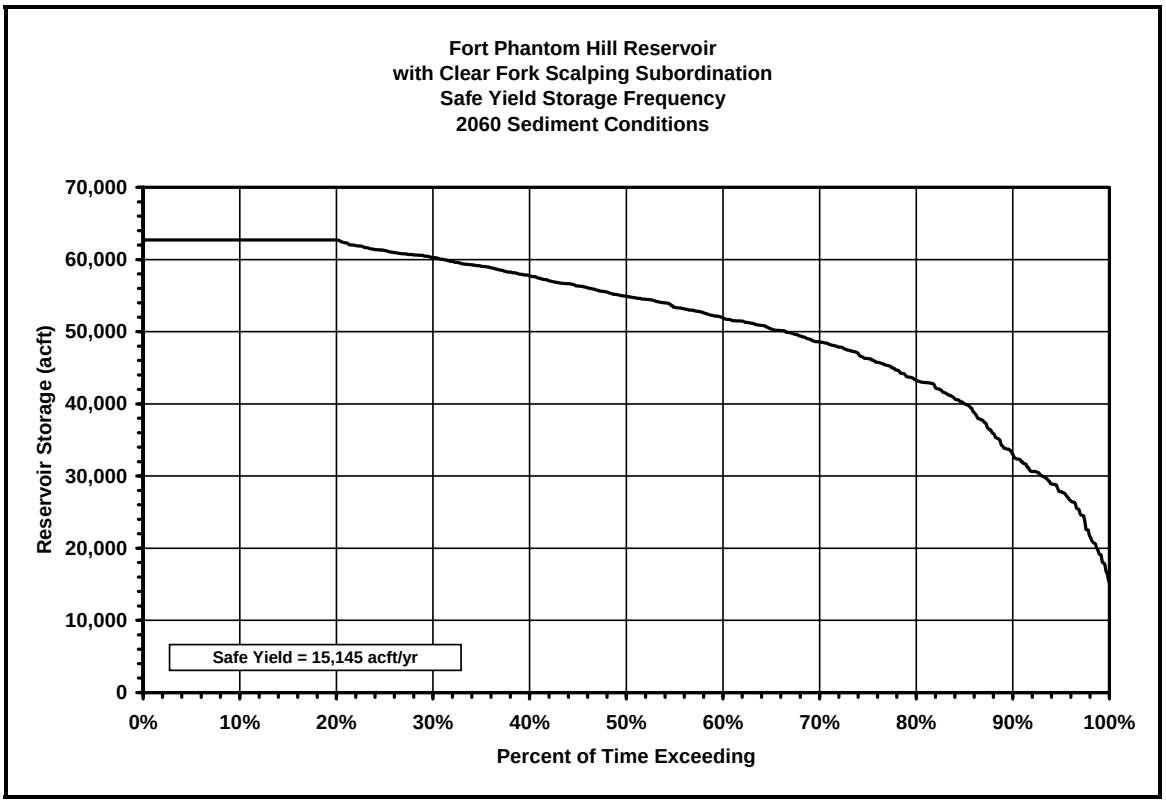

Lake Cisco
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
30,000
25,000
20,000
15,000
10,000
5,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 1,130 acft/yr

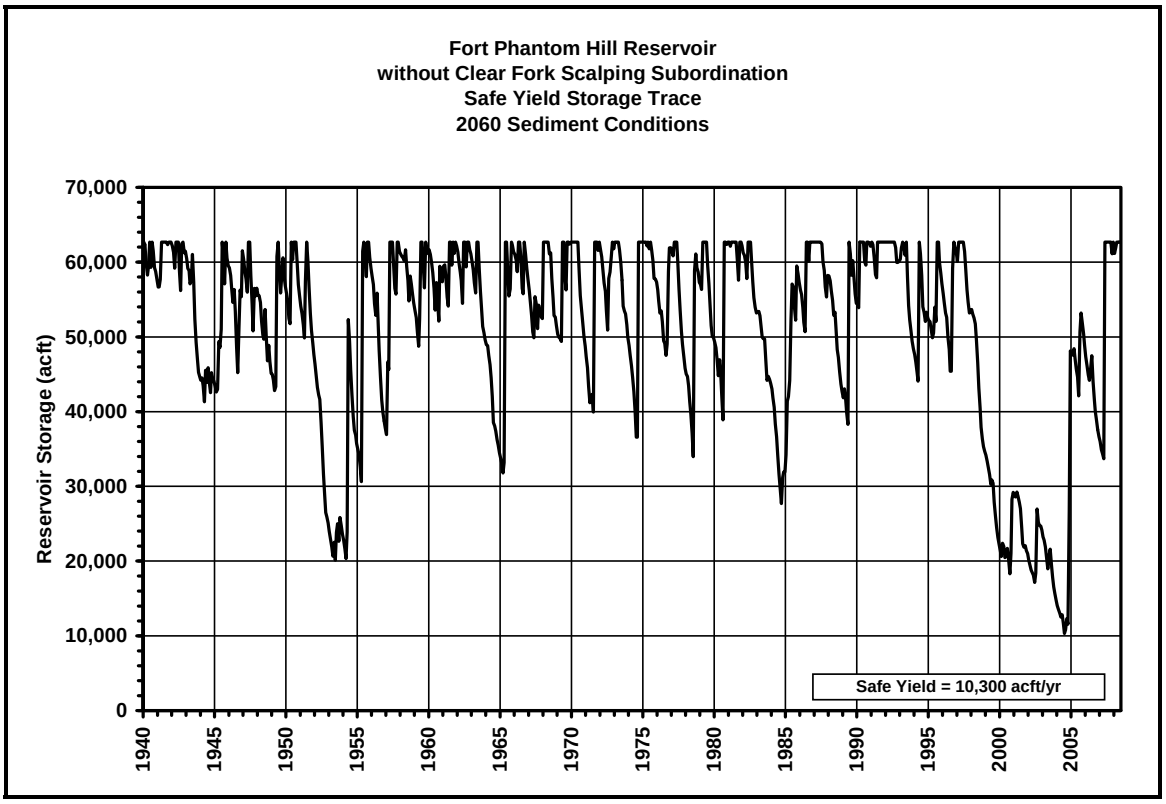

Lake Cisco
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
30,000
25,000
20,000
15,000
10,000
5,000
0
Safe Yield = 1,130 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding

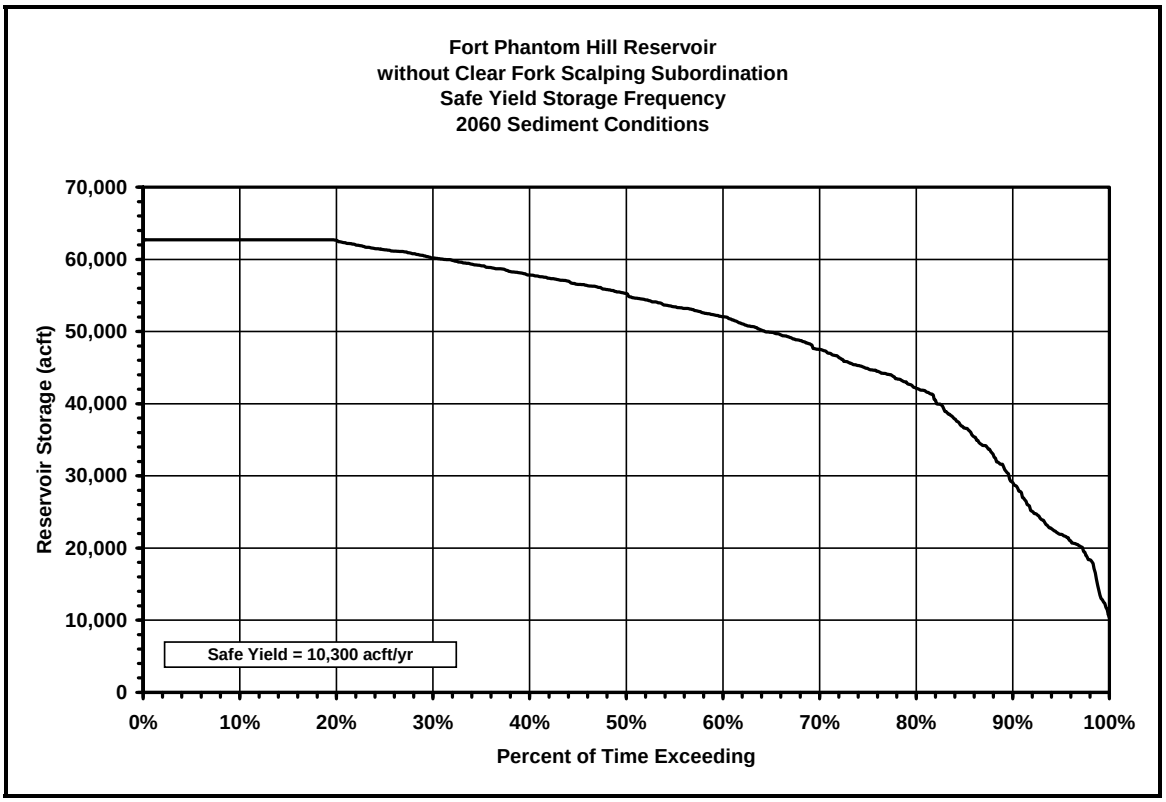

Lake Daniel
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 205 acft/yr

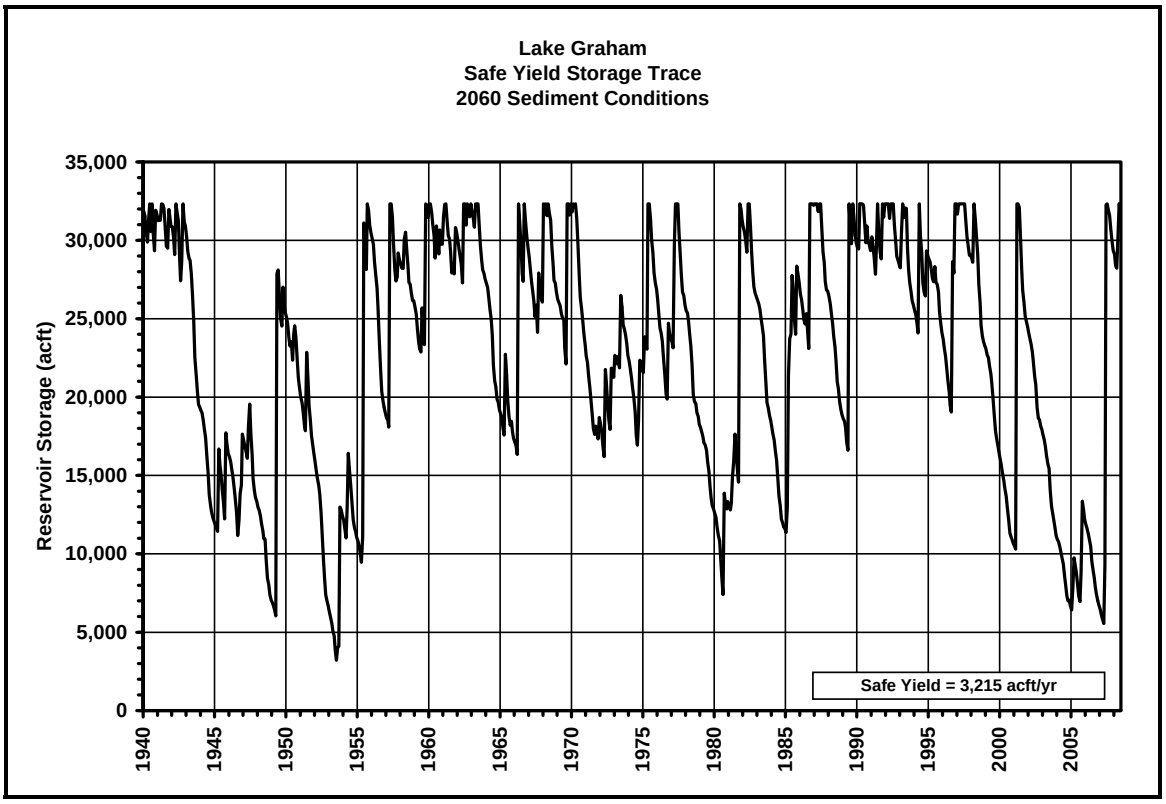

Lake Daniel
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Safe Yield = 205 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding

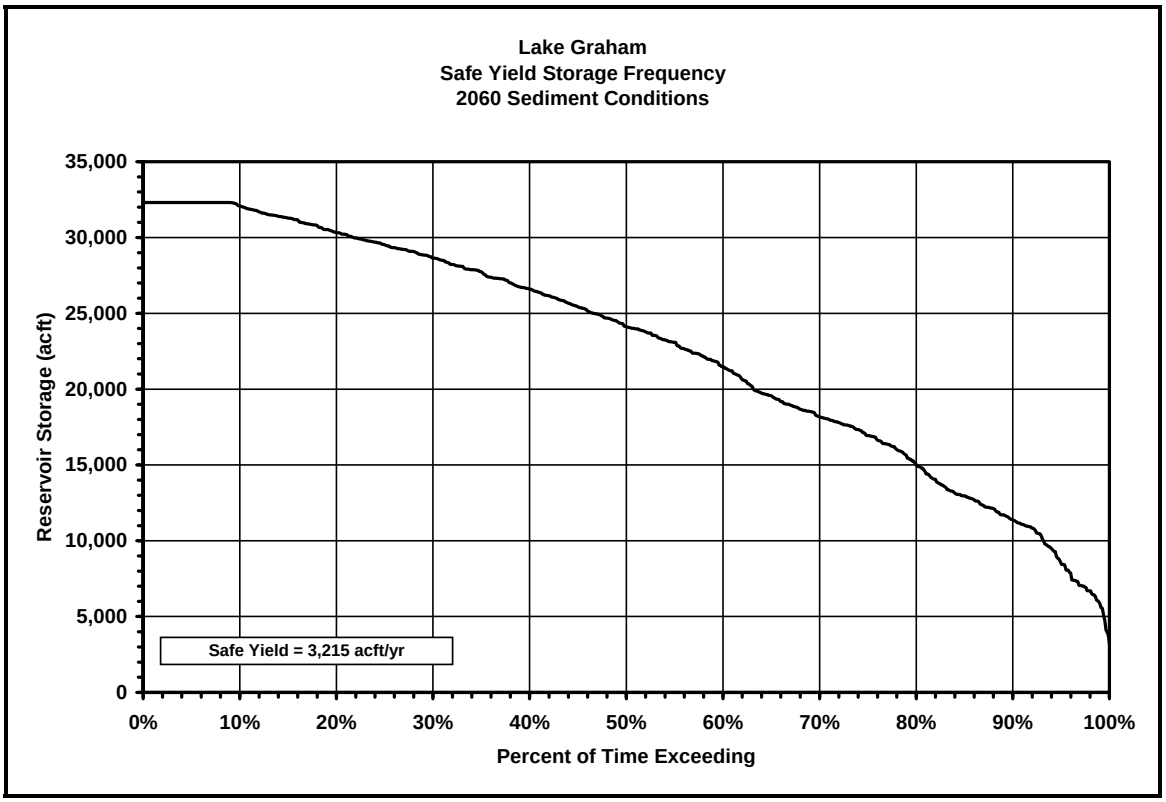

Fort Phantom Hill Reservoir
with Clear Fork Scalping Subordination
Safe Yield Storage Trace
2000 Sediment Conditions
Reservoir Storage (acft)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 16,850 acft/yr

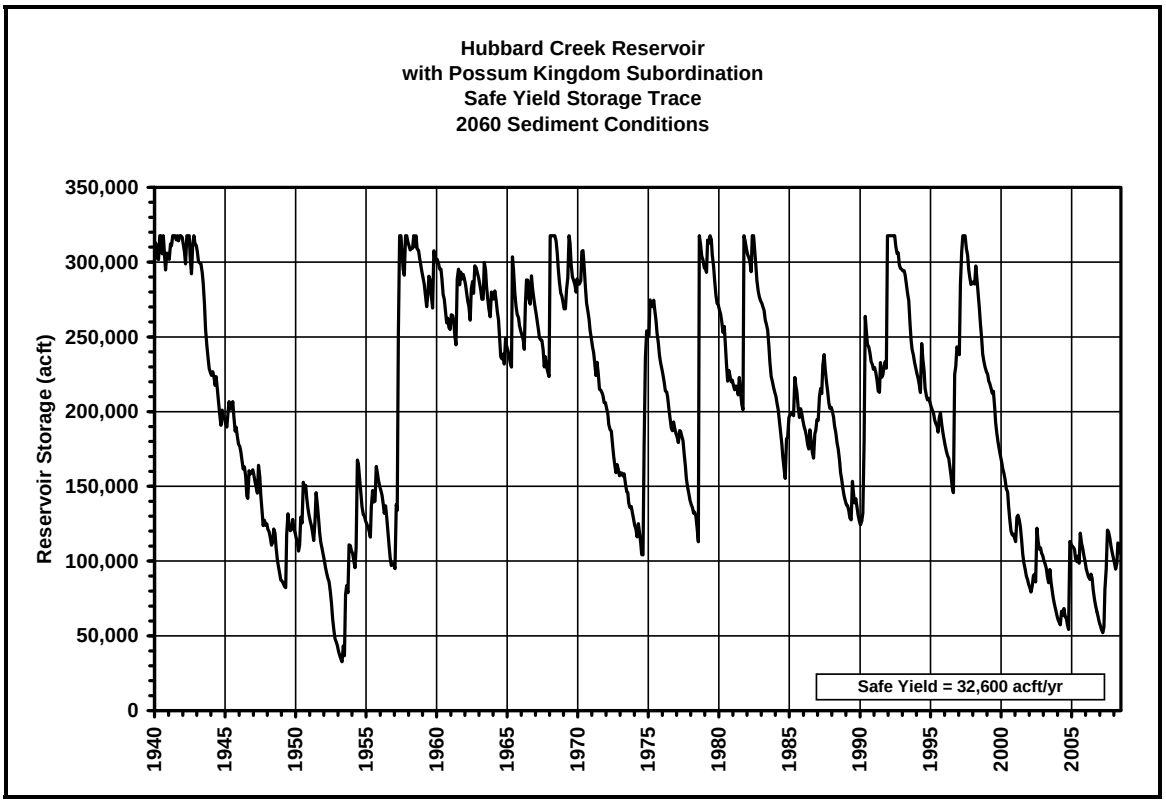

Fort Phantom Hill Reservoir
with Clear Fork Scalping Subordination
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 15,145 acft/yr

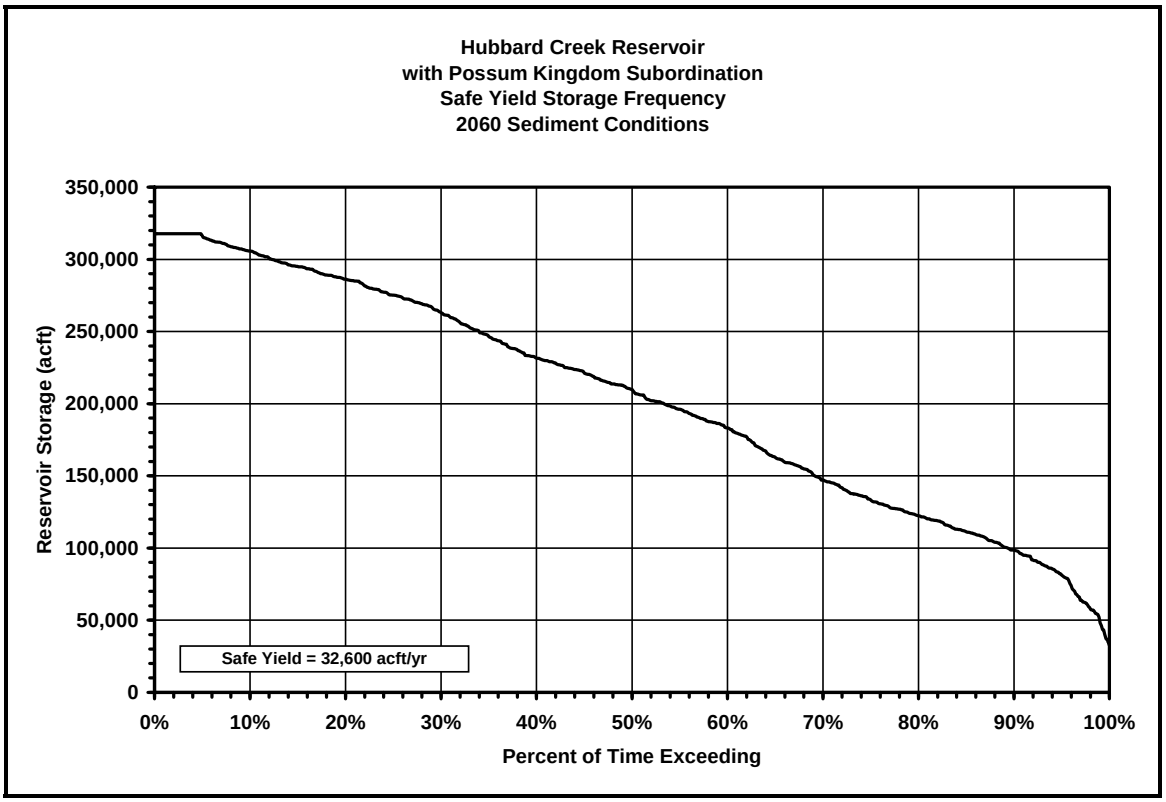

Fort Phantom Hill Reservoir
without Clear Fork Scalping Subordination
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 10,300 acft/yr

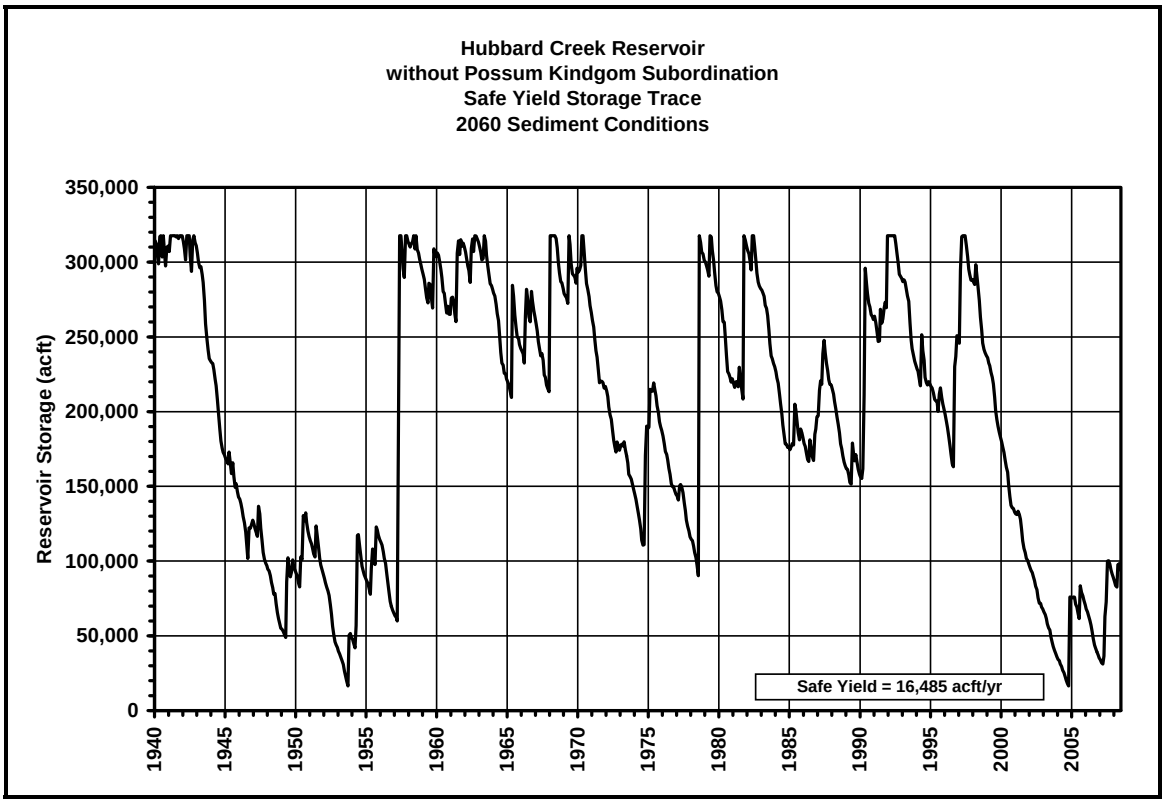

Fort Phantom Hill Reservoir
without Clear Fork Scalping Subordination
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 10,300 acft/yr

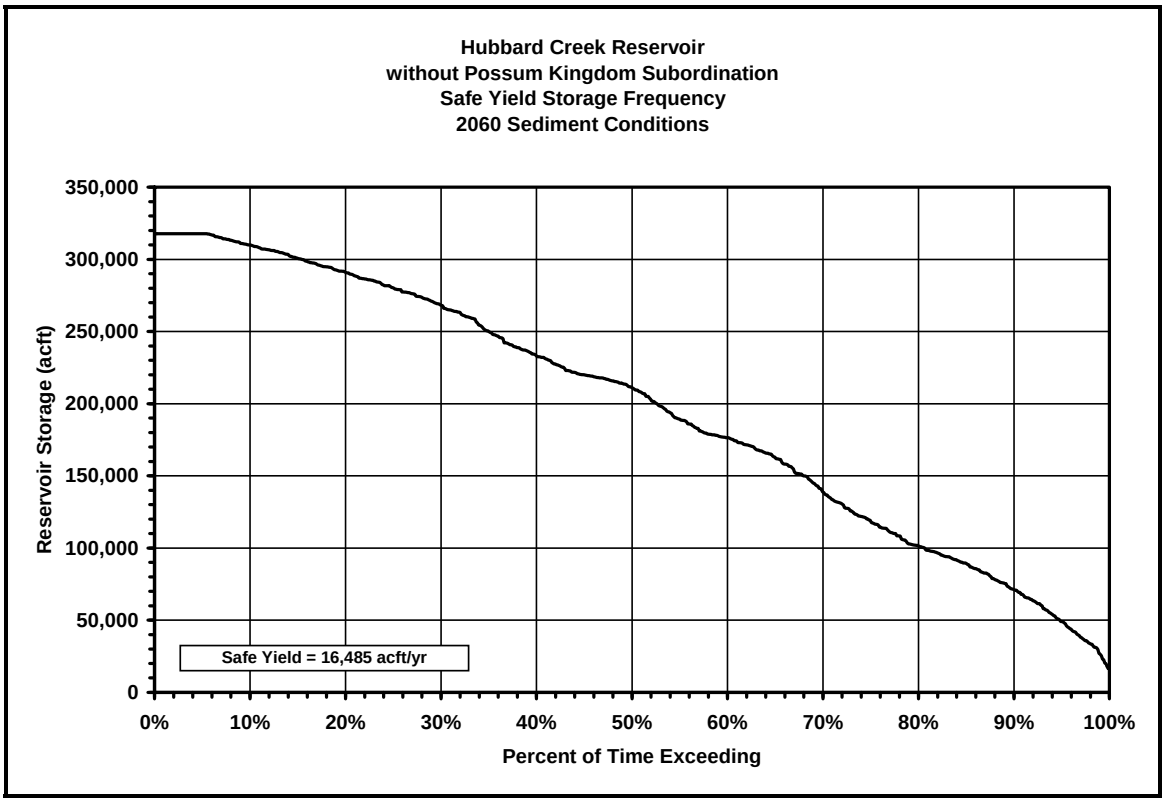

Lake Graham
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 3,215 acft/yr

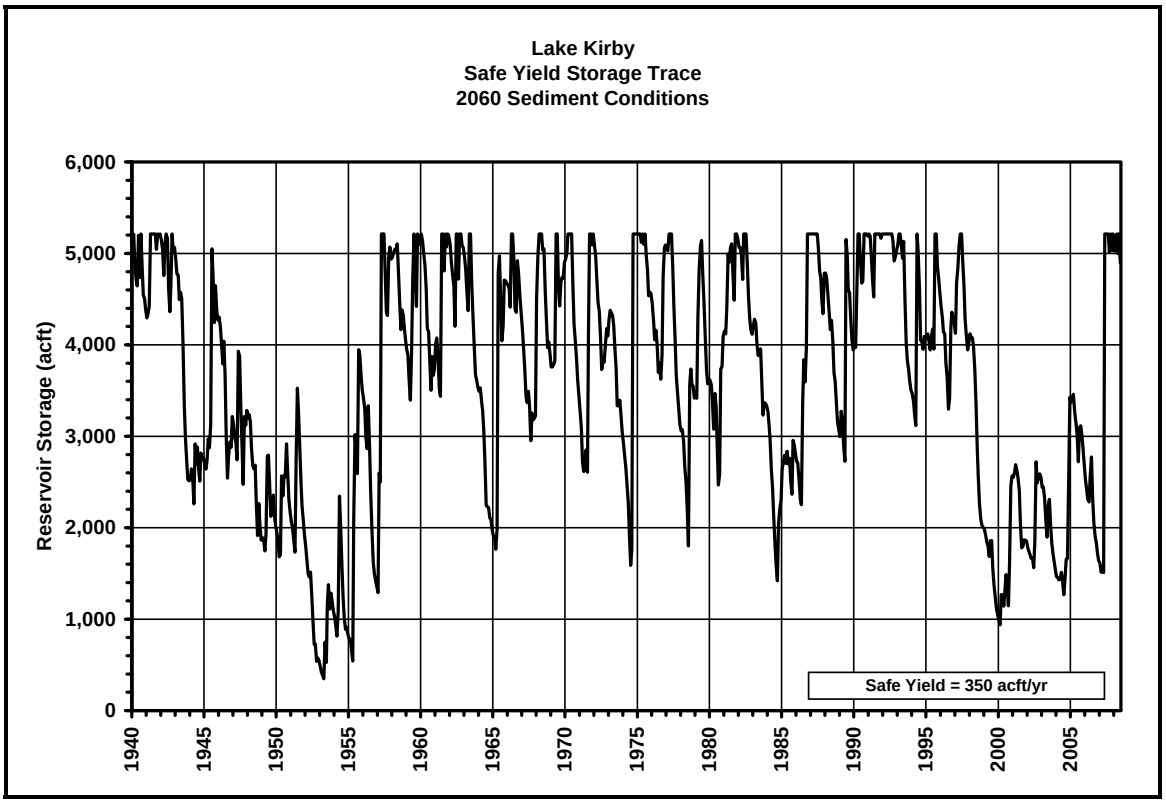

Lake Graham
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 3,215 acft/yr

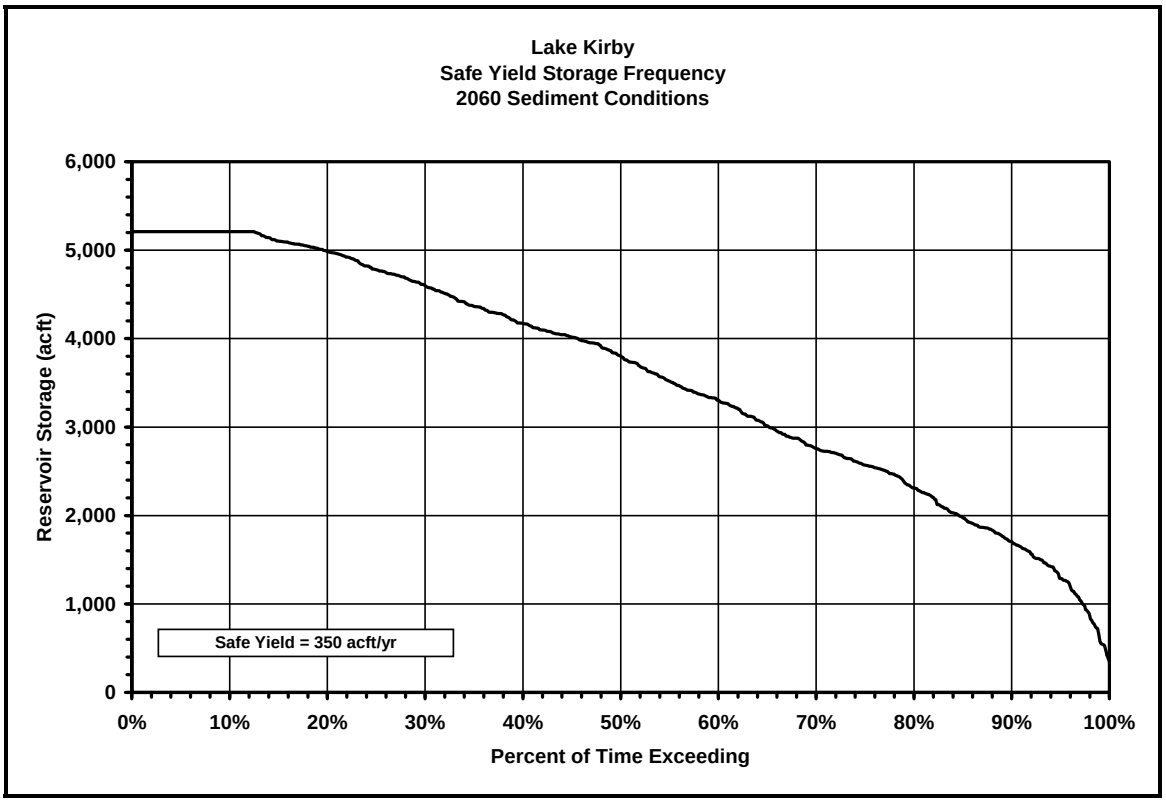

Hubbard Creek Reservoir
with Possum Kingdom Subordination
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 32,600 acft/yr

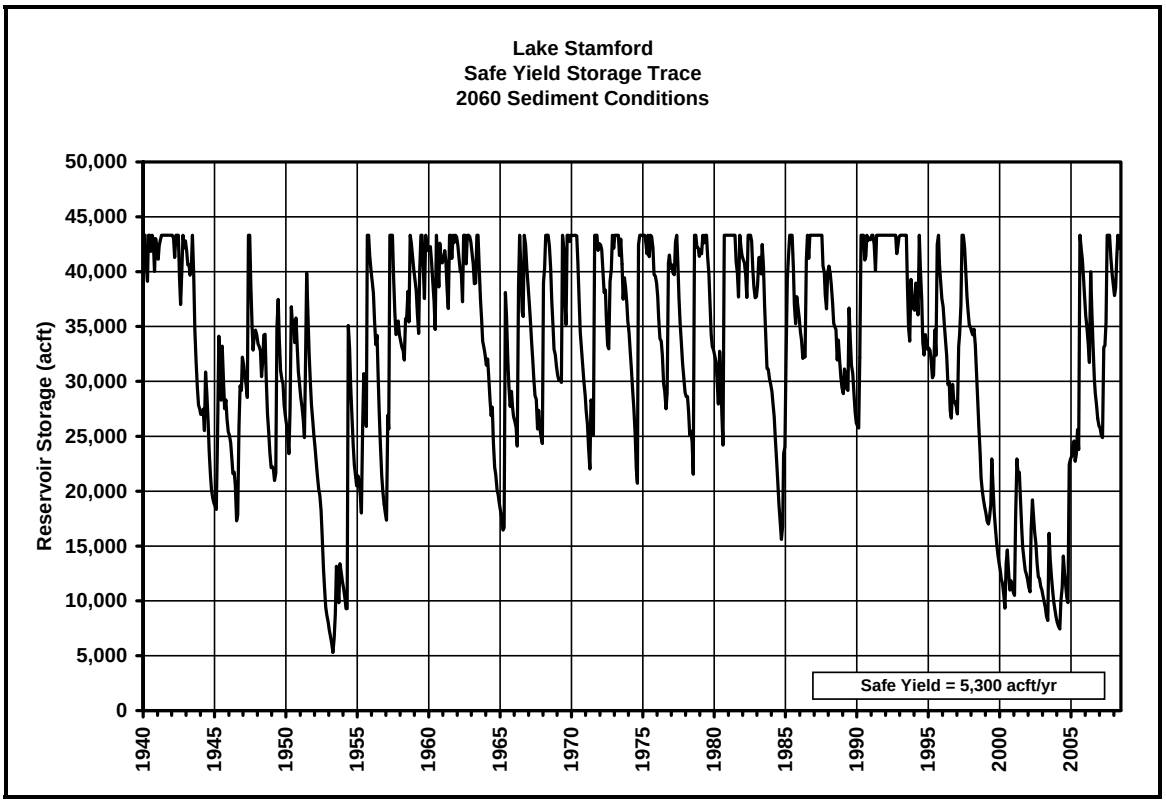

Hubbard Creek Reservoir
with Possum Kingdom Subordination
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 32,600 acft/yr

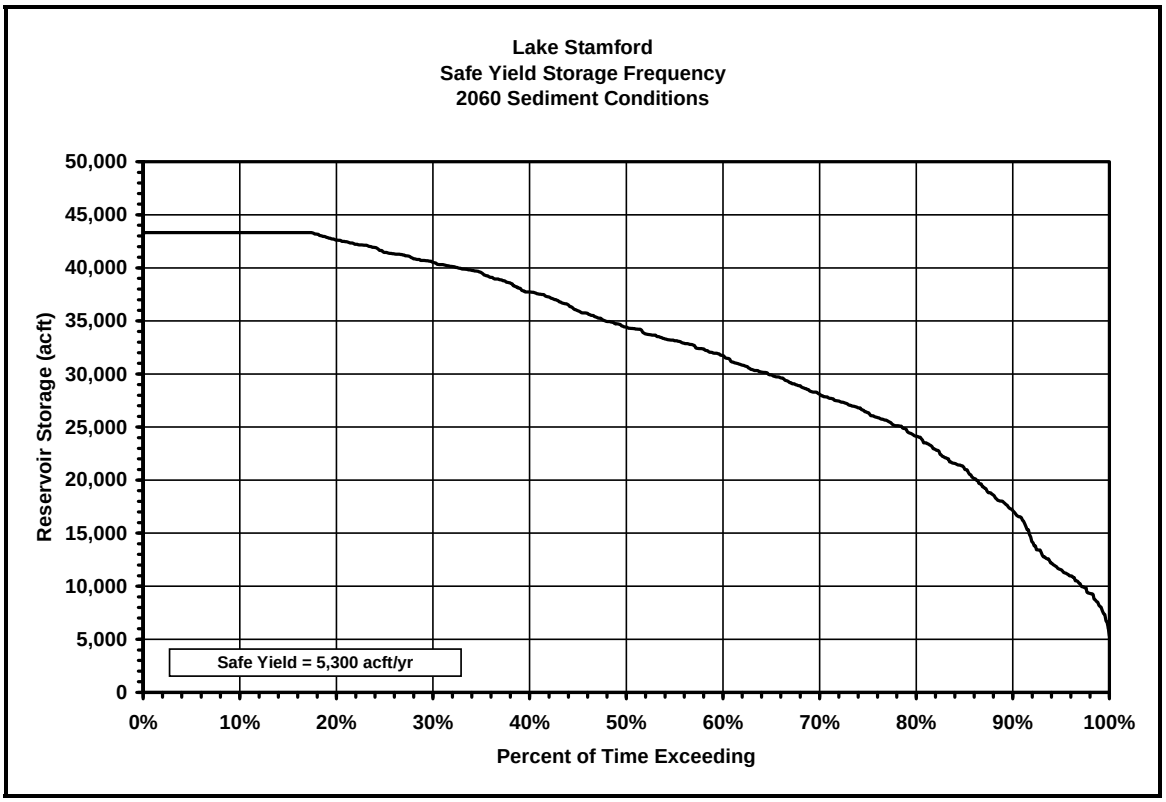

Hubbard Creek Reservoir
without Possum Kindgom Subordination
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 16,485 acft/yr

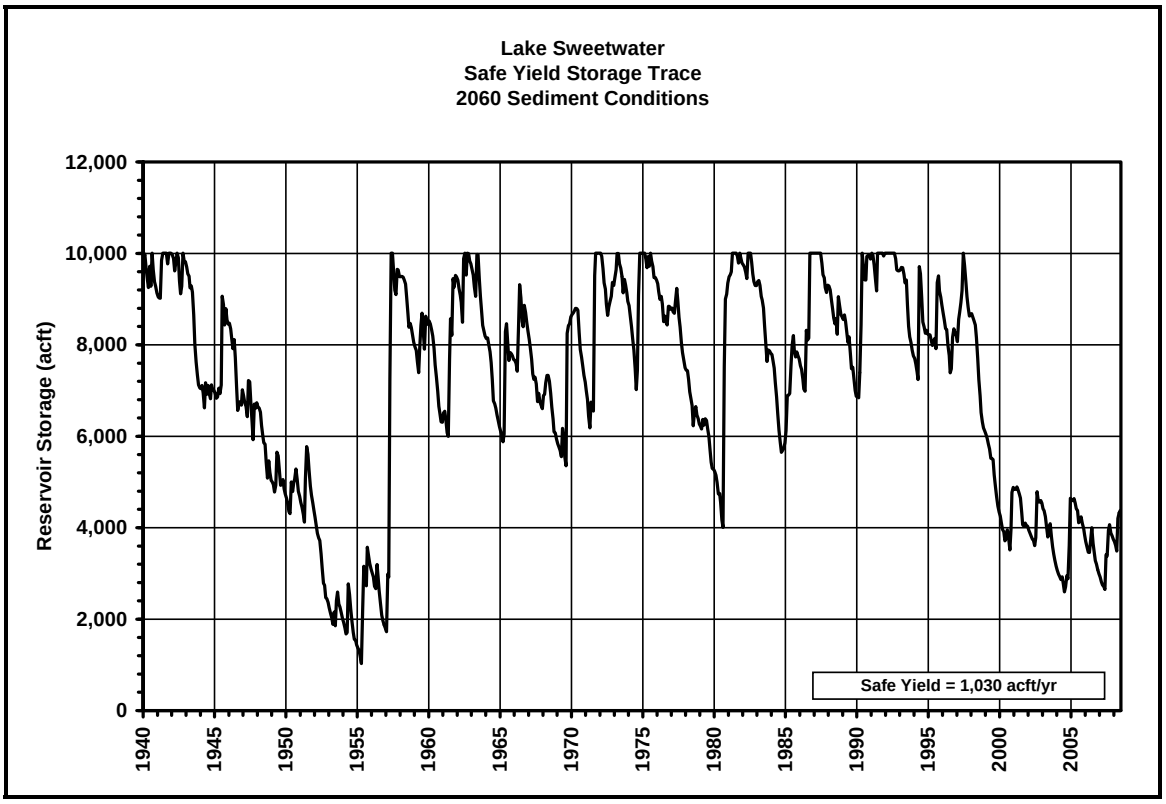

Hubbard Creek Reservoir
without Possum Kingdom Subordination
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 16,485 acft/yr

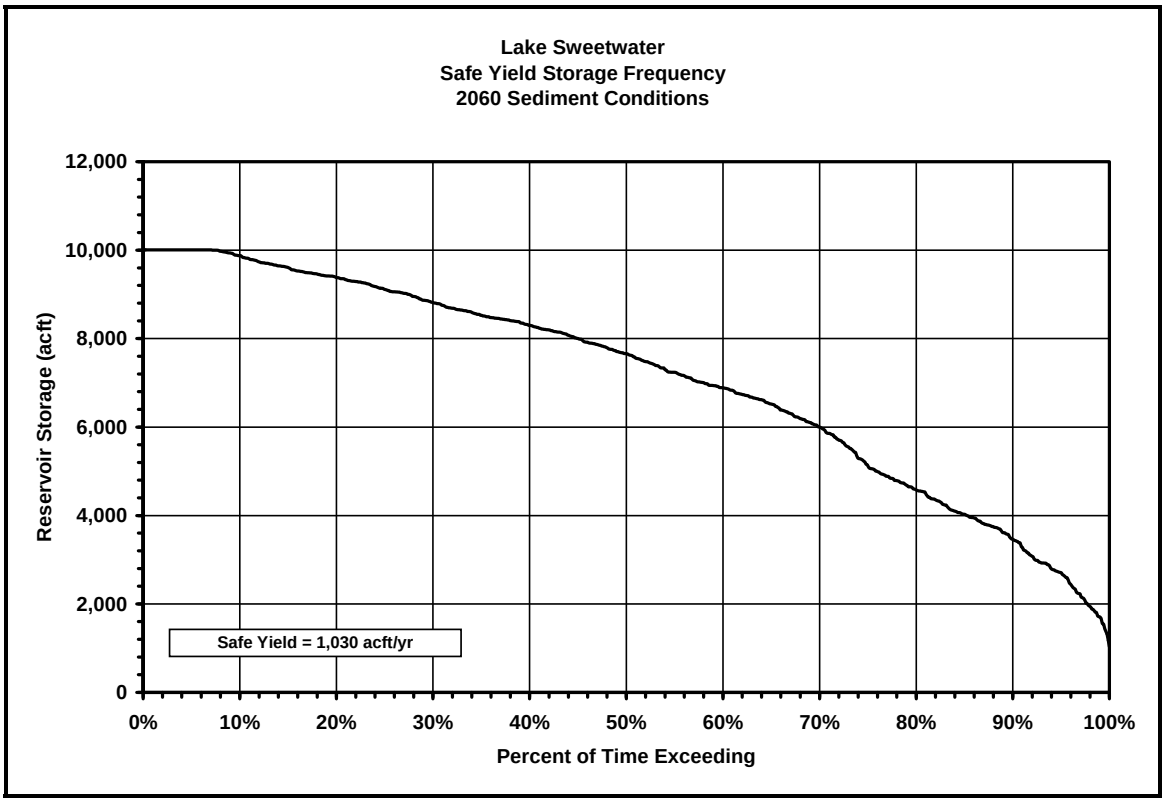

Lake Kirby
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
6,000
5,000
4,000
3,000
2,000
1,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 350 acft/yr


Lake Kirby
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
6,000
5,000
4,000
3,000
2,000
1,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 350 acft/yr


Lake Stamford
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 5,300 acft/yr


Lake Stamford
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Safe Yield = 5,300 acft/yr
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding


Lake Sweetwater
Safe Yield Storage Trace
2060 Sediment Conditions
Reservoir Storage (acft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Safe Yield = 1,030 acft/yr


Lake Sweetwater
Safe Yield Storage Frequency
2060 Sediment Conditions
Reservoir Storage (acft)
12,000
10,000
8,000
6,000
4,000
2,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Exceeding
Safe Yield = 1,030 acft/yr

Appendix C
Updated Model Hydrologic Data
Newly-Developed
Naturalized Flows and Evaporation Rates
January, 1998 – June, 2008

Newly-Developed Naturalized Flows from Brazos Mini-WAM inf File

INBRPP27	1998	23138	15778	153374	14240	12892	8402	6890	2912	0	1305	2039	1439	242409
INBRSB23	1998	8174	10033	106346	10266	5022	4999	12254	0	900	1787	181	911	160873
INBSBR20	1998	355	259	12455	167	0	0	200	0	0	0	0	0	13436
INCAST17	1998	65	91	790	48	0	348	25	0	0	2	65	0	1434
INCCIV25	1998	1303	514	4252	362	687	302	0	250	0	0	160	47	7877
INCFEL22	1998	4771	2882	15361	9364	0	0	3247	0	0	0	0	389	36014
INCFFG18	1998	2991	1807	9631	5871	0	0	2036	0	0	0	0	244	22580
INCFHA14	1998	1998	587	1021	2820	803	36	127	0	0	0	0	293	7685
INCFNU16	1998	4305	1265	2200	6078	1731	77	273	0	0	0	0	632	16561
INCFRO13	1998	48	39	41	31	34	4	1	0	0	1	1	1	201
INGHGH24	1998	4611	1818	15049	1281	2430	1070	0	886	0	0	567	167	27879
INHCAL19	1998	485	348	17492	645	180	135	11	3	4	0	37	63	19403
INHCBR21	1998	3390	1343	37553	278	0	2291	2395	174	0	0	0	0	47424
INMUHA15	1998	353	104	180	498	142	6	22	0	0	0	0	52	1357
INSHGR26	1998	22930	15636	151994	14112	12776	8326	6828	2886	0	1293	2021	1426	240228
INBRPP27	1999	4667	7118	59176	25872	54768	122313	20313	11613	0	7406	1803	1659	316708
INBRSB23	1999	2439	4507	41244	16345	26511	115895	15185	2335	469	0	100	1850	226880
INBSBR20	1999	39	0	836	397	242	3684	0	0	0	0	0	0	5198
INCAST17	1999	115	29	178	905	1839	8477	86	0	0	0	0	8	11637
INCCIV25	1999	196	233	1623	851	2482	778	471	802	0	637	147	0	8220
INCFEL22	1999	1228	1866	1140	8292	5685	32444	6843	0	0	0	0	4846	62344
INCFFG18	1999	770	1170	715	5199	3564	20341	4290	0	0	0	0	3038	39087
INCFHA14	1999	619	687	0	1352	489	3827	3892	0	0	0	0	40	10906
INCFNU16	1999	1333	1481	0	2913	1053	8247	8389	0	0	0	0	87	23503
INCFRO13	1999	0	0	2	3	113	2355	4	0	0	0	0	0	2477
INGHGH24	1999	695	826	5743	3013	8784	2753	1666	2840	0	2254	519	0	29093
INHCAL19	1999	66	9	2309	275	63	5083	206	14	2	2	0	12	8041
INHCBR21	1999	702	0	11352	2633	1255	7892	0	0	0	0	0	0	23834
INMUHA15	1999	109	121	0	239	86	676	688	0	0	0	0	7	1926
INSHGR26	1999	4625	7054	58643	25639	54275	121212	20130	11508	0	7339	1787	1644	313856
INBRPP27	2000	4880	4641	49718	24835	15649	31491	20911	3325	0	5255	57151	11095	228951
INBRSB23	2000	0	166	55354	22740	14898	23878	19473	368	0	7348	45040	10595	199860
INBSBR20	2000	0	0	0	0	0	1291	0	0	0	0	850	0	2141
INCAST17	2000	20	13	216	45	39	5577	1074	27	25	2361	1353	101	10851
INCCIV25	2000	420	385	0	225	94	701	162	255	0	0	1129	64	3435
INCFEL22	2000	0	0	10897	3995	0	10674	22727	2086	0	14352	32621	5094	102446
INCFFG18	2000	0	0	6832	2505	0	6692	14249	1308	0	8998	20452	3194	64230
INCFHA14	2000	177	417	5139	2010	410	2589	5863	1766	0	6040	9722	2539	36672
INCFNU16	2000	382	898	11076	4331	883	5579	12636	3805	0	13017	20953	5472	79032
INCFRO13	2000	0	0	11079	94	2	1007	185	0	0	45	2	0	12414
INGHGH24	2000	1485	1363	0	795	331	2482	572	903	0	0	3997	225	12153
INHCAL19	2000	0	0	0	0	0	1257	117	0	0	0	0	0	1374
INHCBR21	2000	0	279	1621	2020	0	3116	0	0	0	188	2474	527	10225
INMUHA15	2000	31	74	908	355	72	457	1036	312	0	1067	1718	449	6479
INSHGR26	2000	4836	4599	49271	24611	15508	31208	20723	3295	0	5208	56637	10995	226891
INBRPP27	2001	16927	137562	187757	35205	27629	9255	0	1917	1056	10984	12518	7569	448379
INBRSB23	2001	7781	79494	115144	16965	20743	9179	8762	2185	20473	12146	9720	3699	306291
INBSBR20	2001	49	8751	945	594	235	0	0	0	0	0	0	0	10574
INCAST17	2001	49	4201	2421	241	427	0	0	0	228	3224	574	400	11765

INCCIV25	2001	802	5149	6469	1602	633	24	0	0	0	0	260	340	15279
INCFEL22	2001	0	22201	21288	4448	9181	5807	365	0	3925	10640	2861	2453	83169
INCFFG18	2001	0	13919	13347	2789	5756	3641	229	0	2461	6671	1794	1538	52145
INCFHA14	2001	0	575	1430	1618	917	2627	605	0	1661	2500	0	630	12563
INCFNU16	2001	0	1239	3082	3486	1976	5662	1304	0	3580	5388	0	1358	27075
INCFRO13	2001	2	13	15	0	60	55	0	0	140	78	5	2	370
INGHGH24	2001	2838	18224	22898	5669	2239	86	0	0	0	0	919	1204	54077
INHCAL19	2001	0	2915	518	22	0	0	0	0	6	0	276	0	3737
INHCBR21	2001	1011	19072	4009	2187	60	0	0	0	0	733	0	0	27072
INMUHA15	2001	0	102	253	286	162	464	107	0	294	442	0	111	2221
INSHGR26	2001	16775	136324	186067	34888	27380	9172	0	1900	1046	10885	12405	7501	444343
INBRPP27	2002	5719	5620	29452	59317	30717	30458	60438	18530	3799	9677	19593	14192	287512
INBRSB23	2002	2123	811	13168	61326	34275	40580	100986	26391	3062	11100	18806	10269	322897
INBSBR20	2002	0	0	2586	66	2638	39	14128	0	0	2464	37	202	22160
INCAST17	2002	61	126	3035	4633	1693	153	18004	115	117	1001	376	361	29675
INCCIV25	2002	313	415	1426	0	0	0	0	0	69	0	104	357	2684
INCFEL22	2002	1029	67	20094	38038	16079	18145	64519	28121	0	2834	6390	735	196051
INCFFG18	2002	645	42	12598	23848	10081	11376	40451	17631	0	1777	4006	461	122916
INCFHA14	2002	354	71	399	1398	1819	1651	4010	14359	0	133	1789	74	26057
INCFNU16	2002	762	154	860	3013	3921	3559	8643	30946	0	286	3856	159	56159
INCFRO13	2002	0	0	1	0	100	6	56	0	0	12	3	8	186
INGHGH24	2002	1109	1469	5048	0	0	0	0	0	245	0	369	1265	9505
INHCAL19	2002	0	0	3100	10753	1090	80	24618	180	14	786	161	169	40951
INHCBR21	2002	1957	467	7437	10680	5405	415	41376	0	76	2154	430	902	71299
INMUHA15	2002	62	13	71	247	322	292	709	2538	0	23	316	13	4606
INSHGR26	2002	5668	5569	29187	58783	30441	30184	59894	18363	3765	9590	19417	14064	284925
INBRPP27	2003	7522	7372	13116	8784	6035	99162	19456	0	9534	1111	0	363	172455
INBRSB23	2003	4746	3492	4593	2221	1151	95455	20099	0	6150	171	225	151	138454
INBSBR20	2003	0	0	3	0	0	4350	0	0	0	0	0	0	4353
INCAST17	2003	154	102	88	82	1130	32517	566	201	205	71	57	79	35252
INCCIV25	2003	248	340	742	569	422	505	0	0	303	81	0	19	3229
INCFEL22	2003	0	630	2058	2105	0	72558	12719	0	0	0	0	0	90070
INCFFG18	2003	0	395	1290	1320	0	45491	7974	0	0	0	0	0	56470
INCFHA14	2003	0	503	733	636	0	4675	5725	0	0	0	187	117	12576
INCFNU16	2003	0	1084	1580	1371	0	10075	12338	0	0	0	404	252	27104
INCFRO13	2003	0	0	0	0	7	1821	11	0	0	0	0	0	1839
INGHGH24	2003	878	1205	2626	2013	1495	1787	0	0	1073	287	0	66	11430
INHCAL19	2003	65	111	107	31	50	8940	26	482	101	0	0	0	9913
INHCBR21	2003	72	297	1527	565	47	12288	0	0	436	0	0	0	15232
INMUHA15	2003	0	89	130	112	0	826	1012	0	0	0	33	21	2223
INSHGR26	2003	7454	7306	12998	8705	5981	98270	19281	0	9448	1101	0	360	170904
INBRPP27	2004	1474	15342	32046	40140	15697	56419	71258	135407	16922	34132	307112	65608	791557
INBRSB23	2004	672	5339	22098	33240	10661	57651	118253	139319	26026	42495	308553	61868	826175
INBSBR20	2004	0	674	326	2547	556	194	0	116	0	1097	13687	281	19478
INCAST17	2004	111	116	130	1062	2769	4395	1279	989	40	89	6505	481	17966
INCCIV25	2004	70	871	899	658	454	6	0	0	0	0	478	442	3878
INCFEL22	2004	0	297	3627	12892	9339	12821	18129	15958	10383	0	89079	32763	205288
INCFFG18	2004	0	186	2274	8083	5855	8038	11366	10005	6510	0	55849	20541	128707
INCFHA14	2004	0	124	1105	887	3193	630	865	3096	4941	0	8341	12778	35960
INCFNU16	2004	0	268	2382	1912	6882	1357	1864	6673	10648	0	17977	27538	77501
INCFRO13	2004	0	0	2	0	1	157	22	11	0	2	15	0	210

INGHGH24	2004	249	3082	3181	2330	1607	23	0	0	0	0	1691	1565	13728
INHCAL19	2004	0	198	175	8511	852	618	32	3135	118	1132	47743	2333	64847
INHCBR21	2004	641	3389	2160	12398	2265	8219	0	4232	0	1441	66539	2604	103888
INMUHA15	2004	0	22	195	157	564	111	153	547	873	0	1474	2258	6354
INSHGR26	2004	1461	15204	31758	39779	15556	55911	70617	134188	16770	33825	304348	65018	784435
INBRPP27	2005	32143	30716	36695	20187	10628	33027	8714	404076	50035	30635	7747	5794	670397
INBRSB23	2005	32256	24647	26298	14743	11220	32599	8744	459751	42134	16592	8276	6661	683921
INBSBR20	2005	10	50	160	59	260	5504	0	16803	221	0	0	0	23067
INCAST17	2005	631	701	788	624	1341	2517	808	41850	1094	841	632	716	52543
INCCIV25	2005	53	570	945	497	0	100	14	0	762	1240	0	0	4181
INCFEL22	2005	5184	7251	9186	5254	3989	15840	569	289071	12966	927	2048	1188	353473
INCFFG18	2005	3250	4546	5759	3294	2501	9931	357	181236	8129	581	1284	745	221613
INCFHA14	2005	644	607	2143	2096	0	2132	0	1741	3714	0	755	32	13864
INCFNU16	2005	1387	1308	4619	4518	0	4595	0	3752	8004	0	1627	68	29878
INCFRO13	2005	0	0	0	0	0	0	0	5736	1	0	0	1	5738
INGHGH24	2005	188	2017	3346	1759	0	355	51	0	2696	4389	0	0	14801
INHCAL19	2005	1106	1032	2103	599	573	5531	427	3574	18	5	0	0	14968
INHCBR21	2005	1572	1836	2647	1648	1358	10396	1553	23981	0	0	0	347	45338
INMUHA15	2005	114	107	379	370	0	377	0	308	656	0	133	6	2450
INSHGR26	2005	31854	30440	36365	20005	10532	32730	8636	400439	49585	30359	7677	5742	664364
INBRPP27	2006	9185	9541	14459	19710	104519	14064	1344	3016	5250	67247	17875	5290	271500
INBRSB23	2006	6097	4043	8963	11939	82566	12726	838	712	12595	76279	18263	6576	241597
INBSBR20	2006	0	1	37	381	2511	152	0	0	0	0	0	0	3082
INCAST17	2006	702	547	589	659	9787	861	831	720	517	523	463	449	16648
INCCIV25	2006	277	481	490	692	2049	140	45	200	0	0	2	0	4376
INCFEL22	2006	1676	597	2059	3616	38117	13189	0	1502	0	308	0	0	61064
INCFFG18	2006	1051	374	1291	2267	23898	8269	0	942	0	193	0	0	38285
INCFHA14	2006	415	0	413	1587	5549	6228	0	527	0	762	152	0	15633
INCFNU16	2006	894	0	891	3421	11959	13423	0	1135	0	1643	327	0	33693
INCFRO13	2006	1	0	0	0	757	0	0	0	4	0	0	1	763
INGHGH24	2006	982	1701	1735	2448	7252	495	160	706	0	0	8	0	15487
INHCAL19	2006	0	0	0	895	3041	608	5	11	0	0	0	0	4560
INHCBR21	2006	942	682	2492	3999	10249	3876	0	92	0	0	335	109	22776
INMUHA15	2006	73	0	73	281	981	1101	0	93	0	135	27	0	2764
INSHGR26	2006	9102	9455	14329	19533	103578	13937	1332	2989	5203	66642	17714	5242	269056
INBRPP27	2007	5413	9662	100441	39058	204052	583145	334263	163151	40015	8048	5374	7335	1499957
INBRSB23	2007	6321	4999	31053	25247	183197	422164	184527	192873	33635	9317	5764	8454	1107551
INBSBR20	2007	0	0	7987	564	4300	63672	15707	524	93	0	0	0	92847
INCAST17	2007	467	388	1076	2800	14124	11040	1915	37341	1410	848	663	729	72801
INCCIV25	2007	0	411	6028	1237	2151	14667	13237	0	614	0	0	0	38345
INCFEL22	2007	187	868	4294	18502	120769	115918	45864	197461	19646	5681	4945	5225	539360
INCFFG18	2007	117	544	2692	11600	75717	72676	28755	123800	12317	3562	3100	3276	338156
INCFHA14	2007	0	133	1955	0	12986	8181	3078	43332	3236	956	848	754	75459
INCFNU16	2007	0	286	4214	4632	27988	17632	6633	93389	6974	2060	1828	1624	167260
INCFRO13	2007	0	0	7	5	45	182	4	968	37	4	126	626	2004
INGHGH24	2007	0	1454	21336	4378	7612	51916	46853	0	2174	0	0	0	135723
INHCAL19	2007	0	0	0	5	12352	62825	22596	3781	251	37	38	78	101963
INHCBR21	2007	0	317	11770	5281	17203	114287	39370	2297	0	0	0	0	190525
INMUHA15	2007	0	23	346	380	2295	1446	544	7658	572	169	150	133	13716
INSHGR26	2007	5364	9575	99537	38706	202216	577897	331255	161683	39655	7976	5326	7269	1486459
INBRPP27	2008	8764	13247	85699	73356	36337	34591	0	0	0	0	0	0	251994

INBRSB23	2008	7246	10093	39724	52607	27205	32052	0	0	0	0	0	168927
INBSBR20	2008	0	38	5494	9819	70	3681	0	0	0	0	0	19102
INCAST17	2008	664	563	795	6328	8075	8026	0	0	0	0	0	24451
INCCIV25	2008	145	291	4031	1887	838	281	0	0	0	0	0	7473
INCFEL22	2008	4425	3906	23214	25577	27546	27246	0	0	0	0	0	111914
INCFFG18	2008	2774	2449	14554	16036	17270	17082	0	0	0	0	0	70165
INCFHA14	2008	686	751	5961	3707	5404	1131	0	0	0	0	0	17640
INCFNU16	2008	1479	1618	12846	7989	11647	2437	0	0	0	0	0	38016
INCFRO13	2008	8	6	24	1515	1032	245	0	0	0	0	0	2830
INGHGH24	2008	512	1030	14269	6679	2968	994	0	0	0	0	0	26452
INHCAL19	2008	86	73	4247	17966	1003	2529	0	0	0	0	0	25904
INHCBR21	2008	564	5643	8379	28322	1167	4140	0	0	0	0	0	48215
INMUHA15	2008	121	133	1053	655	955	200	0	0	0	0	0	3117
INSHGR26	2008	8685	13128	84928	72696	36010	34280	0	0	0	0	0	249727

Newly-Developed Evaporation Rates from Brazos Mini-WAM eva File

EV220131	1998	-0.023	-0.013	-0.079	0.409	0.340	0.491	0.647	0.477	0.430	0.133	0.000	-0.014
EV341331	1998	0.063	0.053	0.123	0.444	0.488	0.546	0.691	0.652	0.648	0.251	0.149	0.180
EV344801	1998	-0.055	0.017	0.128	0.379	0.458	0.635	0.784	0.658	0.615	0.205	0.120	0.039
EV345831	1998	-0.013	0.030	0.063	0.414	0.436	0.560	0.716	0.586	0.566	0.208	0.093	0.053
EV372031	1998	0.169	0.121	0.239	0.459	0.488	0.685	0.733	0.554	0.618	0.292	0.149	0.104
EV413031	1998	0.139	0.120	0.191	0.483	0.478	0.658	0.742	0.505	0.587	0.285	0.125	0.091
EV413331	1998	0.019	0.098	0.036	0.475	0.464	0.489	0.676	0.489	0.548	0.280	0.097	0.034
EV414231	1998	0.104	0.115	0.136	0.502	0.469	0.618	0.745	0.466	0.558	0.280	0.102	0.077
EV415031	1998	0.079	0.109	0.106	0.494	0.467	0.579	0.725	0.473	0.554	0.280	0.100	0.064
EV416131	1998	0.064	0.105	0.125	0.486	0.486	0.589	0.725	0.536	0.593	0.293	0.132	0.082
EV417931	1998	0.087	0.102	0.182	0.495	0.504	0.653	0.762	0.585	0.633	0.299	0.160	0.128
EV421131	1998	0.028	-0.015	-0.025	0.393	0.359	0.477	0.604	0.433	0.405	0.149	0.033	0.020
EV421331	1998	0.000	0.039	0.035	0.430	0.429	0.529	0.691	0.549	0.543	0.214	0.081	0.048
EV421431	1998	-0.005	0.030	0.011	0.427	0.412	0.521	0.683	0.534	0.521	0.199	0.065	0.034
EV515531	1998	-0.035	-0.001	0.001	0.398	0.385	0.546	0.700	0.546	0.501	0.160	0.046	0.006
EV220131	1999	0.041	0.183	-0.104	0.229	0.152	0.340	0.640	0.607	0.403	0.238	0.210	0.125
EV341331	1999	-0.023	0.226	0.041	0.273	0.069	0.193	0.710	0.619	0.447	0.318	0.288	0.181
EV344801	1999	-0.048	0.120	-0.215	0.198	0.044	0.204	0.593	0.703	0.567	0.211	0.288	0.259
EV345831	1999	-0.004	0.173	-0.090	0.230	0.109	0.236	0.635	0.650	0.477	0.251	0.268	0.198
EV372031	1999	0.193	0.225	0.150	0.354	0.419	0.209	0.654	0.573	0.478	0.397	0.458	0.260
EV413031	1999	0.161	0.227	0.151	0.340	0.376	0.247	0.649	0.588	0.466	0.367	0.393	0.230
EV413331	1999	0.068	0.232	0.093	0.264	0.262	0.220	0.648	0.622	0.396	0.295	0.285	0.174
EV414231	1999	0.126	0.229	0.144	0.319	0.328	0.274	0.642	0.605	0.452	0.336	0.331	0.200
EV415031	1999	0.108	0.230	0.128	0.302	0.307	0.258	0.642	0.610	0.436	0.324	0.317	0.192
EV416131	1999	0.095	0.235	0.108	0.310	0.266	0.220	0.684	0.628	0.427	0.333	0.336	0.206
EV417931	1999	0.092	0.238	0.108	0.337	0.229	0.219	0.720	0.640	0.449	0.355	0.356	0.221
EV421131	1999	0.072	0.203	0.025	0.249	0.168	0.323	0.594	0.612	0.433	0.268	0.250	0.128
EV421331	1999	0.019	0.193	-0.039	0.242	0.148	0.249	0.647	0.632	0.441	0.265	0.262	0.177
EV421431	1999	0.025	0.191	-0.051	0.240	0.151	0.267	0.645	0.628	0.433	0.260	0.253	0.167
EV515531	1999	0.007	0.158	-0.147	0.217	0.110	0.288	0.622	0.644	0.466	0.227	0.240	0.177
EV220131	2000	0.129	0.193	0.233	0.318	0.303	0.199	0.758	0.701	0.517	0.165	-0.102	0.103
EV341331	2000	0.127	0.162	0.095	0.294	0.426	0.134	0.613	0.731	0.692	-0.014	-0.026	0.123
EV344801	2000	0.404	0.163	0.272	0.147	0.399	0.190	0.614	0.771	0.326	-0.263	-0.385	0.098
EV345831	2000	0.250	0.178	0.234	0.267	0.377	0.186	0.670	0.738	0.467	-0.051	-0.185	0.114
EV372031	2000	0.101	0.416	0.278	0.456	0.481	-0.003	0.661	0.726	0.622	0.043	0.033	0.150
EV413031	2000	0.140	0.340	0.297	0.455	0.449	0.043	0.684	0.713	0.568	0.045	-0.006	0.160
EV413331	2000	0.185	0.217	0.309	0.472	0.372	0.218	0.754	0.723	0.486	0.128	0.009	0.163
EV414231	2000	0.177	0.267	0.311	0.453	0.412	0.083	0.707	0.701	0.517	0.050	-0.045	0.169
EV415031	2000	0.180	0.251	0.310	0.456	0.398	0.117	0.719	0.705	0.507	0.071	-0.033	0.167
EV416131	2000	0.161	0.245	0.266	0.447	0.417	0.159	0.725	0.743	0.565	0.120	0.011	0.156
EV417931	2000	0.147	0.237	0.212	0.411	0.448	0.131	0.699	0.761	0.636	0.109	0.006	0.149
EV421131	2000	0.154	0.161	0.275	0.348	0.281	0.119	0.716	0.676	0.474	0.077	-0.147	0.138
EV421331	2000	0.199	0.188	0.237	0.326	0.366	0.191	0.701	0.727	0.504	0.036	-0.109	0.124
EV421431	2000	0.187	0.190	0.239	0.327	0.354	0.194	0.714	0.722	0.504	0.063	-0.108	0.120
EV515531	2000	0.235	0.182	0.248	0.252	0.340	0.196	0.702	0.728	0.443	0.000	-0.211	0.101
EV220131	2001	-0.101	-0.242	-0.042	0.251	0.213	0.566	0.753	0.444	0.187	0.294	0.011	0.048
EV341331	2001	0.023	-0.023	-0.084	0.411	0.153	0.716	0.980	0.576	0.276	0.451	-0.007	0.146

EV344801	2001	-0.026	-0.157	0.001	0.361	0.251	0.692	0.791	0.394	0.204	0.296	0.152	0.098
EV345831	2001	-0.032	-0.139	-0.025	0.337	0.223	0.648	0.811	0.449	0.209	0.324	0.058	0.098
EV372031	2001	-0.060	-0.038	-0.009	0.349	0.179	0.595	0.739	0.496	0.255	0.141	-0.095	0.003
EV413031	2001	-0.032	-0.025	0.018	0.343	0.220	0.615	0.747	0.485	0.244	0.210	-0.066	0.050
EV413331	2001	-0.013	-0.080	0.007	0.315	0.254	0.579	0.749	0.443	0.176	0.291	-0.034	0.114
EV414231	2001	-0.008	-0.020	0.038	0.335	0.257	0.628	0.756	0.475	0.226	0.275	-0.039	0.095
EV415031	2001	-0.009	-0.038	0.028	0.329	0.256	0.614	0.755	0.466	0.210	0.280	-0.037	0.101
EV416131	2001	-0.021	-0.061	-0.018	0.355	0.247	0.626	0.797	0.482	0.237	0.287	-0.034	0.089
EV417931	2001	-0.018	-0.044	-0.046	0.395	0.240	0.679	0.865	0.523	0.288	0.321	-0.023	0.087
EV421131	2001	-0.054	-0.118	0.000	0.270	0.241	0.576	0.762	0.459	0.181	0.307	-0.014	0.078
EV421331	2001	-0.036	-0.134	-0.027	0.322	0.221	0.623	0.803	0.460	0.204	0.324	0.021	0.096
EV421431	2001	-0.049	-0.156	-0.029	0.308	0.221	0.611	0.791	0.455	0.200	0.316	0.019	0.087
EV515531	2001	-0.072	-0.209	-0.025	0.293	0.227	0.614	0.767	0.425	0.193	0.295	0.065	0.067
EV220131	2002	0.126	0.073	-0.043	0.232	-0.036	0.328	0.089	0.633	0.301	-0.291	0.201	-0.067
EV341331	2002	0.195	0.177	0.120	0.083	0.319	0.355	0.088	0.634	0.407	-0.178	0.228	-0.078
EV344801	2002	0.179	0.178	0.078	0.038	0.243	0.187	0.173	0.671	0.413	-0.153	0.208	0.003
EV345831	2002	0.173	0.136	0.056	0.131	0.191	0.303	0.091	0.654	0.380	-0.189	0.212	-0.022
EV372031	2002	0.147	0.012	0.033	0.353	0.213	0.559	0.279	0.520	0.291	-0.193	0.124	-0.026
EV413031	2002	0.168	0.049	0.081	0.359	0.268	0.541	0.198	0.577	0.336	-0.174	0.151	0.012
EV413331	2002	0.203	0.078	0.068	0.283	0.240	0.505	-0.113	0.668	0.385	-0.148	0.219	0.048
EV414231	2002	0.189	0.081	0.117	0.357	0.309	0.524	0.098	0.634	0.378	-0.156	0.181	0.046
EV415031	2002	0.194	0.079	0.103	0.335	0.288	0.519	0.033	0.646	0.380	-0.154	0.193	0.046
EV416131	2002	0.184	0.073	0.076	0.255	0.277	0.500	0.023	0.646	0.388	-0.155	0.208	0.001
EV417931	2002	0.174	0.090	0.094	0.201	0.320	0.473	0.105	0.644	0.405	-0.159	0.212	-0.042
EV421131	2002	0.140	0.055	0.058	0.316	0.157	0.392	-0.030	0.634	0.372	-0.175	0.224	-0.001
EV421331	2002	0.173	0.115	0.045	0.181	0.170	0.359	0.045	0.651	0.368	-0.199	0.213	-0.021
EV421431	2002	0.164	0.105	0.028	0.193	0.129	0.355	0.051	0.649	0.355	-0.217	0.211	-0.028
EV515531	2002	0.146	0.113	0.004	0.157	0.072	0.274	0.121	0.647	0.344	-0.237	0.204	-0.040
EV220131	2003	0.194	0.006	0.254	0.396	0.186	-0.009	0.652	0.441	0.173	0.173	0.148	0.376
EV341331	2003	0.164	0.171	0.293	0.428	0.390	0.062	0.818	0.614	0.384	0.446	0.217	0.328
EV344801	2003	0.171	0.131	0.296	0.405	0.213	-0.032	0.757	0.494	0.210	0.429	0.186	0.306
EV345831	2003	0.172	0.090	0.281	0.414	0.252	-0.017	0.734	0.501	0.256	0.343	0.170	0.300
EV372031	2003	0.204	0.096	0.419	0.623	0.472	0.191	0.898	0.607	0.455	0.345	0.288	0.298
EV413031	2003	0.201	0.075	0.371	0.583	0.441	0.137	0.823	0.570	0.387	0.277	0.256	0.274
EV413331	2003	0.153	0.011	0.271	0.451	0.285	-0.088	0.698	0.473	0.346	0.254	0.105	0.140
EV414231	2003	0.193	0.050	0.323	0.538	0.403	0.072	0.753	0.534	0.327	0.218	0.216	0.242
EV415031	2003	0.180	0.038	0.308	0.512	0.368	0.025	0.737	0.516	0.331	0.227	0.183	0.211
EV416131	2003	0.166	0.056	0.307	0.492	0.357	0.002	0.770	0.539	0.387	0.316	0.172	0.211
EV417931	2003	0.172	0.100	0.321	0.502	0.403	0.055	0.817	0.593	0.411	0.376	0.216	0.270
EV421131	2003	0.169	-0.004	0.249	0.446	0.285	-0.012	0.652	0.470	0.154	0.115	0.188	0.292
EV421331	2003	0.171	0.064	0.275	0.420	0.260	-0.023	0.718	0.494	0.273	0.300	0.156	0.283
EV421431	2003	0.176	0.050	0.271	0.416	0.245	-0.023	0.704	0.482	0.253	0.273	0.153	0.298
EV515531	2003	0.185	0.054	0.270	0.399	0.196	-0.018	0.692	0.461	0.187	0.272	0.163	0.349
EV220131	2004	0.130	-0.191	0.213	0.010	0.251	-0.138	0.493	0.175	0.392	0.070	-0.315	0.217
EV341331	2004	0.153	0.010	0.191	0.156	0.482	0.072	0.313	0.368	0.473	0.113	-0.317	0.198
EV344801	2004	0.138	-0.108	0.184	0.083	0.272	-0.155	0.198	0.303	0.476	0.080	-0.330	0.148
EV345831	2004	0.135	-0.099	0.200	0.075	0.329	-0.045	0.339	0.262	0.452	0.057	-0.311	0.184
EV372031	2004	0.153	0.200	0.374	0.258	0.533	0.396	0.520	0.230	0.397	-0.043	-0.170	0.196
EV413031	2004	0.147	0.127	0.322	0.208	0.503	0.345	0.511	0.206	0.402	-0.063	-0.190	0.206
EV413331	2004	0.115	-0.068	0.236	0.052	0.408	0.233	0.510	0.162	0.455	-0.090	-0.249	0.215
EV414231	2004	0.138	0.048	0.272	0.153	0.471	0.293	0.504	0.182	0.413	-0.079	-0.213	0.216

EV415031	2004	0.132	0.013	0.261	0.122	0.453	0.274	0.505	0.176	0.426	-0.081	-0.224	0.216
EV416131	2004	0.126	0.010	0.247	0.119	0.458	0.220	0.473	0.223	0.446	-0.038	-0.249	0.215
EV417931	2004	0.134	0.049	0.233	0.159	0.492	0.171	0.421	0.287	0.448	0.020	-0.266	0.216
EV421131	2004	0.123	-0.095	0.201	-0.002	0.327	-0.062	0.498	0.073	0.405	-0.004	-0.308	0.216
EV421331	2004	0.132	-0.099	0.210	0.065	0.347	0.010	0.406	0.233	0.443	0.032	-0.299	0.199
EV421431	2004	0.131	-0.118	0.211	0.053	0.327	-0.016	0.426	0.219	0.433	0.037	-0.301	0.203
EV515531	2004	0.133	-0.159	0.202	0.038	0.259	-0.144	0.379	0.225	0.424	0.074	-0.321	0.190
EV220131	2005	0.100	0.021	0.187	0.567	0.104	0.483	0.400	0.078	0.473	0.212	0.314	0.259
EV341331	2005	0.128	0.059	0.239	0.574	0.111	0.358	0.394	-0.216	0.408	0.207	0.336	0.265
EV344801	2005	0.076	0.020	0.261	0.555	0.137	0.453	0.389	0.048	0.463	0.120	0.297	0.250
EV345831	2005	0.076	0.020	0.261	0.555	0.137	0.453	0.389	0.048	0.463	0.120	0.297	0.250
EV372031	2005	0.145	0.050	0.241	0.571	0.112	0.453	0.436	-0.142	0.514	0.186	0.332	0.263
EV413031	2005	0.145	0.050	0.241	0.571	0.112	0.453	0.436	-0.142	0.514	0.186	0.332	0.263
EV413331	2005	0.138	0.019	0.208	0.575	0.115	0.457	0.438	0.010	0.497	0.172	0.328	0.263
EV414231	2005	0.149	-0.027	0.118	0.570	0.059	0.474	0.438	-0.041	0.496	0.150	0.332	0.262
EV415031	2005	0.153	0.006	0.204	0.581	0.160	0.511	0.453	0.009	0.506	0.140	0.328	0.263
EV416131	2005	0.138	0.019	0.208	0.575	0.115	0.457	0.438	0.010	0.497	0.172	0.328	0.263
EV417931	2005	0.128	0.059	0.239	0.574	0.111	0.358	0.394	-0.216	0.408	0.207	0.336	0.265
EV421131	2005	0.103	0.003	0.161	0.561	0.118	0.480	0.469	0.031	0.467	0.227	0.316	0.256
EV421331	2005	0.107	0.035	0.208	0.569	0.089	0.469	0.361	0.017	0.492	0.194	0.315	0.259
EV421431	2005	0.100	0.021	0.187	0.567	0.104	0.483	0.400	0.078	0.473	0.212	0.314	0.259
EV515531	2005	0.075	0.008	0.194	0.547	0.154	0.492	0.411	0.209	0.472	0.199	0.299	0.249
EV220131	2006	0.286	0.124	0.196	0.292	0.323	0.512	0.693	0.631	0.220	0.246	0.223	0.134
EV341331	2006	0.332	0.217	0.299	0.354	0.224	0.669	0.680	0.660	0.235	0.159	0.288	0.098
EV344801	2006	0.282	0.130	0.231	0.237	0.298	0.550	0.659	0.678	0.269	0.198	0.185	0.102
EV345831	2006	0.282	0.130	0.231	0.237	0.298	0.550	0.659	0.678	0.269	0.198	0.185	0.102
EV372031	2006	0.343	0.217	0.307	0.296	0.336	0.633	0.732	0.624	0.220	0.283	0.306	0.112
EV413031	2006	0.343	0.217	0.307	0.296	0.336	0.633	0.732	0.624	0.220	0.283	0.306	0.112
EV413331	2006	0.334	0.180	0.270	0.301	0.319	0.574	0.722	0.593	0.231	0.286	0.314	0.125
EV414231	2006	0.342	0.211	0.226	0.338	0.353	0.454	0.733	0.652	0.225	0.284	0.276	0.144
EV415031	2006	0.338	0.189	0.250	0.318	0.344	0.549	0.733	0.643	0.243	0.291	0.303	0.140
EV416131	2006	0.334	0.180	0.270	0.301	0.319	0.574	0.722	0.593	0.231	0.286	0.314	0.125
EV417931	2006	0.332	0.217	0.299	0.354	0.224	0.669	0.680	0.660	0.235	0.159	0.288	0.098
EV421131	2006	0.307	0.121	0.179	0.303	0.338	0.492	0.697	0.624	0.250	0.237	0.196	0.138
EV421331	2006	0.282	0.141	0.224	0.302	0.317	0.548	0.682	0.643	0.209	0.256	0.240	0.130
EV421431	2006	0.286	0.124	0.196	0.292	0.323	0.512	0.693	0.631	0.220	0.246	0.223	0.134
EV515531	2006	0.263	0.067	0.199	0.208	0.319	0.526	0.674	0.643	0.236	0.224	0.169	0.107
EV220131	2007	-0.013	0.220	-0.189	0.153	-0.378	-0.537	0.216	0.216	0.168	0.326	0.189	0.153
EV341331	2007	0.048	0.228	-0.052	0.094	-0.120	-0.108	0.280	0.060	0.253	0.381	0.242	0.137
EV344801	2007	0.054	0.219	0.007	0.151	-0.326	-0.378	0.227	0.333	-0.014	0.351	0.237	0.161
EV345831	2007	0.054	0.219	0.007	0.151	-0.326	-0.378	0.227	0.333	-0.014	0.351	0.237	0.161
EV372031	2007	0.046	0.238	-0.016	0.148	-0.135	0.041	0.242	-0.069	0.240	0.387	0.218	0.157
EV413031	2007	0.046	0.238	-0.016	0.148	-0.135	0.041	0.242	-0.069	0.240	0.387	0.218	0.157
EV413331	2007	0.022	0.231	-0.072	0.123	-0.146	-0.143	0.242	-0.018	0.268	0.330	0.214	0.161
EV414231	2007	0.025	0.234	-0.082	0.122	-0.106	-0.214	0.198	-0.004	0.223	0.304	0.211	0.182
EV415031	2007	0.022	0.232	-0.079	0.162	-0.117	-0.159	0.227	0.029	0.265	0.305	0.216	0.180
EV416131	2007	0.022	0.231	-0.072	0.123	-0.146	-0.143	0.242	-0.018	0.268	0.330	0.214	0.161
EV417931	2007	0.048	0.228	-0.052	0.094	-0.120	-0.108	0.280	0.060	0.253	0.381	0.242	0.137
EV421131	2007	0.003	0.222	-0.225	0.144	-0.293	-0.548	0.213	0.201	0.216	0.289	0.176	0.162
EV421331	2007	0.008	0.217	-0.130	0.129	-0.366	-0.462	0.221	0.233	0.172	0.346	0.208	0.152
EV421431	2007	-0.013	0.220	-0.189	0.153	-0.378	-0.537	0.216	0.216	0.168	0.326	0.189	0.153

EV515531	2007	-0.025	0.206	-0.187	0.138	-0.332	-0.486	0.216	0.233	0.059	0.324	0.181	0.150
EV220131	2008	0.228	0.248	-0.108	0.109	0.232	0.569	0.000	0.000	0.000	0.000	0.000	0.000
EV341331	2008	0.244	0.257	0.198	0.264	0.221	0.646	0.000	0.000	0.000	0.000	0.000	0.000
EV344801	2008	0.236	0.239	-0.071	0.224	0.129	0.568	0.000	0.000	0.000	0.000	0.000	0.000
EV345831	2008	0.236	0.239	-0.071	0.224	0.129	0.568	0.000	0.000	0.000	0.000	0.000	0.000
EV372031	2008	0.234	0.292	0.174	0.241	0.337	0.612	0.000	0.000	0.000	0.000	0.000	0.000
EV413031	2008	0.234	0.292	0.174	0.241	0.337	0.612	0.000	0.000	0.000	0.000	0.000	0.000
EV413331	2008	0.235	0.262	0.125	0.244	0.258	0.584	0.000	0.000	0.000	0.000	0.000	0.000
EV414231	2008	0.230	0.274	0.079	0.260	0.345	0.603	0.000	0.000	0.000	0.000	0.000	0.000
EV415031	2008	0.232	0.270	0.100	0.256	0.335	0.588	0.000	0.000	0.000	0.000	0.000	0.000
EV416131	2008	0.235	0.262	0.125	0.244	0.258	0.584	0.000	0.000	0.000	0.000	0.000	0.000
EV417931	2008	0.244	0.257	0.198	0.264	0.221	0.646	0.000	0.000	0.000	0.000	0.000	0.000
EV421131	2008	0.222	0.250	-0.110	0.131	0.270	0.473	0.000	0.000	0.000	0.000	0.000	0.000
EV421331	2008	0.236	0.248	-0.099	0.133	0.196	0.584	0.000	0.000	0.000	0.000	0.000	0.000
EV421431	2008	0.228	0.248	-0.108	0.109	0.232	0.569	0.000	0.000	0.000	0.000	0.000	0.000
EV515531	2008	0.226	0.229	-0.154	0.106	0.168	0.630	0.000	0.000	0.000	0.000	0.000	0.000

Appendix D
Comments from the Texas Water Development Board Regarding Phase I Reports and Responses from the Brazos G Regional Water Planning Group

TEXAS WATER DEVELOPMENT BOARD

February 20, 2009

RECEIVED
MAR 3 2009
GENERAL MANAGER

A copy to Trey Burgher

Mr. Phillip J. Ford
General Manager/CEO
Brazos River Authority
P.O. Box 7555
Waco, Texas 76714-7555

Re: Region G, Region-Specific Studies Contract for Regional Water Planning between the Texas Water Development Board (TWDB) and the Brazos River Authority (BRA), TWDB Contract No. 0704830692, Draft Final Study Report Comments.

Dear Mr. Ford:

Staff members of TWDB have completed a review of the Draft Final Study Report under TWDB Contract No. 0704830692. As stated in the above-referenced contract, BRA will consider incorporating Draft Final Study Report comments, shown in Attachment 1, as well as other comments received, into the Final Study Report. In accordance with paragraph F, Article III, Section II of the contract, a copy of these TWDB Executive Administrator comments as well as a written summary of how the Draft Final Study Report was revised in response must be included in all the Final Study Report documents, for example, as an appendix.

TWDB looks forward to receiving one (1) electronic copy of all files, one electronic copy of each Final Study Report in Portable Document Format (PDF), and nine (9) bound double-sided copies of each Final Study Report to the TWDB Executive Administrator no later than the contract Final Study Report Deadline (April 30, 2009 for most reports). Please also transfer copies of all data and reports generated by the planning process and used in developing the Final Study Report to the TWDB Executive Administrator no later than the contract Final Study Report Deadline.

As a reminder, if any portion of the Final Study Report is to be included in a 2011 regional water plan it will be reviewed as part of the Initially Prepared Plan for meeting all statutory and agency rule requirements regarding the preparation of regional water plans.

If you have any questions concerning this contract, please contact Matt Nelson, TWDB's designated Contract Manager for this study at (512) 936-0829.

Sincerely,

for Dan Hardin
Carolyn L. Brittin
Deputy Executive Administrator
Water Resources Planning and Information

Enclosures
Attachment 1

c: Matt Nelson, TWDB

ATTACHMENT 1

TWDB Contract No. 0704830692

Region G, Region-Specific Studies 1-5:

TWDB Comments on Draft Final Region-Specific Study Reports:

1) Updated Drought of Record and Water Quality Implications for Reservoirs Upstream of Possum Kingdom Reservoir

2) Groundwater Availability Model of the Edwards-Trinity (Plateau) and Dockum Aquifer in Western Nolan and Eastern Mitchell Counties, Texas

3) Regionalization Strategies to Assist Small Water Systems in Meeting New SDWA Requirements

4) Brazos G Activities in Support of Region C's Water Supply Study for Ellis, Johnson, Southern Dallas, and Southern Tarrant Counties

5) Updated Water Management Strategies for Water User Groups in McLennan County

Region-Specific Study 1: Updated Drought of Record and Water Quality Implications for Reservoirs Upstream of Possum Kingdom Reservoir

1. Report does not present newly developed model input datasets developed under Task 1, for example, the raw numerical naturalized flow dataset (including from 1998) through June 2008 as used in the model. Please present these data as appendices in report.

2. Page 8, Table 2.1: Please clarify where the rating curves came from for elevation-content calculations.

Region-Specific Study 2: Groundwater Availability Model of the Edwards-Trinity (Plateau) and Dockum Aquifer in Western Nolan and Eastern Mitchell Counties, Texas

1. The data discussed on page 12 does not appear to match the data referred to in Appendix A. In the second to last paragraph, the report refers to the data showing 4,300 acre-feet of municipal pumpage in year 2005. The data in Appendix A do not appear to support this total. Please correct or clarify the basis of the 4,300 reference in the report.

2. Page 12, last paragraph discusses data in Appendix A and states that the total pumping in 2003 was 4,600 acre-feet. The value for 2003 in the Appendix A table however, appears to be 3,823 acre-feet. This paragraph also states the average is 3,240 acft/year, although the data as presented in the Appendix averages 2,851 acre-feet/year. Please correct

reference or clarify how numbers referred to in text were derived. Also, it appears that the totals for years 2001-2004 and 2007 are off by 1 acre-foot.

3. According to Task 1, subtask C in the contract Scope of Work, the report was to "estimate long-term supplies available from the well field." The report does not appear to directly provide estimates of long-term supplies. Please provide information regarding estimated long-term supplies in the report.

Region-Specific Study 3: Regionalization Strategies to Assist Small Water Systems in Meeting New SDWA Requirements

1. Page 58, paragraph 3 states that "the TWDB Regional Water Supply and Wastewater Facilities Planning Program could be used to provide up to 50 % of the cost of a detailed analysis of regionalization opportunities to encourage small water systems to actively consider and begin implementation of a regionalization strategy". Please clarify in the report that "TWDB can pay up to 50% of the study costs (75% in areas which have unemployment rates exceeding the state average by 50% or more and per-capita income is 65% or less than the state average for the last reporting period available)..."

Region-Specific Study 4: Brazos G Activities in Support of Region C's Water Supply Study for Ellis, Johnson, Southern Dallas, and Southern Tarrant Counties

TWDB's acceptance of the final report does not constitute approval of any revised population or water demand projections contained therein. The formal procedure for requesting revised projections is stated in TAC 357.5 (d) (2):

> *"Before requesting a revision to the population and water demand projections, the regional water planning group shall discuss the issue at a public meeting for which notice has been posted pursuant to the Open Meetings Act in addition to being published on the internet and mailed at least 14 days before the meeting to every person or entity that has requested notice of regional water planning group activities. The public will be able to submit oral or written comment at the meeting and written comments for 14 days following the meeting. The regional water planning group will summarize the public comments received in its request for projection revisions. Within 45 days of receipt of a request from a regional water planning group for revision of population or water demand projections, the executive administrator shall consult with the requesting regional water planning group and respond to their request."*

All requested revisions which receive a consensus recommendation from TWDB, the Texas Department of Agriculture, Texas Commission on Environmental Quality, and Texas Parks and Wildlife Department, will then be presented for consideration of Board approval at the next scheduled meeting.

1. Task 1 of the contract Scope of Work refers to reviewing recent studies. Please provide a general summary of findings regarding recent supply studies and activities in the area since the 2006 Brazos G Regional Water Plan was adopted.

2. Tasks 1 and 4 of the contract Scope of Work refer to reviews of studies and reviews of population projection estimates. While Section 1.0 of the report summarizes the associated activities performed by date, it does not provide a general summary of the findings of these reviews or copies of or summaries of the comments that were provided by Region G consultant as a result of these reviews. Please provide a summary of findings or copies of written comments resulting from this work, for example, as an appendix in the report.

3. The report does not include or make specific reference to the raw population/water demand projections that were provided from individual water providers in the regional study area (e.g. Alvarado, Burleson, JCSUD, Mansfield, and Venus). Please provide copies of these water planning projections that are generally greater than TWDB population and/or water demand projections. If this raw data was included in another available report, please provide a reference.

4. Please consider adding clarifying language to the Executive Summary that more clearly sets forth the purpose and content of this specific report and that explains the need for a reader to also review the "Region C Water Supply Study for Johnson, Southern Dallas, and Southern Tarrant Counties". Consider including a copy of the associated Region C study Table of Contents for reference, for example, in an appendix.

5. Page B-3: Table B-2 is missing from report. Please include in final report.

Region-Specific Study 5: Updated Water Management Strategies for Water User Groups in McLennan County

1. Task 3 of the contract scope of work states that the following sections will be included in the draft and final report: "... purpose of study including how the study supports regional water planning, methodology, results, and recommendations, if applicable." These sections are not present in the draft report. Please include them in the final report.

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Memo

To: Brazos G Regional Water Planning Group	
From: David Dunn, PE	Project: Brazos G 2011 Regional Water Plan
CC: Trey Buzbee, Brazos River Authority	
Date: April 7, 2009	Job No: 00044257-001

RE: Suggested responses to TWDB comments regarding the five Phase I Reports

On December 29, 2008, HDR submitted to the Texas Water Development Board (TWDB) draft copies of the reports summarizing the five Phase I studies completed pursuant to the 2011 Brazos G Regional Water Plan. On February 20, 2009, the TWDB provided review comments on each draft report. Those review comments are repeated in this memorandum, followed by HDR's suggested response to each comment.

HDR recommends that the Brazos G RWPG accept these suggested responses to the TWDB comments, and direct HDR and the Brazos River Authority to incorporate the responses into the final versions of the reports, and submit the final reports to the TWDB prior to the report submission deadline of April 30, 2009. A copy of the TWDB review comments and the planning group's responses will be included as an appendix to each report.

Region-Specific Study 1: Updated Drought of Record and Water Quality Implications for Reservoirs Upstream of Possum Kingdom Reservoir

1. Report does not present newly developed model input datasets developed under Task 1, for example, the raw numerical naturalized flow dataset (including from 1998) through June 2008 as used in the model. Please present these data as appendices in report.

Suggested Response: The newly developed data sets have been printed and included as an appendix to the report.

2. Page 8, Table 2.1: Please clarify where the rating curves came from for elevation-content calculations.

Suggested Response: The reservoir elevation-area-capacity relations were obtained from the most recent bathymetric survey available for each reservoir. The last paragraph on page 7 has been updated to make the source of the data more clear.

Region-Specific Study 2: Groundwater Availability Model of the Edwards-Trinity (Plateau) and Dockum Aquifer in Western Nolan and Eastern Mitchell Counties, Texas

1. The data discussed on page 12 does not appear to match the data referred to in Appendix A. In the second to last paragraph, the report refers to the data showing 4,300 acre-feet of

municipal pumpage in year 2005. The data in Appendix A do not appear to support this total. Please correct or clarify the basis of the 4,300 reference in the report.

Suggested Response: The data shown in Table A-3 of Appendix A have been corrected.

2. Page 12, last paragraph discusses data in Appendix A and states that the total pumping in 2003 was 4,600 acre-feet. The value for 2003 in the Appendix A table however, appears to be 3,823 acre-feet. This paragraph also states the average is 3,240 acft/year, although the data as presented in the Appendix averages 2,851 acre-feet/year. Please correct reference or clarify how numbers referred to in text were derived. Also, it appears that the totals for years 2001-2004 and 2007 are off by 1 acre-foot.

Suggested Response: The numbers in the text have been corrected.

3. According to Task 1, subtask C in the contract Scope of Work, the report was to "estimate long-term supplies available from the well field." The report does not appear to directly provide estimates of long-term supplies. Please provide information regarding estimated long-term supplies in the report.

Suggested Response: The following text has been added to the report as a final paragraph in Section 7 Water Management Strategy for Sweetwater:

"If a groundwater only strategy is considered, the performance of the current Champion Well Field from 2001-2007 and the groundwater modeling suggests that the Edwards-Trinity and Dockum Aquifers could meet this average demand, which was about 2,850 acft/yr. If the well field was substantially expanded to the south-southwest, the modeling analysis suggests that it could meet the projected demand of 3,900 acft/yr for the planning period."

And the following text has been added to Section 9 Conclusions:

"If a groundwater only strategy is considered, the analysis suggests that the aquifers could meet 2001-2007 average demand of about 2,850 acft/yr. If the well field was substantially expanded to the south-southwest, the analysis suggests that the projected demand of 3,900 acft/yr for the planning period could be met."

Region-Specific Study 3: Regionalization Strategies to Assist Small Water Systems in Meeting New SDWA Requirements

1. Page 58, paragraph 3 states that "the TWDB Regional Water Supply and Wastewater Facilities Planning Program could be used to provide up to 50 % of the cost of a detailed analysis of regionalization opportunities to encourage small water systems to actively consider and begin implementation of a regionalization strategy". Please clarify in the report that "TWDB can pay up to 50% of the study costs (75% in areas which have unemployment rates exceeding the state average by 50% or more and per-capita income is 65% or less than the state average for the last reporting period available)..."

Suggested Response: The following text has been added as the second sentence of paragraph 3 on page 58:

"In some instances, the TWDB can pay for more than 50% of the study costs (75% in areas which have unemployment rates exceeding the state average by 50% or more and per-capita income is 65% or less than the state average for the last reporting period available)."

Region-Specific Study 4: Brazos G Activities in Support of Region C's Water Supply Study for Ellis, Johnson, Southern Dallas, and Southern Tarrant Counties

1. Task 1 of the contract Scope of Work refers to reviewing recent studies. Please provide a general summary of findings regarding recent supply studies and activities in the area since the 2006 Brazos G Regional Water Plan was adopted.

Suggested Response: The following text will be added to Section 1.0:

"A review was conducted of recent water supply studies in the four-county area, with a primary emphasis on Johnson County entities. The overall message from the studies indicates that population and water demand projections are increasing at a faster pace than the Texas Water Development Board (TWDB) projections from the 2006 Plan. The City of Cleburne conducted a study[1] in May 2007 that showed that new industrial development and oil and gas exploration in the area have increased rapidly, which has led to increased water requirements. A study conducted by Johnson County Special Utility District (JCSUD)[2] showed substantially higher projected population and water demands in Year 2030 than TWDB estimates. The JCSUD study was used as a basis for recommending population and water demand updates, which show a 37% increase in projected population in Year 2030 and nearly 40% increase in projected Year 2030 water demands as compared to TWDB projections used in the 2006 Brazos G Plan. Since the 2006 Brazos G Plan, Johnson County Fresh Water Supply District No. 1 has merged with JCSUD and is shown accordingly in the Four County Study report. Additional studies in the area were reviewed and considered including: information from the City of Arlington regarding their wholesale water rate study, and a report developed jointly by the Brazos River Authority and Tarrant Regional Water District in April 2004 entitled "Regional Water Supply and Wastewater Service Study for Johnson and Parker County."

2. Tasks 1 and 4 of the contract Scope of Work refer to reviews of studies and reviews of population projection estimates. While Section 1.0 of the report summarizes the associated activities performed by date, it does not provide a general summary of the findings of these reviews or copies of or summaries of the comments that were provided by Region G consultant as a result of these reviews. Please provide a summary of findings or copies of written comments resulting from this work, for example, as an appendix in the report.

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[1] *City of Cleburne and Freese and Nichols, "Cleburne Long-Range Water Supply Study- Draft," May 2007.*

[2] *Johnson County Special Utility District and HDR Engineering, Inc, "Evaluation of Additional Water Supplies from the Trinity and Brazos River Basins," December 2006.*

Suggested Response: Copies of selected email correspondence with comments provided by Brazos G consultants have been added as Attachment B-1. An interim progress report update with proposed population and water demand projections was provided to the Brazos G RWPG on October 28, 2008 (as described in Section 1.0). A copy of this presentation has been added as Attachment B-2.

In addition, the following text will be added to Section 1:0:

"The population and water demand recommendations were reviewed for consistency with information provided by each of the Johnson County entities. In some cases, historical population and water use information was provided which was used to assess the reasonableness of extrapolating historical trends to future population and water demands projections. Due to the large number of entities over the study area, there were numerous review processes required to ensure that the recommended population and water demand projections used in the study were consistent with current trends that Johnson County entities are experiencing and their local plans. A copy of selected email correspondence from Brazos G consultants with comments and results of their reviews of Region C's interim analyses and reported results is presented in Attachment B-1."

3. The report does not include or make specific reference to the raw population/water demand projections that were provided from individual water providers in the regional study area (e.g. Alvarado, Burleson, JCSUD, Mansfield, and Venus). Please provide copies of these water planning projections that are generally greater than TWDB population and/or water demand projections. If this raw data was included in another available report, please provide a reference.

Suggested Response: The raw population and water demand projections provided by Johnson County water entities will be provided as Attachment A. Text will be added to Section 1.0 to reference Attachment A. For more information regarding how raw population and water demand projections were used to develop recommended projections, please consult Region C's report entitled "Water Supply Study for Ellis County, Johnson County, Southern Dallas County, and Southern Tarrant County."

4. Please consider adding clarifying language to the Executive Summary that more clearly sets forth the purpose and content of this specific report and that explains the need for a reader to also review the "Region C Water Supply Study for Johnson, Southern Dallas, and Southern Tarrant Counties". Consider including a copy of the associated Region C study Table of Contents for reference, for example, in an appendix.

Suggested Response: The purpose and content of the specific report was included in the draft report in the executive summary as follows:

"The purpose of this study is to review recent growth in the study area, make adjustments to population and demand projections to account for the growth, and update the current and future water plans of the water user groups and wholesale water providers in the study area. This study included conducting meetings and compiling survey data provided by water suppliers regarding their current and future water plans, determining revisions to population and demand projections, and developing a water supply plan for the study area. This report describes the

assistance provided by Brazos G to the study effort, and summarizes the information resulting from the study that is pertinent to the Brazos G Area."

The following additional text will be added to the Executive Summary:

"Those reading this summary should also consult the 'Region C Water Supply Study for Ellis County, Johnson County, Southern Dallas County, and Southern Tarrant County,' which provides the full report and results of the Four County study."

5. Page B-3: Table B-2 is missing from report. Please include in final report.

Suggested Response: Table B-2 (which has been relabeled as Table D-2 in response to renumbering attachments) will be included in the final report.

Region-Specific Study 5: Updated Water Management Strategies for Water User Groups in McLennan County

1. Task 3 of the contract scope of work states that the following sections will be included in the draft and final report: "… purpose of study including how the study supports regional water planning, methodology, results, and recommendations, if applicable." These sections are not present in the draft report. Please include them in the final report.

Suggested Response: The organization of the report has been restructured as follows:

Section 1.0 Introduction has been subdivided into Section 1.1 Purpose of Study and Section 1.2 Methodology. The text states how the study supports regional water planning. Sections 2.0 through 5.0 have been made subdivisions 2.1 through 2.4 of a new Section 2.0 Results, while retaining their original text and organization. Section 5.0 Summary has been titled Section 3.0 Summary and Recommendations with two new subdivisions 3.1 Summary and 3.2 Recommendations, while retaining its original text.

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