BRAZOS RIVER AND ASSOCIATED BAY AND ESTUARY SYSTEM BASIN AND BAY AREA STAKEHOLDERS COMMITTEE

ENVIRONMENTAL FLOW STANDARDS AND STRATEGIES RECOMMENDATIONS REPORT

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***Submission letter** to the Environmental Flows Advisory Group and the Texas Commission on Environmental Quality*

September 1, 2012

The Honorable Troy Fraser, Co-Presiding Officer
The Honorable Allan Ritter, Co-Presiding Officer
Environmental Flows Advisory Group (EFAG)

Mr. Zak Covar, Executive Director
Texas Commission on Environmental Quality (TCEQ)

Dear Chairman Fraser, Chairman Ritter and Mr. Covar;

On behalf of the Brazos River Associated Bay and Estuary System Basin and Bay Area Stakeholders Committee (BBASC) we respectfully submit the Environmental Flow Standards and Strategies Recommendations Report for the longest river basin in the State of Texas.

The Brazos River BBASC during the last eighteen months has appointed and received the Brazos River Basin and Bay Expert Science Team Environmental Flow Regime Recommendation Report (BBEST) and has devoted our efforts to completing this report according to our charge under Senate Bill 3 (SB3) of the 80th Texas Legislative Session. Following an intense exercise of incorporating the economic factors, human and other water needs, and other appropriate information, the BBASC evaluated the BBEST report and balancing all of the factors according to our charge, we reached consensus on all but three of twenty gauge locations for the Brazos Basin.

The BBASC has devoted their efforts to overcome the issues of time constraints, need for additional information and lack of funding from the Texas Legislature for the Brazos River BBASC. The BBASC wants to acknowledge our appreciation for the members of this group who solicited and received financial donations to fund the expenses that supported the results of this process. The BBASC respectfully request that the Texas Legislature fully fund this ongoing process as the development of the Work Plan is soon to begin and not create another unfunded mandate on this serious challenge facing our State.

The Brazos River referred to as *Rio de los Brazos de Dios* by early Spanish explorers is translated as "The River of the Arms of God" certainly describes the dependence on this River Basin for the past, present, and future generations of the State of Texas.

Respectfully Submitted;

Dale Spurgin, Chairman
Brazos River BBASC

ACKNOWLEDGMENTS

The BBASC wishes to acknowledge the contributions of many people and organizations that made the successful completion of the BBASC's task possible. First, and foremost, we recognize the dedication and commitment of our fellow BBASC members and alternates. The full Committee met on twenty days, with much additional time spent in conference calls and subcommittee meetings, in preparing recommendations and this report. Many of those members not only contributed their time and energy, but took uncompensated time away from earning their living, to complete this assigned task. In addition, many members absorbed travel costs out of their own pockets.

The BBASC is especially grateful to the members of the Bay and Basin Expert Science Team (BBEST) for their diligent efforts in developing and presenting a set of comprehensive recommendations achieved by consensus. We express our thanks to BBEST members for providing support to the BBASC during our learning process and throughout our deliberations in developing these recommendations.

The BBASC thanks the staff members of the Texas Commission on Environmental Quality, the Texas Parks and Wildlife Department, the Texas Water Development Board, and the US Army Corp of Engineers, as well as consultants from HDR Engineering for their significant assistance to the Committee. Their continual support and technical expertise were instrumental in this endeavor.

We owe much of our success to the support of our professional facilitators, Suzanne Schwartz and Margaret Menicucci, with the Center for Public Policy Dispute Resolution at the University of Texas School of Law. Their guidance, advice, and tireless dedication were invaluable in keeping us moving forward and bringing us to a successful conclusion.

Those facilitation services that were so important were available because of the generosity of a number of individuals and organizations that donated funds for our use. We are well aware that since the BBASC had no state funding, our task simply could not have been done without these private donations.

The BBASC recognizes the substantial contributions by the Brazos River Authority to the successful completion of our task. The BRA hosted most of the meetings for the BBASC, graciously and generously providing hospitality and technical support, as well as computer, clerical and personnel resources. Additionally, BRA's contribution included the valuable time of three staff members who both actively participated on the BBEST, as well as attended much of the deliberation by the BBASC, for no additional compensation or fee.

The members of the BBASC were continually impressed by the professionalism, technical and scientific expertise, and dedication of all those that supported our mission whether in front of or behind the scenes. You all have our sincere thanks for taking part in this important work.

Common Abbreviations

Ac/ft	acre-feet (43,560 cubic feet or 325,851 gallons)
Ac/ft/yr	acre-feet per year
Cfs	cubic feet per second
BBASC	Brazos River and Associated Bay and Estuary System Basin and Bay Area Stakeholders Committee
BBEST	Brazos River and Associated Bay and Estuary System Basin and Bay Expert Science Team
BRA	Brazos River Authority
CCEFN	Consensus Criteria for Environmental Flow Needs
CCM	Comparative Cross-Section Methodology
DFC	Desired Future Conditions
D&L	Domestic and Livestock
EFAG	Environmental Flows Advisory Group
EFR	Environmental Flow Recommendation(s)
EQIP	Environmental Quality Incentives Program
FRAT	Flow Regime Application Tool
GCD	Groundwater Conservation District
GAM	Groundwater Availability Model
GMA	Groundwater Management Area
HEFR	Hydrology-based Environmental Flow Regime (model)
HFP	High flow pulse
Kac/ft	thousand acre-feet
Kac/ft/yr	thousand acre-feet per year
NWF	National Wildlife Federation
PHDI	Palmer Hydrologic Drought Index
PHABSIM	Physical Habitat Simulation
Q	A percentage flow definition, e.g. 7Q2 (see below)
SB 2	Senate Bill 2
SB 3	Senate Bill 3
SEE	Sound Ecological Environment
SAC	The Texas Flows Science Advisory Committee
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids (pass a 0.45 micron filter)
TIFP	Texas Instream Flow Program
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
USGS	United States Geological Survey
WAM	Water Availability Model
WUA	Weighted Usable Area
Q95	Daily average flow rate exceeded 95 percent of the time
7Q2	Annual lowest mean discharge for seven consecutive days with a two-year recurrence interval
50% Rule	50 percent of the difference between the daily flow and the recommended subsistence flow is passed when inflows are between the specified seasonal base flow and the subsistence values under dry hydrologic conditions (BBEST Report page 6-1)

Executive Summary

Committee Charge

Texas Water Code Section 11.02362 states:

(i) Each basin and bay area stakeholders committee shall establish a basin and bay expert science team for the river basin and bay system for which the committee is established. The basin and bay expert science team must be established not later than six months after the date the basin and bay area stakeholders committee is established.

(o) Each basin and bay area stakeholders committee shall review the environmental flow analyses and environmental flow regime recommendations submitted by the committee's basin and bay expert science team and shall consider them in conjunction with other factors, including the present and future needs for water for other uses related to water supply planning in the pertinent river basin and bay system.
The basin and bay area stakeholders committee shall develop recommendations regarding environmental flow standards and strategies to meet the environmental flow standards and submit those recommendations to the commission and to the advisory group .... In developing its recommendations, the basin and bay area stakeholders committee shall operate on a consensus basis to the maximum extent possible.

(p) In recognition of the importance of adaptive management, after submitting its recommendations regarding environmental flow standards and strategies to meet the environmental flow standards to the commission, each basin and bay area stakeholders committee, with the assistance of the pertinent basin and bay expert science team, shall prepare and submit for approval by the advisory group a work plan. The work plan must:
(1) establish a periodic review of the basin and bay environmental flow analyses and environmental flow regime recommendations, environmental flow standards, and strategies, to occur at least once every 10 years;
(2) prescribe specific monitoring, studies, and activities; and
(3) establish a schedule for continuing the validation or refinement of the basin and bay environmental flow analyses and environmental flow regime recommendations, the environmental flow standards adopted by the commission, and the strategies to achieve those standards.

The Texas Commission on Environmental Quality (TCEQ) is the state agency with primary responsibility for implementing the constitution and laws of this state relating to the conservation of natural resources and protection of the environment, including water rights permitting and administration. (Texas Water Code Section 5.012, 5.013) Under statute, the TCEQ sets environmental flow standards for each basin and bay system. In doing so, the TCEQ is required to consider the environmental flow regime developed by each basin's expert science team (BBEST), the recommendations of each basin's Basin and Bay Area Stakeholders Committee (BBASC), economic factors, human and other water needs, and other appropriate information (Texas Water Code Section 11.1471).

> Water is a life necessity – we **must** use it wisely – *Tommy O'Brien*

The BBASC defined its goal:

"Create a set of environmental flow recommendations on which future water rights permits are considered that balances all water needs within the basin and that are understandable and are reasonable to implement."

Further, the BBASC utilized these concepts in its deliberations:

1) The base and subsistence flow numbers are derived with flow measurements that include managed water that may benefit the environment, but that are not necessarily natural flows and that could change in the future. In some areas, these historical gaged flows include releases of water from upstream reservoir storage that would not have been present under natural, pre-reservoir conditions, and are not guaranteed to be there in the future.

> The Brazos River has been the life blood of Texas for eons. It has served as a transportation route; a provider of food, recreational activities and water for human needs; as a means of re-fertilizing the land during flooding and has contributed to economic development along its shores. As time goes on man has manipulated the flows and flooding – future generations will determine whether this is good or bad.
> *Mary Ruth Rhodenbaugh*

2) The BBASC wants to make clear that it does not intend that the environmental flow standards should require any water rights permit holder to release previously stored water from storage or to take other action to produce a pulse flow event that would not have occurred naturally to maintain base or subsistence flows.

Issues

There are several important issues identified by the BBASC in the process:

Funding and Time for the Process

The BBEST had less than 12 months to fulfill the SB3 charge, and had very limited funding to compile, evaluate and then make determinations from existing data.

The BBASC had six months from the submission of the BBEST report until the September 1st deadline to submit its recommendations. Further, all the funding for the process had to be raised by the committee, from donations.

It is unrealistic to expect the Work Plan process will be successful without funding to generate data and assess those data. It is recommended and anticipated that State funds will be allocated to assist Federal and other funding sources to implement this process.

Overbank Flows

Overbank flows are naturally occurring flows that exceed the carrying capacity of the normal channel. The BBASC recognizes the importance of overbank flows for sediment and nutrient transfer, moving the river channel, maintaining the riparian ecology and for the maintenance of oxbows. As noted in the BBEST report, *"Periodic inundation provides opportunities for aquatic organisms to move into off-channel floodplain habitats such as oxbow lakes, sloughs, and marshes that promote growth and reproduction of certain species (Swales et al. 2000; Sommer et al. 2002, 2004) and support fish diversity and production in the overall river ecosystem (Welcomme 1979; Winemiller 1996; Zeug and Winemiller 2007, 2008a; Lyon et al. 2010)."*

However the consensus of the BBASC is to not recommend overbank flows as potential flow standards for the Brazos and San Bernard River basins for the following reasons:

- The potential for flood damage to both property and human life;
- Time constraints imposed by Senate Bill 3 do not allow for sufficient consideration;
- The history of TCEQ not approving overbank flows in previously submitted BBASC Environmental Recommendations Reports; and
- Overbank flows are likely to continue to occur naturally.

The BBASC will include in the Work Plan a recommendation for studies of the benefits of overbank flows to help maintain a healthy river system.

The BBASC also recognizes that the BBEST did determine the importance of over bank flows to maintain oxbows and that, even with the storage capacity of the Brazos River System, overbank flows will continue to occur, but possibly with reduced frequency.

Environmental Flow Recommendation Risk Viewpoints

One theme recurred in the discussion among BBASC members: how to allocate risk that would arise from decisions that they made and that might ultimately be adopted by TCEQ. While recognizing that environmental flow standards adopted by TCEQ must be reviewed at least every ten years, and could be modified, members were keenly aware that the decisions made in the current process could affect those future reviews.

Those members advocating for a balance that provided greater water availability for future water rights expressed concern that once environmental flow standards (EFS) were adopted, it would be difficult to change the standards to provide for future water rights development and less environmental flow.

Similarly, those members advocating for a balance that provided more protection for environmental flows expressed concern that the Texas Water Code limits how much EFS can be modified in relation to a permit once the permit is issued, thus limiting the practical ability to add more environmental flow protections in the future.

The BBASC recognized that a few immediate new water rights might be issued in the next five to ten years. Those favoring less stringent environmental flow protection relied on that circumstance to support an approach that would not impose more stringent EFSs in this cycle, while those favoring more stringent environmental flow protections felt it, similarly, justified increased flow protections now that could be revised later. This dichotomy persisted in discussions among members, and no clear solution was found that allowed the members to move past this inherent concern.

Environmental Flow Recommendations were developed through use of “templates” derived by a compromise to provide the most flow for the environment with the least impact (reduction in yield) for potential public water supply projects. Two primary “templates” were used, a 1-2-1 for the Upper basin, and a 1-3-2 for the Lower basin.

Both “templates” were altered slightly to provide better flow regimes, particularly in tributaries within the Lower basin. Please refer to discussion in pages 32-39.

Lack of Consensus on Upper Gages of the Brazos

The BBBASC was unable to develop consensus environmental flow recommendations for the three upper-most gages within the Brazos River basin: the Double Mountain Fork of the Brazos near Aspermont (gage 1); the Salt Fork of the Brazos near Aspermont (gage 2); and the Brazos River at Seymour (gage 3).

Two aquatic species, the Sharpnose Shiner and the Smalleye Shiner, are found in the three river reaches represented by these gages. These species are both Federal candidate species currently under review for listing as either threatened or endangered under the Endangered Species Act.

While the BBASC was able to reach consensus for subsistence and base flow recommendations at these gages, they were unable to reach consensus on pulse flow recommendations. The majority favored a position for pulse flows protective of water supplies in the Upper Basin. The minority position expressed concern for pulse flows protective of these two species.

Tables E-1 and E-2 provide an abbreviated summary of the BBASC Environmental Flow Recommendations. For the complete recommendation of implementation see Section 3; for the recommendations by gage see Appendix B

BBASC Environmental Flow Recommendations

The specific recommendations by the USGS gages are included in Appendix B. The following tables summarize the BBASC environmental flow recommendations. Table E-1 is the base flow, Table E-2 is the high (pulse) flow.

Table E-1

Gage No.	BBEST Report Page	USGS Gage	Gage Name	Basin Division	Subsistence EFR	Base Flow EFR	Comment
1	**5-3**	8080500	Double Mountain Fork – Aspermont	Upper	BBEST EFR	*BBEST and 50% Rule*	Concern: small users, Shiners
2	**5-4**	8082000	Salt Fork – Aspermont	Upper	BBEST EFR	*BBEST and 50% Rule*	Concern: small users, Shiners
3	**5-5**	8082500	Brazos at Seymour	Upper	BBEST EFR	*BBEST and 50% Rule*	Concern: small users, Shiners
4	**5-7**	8084000	Clear Fork – Nugent	Upper	BBEST EFR	*BBEST and 50% Rule*	Concern: small users
5	**5-8**	8085500	Clear Fork – Fort Griffin	Upper	BBEST EFR	*BBEST and 50% Rule*	Concern: small users
6	**5-10**	8088000	Brazos near South Bend	Upper	BBEST EFR	*BBEST and 50% Rule*	Concern: small users
7	**5-12**	8089000	Brazos at Palo Pinto	Middle	BBEST EFR	*BBEST and 50% Rule*	Concern: Recreation and City of Granbury, ecological concerns
8	**5-14**	8091000	Brazos at Glen Rose	Middle	BBEST EFR	*BBEST and 50% Rule*	Concern: Recreation and City of Granbury, ecological concerns
9	**5-16**	8095000	North Bosque at Clifton	Lower	BBEST EFR	*BBEST and 50% Rule*	
10	**5-18**	8096500	Brazos at Waco	Lower	BBEST EFR	*BBEST and 50% Rule*	
11	**5-20**	8100500	Leon near Gatesville	Lower	BBEST EFR	*BBEST and 50% Rule*	
12	**5-22**	8103800	Lampasas near Kempner	Lower	BBEST EFR	*BBEST and 50% Rule*	

Gage No.	BBEST Report Page	USGS Gage	Gage Name	Basin Division	Subsistence EFR	Base Flow EFR	Comment
13	**5-24**	8104500	Little River at Little River	Lower	BBEST EFR	*BBEST and 50% Rule*	
14	**5-25**	8106500	Little River near Cameron	Lower	BBEST EFR	*BBEST and 50% Rule*	
15	**5-26**	8108700	Brazos near Bryan	Lower	BBEST EFR	*BBEST and 50% Rule*	
16	**5-28**	8110500	Navasota near Easterly	Lower	BBEST EFR	*BBEST and 50% Rule*	
17	**5-30**	8111500	Brazos near Hempstead	Lower	BBEST EFR	*BBEST and 50% Rule*	
18	**5-32**	8114000	Brazos near Richmond	Lower	BBEST EFR	*BBEST and 50% Rule*	Estuarine flows
19	**5-34**	8116650	Brazos near Rosharon	Lower/ Gulf	BBEST EFR	*BBEST and 50% Rule*	Estuarine flows
20	**5-36**	8117500	San Bernard near Boling	Lower/ Gulf	BBEST EFR	*BBEST and 50% Rule*	Estuarine flows

Table E-2 Recommended "Pulse" Flows

Gage Name	Flow Conditions	Winter *(Nov; Dec; Jan; Feb)*	Spring *(Mar; Apr; May; June)*	Summer *(July; Aug; Sept; Oct)*
		Cfs/Frequency/days	Cfs/Frequency/days	Cfs/Frequency/days
Double Mountain Fork – Aspermont*	Dry	**None**	280/ 1/ 10	230/ 1/ 9
Non-consensus Vote	Avg	**None**	280/ 2/ 10	230/ 2/ 9
	Wet	**None**	570/ 1/ 12	480/ 1/ 12
Salt Fork – Aspermont*	Dry	**None**	160/ 1/ 10	140/ 1/ 8
Non-consensus Vote	Avg	**None**	160/ 2/ 10	140/ 2/ 8
	Wet	**None**	300/ 1/ 11	260/ 1/ 10
Brazos at Seymour*	Dry	**None**	560/ 1/ 10	370/ 1/ 8
Non-consensus Vote	Avg	**None**	560/ 2/ 10	370/ 2/ 8
	Wet	**None**	1,040/ 1/ 12	800/ 1/ 11
Clear Fork – Nugent	Dry	**None**	180/ 1 /10	100/ 1/ 8
	Avg	**None**	180/ 2 /10	100/ 2/ 8
	Wet	26/ 1/ 9	590/ 1/ 12	390/ 1/ 12
Clear Fork – Fort Griffin	Dry	**None**	360/ 1/ 12	110/ 1/ 10
	Avg	**None**	360/ 2/ 12	110/ 2/ 10
	Wet	61/ 1/ 11	1,230/ 1/ 15	700/ 1/ 16
Brazos near South Bend	Dry	None	1,260/ 1/ 10	580/ 1/ 8
	Avg	**None**	1,260/ 2/ 10	580/ 2/ 8
	Wet	**None**	2,480/ 1/ 13	1,180/ 1/ 11
Brazos at Palo Pinto	Dry	850/ 2/ 5	1,400/ 2/ 6	1,230/ 2/ 6
	Avg	850/ 4/ 5 & 1,390/ 2/ 7	1,400/ 4/ 6 & 3,370/2/ 10	1,230/ 4/ 6 & 2,260/ 2/ 9
	Wet	850/ 4/ 5 & 1,390/ 3/ 7	1,400/ 4/ 6 & 3,370/ 3/ 10	1,230/ 4/ 6 & 2,260/ 3/ 9

		Winter Cfs/Frequency/days	Spring Cfs/Frequency/days	Summer Cfs/Frequency/days
Brazos at Glen Rose	Dry	930/ 2/ 8	2,350/ 2/ 10	1,320/ 2/ 8
	Avg	930/ 4/ 8 & 1,390/ 2/ 7	2,350/ 4/ 10 & 6.480/ 2/ 14	1,320/ 4/ 8 & 3.090/ 2/ 12
	Wet	930/ 4/ 8 & 1,390/ 3/ 7	2,350/ 4/ 10 & 6,480/ 3/ 14	1,320/ 4/ 8 & 3,090/ 3/ 12
North Bosque at Clifton	Dry	**None**	710/ 1/ 12	**None**
	Avg	**None**	710/ 3/ 12	**None**
	Wet	120/ 2/ 10	710/ 3/ 12	130/ 2/ 6
Brazos at Waco	Dry	2,320/ 1/ 7	5,330/ 1/ 10	1,980/ 1/ 7
	Avg	2,320/ 3/ 7	5,330/ 3/ 10	1,980/ 3/ 7
	Wet	4,180/ 2/ 9	13,600/ 2/ 14	4,160/ 2/ 10
Leon near Gatesville	Dry	**None**	340/ 1/ 10	58/ 1/ 4
	Avg	**None**	340/ 3/ 10	58/ 3/ 4
	Wet	100/ 2/ 6	630/ 2/ 13	140/ 2/ 6
Lampasas near Kempner	Dry	78/ 1/ 8	780/ 1/ 13	77/ 1/ 4
	Avg	78/ 3/ 8	780/ 3/ 13	77/ 3/ 4
	Wet	190/ 2/ 11	1,310/ 2/ 16	190/ 2/ 6
Little River at Little River	Dry	520/ 1/ 5	1,420/ 1/ 10	430/ 1/ 4
	Avg	520/3/5	1,420/ 3/ 10	430/ 3/ 4
	Wet	1,600/ 2/ 11	3,290/ 2/ 17	1,060/ 2/ 8
Little River near Cameron	Dry	1,080/ 1/ 8	3,200/ 1/ 12	560/ 1/ 6
	Avg	1,080/ 3/ 8	3,200/ 3/ 12	560/ 3/ 6
	Wet	2,140/ 2/ 10	4,790/ 2/ 14	990/ 2/ 8
Brazos near Bryan	Dry	3,230/ 1/ 7	6,050/ 1/ 11	2,060/ 1/ 7
	Avg	3,230/ 3/ 7	6,050 / 3/ 11	2,060/ 3/ 7
	Wet	5,570/ 2/ 10	10,400/ 2/ 14	2,990 / 2/ 8

		Winter Cfs/Frequency/days	Spring Cfs/Frequency/days	Summer Cfs/Frequency/days
Navasota near Easterly	Dry	260/ 1/ 9	720/ 1/ 11	**None**
	Avg	260/ 3/ 9	720/ 3/ 11	**None**
	Wet	800/ 2/ 12	1,340/ 2/ 13	49/ 2/ 5
Brazos near Hempstead	Dry	5,720/ 1/ 10	8,530/ 1/ 13	2,620/ 1/ 7
	Avg	5,720/ 3/ 10	8,530/ 3/ 13	2,620/ 3/ 7
		Cfs/Frequency/days	Cfs/Frequency/days	Cfs/Frequency/days
	Wet	11,200/ 2/ 15	16,800/ 2/ 19	5,090/ 2/ 9
Brazos near Richmond	Dry	6,410/ 1/ 11	8,930/ 1/ 13	2,460/ 1/ 6
	Avg	6,410/ 3/ 11	8,930/ 3/ 13	2,460/ 3/ 6
	Wet	12,400/ 2/ 16	16,300/ 2/ 19	5,430/ 2/ 10
Brazos near Rosharon	Dry	9,090/ 1/ 12	6,580/ 1/ 10	2,490/ 1/ 6
	Avg	9,090/ 3/ 12	6,580/ 3/ 10	2,490/ 3/ 6
	Wet	13,600/ 2/ 16	14,200/ 2/ 18	4,980/ 2/ 9
San Bernard near Boling	Dry	510/ 1/ 8	350/ 1/ 7	300/ 1/ 9
	Avg	510/ 3/ 8	350/ 3/ 7	300/ 3/ 9
	Wet	1,060/ 2/ 12	680/ 2/ 10	470/ 2/ 10
No overbank flows are recommended, but the importance of overbank flows is acknowledged in report				
Hydrologic Triggers - Use the Palmer Hydrologic Drought Index for the day preceding the three "seasons"(Winter; Spring; Summer) in the climatic zones (Upper, Middle, Lower) to determine applicable base flow conditions (wet; average; dry)				

***Pulse Flow Recommendations for Gages 1-3 were determined by a committee vote. The Committee was unable to reach consensus, so according to the Committee rules, a vote to suspend the rules was initiated and unanimously approved. The vote for the Gage 1-3 recommendations in this table was 18 for and 4 against. The minority report is in Appendix E.**

1.0 BBASC Approach to Environmental Flows Assessment

1.1 The Brazos and San Bernard River Basins and Estuaries

1.1.1 Geographic Area

The Brazos River is the third largest river in Texas and the largest river between the Rio Grande and the Red River in terms of total watershed area. The headwaters of the Brazos River (Double Mountain Fork, Salt Fork, and Clear Fork) are located at the foot of the south plains near the Texas-New Mexico border.

The Brazos River Basin is the largest of the fifteen major river basins in Texas, with a contributing drainage area of approximately 42,000 square miles and 14 major subwatersheds, each with distinctive climate, topography, land-uses, and water needs.

By the time it reaches the Gulf of Mexico, the river has provided more than 6.75 billion gallons of water each year for cities, agriculture, industry, and mining; has served more than 3.9 million Texans living within the basin; and has provided abundant recreational opportunities, such as boating, swimming, and fishing.

The Brazos River Basin is one of the most diverse in the state and spans six ecoregions with distinctive geology, soils, vegetation, and climate. The basin spans three climatological zones:

- Continental Steppe zone, characterized by large variations in daily temperatures, low humidity, and irregularly spaced rainfall of moderate amounts;
- Subtropical Subhumid zone, characterized by hot summers and dry winters; and
- Subtropical Humid zone, characterized by warm summers and high humidity.

> A Brazos geographic footnote is John Graves' 200 mile canoe trip from Possum Kingdom Lake to just downstream of Hwy. 67 in 1957; which led to "Goodbye to a River" considered by many to be the best book ever written about Texas. It ultimately led to the "John Graves Scenic Riverway" designation by the State Legislature in Parker and Palo Pinto Counties. *Ed Lowe*

Average annual precipitation varies from 15 to 25 inches per year in the northern part of the basin, 35 to 40 inches per year in the central basin, and 45 to 50 inches per year in the southern basin.

Topography ranges from just over 4,385 feet in the northern portion of the basin to near sea level at the confluence with the Gulf of Mexico. Terrain is rugged in the northwestern part of the basin and landscapes tend to be flat and forested with richer soils in the southern Gulf prairies.

Two aquatic species of concern, Sharpnose Shiner and Smalleye Shiner, are found in the upper watershed of the Brazos River. Both of these species are candidate species currently under review for listing as either threatened or endangered under the Endangered Species Act. Historically, the range of these fish included most of the Brazos River, but these species are currently isolated within the river upstream of the Possum Kingdom reservoir.

The BBASC area of responsibility includes both the Brazos and San Bernard rivers, and was further delineated into subwatersheds based on tributaries and hydrologic characteristics by the BBEST and the BBASC (Figure 1).

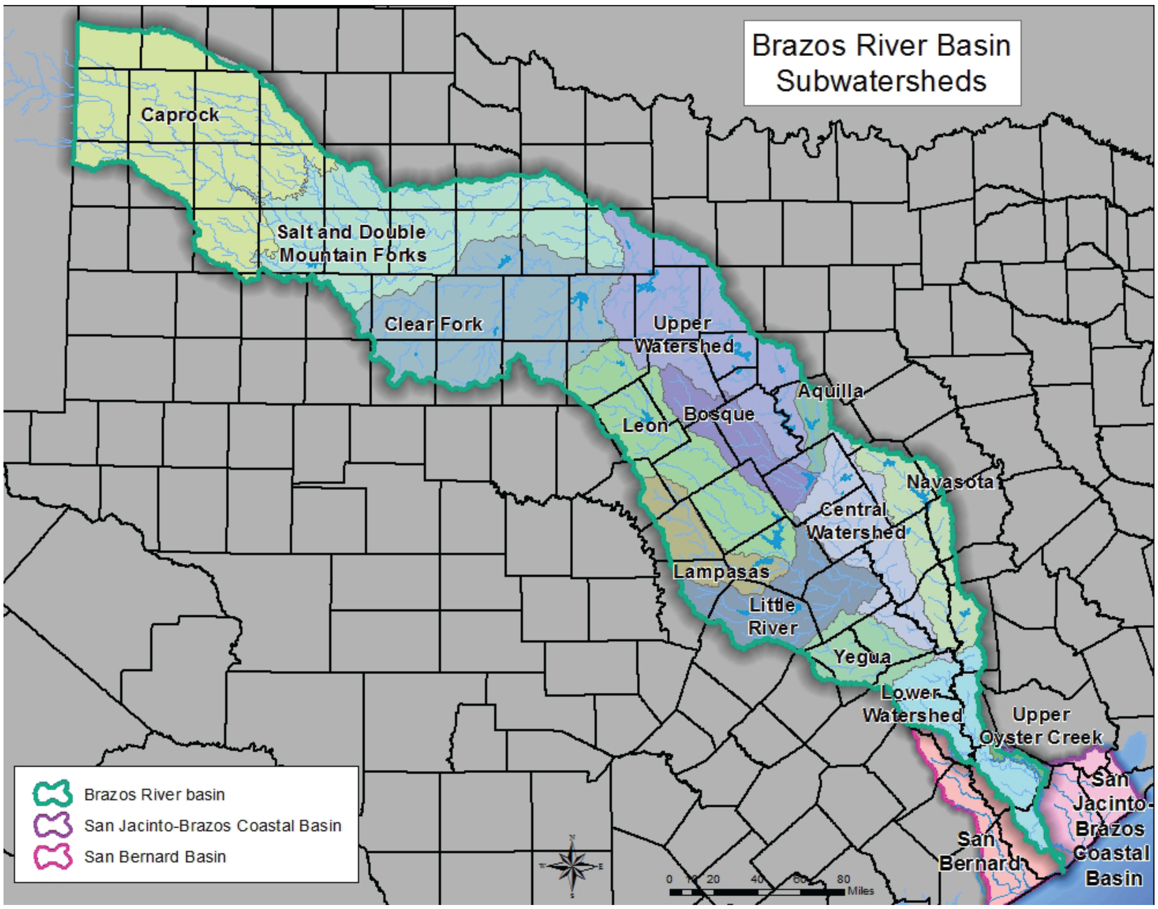


Figure 1. Map of the Brazos BBASC area showing 14 major subwatersheds of the Brazos, San Bernard, and San Jacinto-Brazos Coastal basins.

The San Bernard River flows from a spring near New Ulm, Texas to its mouth on the Gulf of Mexico, some 120 miles (190 km) to the southeast of the source. Its principal tributary is Caney Creek. Along its course, it passes through portions of Austin, Brazoria, Colorado, Fort Bend, Matagorda and Wharton counties.

It passes alongside the Attwater Prairie Chicken National Wildlife Refuge, which shelters one of the last populations of the critically endangered Attwater's prairie-chicken, a ground-dwelling grouse of the coastal prairie ecosystem.

The San Bernard drains approximately 1,850 square miles (4800 km²) of land, and its basin area is home to approximately 87,000 people according to the 1990 census. The region was once the home of the Karankawa Indians. The river runs near West Columbia, Texas and along one side of Camp Karankawa, a camping facility of the Boy Scouts of America. The basin receives approximately 35 to 70 inches (890 to 1,800 mm) of rainfall annually.

In November 2005 three of us put in at the boat ramp near FM 2918 and the Intracoastal Waterway. We had done the trip several times, kayaking the ICWW to the San Bernard and then down to the mouth where the river spills into the Gulf of Mexico. We paddled and paddled and paddled some more. It had been a while since we'd done the trip but it seemed like we should've been to the gulf in the amount of time that had passed. Finally, another kayaker paddling toward us explained that the mouth of the river had shifted downstream, the river running parallel with the gulf due to the buildup of sand and sediment stemming from a channelization project 80 years earlier. By 2006 the mouth of the San Bernard River was completely closed and took a walk of 300 yards on sand to reach the Gulf. A local campaign was initiated to dredge the mouth and in February of 2009 the dredge broke through, and the San Bernard River once again flowed to the Gulf of Mexico. *Cindy Bartos*

Estuary Areas

Extensive use of the lower river by estuarine organisms was documented in the San Bernard, Brazos, and adjoining tidal creeks. In areas 12 miles or more upstream, a mixture of freshwater fish species and estuarine organisms, including blue crabs, was collected. Salinities ranged between 0 and 25 practical salinity units at sites located up to 25 miles upstream. Distinct seasonality was observed irrespective of salinity regime, with certain marine species, such as gafftopsail catfish, invading the lower Brazos River during summer months along with other "seasonally migratory" species.

Depending on salinity regime, the lower Brazos River appears to serves as nursery habitat for many immature fish and shellfish species including juvenile white shrimp, brown shrimp, and blue crab. Johnson (1977) found evidence that these species also residence in adjacent marshes, and larger individuals were captured later in the year within deeper areas of the river channel. However, densities of these species in trawl samples declined greatly between the mouth and six miles upstream. Blue catfish and other freshwater fishes were collected in higher numbers during wet years, whereas marine species were more common during drier periods. Similar patterns in species composition and abundance were observed in the San Bernard River.

Coastal wetlands (saline to freshwater) are important natural resources that provide essential habitat for fish, shellfish, and other wildlife. Coastal wetlands also serve to filter and process agricultural and urban runoff and buffer coastal areas against storm and wave damage. The condition and distribution of wetland types can be affected by changes in depth and frequency of inundation as well as salinity. Periodic inflows delivering sediment are necessary to support marsh creation and maintenance within areas affected by coastal subsidence or sea-level rise. Extensive wetlands are found along the delta of the Brazos River and fringing marsh lines the banks of the lower-most river channel. Extensive coastal wetlands are present in the adjoining Cedar Lakes area, adjacent coastal areas drained by tidal creeks, and the San Bernard River estuary (White et al. 1988).

In the active Brazos River delta, White et al. (1988) described some of the marshes that occur in the swales between upland ridges (relict beach ridges). Smooth cordgrass (*Spartina alterniflora*) dominates the low-lying saltwater marshes and coexists with saltgrass (*Distichlis spicata*) at higher elevations. There are brackish marshes within the delta that support cattails (*Typha* sp.), saltmarsh bulrush (*Schoenoplectus robustus*), American bulrush (*Schoenoplectus pungens* var. *longispicatus*), jointed flatsedge (*Cyperus articulatus*), black rush (*Juncus roemerianus*), and saltgrass. White et al. (1988) also report extensive stands of black rush and cattails in the swales near Quintana.

Only scattered patch reefs of Eastern oyster are found in the vicinity of the Brazos and San Bernard river estuaries and adjacent marsh areas. Oysters (*Crassostrea virginica*) are not commercially harvested from the Brazos River estuary.

Aquifers within the Brazos Basin

Water can be divided into two general sources: surface water, such as the water within the Brazos River and groundwater, found beneath the land's surface in confined and unconfined aquifers. Aquifers and the Brazos River interact with each other, generally with groundwater seeping into the river bed when river flow is low and surface water seeping into the surrounding aquifer when river flow is high. Additionally, spring flows from aquifers in some areas can feed a river and conversely, rivers can sometimes overflow and directly recharge an aquifer through natural or man-made conduits.

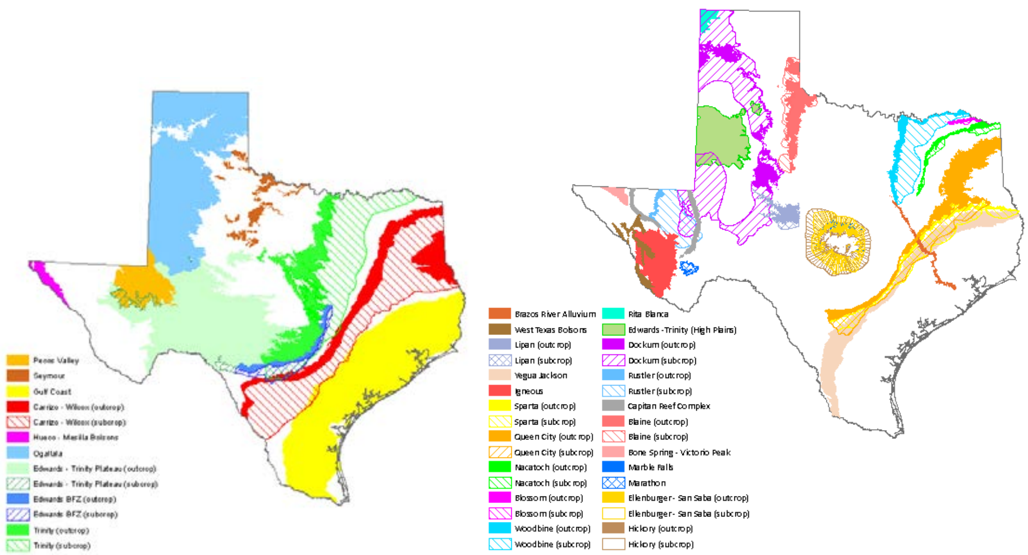
Generally, the Brazos River gains flow from the aquifers it crosses. *USGS*

The length of the Brazos River, the varying geologic and hydro-geologic conditions, and vastly different climatic conditions, create very different aquifer conditions in the upper, middle, and lower basins of the River. The Brazos River basin encompasses parts of the following major aquifers within Texas (Figure 2, beginning in the upper and following the natural flow of the River to the coast): Ogallala, Seymour, Edwards-Trinity (Plateau), Trinity, Carrizo, and Gulf Coast Aquifer.

The area also includes the following minor aquifers within Texas (Figure 2): Edwards-Trinity (High Plains), Dockum, Blaine, Woodbine, Queen City, Sparta, and the Brazos River Alluvium along with very small areas of Marble Falls, Ellenburger-San Saba, and Hickory.

Each aquifer is different from the others. Storage, water quality, and recharge rates differ greatly within these aquifers. For specific historical and projected groundwater supplies, the 2011 Regional Water Plans of Llano Estacado (Region O), Region G, and Region H can be obtained at the Texas Water Development Board's website www.twdb.state.tx.us .

Figure 2.



The Brazos BBASC divided the basin into three regions: upper, middle, and lower basins in order to utilize the Palmer Hydrologic Climatic Conditions to establish environmental flow recommendations.

Aquifers – Upper Basin

The upper basin of the Brazos River, as defined by the BBASC is located from the Texas-New Mexico border to Lake Possum Kingdom headwaters. This area can generally be described climactically as arid with low rainfall and hot summers. The western portion of the upper basin is mainly supplied by the Ogallala Aquifer. The Ogallala extends from South Dakota in the north, through Nebraska, Kansas, and Oklahoma, before it enters Texas and extends south of the Lubbock area. The Ogallala is a relatively shallow water table aquifer. Much of the Ogallala Aquifer is covered by an fairly impermeable layer of sediments. The combination of low rainfall and rather impermeable cover, create little to no recharge into the Aquifer within the Texas portion of the Ogallala.

Current groundwater withdrawal rates from the Ogallala outpace recharge, creating declining water-levels. Several groundwater conservation districts have been created to monitor and regulate groundwater pumpage in order to extend the groundwater supply into the future. Groundwater is the major water supply for the

Lubbock area for all uses: municipal, agricultural, commercial, industrial, etc. Water quality is generally good within the Ogallala.

The remaining portion of groundwater supplies within the upper basin comes from portions of the Seymour and Edwards-Trinity Aquifers and several minor aquifers. Most of these remaining aquifers have limited extent into the upper basin or they are either fully developed or over-developed. There is little naturally added groundwater into the upper basin of the Brazos River but groundwater based treated wastewater is added into the River.

Aquifers - Middle Basin

The middle basin of the Brazos River, as defined by the BBASC is located from Lake Possum Kingdom to the Lake Whitney dam. This area typically gets more rainfall than the upper basin but still can be considered semi-arid and hot within the summer months. Today, the middle basin is mainly supplied by surface-water but historically groundwater from the Trinity Aquifer was the major source of water.

The Brazos has nine aquifers in 46 counties that can produce 400,000 acre-feet of groundwater annually. *Horace Grace*

Within Texas, the Trinity Aquifer extends from Texas-Oklahoma border, north of the Dallas/Fort Worth area, south-southwest past the Austin/San Antonio area. The Trinity is a confined, artesian aquifer. Historically, the Trinity has been over-developed with significant water-level declines of 350-1,000 feet. The Trinity Aquifer continues to be the largest groundwater source within the middle basin but has decreased from historical pumpages. Surface-water within the middle basin makes up the majority of water supplies, however, conjunctive surface-water/groundwater continues to occur for municipal, agricultural, commercial, and industrial uses. Water quality is generally good within the Trinity Aquifer.

The remaining portion of groundwater supplies within the middle basin comes from portions of several minor aquifers. Most of these remaining aquifers have limited extent into the middle basin or they are either fully developed or over-developed. Like the upper basin, there is little naturally added groundwater into the middle basin of the Brazos River but groundwater based treated wastewater is added into the River.

Aquifers - Lower Basin

The lower basin of the Brazos River, as defined by the BBASC is located from the Lake Whitney dam to the River's entrance into the Gulf of Mexico, just southwest of Houston. This area typically gets more rainfall than the middle basin, and is considered wet to very wet and hot within the summer months. The greater Houston area averages 45-50 inches of rain each year. The Carrizo-Wilcox and the Gulf Coast Aquifer are significant water supplies within the lower basin of the Brazos River.

The Carrizo-Wilcox Aquifer, within Texas, extends from the northeast corner of the State, southwest to roughly the Laredo area and then extending into Mexico. The Carrizo-Wilcox is a confined, artesian aquifer. It has historically been underutilized within the lower basin of the Brazos River but has the potential to be used to a larger extent in the future. The water quality of the Carrizo-Wilcox aquifer is generally good.

The Gulf Coast Aquifer within Texas makes up the majority of groundwater use within the lower basin of the Brazos River. The Gulf Coast Aquifer, within Texas, extends along the Gulf Coast from the Texas-Louisiana border to the Texas-Mexico border. Within the Lower basin, the Gulf Coast Aquifer extends from the coastline, inland to Brazos County. The Gulf Coast Aquifer is a system of layered, confined, artesian aquifers, sometimes referred to as the Gulf Coast Aquifer System. The portion of the Gulf Coast Aquifer immediately adjacent to the coastline is generally salty from saltwater intrusion from the Gulf of Mexico and is not used as a source of water. **However, the aquifer in the greater Houston area has historically been over-utilized, resulting in significant declines in water-levels, as much as 500 feet and land-surface elevation loss called subsidence.**

> The Brazos River has been a major component of the greater Houston area's solution to the land-surface subsidence issue. Over-reliance on groundwater caused the land to sink, increasing tidal and inland flooding. Therefore groundwater pumpage is being reduced and replaced with surface water supplies {Brazos River water} in much of Galveston and Fort Bend Counties and continues to be a significant water provider to Brazoria County. Based on the 2012 State Water Plan (Region H), roughly 878,000 people and the industrial bases within Galveston and Brazoria Counties currently depend largely upon Brazos River water - totaling a 2010 need of 526 million gallons per day (588,900 acft) and a projected 2060 need of 737 million gallons per day (825,300 acft).
> *Tom Michel – Harris-Galveston Subsidence District & Fort Bend Subsidence District*

As groundwater is pumped at historical rates, water extracted from layers of clay within the aquifer, which allows compacting of the layers of clay, resulting in elevation losses of as much as 6-12 feet in the coastal areas of Houston/Galveston, and contributing significantly to flooding in an already flood prone area. The Harris-Galveston Subsidence District and the Fort Bend Subsidence District were created in 1975 and 1989 respectively to regulate groundwater in the greater Houston area. Those regulations have required reductions in groundwater pumpage/conversions to alternative water supplies, namely from the Brazos River in Fort Bend and Galveston Counties.

The remaining portion of groundwater supplies within the lower basin comes from portions of several minor aquifers. The Queen City and Sparta minor aquifers supply some demands near the College Station/Bryan area. The Brazos River Alluvium develops along the River from McLennan County to Fort Bend County, generally supplying small users. Like the upper and middle basins, there is little naturally added groundwater into the lower basin of the Brazos River but groundwater based treated wastewater has historically been added into the River.

Major Springs

The Brazos River Basin contains few major springs, defined as springs with discharges commonly greater than 1 cubic foot per second (cfs). Most of these springs issue from the Edwards-Balcones Fault Zone (BFZ) Aquifer in Bell and Williamson counties and from the Marble Falls Aquifer in Lampasas County. The three largest Edwards Aquifer springs within the Brazos basin are: 1) Salado Springs at Salado along the Lampasas River; 2) Berry Springs, located five miles north of Georgetown; and 3) San Gabriel Springs at Georgetown.

Springs from the Marble Falls Aquifer are both in the City of Lampasas and include Hancock Park Springs, and Swimming Pool Springs at Hancock Park, along Sulfur Creek which is a tributary to the Lampasas River.

Some springs in the upper basin significantly affect water quality in the Brazos River. These are primarily the salt springs and seeps, such as those along Salt Croton and Croton Creeks, in the upper Brazos River Basin. These natural saltwater sources in the main stem of the Brazos River above Possum Kingdom Lake cause the water to be more saline during low flow periods. For example, from 1963 to 1986, total dissolved solids (TDS) and chloride concentrations in Croton Creek near Jayton averaged 7,933 mg/L and 3,169 mg/L, respectively. Mean values for TDS and chlorides in the Salt Croton Creek near Aspermont from 1969 to 1977 were 71,237 mg/L and 41,516 mg/L, respectively. Secondary water quality standards for salinity can vary, although 1,000 to 2,000 is high.

Water in Possum Kingdom Lake usually contains more than 400 mg/L chloride and 1,200 mg/L TDS. The natural chloride sources in the upper Brazos River can affect water quality in the lower basin. In the Brazos River at Richmond, it has been estimated that 85 percent (or about 95 mg/L for the years 1946 to 1986) of the chloride is from the upper basin. Despite the fact that a majority of the chlorides in the lower portion of the river originate from the upper basin, most of the time chloride levels in the lower basin are not an issue.

Reservoirs

There are 16 major reservoirs in the Brazos River Basin with authorized storage in excess of 50,000 acre-feet each and 13 smaller regional water supply reservoirs with authorized storage in excess of 10,000 acre-feet each. The current storage capacities of these reservoirs range from approximately 10,000 to over 500,000 acre-feet. The system of reservoirs is managed for both flood control and water supply.

> Over the last several years, the Friends of the Brazos has removed 1600 tires and tons of trash from FM 67 to the headwaters of Lake Whitney.
> *Ed Lowe*

Lakes in the Brazos River Basin associated with steam electric power generation facilities include: Millers Creek Reservoir, Lake Palo Pinto, Lake Granbury, Squaw Creek Reservoir, Lake Whitney, Tradinghouse Creek Reservoir, Lake Limestone, Twin Oaks Reservoir, Gibbons Creek Reservoir, Lake Creek Lake, and Alcoa Lake. There are other steam electric power generation facilities using Brazos River water, including the Parish power plant in Fort Bend County.

1.1.2 Watershed Land Use

Layered over the diverse climatic zones, landscapes, and ecosystems within the basin are diverse patterns of land use that range from extreme rural areas with little to no development to areas of scattered development to areas with dense industrial, commercial, and residential development. Lubbock, Taylor, Hood, Johnson, McLennan, Bell, Williamson, Brazos, and Fort Bend counties have major cities, and some have industries that use surface waters. Industrial activities in the two most downstream counties, Fort Bend and Brazoria, are dominated by the petrochemical industry.

Natural gas exploration is increasing basin wide and places further demand on water supplies.

Agriculture is the mainstay of the rural economy within the basin. In the upper region, major products are row crops, such as cotton and wheat. Hay and silage are also produced in the upper region; however, due to low rainfall, their acreage is much less than those in other regions of the basin.

> The Brazos River has been the life blood for livestock and crop growers from the beginning of the settling of Texas. This industry continues to generate a huge economic benefit to the basin and would suffer significantly without the availability of the resources of the river. *Ned Meister*

Dairy farming, including confined animal feed operations (CAFOs), have recently begun to shift from central (Erath and Comanche counties) to northern (Panhandle) areas of the basin. Dairy farmers have found the arid climate in the northern area to be conducive to production, and lower storm water runoff in this area reduces nonpoint source pollution problems. As dairy operations move north, the central and lower portions of the basin are experiencing growth in the poultry industry.

The central region of the Brazos River Basin is noted for its production of a variety of crops, including hay, silage, peanuts, pecans, vegetables, corn, wheat, and cotton. Comanche, Eastland, Erath, and Somervell counties collectively lead the state in dairy production. This is due to several factors, such as available groundwater, soil suitable for forage production, and existing infrastructure.

The lower region of the Brazos River Basin produces hay, silage, beef cattle, and poultry. The Brazos River Bottoms counties (Brazos, Burleson, and Robertson) produce most of the crops in the region, including corn, sorghum, and cotton. Fertile soils of the Gulf Prairies in Fort Bend and Brazoria counties support the production of rice and cotton.

1.1.3 Water Quality

While some forms of land cover, such as wetlands, have properties that provide water purification and buffering capabilities, many of the waterways are affected by human impacts. The water quality in the Brazos River Basin is generally good, and the majority of the basin supports aquatic life and recreational uses. Two issues that commonly affect water quality are excessive levels of chloride and nonpoint source pollution. Water quality can also be impacted by the drought/flood cycle.

> I was reminded yesterday as I crossed the Brazos River at Waco of the major fish kills that had occurred between 2001 and 2002 due to Golden Algae. Some folks estimated as many as 2.3 million fish were killed during that period. As a result, recreational fishing was severely impacted. While little is known about the environmental requirements of Golden Algae, or what allows it to gain a competitive advantage over species, it is important that the BBASC encourage research that will lead to its demise. *Horace Grace*

The primary water quality concern along the main stem of the Brazos River continues to be elevated chloride and TDS concentrations. Elevated chloride and associated TDS concentrations increase drinking water treatment costs and can stress aquatic organisms. Chloride in the main stem of the Brazos River comes from natural brine springs in Stonewall, Kent, and Garza counties that discharge into the Salt Fork and Double Mountain Fork of the Brazos. The natural salt produced in the uppermost portion of the Brazos River Basin affects the main stem throughout its entire reach but less significantly as one moves downstream due to dilution resulting from intervening fresh water flows from the various tributary streams of the basin.

> The Brazos River basin contains some of the most productive agricultural lands in the state. From fertile fields of the High Plains, the Rolling Plains rangelands and cotton country, the diverse crop and livestock regions of Central Texas, to the prolific upper Coastal Bend, agriculture in the basin is a big contributor to the Texas economy. Texas farmers and ranchers understand that as stewards of the land, not only do they provide food to a hungry world, they also provide critical wildlife habitat and play an increasingly important role in water quality as well as quantity. With technology advances, over the past 34 years irrigated farm acres in Texas have dropped 18% while water usage has decreased by 32%. Irrigated corn yields over a similar period have increased 46% per acre and irrigated cotton yields have increased over 300% per acre. Nationally, each pound of beef produced today takes 30% less land and requires 14% less water than in 1977. Since most of Texas is privately owned, it is important to maintain an effective partnership with Texas farmers and ranchers, providing appropriate incentives to encourage sound land stewardship practices and promoting public policies that will support their ability to make a living off the land that we all love. *Lloyd Huggins*

The most common nonpoint source pollution issue in the Brazos River Basin is nutrient loading and increases in suspended solids. It can be difficult to characterize and mitigate nutrient and sediment sources because they originate from multiple locations, and evidence often is most pronounced immediately after rainfall events.

Stormwater runoff carries nutrients and sediments into the lakes and streams where they can cause eutrophication. Greater coverage of impervious surfaces associated with urban and suburban development results in faster runoff and delivery of nonpoint source pollution.

The BBEST report states, "In a recent study, Zeng et al. (2011) concluded that human activities dominate the physical and chemical processes controlling the origin and metabolism of dissolved inorganic carbon (DIC) in the Brazos River Basin. Their analysis reflected efficient air–water CO_2 exchange, degradation of relatively young organic matter, and photosynthesis in the middle reaches of the Brazos River as a result of damming and urban-treated wastewater input. They concluded that, in addition to natural soil carbonate, oyster shells and crushed carbonate minerals used in road construction were likely sources of carbonate in the lower reaches of the Brazos. Further understanding of freshwater sources and amounts of carbon contributions to the global carbon cycle is needed (Butman and Raymond 2011). Freshwater contributions to atmospheric CO_2 levels may eventually have a role in future carbon-sequestration strategies."

1.2 Definition of approach

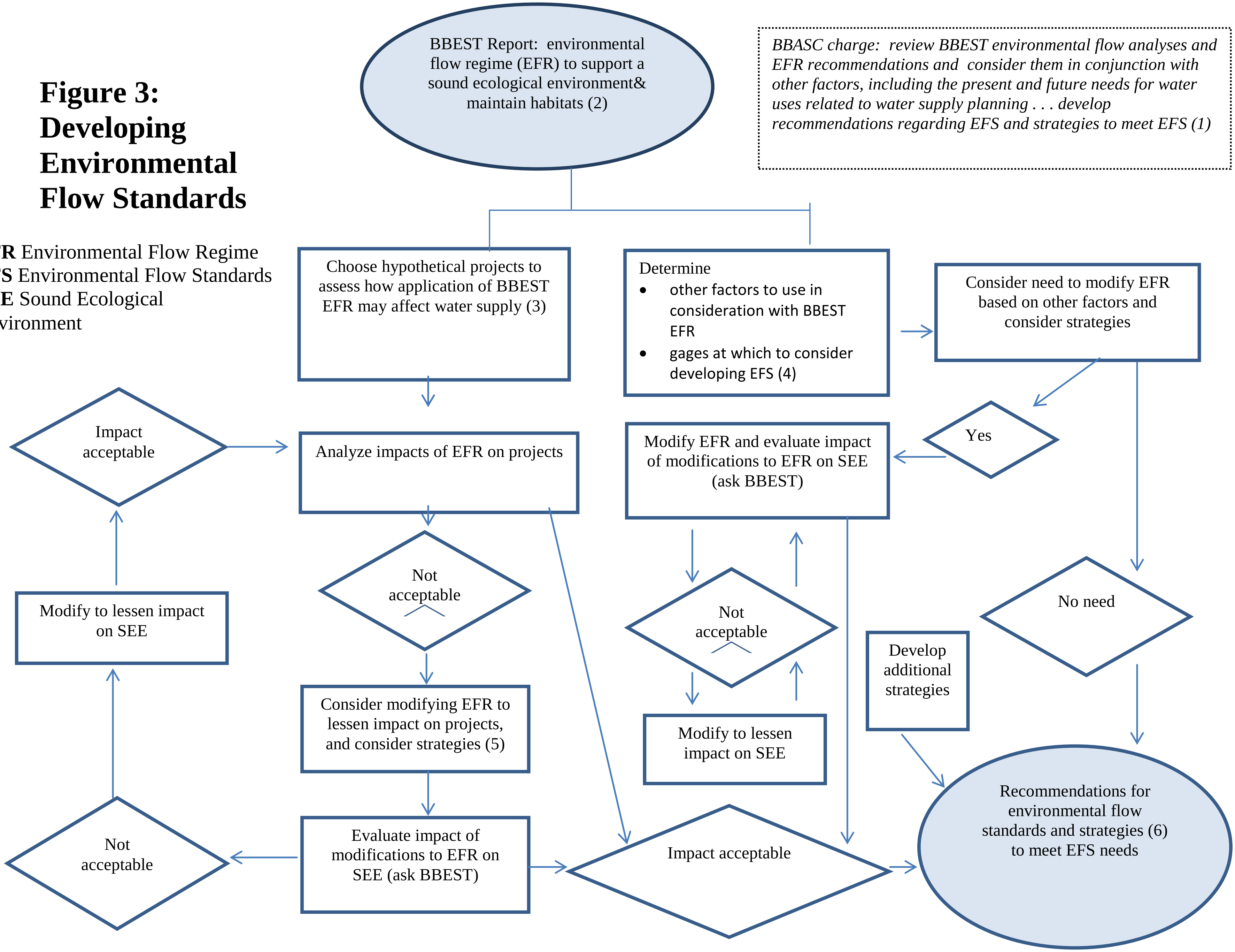
In developing its recommendations, the BBASC attempted to operate on a consensus basis. Figure 3 presents the discussion and decision flow employed by the BBASC throughout most of it deliberations.

As a landowner in the Upper Brazos region I am aware of the effect the salt cedar trees have on the water availability in the area. As a part-time resident of the Abilene area I appreciate the challenge of providing a water supply for the City of Abilene.

> The environment in and around Lake Granbury drives high property values which in turn drives high property taxes. The property values suffer when lake levels are low. Maintaining the lake levels and providing for the environmental flows will be challenging. *Sue Williams*

Figure 3: Developing Environmental Flow Standards

EFR Environmental Flow Regime
EFS Environmental Flow Standards
SEE Sound Ecological Environment



1.3 Presentations to the BBASC

Appendix C contains the list of invited presentations to the BBASC. Public comment opportunity was afforded at the beginning and end of each meeting. Minutes of each meeting are available on the TCEQ website http://m.tceq.texas.gov/permitting/water_rights/eflows/brazos-river-and-associated-bay-and-estuary-system-stakeholder-committee-and-expert-science-team

1.4 BBASC Assessment of BBEST Environmental Flow Regime Recommendations

The BBASC appreciates the expertise, commitment and work of the BBEST. This initial work and report assuaged many questions and concerns, allowing the BBASC to concentrate more on the mandated human needs and uses for the Brazos River basin and the San Bernard River basin.

The Texas Environmental Flows Science Advisory Committee and the Texas Parks and Wildlife Department have commented on the BBEST report. Those comments can be accessed at http://www.tceq.state.tx.us/permitting/water_supply/water_rights/eflows/brazos-river-and-associated-bay-and-estuary-system-stakeholder-committee-and-expert-science-team

2.0 BBASC Committee Discussions

2.1 Senate Bill 3 Environmental Flows Process

In 2007, the 80th Texas Legislature passed Senate Bill 3, which created a process to set environmental flow standards for several Texas river basin and bay systems. The process includes the appointment of basin-specific stakeholder committees tasked with making recommendations to the TCEQ regarding environmental flow standards and strategies to meet those standards. TCEQ is directed to consider these recommendations, along with other factors, to promulgate rules for environmental flow standards adequate to support a sound ecological environment, to the maximum extent reasonable considering other public interests and other relevant factors. TCEQ then considers its adopted environmental flows standards when granting future water rights appropriations. Provisions of SB3 are codified in the Texas Water Code.

In January 2011, the Environmental Flows Advisory Group (EFAG) appointed the Brazos BBASC and directed it to develop recommendations for the Brazos River Basin and the San Bernard River Basin and associated bays and estuary systems.

The Brazos BBASC appointed the Brazos BBEST. The BBEST developed a consensus report describing an environmental flow regime for the Brazos and San Bernard basins using the best available science. The BBASC, TCEQ and EFAG received this report on March 1, 2012.

"Eventually, all things merge into one, and a river runs through it. The river was cut by the world's great flood and runs over rocks from the basement of time" - Norman Maclean "A River Runs Through It."
So the river becomes the thread connecting all past issues and activities with our present condition, and is the passageway to what will be our future. We must be jealous in its use and vigilant against its abuse. How dare we not leave this river better than we found it? *Tom Conry*

To develop its environmental flow standard recommendations and strategies to meet those recommendations, the BBASC, in accordance with its statutory charge, considered the BBEST's environmental flow analyses and environmental flow regime recommendations in conjunction with other factors, including the present and future needs for water for other uses related to water supply planning in the Brazos and San Bernard River basins (Texas Water Code Section 11.02362). The BBASC's recommendations are included in this report.

The TCEQ is required to consider the environmental flow regime developed by the BBEST, the recommendations of the BBASC, economic factors, human and other water needs, and other appropriate information in promulgating rules regarding environmental flow standards for the Brazos and San Bernard River Basins (Texas Water Code Section 11.1471).

2.2 The BBASC defined its goal:

"Create a set of environmental flow recommendations on which future water rights permits are considered that balances all water needs within the basin and that are understandable and are reasonable to implement."

The BBASC wants to make clear that it does not intend that the environmental flows standards should require any water rights permit holder to release previously stored water from storage or to take other action to produce a pulse flow event that would not have occurred naturally or to maintain base or subsistence flows.

> "I frequently tell people that police officers and firefighters and libraries and streets and parks are important to every community…but, that none of those things matter if we don't have water. With a population that is expected to more than double over the next 50 years, Texas' single biggest threat to continued growth and prosperity is in not managing our water resources…and managing it means being good stewards of it, balancing the needs of a growing population with the needs of the environment." *David Blackburn*

Additionally, the BBASC utilized this concept in its deliberations: The base and subsistence flow numbers are derived with flow measurements that include managed water that may benefit the environment, but that are not necessarily natural flows and that could change in the future.

Further, in some areas, these historical gaged flows include releases of water from upstream reservoir storage that would not have been present under natural, pre-reservoir conditions, and are not guaranteed to be there in the future.

2.3 Environmental Flow Recommendation Risk Viewpoints

One theme recurred in the discussion among BBASC members: how to allocate risk that would arise from decisions that they made and that might ultimately be adopted by TCEQ. While recognizing that environmental flow standards adopted by TCEQ must be reviewed at least every ten years, and could be modified, members were keenly aware that the decisions made in the current process could affect those future reviews.

> The population of the State of Texas is expected to double over the period from 2010 to 2060, and the Brazos Basin will mirror this increase. Water is the lifeblood of municipalities, industry, and agriculture, thereby driving an economy that has helped Texas avoid the more devastating effects of two recent significant events: drought and recession. Balancing the needs of people and the environment is a delicate process, and we need not lose site of the importance of either element. *Phil Ford*

Those members advocating for a balance that provided greater water availability for future water rights expressed concern that once environmental flow standards were adopted, it would be difficult to change the standards to provide for future water rights development and less environmental flow.

Similarly, those members advocating for a balance that provided more protection for environmental flows expressed concern that the Texas Water Code limits how much EFS can be modified in relation to a permit once the permit is issued, thus limiting the practical ability to add more environmental flow protections in the future.

The BBASC recognized that a few immediate new water rights might be issued in the next five to ten years. Those favoring less stringent environmental flow protection relied on that circumstance to support an approach that would not impose more stringent conditions in this cycle, while those favoring more stringent environmental flow protections felt it, similarly, justified increased flow protections now that could be revised later. This dichotomy persisted in discussions among members, and no clear solution was found that allowed the members to move past this inherent concern.

Considerable time was spent comparing the environmental flow recommendations from the BBEST to those contained within the Brazos River Authority's pending System Operation Permit, and what implications the BBASC's recommendations might have on Brazos River Authority's permit, especially in light of the parallel schedules being followed in the Brazos Basin for SB3 and for Brazos River Authority's permit based on direction from the TCEQ Commissioners. The interim environmental flow special conditions in Brazos River Authority's permit are specific to that permit and that they may be modified in the future by the environmental flow recommendations ultimately adopted by TCEQ as a result of SB3.

Environmental Flow Recommendations were developed through use of "templates" derived by a compromise to provide the most flow for the environment with the least impact (reduction in yield) for potential public water supply projects. Two primary "templates" were used, a 1-2-1 for the Upper basin, and a 1-3-2 for the Lower basin.

Both "templates" were altered slightly to provide better flow regimes, particularly in tributaries within the Lower basin.

2.4 Overbank Flows

Overbank flows are naturally occurring flows that exceed the carrying capacity of the normal channel. The BBASC recognizes the importance of overbank flows for sediment and nutrient transfer, moving the river channel, maintaining the riparian ecology and for the maintenance of oxbows. As noted in the BBEST report, *"Periodic inundation provides opportunities for aquatic organisms to move into off-channel floodplain habitats such as oxbow lakes, sloughs, and marshes that promote growth and reproduction of certain species (Swales et al. 2000; Sommer et al. 2002, 2004) and support fish diversity and production in the overall river ecosystem (Welcomme 1979; Winemiller 1996; Zeug and Winemiller 2007, 2008a; Lyon et al. 2010)."*

However the consensus of the Stakeholder Committee is to not recommend overbank flows as potential flow standards on the Brazos River for the following reasons:

- The potential for flood damage to both property and human life;
- Time constraints imposed by Senate Bill 3 do not allow for sufficient consideration;
- The history of TCEQ not approving overbank flows in previously submitted BBASC Environmental Recommendations Reports; and
- Overbank flows are likely to continue to occur naturally.

The BBASC will include in the Work Plan a recommendation for studies of the benefits of overbank flows to help maintain a healthy river system.

The BBASC also recognizes that the BBEST did determine the importance of over bank flows to maintain oxbows and that even with the storage capacity of the Brazos River System over bank flows will continue to occur although possibly at a reduced magnitude and frequency.

2.5 Funding and Time for the Process

The BBEST had less than 12 months to fulfill the SB3 charge, and had very limited funding to compile, evaluate and then make determinations from existing data.

The BBASC had six months from the submission of the BBEST report until the September 1st deadline to submit its recommendations. Further, all the funding for the process had to be raised by the committee, from donations.

It is unrealistic to expect the Work Plan process will be successful without funding to generate data and assess those data. It is not extreme to state this process becomes useless if it is completely an unfunded mandate.

2.6 Building Consensus

The Brazos BBASC stakeholders agreed that consensus is reached when all member participating in a meeting at which there is a quorum agree that their major interests have been taken into consideration and addressed in a satisfactory manner so they can support the decision of the group.

BBASC discussions were successful due to the extent of the discussions. An example from the May 31st meeting, provided by Lloyd Huggins demonstrates the breadth of committee members' consideration of each topic:

"The Brazos BBASC, through consensus, adopted the BBEST recommendations for Base and Subsistence flows for the five "flashy" upstream gages on the Brazos River. These include five of the six gages in the BBEST recommendations that are upstream of Lake Possum Kingdom. The gage not included in this decision was the

Seymour gage. Additionally, the BBASC also adopted the "50% rule" which would be applied only to Low Flow periods for these same five gages.

Initially a suggestion was made to simplify the Base Flow regimes into a single number, which would be the Medium (50th percentile) flow regime. It was pointed out, with much discussion, that implementation of this suggestion would result in less water being available for human needs during low flow periods. It was also recognized that variation of flows was important to stream health. Then a suggestion was made that BBASC adopt all the BBEST Base Flows and Subsistence Flows, with the "50% rule" being applied to all Base flows from High flows to Low flows. There was a concern expressed that the "50% rule" being applied to all flows would potentially result in High flows becoming Medium flows due to the increased withdrawal, in effect ruling out any High flow conditions and thus being detrimental to stream health. Then the suggestion as ultimately adopted was made and consensus was reached."

2.7 Summary of Technical Analyses

The BBASC was assisted by a technical workgroup, which initially consisted of Brazos River Authority staff, state agency staff and selected members of the BBASC and BBEST. At various times, HDR Engineering, Inc. (HDR) staff and Joe Trungale, Trungale Engineering & Science, participated in this workgroup.

At its April 24, 2012 meeting, the BBASC identified two hypothetical reservoir projects for analysis to illustrate the impact of various environmental flow regimes (EFRs) on yield when considering implementing the BBEST EFR recommendations balanced with other present and future needs for the water. These projects were the Double Mountain Fork West Reservoir near Aspermont in the upper basin, and the off-channel Allens Creek Reservoir near Richmond in the lower basin.

The technical workgroup compared impacts on yield when environmental flow criteria were imposed derived from (1) the current TCEQ default methodology (called the Lyon's method) and (2) the BBEST EFR. The analyses were run using TCEQ's Water Availability Model (WAM) Run 3 to determine how much unappropriated water would be available for the projects after the environmental flows were imposed, assuming full use of senior water rights with no return flows. The projects were assigned a junior priority to all other water rights.

The technical workgroup used the Flow Regime Analysis Tool (FRAT) to estimate firm yields (amount of water that could be reliably diverted during a repeat of the drought of record) for the two projects. The period of record used in the analysis was January 1, 1940 through December 31, 1997. The drought of record, for Allens Creek, is 1950 through 1953, while the worst recorded drought for the Double Mountain Fork Reservoir begins in 1962. The firm yield numbers listed below and displayed on the figures are hypothetical and only for comparison purposes.

The reduction in yield when applying the BBEST EFR at Allens Creek was 5%; the reduction in yield at Double Mountain Fork was 40%.

Table 1: Summary of Yield Analysis Results

Environment Flows	Allens Creek	DMF West
Lyons	66,400 af/yr	15,052 af/yr
BBEST	63,100 af/yr	9,011 af/yr

Using FRAT, the workgroup provided annual flow frequency curves to compare estimated after-project flows downstream of each hypothetical reservoir or diversion, applying (1) the EFR derived from Lyons method, and (2) the BBEST EFR. Annual flow frequency curves included flow for all seasons and indicated how frequently a given daily stream flow would be met or exceeded. Annual flow frequency curves do not show how often different elements of the seasonal flow regime matrix (i.e. subsistence, base, pulse or overbank during the spring season) are met. The annual flow frequency curves in Figures 4 and 5 were provided to the BBASC at the May meeting.

Figure 4

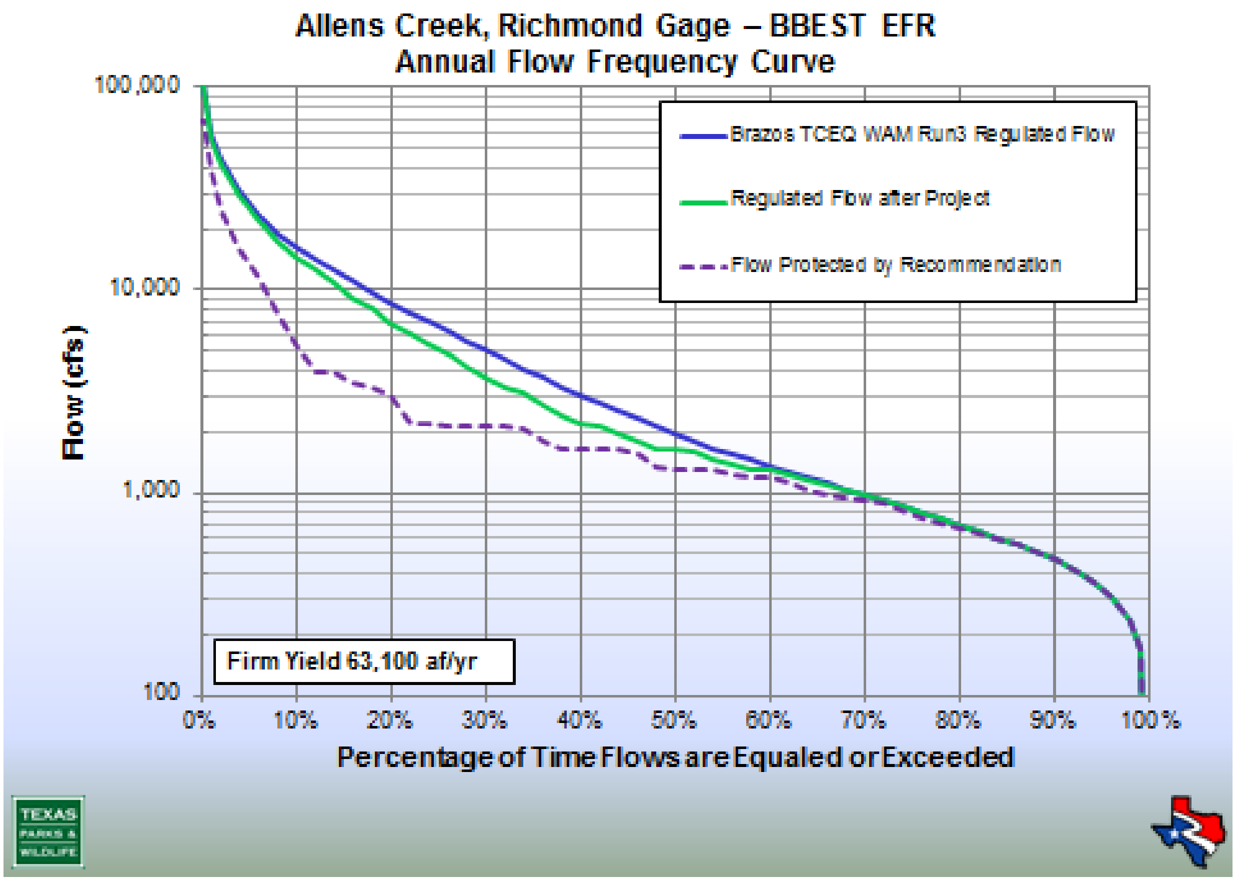
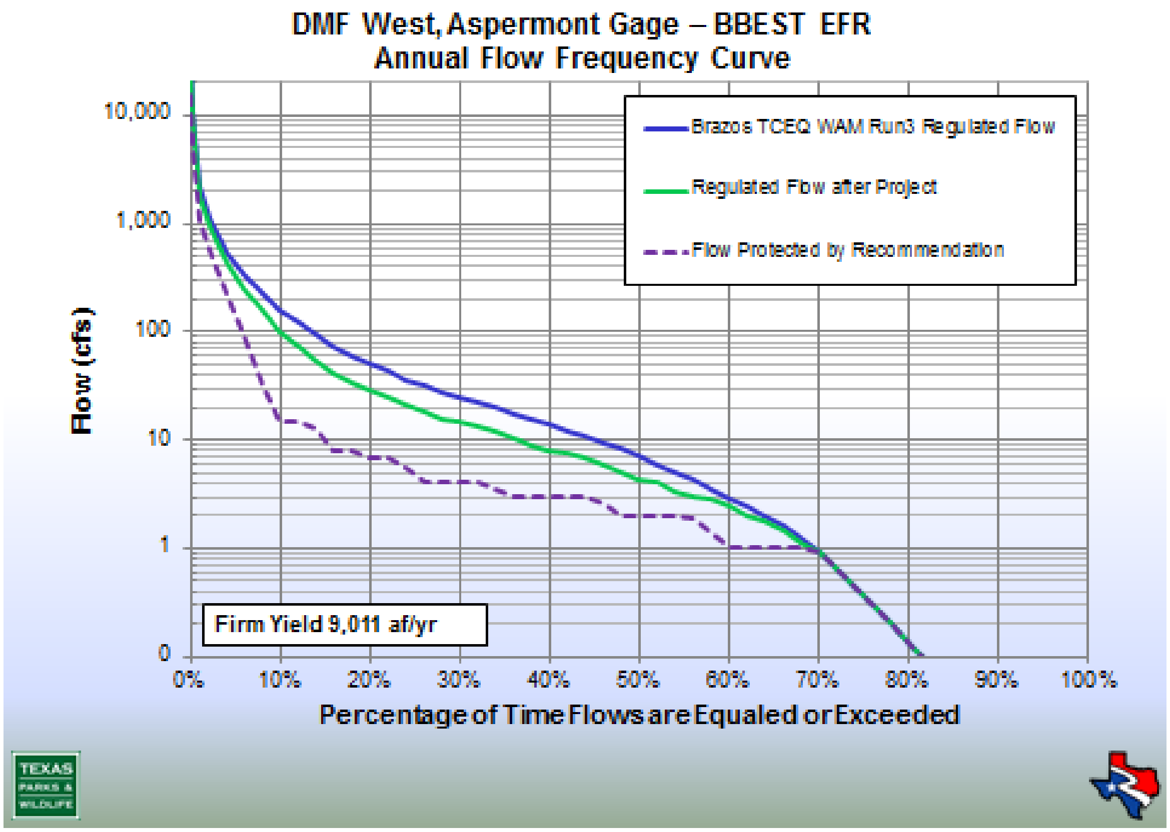


Figure 5



At the May 30-31 meeting, the City of Abilene presented information about, and the BBASC discussed, the proposed Cedar Ridge Reservoir, a project being pursued by the City of Abilene. The City has submitted a permit application for this reservoir. HDR provided the BBASC with information about the impact of various EFRs on yield. The four EFRs included in the FRAT analyses were:

- the no-environmental flows scenario;
- the Region G consensus criteria (called CCEFN) (6% impact);
- the Cedar Ridge Reservoir application EFR (8% impact); and
- the BBEST EFR (40% impact).

In this presentation, HDR discussed hydrologic characteristics of this part of the basin stating that, in 2011, zero flow was recorded at the Nugent gage on 77 days and at the Fort Griffin gage on 168 days. They stated that channel losses, as summarized from the Brazos WAM, were 55% from Cedar Ridge Reservoir site to Possum Kingdom reservoir, 71% from Brazos River gage at Aspermont to Possum Kingdom Reservoir, and 14% from Possum Kingdom Reservoir to the Brazos River at Rosharon gage. HDR explained how these losses contribute to minimizing the impact that changes in flow at the Cedar Ridge Reservoir location may have at downstream locations.

For the June 27-28 meeting, the BBASC asked the technical workgroup to conduct analysis for the Allens Creek and Double Mountain Fork projects:

- additional FRAT runs assuming a modified version of the BBEST EFR that used a structure similar to the TCEQ proposed rules for the Colorado and Lavaca River Basins (this structure deleted high flow pulse (HPF) events greater than the National Weather Service flood action stage, pulses that are longer than 30 days and the 3 and 4 per season pulses);
- compliance frequency analyses of the two projects under historical conditions, WAM Run 3, Lyons methodology, the BBEST EFR, and modified BBEST EFR consistent with Colorado-Lavaca proposed rules; and
- analysis of the “infinite infrastructure” scenario-- a scenario that would result if reservoirs and/or diversions existed that were large enough to divert all water except the BBEST EFR.

The compliance frequency results compare how much of the time environmental flows are met under each scenario. The percent of time flow equals or exceeds the BBEST EFR recommendations is the metric for non-pulse flows (subsistence, base low, base medium and base high). The total number of HFP events occurring over the analysis period is the metric for seasonal and annual pulses.

Results are summarized in Figures 6 and 7 below.

Figure 6

Compliance Results for Environmental Flow Recommendations
Allens Creek Reservoir

Project	No Project		Infinite Project	With Allens Creek Reservoir in Place		
Scenario	Historical	WAM Run3 for Project	Infinite Infrastructure	Lyons Method	BBEST EFR	Modified BBEST EFR
Firm Yield (AF/YR)	NA	NA	NA	66,400	63,100	63,215
Non-Pulse Flows (Percent of time flow equals or exceeds BBEST EFR recommendations)						
Subsistence	87%	62%	62%	62%	62%	62%
Base Low	55%	40%	40%	37%	40%	40%
Base Medium	75%	60%	60%	47%	60%	60%
Base High	69%	59%	59%	44%	59%	59%
Pulse Flows (Total number of HFP events occurring)						
3 per season	2,546	1,983	799	1,447	1,578	1,559
2 per season	1,106	831	370	664	715	675
1 per season	317	245	118	211	227	223
1 per year	82	66	35	59	61	59
1 per 2 year	34	31	13	29	30	29

Figure 7

Compliance Results for Environmental Flow Recommendations Double Mtn. Fork Reservoir

Project	No Project		Infinite Project	With Double Mtn. Fork Reservoir in Place		
Scenario	Historical	WAM Run3 for Project	Infinite Infrastructure	Lyons Method	BBEST EFR	Modified BBEST EFR
Firm Yield (AF/YR)	NA	NA	NA	15,052	9,011	11,032
Non-Pulse Flows (Percent of time flow equals or exceeds BBEST EFR recommendations)						
Subsistence	45%	48%	48%	48%	48%	48%
Base Low	45%	48%	48%	48%	48%	48%
Base Medium	60%	62%	62%	57%	62%	62%
Base High	56%	54%	54%	36%	54%	54%
Pulse Flows (Total number of HFP events occurring)						
4 per season	849	766	478	525	650	604
3 per season	543	485	313	338	419	394
2 per season	847	724	276	452	528	530
1 per season	275	228	102	137	165	164
1 per year	65	51	31	33	45	44
1 per 2 year	31	22	13	16	20	15
1 per 5 year	13	6	5	4	5	4

During the June 27-28 meeting, HDR provided additional information about the impact of various EFRs on the yield of the Cedar Ridge Reservoir and the hypothetical Double Mountain Fork Reservoir. For this presentation, HDR added two EFR analyses:

1) an EFR based on the TCEQ proposed rules for the Colorado/Lavaca Basins, which included 2-3 tiers of HFPs; and

2) an EFR based on TCEQ's adopted rules for the Trinity/San Jacinto Basins and the Sabine/Neches Basins (TCEQ Adopted Rules), which had one tier of HFPs.

The reduction in yield for the Cedar Ridge Reservoir was 36% for the Colorado/Lavaca EFR and 19% for the EFR based on the TCEQ Adopted Rules. For the Double Mountain Fork project, the results were similar with a 28% impact from the Colorado EFR and a 16% impact from the EFR based on the TCEQ Adopted Rules.

HDR presented information on the impact of a proposed EFR using the flow levels from the BBEST EFR but within a template that is based on the Cedar Ridge Permit Application (the “1-2-1 Template”).

The modified BBEST Template consists of BBEST base and subsistence recommendations and a HFP regime imposed based on hydrologic conditions. The pulse flow pattern of the 1-2-1 Template uses the flow amounts but not frequency of the first two tiers of BBEST-recommended HFPs: an HFP 2 one time during a wet hydrologic condition, an HFP 1 two times during an average hydrologic condition, and HFP 1 one time during a dry hydrologic condition. HDR’s analysis showed that the 1-2-1Template EFR reduced yield at the proposed Cedar Ridge Reservoir by12%. Ed Oborny with Bio-West presented information on the biological components of the proposed 1-2-1 Template and how this template was protective of the ecology at the Cedar Ridge site.

HDR applied the 1-2-1 Template to the Double Mountain Fork project and the on-channel Little River project. At Double Mountain Fork, the 1-2-1Template EFR reduced yield 8%. For the Little River project, this EFR reduced yield 12% (the BBEST EFR reduced yield 43%).

Reduction by the 1-2-1Template EFR was 6%; and the BBEST EFR was 11% on the Little River off-channel project. The times that an off-channel reservoir, with limited diversion infrastructure, can impact streamflow by its diversion under the BBEST EFR are reduced compared to an on-channel reservoir with an unlimited diversion capacity.

For the July 17 and July 31 meetings, the BBASC asked HDR to analyze the impact on yield of EFR variations that:

(1) added pulses to make a 1-3-2 Template; and
(2) incrementally removed pulse tiers from the BBEST EFR.

The hypothetical projects analyzed were the Double Mountain Fork Reservoir and Little River on-channel and off-channel reservoirs.

Three levels of variation analyzed were 2-2-1, 2-3-2, and 3-4-3; these showed reduction in yield ranging from 8% to 13%, depending on the project.

The second set of EFR variations involved incrementally removing pulse tiers from the BBEST EFR. For example, one variation would be the BBEST EFR without the two highest pulse flow tiers. The variations were compared to the 1-2-1 Template. The reductions in yield for Double Mountain Fork and Little River (on-channel) were 10% and 13%, respectively, when only HFP1 was included. The impacts increased as more tiers of HFPs were included in the EFR. To demonstrate stream flow impacts, HDR used a histogram showing the period of record of the model on the x-axis with the y-axis showing the number of the different level of high flow pulses that occur under the selected flow regime.

At the July 31st meeting, at the request of several BBASC members, Joe Trungale with Trungale Engineering & Science, presented an alternative, compromise proposal for recommending pulse flows based on a FRAT analysis at the Double Mountain Fork site. Mr. Trungale demonstrated that hydrologic conditions are better represented by a metric that relies on both Palmer Hydrologic Drought Index and Reservoir Storage, and that this dual metric provides better flexibility to develop recommendations whereby a modified BBEST template be used during "Wet" conditions and a modified BBEST template that protects fewer HFPs be used during "Dry" conditions.

For the August 15-16 meetings, the BBASC asked HDR to determine what impact imposition of the BBEST EFR in the middle basin (between Possum Kingdom dam and Lake Whitney dam), would have on water availability for the upstream Cedar Ridge project. The purpose was to determine if use of a different, and more stringent, EFR in the middle basin would impact water rights analysis for the upper basin. HDR concluded that, under the current modeling assumptions, using the BBEST EFR in the middle basin did not reduce the yield of Cedar Ridge Reservoir.

The BBASC also asked HDR to evaluate yield impacts on a hypothetical mid-basin project using varied EFRs. HDR used the Bee Mountain project, which was identified in a 1960's U.S. Study Commission report and also discussed briefly in the TWDB Reservoir Site Protection Study. This proposed reservoir project was located near the Brazos at Glen Rose gage and was simulated at a capacity of about 497,000 acre feet. The various EFRs resulted in the following reductions in yield:

- a Template with 2-3-1 pulse configuration, 4%;
- HPF1 only, 9%;
- HPF 1 and 2, 13%;
- HPF 1 through 3, 15%;
- HPF 1 through 4, 33%; and
- BBEST EFR, 33%.

During August 15 meetings, several stakeholders presented a compromise proposal for the upper gages (1,2,3) resulting from their FRAT analysis of the Double Mountain Fork site. This proposal, allowed for reduced frequencies of pulses during "Dry" conditions, but provided for additional levels and frequencies of pulses during "Wet" conditions.

3.0 BBASC Recommendations

3.1 Environmental Flow Standards Recommendations

Environmental flow standards recommendations are listed by individual gage in Appendix B. There are 20 gages and sets of flow recommendations. The subsistence, base and overbank flow recommendations for all gages were developed through consensus. The pulse flow recommendations for seventeen of the gages were developed through consensus. The pulse flow recommendations for Gages 1 (Double Mountain Fork Brazos River near Aspermont), 2 (Salt Fork Brazos River near Aspermont) and 3 (Brazos River near Seymour) were determined by a BBASC vote. For those three gages, the Committee was unable to reach consensus on the pulse flow recommendations. According to the Committee rules, a vote to suspend the rules was initiated and unanimously approved. The vote for the Gages 1-3 recommendations were 18 for and 4 against. The minority report relating to the recommended pulse flows at Gages 1-3 may be found at Appendix E.

3.2 Exemption from PULSE flow – Small Quantity User

The BBASC recommends a small-user exemption from pulse flows, based on the likelihood that the available pumping capacity would not be able to extract enough water to adversely impact the overall pulse event. The BBASC recommendation, made by consensus, is:

If the diversion rate for the new permit is less than 20% of an individual pulse flow trigger requirement (for a season), the permit will not have to pass that high flow pulse and a requirement for that pulse will not be included in the permit. If the diversion rate for the new permit is greater than 20% of an individual pulse flow trigger requirement; the permit will have to pass the high flow pulse and that high flow pulse requirement will be included in the permit.

3.3 Exemption from PULSE flow - Palo Pinto Creek Watershed

The BBASC recommends, by consensus, the following exemption from pulse flows for the Palo Pinto Creek watershed:

Requests by an existing permit holder, at the time the environmental flow standards are adopted, in the Palo Pinto Creek watershed to increase authorized storage by up to 15% does not require application of high flow pulse standards on the new appropriation.

3.4 Estuarine Freshwater Inflow Recommendations

The BBASC makes the following recommendation, by consensus, for the Brazos River estuary:

The BBASC recognizes that periodic freshwater pulses of varying magnitudes are necessary to maintain the health of the riverine estuaries of both the Brazos and San Bernard rivers. The growing delta of the Brazos river in particular is dependent upon high magnitude pulses of a few to several tens of thousands cfs which statistically occur on average from a few per season for the smaller pulses, to one every couple of years for the overbank events.

The Brazos BBEST based their recommendation on the assumption that inflow into the estuary would equate to the BBEST environmental flow recommendations (EFR) for the Brazos River at Richmond.

BBASC did not have the opportunity to fully vet and analyze what potential impacts to the estuary may result from BBASC modifications of the EFR at Richmond, specifically, not adopting high flow pulses, annual pulses, and one level of seasonal pulse. The BBASC believes that short of development of an on-channel reservoir upon the main stem of the Lower Brazos, or several on-channel reservoirs upon the main tributaries of the Lower Brazos, it is expected that some pulses will continue to occur and sufficient sediment and nutrient delivery will be available into the foreseeable future.

Thus, while these high magnitude pulses are not specifically prescribed in the BBASC recommendation for the Richmond gage, the group anticipates that these high flow pulses will likely continue to maintain the health of the Brazos and San Bernard estuaries.   Brazos BBASC recommends that a long-term study be commissioned to monitor salinity, nutrient transport, and sediment transport and deposition and associated estuarine health in order to detect any negative effects as upstream projects are implemented over the next few decades.

3.5 Implementation Rules

The BBASC notes the following discussion, and consensus recommendations, relating to implementation rules for the environmental flow standards that it is recommending:

3.5.1 Definition of Seasons

The Brazos BBASC adopts the definitions of seasons adopted by the BBEST, which conducted an extensive evaluation of available biology, hydrology, and water quality data to determine the appropriate grouping of months to apply to the HEFR methodology to reflect naturally occurring variations in flow. A thorough description of the analysis undertaken can be located in Appendix F of the BBEST report. The Brazos BBEST selected three 4-month seasons as follows: winter (November–February), spring (April–June), and summer (July–September). The BBEST concluded, and the BBASC agrees, that this seasonal separation will ensure that the BBASC's instream flow recommendations reflect observed, natural, intra-annual variability in flow conditions.

3.5.2 Hydrographic Separation of Flow Components

The BBASC recommends using the methodology adopted by the BBEST for establishing different flow components for the BBASC environmental flow component standards. The BBEST developed an environmental flow regime for each location using the HEFR methodology, e.g. the separation of flows into flow components. HEFR defines all flows in the historical record under analysis as subsistence flows, base flows, pulse flows, or overbank flows. The HEFR program developed by the TPWD supports two methods for flow separation:

- MBFIT (Modified Base Flow Index with Threshold)
- IHA (Indicators of Hydrologic Alteration)

Each of these methods has multiple parameters that are used to define and control the flow separation process. The Brazos BBEST selected the IHA methodology for the separation of gage flows. This selection was confirmed after review of the hydrograph separation for all of the selected gages.

The BBEST selected the following methodology and parameters (based on IHA methodology) to separate flows into subsistence, base, pulse and overbank flows:

- **Subsistence Flow Limit:** flows below this value are subsistence flows. Consistent with the BBEST, the BBASC uses the 5^{th} percentile of all flows as the subsistence flow limit.
- **Minimum Flow for Pulse Flows:** flows below this limit cannot be pulse or overbank flows. They are subsistence or base flows.
- **Maximum Flow for Base Flows:** flows above the 75^{th} percentile cannot be base or subsistence flows. They are pulse or overbank flows.

Flows between the minimum flow for pulse flows and the maximum flow for base flows can be classified as either base/subsistence flows or pulse/overbank flows. Flows remain at the classification of the previous day unless certain criteria are met, as follows:

- **Percent Increase that Changes Base Flow to Pulse Flow (Applies for Flows between the Maximum and Minimum):** A base or subsistence flow changes to a pulse flow under the following conditions: if the previous day's flow is base or subsistence flow and if the current day's flow is between the maximum flow for base flows and the minimum flow for pulse flows, then the day is classified as a pulse if the flow increases by more than 25 percent. If the increase is less than this value (or if there is a decrease), the flow remains a base or subsistence flow, like the previous day's flow.
- **Percent Decrease Below Which Pulse Flow Changes to Base Flow (Applies for Flows between the Maximum and Minimum):** A pulse flow changes to a base flow or subsistence flow under the following conditions: if the previous day's flow is a pulse or overbank flow and if the current day's flow is between the maximum base flow and minimum pulse flow, then the day is classified as a base flow or subsistence flow if the flow decreases less than 5 percent. If the increase is greater than this value or if the flow increases, the flow remains a pulse/overbank flow, like the previous day's flow.

3.5.3 Definition of Hydrologic Condition—Wet, Average, Dry

The Brazos BBASC has recommended environmental flow standards for base flows and pulse flows that differ depending on whether the area is in dry, average or wet hydrologic conditions. The BBASC recommends using the Palmer Hydrological Drought Index (PHDI) to determine when a particular part of the basin was considered to be dry, average or wet. The Brazos BBEST utilized this concept only for the base flow conditions. The BBASC has recommended that hydrologic condition for base flows and for high flow pulses should be defined on the basis of the PHDI.

The PDHI was designed to reflect longer-term hydrological drought impacts that are usually slow to develop and persist longer than a meteorological drought. The index uses an arbitrary scale from -6.0 and +6.0 and represents the severity of moisture conditions from extremely dry to extremely wet.

Texas is divided into ten climatic divisions structured to coincide with county boundaries and cover the total area of the state. The National Weather Service maintains near-real-time updates of climatic data in each of the divisions in cooperation with the National Climatic Data Center (CDC). The divisional dataset of climatic variables has been compiled for the period of record beginning in 1895. These data have been used by the CDC to compute and publish a historical account of the monthly PHDI indices for the entire period of record from 1895 to present. Updates to the PHDI are available from the CDC weekly and monthly. The Brazos BBEST used the monthly PHDI published by the CDC to characterize the hydrologic condition at each gage station. Using the period of record, a dry (lowest 25% of PHDI), an average (25 to 75% of PHDI) and a wet (75% or higher) hydrologic conditions were defined by the BBEST. The BBASC incorporates the BBEST methodology for developing the dry, average and wet conditions, which themselves are consistent with the BBEST methodology for computing base flow statistics.

The Brazos BBEST recommended that the hydrologic condition be updated monthly as the monthly PHDI values are published by the CDC. The BBASC has determined that the hydrologic condition should be updated only on the last day of the month before the start of a new season, in order to simplify the administration of the environmental flow standards. The three hydrologic conditions (dry, average and wet) are applicable to the base flow recommendations and to the pulse flow recommendations.

Although the BBEST decided that a PHDI index should be computed specific to each gage location, the BBASC has chosen to divide the basin into three areas for the imposition of the PHDI. The BBASC made this decision based on information from TCEQ that the administration of the senior water rights system could have unforeseen problems if the PHDI were different for each gage where there was not a clear hydrologic break in the system. The BBASC determined that a regional PHDI should be computed for each of the following three geographic locations, using the methodology the BBEST selected to develop gage-specific PHDI numbers:

(1) All watersheds upstream from and draining into Possum Kingdom Lake;

(2) All watersheds draining into the Brazos River and its tributaries downstream of Possum Kingdom dam, but before Lake Whitney Dam;
(3) All of the watersheds below Lake Whitney dam, including the San Bernard River and coastal watersheds.

As mentioned above, the BBASC defined three areas within the Brazos River basin – Upper basin from the source waters to the headwaters of Possum Kingdom Lake; Middle basin from Possum Kingdom to the Lake Whitney dam; and Lower beginning at the Lake Whitney dam and continuing to the Gulf of Mexico. These three basin divisions were used to define hydrologic and habitat considerations for the BBASC.

Table 2 Percent of Climatic Zone in each basin division.

	Basin Division		
Climatic Zone	Upper Basin	Middle Basin	Lower Basin
Zone 1 - High Plains	2.7%	0.0%	0.0%
Zone 2 - Low Rolling Plains	64.7%	0.0%	0.0%
Zone 3 - North Central	32.6%	100.0%	61.9%
Zone 4 - East Texas	0.0%	0.0%	14.7%
Zone 5 - Trans Pecos	0.0%	0.0%	0.0%
Zone 6 - Edwards Plateau	0.0%	0.0%	5.7%
Zone 7 - South Central	0.0%	0.0%	13.2%
Zone 8 - Upper Coast	0.0%	0.0%	4.5%
Zone 9 - Southern	0.0%	0.0%	0.0%
Zone 10 - Lower Valley	0.0%	0.0%	0.0%

Table 3 Percentile Statistics of Palmer Hydrological Drought Index by basin division.

	Basin Division		
Percentile	Upper Basin	Middle Basin	Lower Basin
25th percentile	-1.78	-1.95	-1.73
75th percentile	2.18	2.39	2.13

Here is the reference for obtaining updated PHDI values.
ftp://ftp.ncdc.noaa.gov/pub/data/cirs/drought.README
ftp://ftp.ncdc.noaa.gov/pub/data/cirs/drd964x.phdi.txt

3.5.4 Implementation between Base Flow and Subsistence Flow

The BBASC adopts by consensus the following implementation rules when flows fall between base and subsistence flows, consistent with the BBEST recommendation:

Dry conditions. Under dry hydrologic conditions, if the mean daily streamflow is less than the seasonal base flow and greater than subsistence flow, then 50 percent of the difference between streamflow and the recommended subsistence flow should be passed.

Average and wet hydrologic conditions. Under average and wet hydrologic conditions, if the mean daily streamflow is less than the seasonal base flow, then all streamflow must be passed and none may be impounded or diverted.

3.5.5 Implementation of High Flow Pulses

The BBASC recommends, by consensus, the following additional rules relating the high flow pulses:
A qualifying high flow pulse event is initiated when flow exceeds the prescribed pulse peak trigger flow (i.e. pulse peak flow magnitude) found in the BBASC environmental flow standard recommendations, Appendix B. Qualifying events are counted in the season or year in which they begin and are assumed to continue into the following season or year as necessary to meet prescribed high flow pulse characteristics.

The qualifying event continues (which means flows are passed up to that trigger magnitude) until one of the following conditions identifies its termination:

- The prescribed volume is passed;
- The mean daily streamflow recedes to less than or equal to *minimum flow for pulse flows* as defined in Table 6.1 from BBEST;
- The prescribed duration is met; or
- The mean daily streamflow recedes to less than or equal to *maximum flow for base flows* and decreases by 5 percent or less in a day. The *maximum flow for base flows* is summarized for each focal reach in Table 6.2 from BBEST

For gages 7 (Brazos near Palo Pinto) and 8 (Brazos near Glen Rose), the following applies: If, during a qualifying event at one magnitude, flows increase to a magnitude that exceeds a greater magnitude event trigger, the pulse recommendations of the higher qualifying pulse control passage of the flows. In this case, the higher magnitude event is considered to satisfy one lower magnitude event in each category in the same season.

4.0 Strategies to Meet Environmental Flow Standards

Senate Bill 3 (SB3) mandates that in addition to developing recommendations for environmental flow standards, each bay/basin area stakeholder committee also develop recommendations for strategies to meet these standards.

Environmental and water management strategies were viewed by the BBASC as a list of potential measures to meet the environmental flow standards. While these strategies are separate and apart from the environmental flow standards, they should work in concert with a regime that balances ecological needs and human needs. The BBASC viewed workable strategies as an integral component for achieving the recommended environmental flow standards for the basin. These strategies could be considered by water planners, state or federal agencies, legislators, or permit holders to pursue the protection goals established by the BBASC.

To that end, the Brazos River Basin and Bay Stakeholder Committee has developed a list of strategies explained in detail below. It is important to note that in recommending these strategies the BBASC does not intend for them to be viewed or implemented as mandates on individuals, local governments or water right permit holders. Instead, the BBASC recommends that this list of strategies be viewed as a set of voluntary or incentive-based measures that could be used to achieve environmental flow standards within the Brazos basin.

The applicability of individual strategies should be considered on a case-by-case basis, and must produce a benefit to environmental flow, or at least no adverse effects. The BBASC also believes that, just as the environmental flow regimes will evolve over the coming years, so too should the environmental and water management strategies designed to meet those regimes.

- Consider the use of incentives, such as tax incentives to encourage donation of water rights for environmental flows (environmental flows). Rights could be dedicated to the Texas Water Trust or private water trusts.

- Explore opportunities for individuals to obtain grants, donations, or state or federal funding to purchase or lease water rights for use in dedicating such water for environmental flows through the Texas Water Trust or private water trusts.

- Consider the voluntary dedication of return flows (treated wastewater effluent) for purposes of environmental flows, and whether incentives would be beneficial to promote such dedication. This could be a dedication of some or all of the wastewater return flows associated with a permit.

- Promote the beneficial reuse of treated wastewater effluent for uses such as irrigation of large landscaped areas (golf courses, parks, etc) to reduce the demand of potable water, thereby reducing or delaying the need for future raw water supplies. This is essentially a conservation or demand reduction strategy. The less water being used, the more that could be available for environmental flows.

- Consider developing cost incentive programs for entities that promote conservation and dedicate conserved water to environmental flows. This would encourage entities to implement specialized and targeted conservation measures and dedicate all or a portion of the savings experienced to environmental flows. It would need to be clear that the entities would not be subject to water right cancellation for non-use if they are saving water for the purpose of environmental flows.

- Explore conjunctive use of groundwater and surface water to determine whether such conjunctive use would benefit environmental flows. Conjunctive use allows a water user to toggle back and forth between surface and groundwater depending on conditions. In some cases, during dry times, a water user could rely more heavily on groundwater so as to protect river environmental flows.

- Explore the benefits for graywater use in reducing the use of potable water for uses such as lawn irrigation and other innovative uses which could use graywater rather than potable water. Graywater shall mean wastewater from showers, bathtubs, handwashing lavatories, sinks not used for food preparation or disposal and clothes-washing machines. Graywater does not include wastewater from the washing of material, including diapers, soiled with human excreta or wastewater that has come in contact with toilet waste. Use of graywater shall be in accordance with Title 30 Texas Administrative Code, Chapter 285.

- Provide information to and support the Groundwater Management Area (GMA) process so that the establishment or consideration of Desired Future Conditions (DFC) takes into account any potential impact that DFCs may have on environmental flows, particularly spring-flow, and how groundwater could be used to benefit environmental flows.

- Encourage stewardship activities on private lands by providing incentives or funding to landowners who engage in land management practices that benefit water quality and environmental flows. These could include activities such as riparian protection or wetlands restoration that have a proven benefit to environmental flows.

- Encourage stewardship activities on public lands that benefit water quality and environmental flows. Where possible, public entities with landholdings could engage in activities on those lands such as riparian protection, invasive species control, wetlands restoration, etc that provide a benefit to environmental flows.

- Increase EQIP contract awards for water conservation and water quality improvement. The Environmental Quality Incentives Program (EQIP) is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years in length. To increase available water supply, increase the federal cost share paid under EQIP contracts for control of invasive water-robbing species such as juniper, mesquite, salt cedar, and others. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland.

- Encourage and increase public acceptance of prescribed burning as a rangeland management tool. Reduce legal and regulatory hurdles to prescribed burning. Consider a government-subsidized liability insurance program for trained prescribed burners who are affiliated with an established prescribed burn organization. Increase application of prescribed burning under EQIP contracts. Prescribed fire has been shown to control the spread of woody invasive species, provide improved water quality to rivers and streams, improve wildlife habitat, and increase available forage.

- Evaluate additional strategies to control invasive species such as salt cedar, mesquite, the giant cane *Arundo donax* and juniper. Seek state funding, tax incentives, or similar monetary incentives to support evaluations and implement recommended eradication/control strategies. Removal of invasive species, particularly those that are heavy water users has been shown over time to increase flows and such removal should be encouraged or incentivized where possible.

- Consider forming a group of reservoir owners (such as those that operate more than one reservoir, various owners from several reservoirs, etc.) to periodically review ways and means to improve reservoir operations to enhance both environmental flows and water supply. This could include scheduling releases to better mimic natural flow patterns and could be done for individual dams or multiple dams. It may also include consideration of attenuation and travel time for downstream water supply releases. For example, in some cases water supply releases may be scheduled at different flow rates and times while still delivering the same volume of water to the downstream location. In some instances, this flexibility might better provide for environmental flow needs.

- Consider a voluntary dry-year option program for irrigators in the Brazos basin like the Voluntary Irrigation Suspension Program Option in the Edwards Aquifer area. This program is a voluntary program open to participation to eligible holders of irrigation water rights from the Edwards Aquifer Authority (EAA) in Atascosa, Bexar, Comal, Hays, Medina and Uvalde counties who are willing to suspend exercising all or a portion of their authorized withdrawal rights in exchange for financial compensation.

- Explore water right management options to look for efficiencies that could benefit environmental flows. This could include finding opportunities where water right diversion points could be relocated to improve delivery efficiencies to both water users and the environment.

- Consider the construction of a salt water barrier to prevent saltwater intrusion in the lower basin. During periods of low-flow in the river, saltwater can intrude into the mouth of the Brazos, at times reaching as far as forty miles upstream. Constructing a saltwater barrier, which could take the form of a passable dam structure, could prevent this intrusion and improve water quality in that area of the basin.

- Consider creating opportunities to educate the public, including creating school curriculum, regarding water conservation, land and water stewardship, and other issues related to environmental flows.

5.0 Work Plan Recommendations

The exceedingly short time for the BBEST to evaluate scientific data (about 12 months), the low level of funding for BBEST activities, the six-month timeline for the BBASC deliberations to a recommendation report and the de facto requirement to raise all funds itself (no funding provided to the BBASC) reduced the ability of both groups to fully complete their mandates. Therefore, Work Plan issues were not explored definitively and will be a task for the BBASC and BBEST in developing the Work Plan.

Work Plan items include, but will not be limited to:

1) Long term study be commissioned to monitor salinity, nutrient transport, and sediment transport and deposition and associated estuarine health in order to detect any negative effects as upstream projects are implemented over the next few decades.

2) An analysis of BBASC environmental flow recommendations at the Richmond gage be evaluated and compared to the results of the BBEST analysis. Initiate Estuarine studies to supplement existing 40-year old assessments of sediment and nutrient inflows, and delta formation on the aquatic community under EFR flows.

3) Additional studies for the area from Possum Kingdom to Whitney, including the golden algae issue.

4) Oxbow and overbank formation issues.

5) Continue the fish surveys (of all species) on the Middle Brazos at Brazos R. downstream of US 281 at Rivercrest Campground, Brazos R. downstream of Allied Rock Mine at 5500 Lazy Bend Road and Brazos R. at FM 200 NE of Glen Rose. These surveys should be taken twice each year in May and August.

6.0 Appendices Table of Contents

Gage No.	USGSGage	Gage Name	Basin Division
1	8080500	Double Mountain Fork – Aspermont	Upper
2	8082000	Salt Fork – Aspermont	Upper
3	8082500	Brazos at Seymour	Upper
4	8084000	Clear Fork – Nugent	Upper
5	8085500	Clear Fork – Fort Griffin	Upper
6	8088000	Brazos near South Bend	Upper
7	8089000	Brazos at Palo Pinto	Middle
8	8091000	Brazos at Glen Rose	Middle
9	8095000	North Bosque at Clifton	Lower
10	8096500	Brazos at Waco	Lower
11	8100500	Leon near Gatesville	Lower
12	8103800	Lampasas near Kempner	Lower
13	8104500	Little River at Little River	Lower
14	8106500	Little River near Cameron	Lower
15	8108700	Brazos near Bryan	Lower
16	8110500	Navasota near Easterly	Lower
17	8111500	Brazos near Hempstead	Lower
18	8114000	Brazos near Richmond	Lower
19	8116650	Brazos near Rosharon	Lower/Gulf
20	8117500	San Bernard near Boling	Lower/Gulf

BBASC Member	Interest Group	Preferred Title	Alternate	Preferred Title
Dale Spurgin, Chair	Regional Water Planning Groups	None		
Tom Michel, Vice-Chair	Regional Water Planning Groups	General Manager Ft. Bend Subsidence Dist.	None	
Cindy Bartos	Recreational Water Users		Tyson Broad	Research Associate Lone Star Sierra Club
David Blackburn	Municipalities	City Manager	Nicole Torralva	Director of Public Works
Tom Conry	Municipalities	Program Manager Water Utilities	Ricky Garrett, PE	Department Director Water Utilities
Phil Ford	River Authorities	General Manager/CEO	Brad Brunett	Water Services Manager
Willie Gavranovic	Agricultural Irrigation	Owner/Manager		
Horace Grace	Groundwater Conservation Districts	None	Judy Parker	Director Clearwater UWCD
Brian Hays	Free-Range Livestock	None	Brandon Belt	None
Lloyd Huggins	Free-Range Livestock	None		
Joe S. Langdon	Brazos Valley Soil and Water Conservation Districts			
Gena Leathers	Chemical Manufacturing	Water Technology Leader		
Dan Loomis	Recreational Water Users	None		
Ed Lowe	Environmental Interests	President, Friends of the Brazos	Jennifer Ellis	Senior Project Coordinator National Wildlife Federation

BBASC Member	Interest Group	Preferred Title	Alternate	Preferred Title
Ned Meister	Concentrated Animal Feeding Operations	Director, Commodity & Regulator Dept. Texas Farm Bureau	Jay Bragg	Associate Director Commodity & Regulatory Dept. Texas Farm Bureau
Curt Mowery	Agricultural Irrigation	None	Jay Bragg	
Tommy O'Brien	Municipalities	Director of Water Utilities	Scott Hibbs Wayne Lisenbee	Consultant Assistant Director
Keith Pate	Environmental Interests			
Matt Phillips	Environmental Interests	Director of Government Relations	Ryan Smith	Freshwater Ecologist
Mary Ruth Rhodenbaugh	Public Interest Groups	Community Development Officer Texas Gulf Bank		
Patrick Riley	Commercial Fishermen		Tyson Broad	Research Associate Lone Star Sierra Club
Eddie Saucedo	Refining	Environmental Manager		
Gary Spicer	Electricity Generation	Water Quality Manager	Scott Hibbs Kim Mireles	Consultant Director Environmental Generation
SuEllen Staggs	Municipalities	Director of Utilities, City of Sugarland		
Sue Campbell Williams	Public Interest	None		

APPENDIX B Environmental Flow Recommendations by Gage

Non-consensus Vote for Pulse Flows

Gage Number 1- USGS Gage 8080500 Double Mountain Fork Brazos River near Aspermont *

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	**Dry**	1cfs		Not Recommended	Not Recommended	Not Recommended
		Average	4cfs				
		Wet	15cfs				
Spring	1cfs	**Dry**	1cfs		Pulse(s) 1 Qp:280 Volume 1,270 Duration 10	Pulse(s) 2 Qp:280 Volume 1,270 Duration 10	Pulse(s) 1 Qp:570 Volume 2,600 Duration 12
		Average	3cfs				
		Wet	8cfs				
Summer	1cfs	**Dry**	1cfs		Pulse(s) 1 Qp:230 Volume 990 Duration 9	Pulse(s) 2 Qp:230 Volume 990 Duration 9	Pulse(s) 1 Qp:480 Volume 2,160 Duration 12
		Average	2cfs				
		Wet	7cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet

50% Rule applies for Dry conditions Base Flow

Over-bank flows not adopted

Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Non-consensus Vote for Pulse Flows

Gage Number 2- USGS Gage 8082000 Salt Fork Brazos River near Aspermont *

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	**Dry**	1cfs		Not Recommended	Not Recommended	Not Recommended
		Average	4cfs				
		Wet	9cfs				
Spring	1cfs	**Dry**	1cfs		Pulse(s) 1 Qp:160 Volume 720 Duration 10	Pulse(s) 2 Qp:160 Volume 720 Duration 10	Pulse(s) 1 Qp:300 Volume 1,350 Duration 11
		Average	2cfs				
		Wet	5cfs				
Summer	1cfs	**Dry**	1cfs		Pulse(s) 1 Qp:140 Volume 560 Duration 8	Pulse(s) 2 Qp:140 Volume 560 Duration 8	Pulse(s) 1 Qp:260 Volume 1,090 Duration 10
		Average	1cfs				
		Wet	3cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Non-consensus Vote for Pulse Flows

Gage Number 3- USGS Gage 8082500 Brazos River at Seymour*

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	**Dry**	10 cfs		Not Recommended	Not Recommended	Not Recommended
		Average	25 cfs				
		Wet	46 cfs				
Spring	1cfs	**Dry**	7 cfs		Pulse(s) 1 Qp:560 Volume 2,960 Duration 10	Pulse(s) 2 Qp:560 Volume 2,960 Duration 10	Pulse(s) 1 Qp1,040 Volume 5,870 Duration 12
		Average	19 cfs				
		Wet	35 cfs				
Summer	1cfs	**Dry**	4 cfs		Pulse(s) 1 Qp: 370 Volume 1,870 Duration 8	Pulse(s) 2 Qp: 370 Volume 1,870 Duration 8	Pulse(s) 1 Qp:800 Volume 4,290 Duration 11
		Average	13 cfs				
		Wet	32 cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet

50% Rule applies for Dry conditions Base Flow

Over-bank flows not adopted

Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 4- USGS Gage 8084000 Clear Fk Brazos River at Nugent

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	**Dry**	5cfs		Not Recommended	Not Recommended	Pulse(s) 1 Qp:26 Volume 160 Duration 9
		Average	8cfs				
		Wet	13cfs				
Spring	1cfs	**Dry**	3cfs		Pulse(s) 1 Qp:180 Volume 860 Duration 9	Pulse(s) 2 Qp:180 Volume 860 Duration 9	Pulse(s) 1 Qp: 590 Volume 2,800 Duration 12
		Average	6cfs				
		Wet	12cfs				
Summer	1cfs	**Dry**	1cfs		Pulse(s) 1 Qp:100 Volume 460 Duration 8	Pulse(s) 2 Qp:100 Volume 460 Duration 8	Pulse(s) 1 Qp:390 Volume 1,890 Duration 12
		Average	4cfs				
		Wet	9cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 5- USGS Gage 8085500 Clear Fork Brazos River at Ft Griffin

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	Dry	8cfs		Not Recommended	Not Recommended	Pulse(s) 1 Qp:61 Volume 430 Duration 11
		Average	17cfs				
		Wet	34cfs				
Spring	1cfs	Dry	4cfs		Pulse(s) 1 Qp:360 Volume 2,120 Duration 12	Pulse(s) 2 Qp:360 Volume 2,120 Duration 12	Pulse(s) 1 Qp:1,230 Volume 7,310 Duration 15
		Average	13cfs				
		Wet	27cfs				
Summer	1cfs	Dry	1cfs		Pulse(s) 1 Qp:110 Volume 620 Duration 10	Pulse(s) 2 Qp:110 Volume 620 Duration 10	Pulse(s) 1 Qp:700 Volume 4,110 Duration 16
		Average	5cfs				
		Wet	20cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 6- USGS Gage 8088000 Brazos River near South Bend

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	**Dry**	36cfs		Not Recommended	Not Recommended	Not Recommended
		Average	73cfs				
		Wet	120cfs				
Spring	1cfs	**Dry**	29cfs		Pulse(s) 1 Qp:1,260 Volume 7,280 Duration 10	Pulse(s) 2 Qp:1,260 Volume 7,280 Duration 10	Pulse(s) 1 Qp:2,480 Volume 15,700 Duration 13
		Average	60cfs				
		Wet	100cfs				
Summer	1cfs	**Dry**	16cfs		Pulse(s) 1 Qp:580 Volume 3,140 Duration 8	Pulse(s) 2 Qp:580 Volume 3,140 Duration 8	Pulse(s) 1 Qp:1,180 Volume 7,050 Duration 11
		Average	46cfs				
		Wet	95cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second   Volume is in ac/ft   Duration is in Days

Gage Number 7- USGS Gage 08089000 Brazos River near Palo Pinto

Season	Subsis-tence	Hydrological conditions	Base	High Flow Pulses				
				Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season		Wet Hydrological Conditions Pulse per Season	
Winter	17cfs	**Dry**	40cfs	Pulse(s) 2 Qp:850 Volume 3,690 Duration 5	Pulse(s) 4 Qp:850 Vol. 3,690 Duration 5	Pulse(s) 2 Qp: 1,390 Vol. 7,180 Duration 7	Pulse(s) 4 Qp:850 Vol. 3,690 Duration 5	Pulse(s) 3 Qp: 1,390 Vol. 7,180 Duration 7
		Average	61cfs					
		Wet	100cfs					
Spring	17cfs	**Dry**	39cfs	Pulse(s) 2 Qp:1,400 Volume 6,600 Duration 6	Pulse(s) 4 Qp:1,400 Vol. 6,600 Duration 6	Pulse(s) 2 Qp:3,370 Vol. 20,200 Duration 10	Pulse(s) 4 Qp:1,400 Vol. 6,600 Duration 6	Pulse(s) 3 Qp:3,370 Vol. 20,200 Duration 10
		Average	75cfs					
		Wet	120cfs					
Summer	17cfs	**Dry**	40cfs	Pulse(s) 2 Qp:1,230 Volume 5,920 Duration 6	Pulse(s) 4 Qp:1,230 Vol. 5,920 Duration 6	Pulse(s) 2 Qp:2,260 Vol. 13,000 Duration 9	Pulse(s) 4 Qp:1,230 Vol. 5,920 Duration 6	Pulse(s) 3 Qp:2,260 Vol. 13,000 Duration 9
		Average	72cfs					
		Wet	120cfs					

Over-bank flows not adopted
Qp is in Cubic Feet per second
Duration is in days
volume is in ac/ft

For pulse flows during average and wet hydrological conditions, both levels of pulses and their frequency must be met during each season if flows are adequate; provided that if during a qualifying event at one magnitude, flows increase to a magnitude that exceeds the next higher pulse flow trigger, the higher flow pulse controls passage of flows and is considered to satisfy one lower magnitude event of the same season.

Gage Number 8- USGS Gage 8091000 Brazos River near Glen Rose

Season	Subsis -tence	Hydrological conditions	Base	High Flow Pulses				
				Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season		Wet Hydrological Conditions Pulse per Season	
Winter	16cfs	**Dry**	42cfs	Pulse(s) 2 Qp:930 Volume 5,400 Duration 8	Pulse(s) 4 Qp:930 Vol. 5,400 Duration 8	Pulse(s) 2 Qp: 1,700 Vol. 10,800 Duration 10	Pulse(s) 4 Qp:930 Vol. 5,400 Duration 8	Pulse(s) 3 Qp: 1,700 Vol. 10,800 Duration 10
		Average	77cfs					
		Wet	160cfs					
Spring	16cfs	**Dry**	47cfs	Pulse(s) 2 Qp:2,350 Volume 14,300 Duration 10	Pulse(s) 4 Qp: 2,350 Vol. 14,300 Duration 10	Pulse(s) 2 Qp:6,480 Vol. 46,700 Duration 14	Pulse(s) 4 Qp: 2,350 Vol. 14,300 Duration 10	Pulse(s) 3 Qp:6,480 Vol. 46,700 Duration 14
		Average	92cfs					
		Wet	170cfs					
Summer	16cfs	**Dry**	37cfs	Pulse(s) 2 Qp:1,320 Volume 7,830 Duration 8	Pulse(s) 4 Qp:1,320 Vol. 5,920 Duration 6	Pulse(s) 2 Qp:3,090 Vol. 21,200 Duration 12	Pulse(s) 4 Qp:1,230 Vol. 5,920 Duration 6	Pulse(s) 3 Qp:3,090 Vol. 21,200 Duration 12
		Average	70cfs					
		Wet	160cfs					

Over-bank flows not adopted
Qp is in Cubic Feet per second
Duration is in days
volume is in ac/ft

For pulse flows during average and wet hydrological conditions, both levels of pulses and their frequency must be met during each season if flows are adequate; provided that if during a qualifying event at one magnitude, flows increase to a magnitude that exceeds the next higher pulse flow trigger, the higher flow pulse controls passage of flows and is considered to satisfy one lower magnitude event of the same season.

Gage Number 9- USGS Gage 8095000 North Bosque River near Clifton

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	**Dry**	5cfs		Not Recommended	Not Recommended	Pulse(s) 2 Qp:120 Volume 750 Duration 10
		Average	12cfs				
		Wet	25cfs				
Spring	1cfs	**Dry**	7cfs		Pulse(s) 1 Qp:710 Volume 3,490 Duration 12	Pulse(s) 3 Qp:710 Volume 3,490 Duration 12	Pulse(s) 3 Qp:710 Volume 3,490 Duration 12
		Average	16cfs				
		Wet	33cfs				
Summer	1cfs	**Dry**	3cfs		Not Recommended	Not Recommended	Pulse(s) 2 Qp:130 Volume 500 Duration 6
		Average	8cfs				
		Wet	17cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 10- USGS Gage 8096500 Brazos River at Waco

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	56cfs	**Dry**	120cfs		Pulse(s) 1 Qp:2,320 Volume 12,400 Duration 7	Pulse(s) 3 Qp:2,320 Volume 12,400 Duration 7	Pulse(s) 2 Qp:4,180 Volume 25,700 Duration 9
		Average	210cfs				
		Wet	480cfs				
Spring	56cfs	**Dry**	150cfs		Pulse(s) 1 Qp:5,330 Volume 32,700 Duration 10	Pulse(s) 3 Qp:5,330 Volume 32,700 Duration 10	Pulse(s) 2 Qp:13,600 Volume 102,000 Duration 14
		Average	270cfs				
		Wet	690cfs				
Summer	56cfs	**Dry**	140cfs		Pulse(s) 1 Qp:1,980 Volume 10,500 Duration 7	Pulse(s) 3 Qp:1,980 Volume 10,500 Duration 7	Pulse(s) 2 Qp:4,160 Volume 26,400 Duration 10
		Average	250cfs				
		Wet	590cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 11- USGS Gage 8100500 Leon River at Gatesville

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	**Dry**	9cfs		Not Recommended	Not Recommended	Pulse(s) 2 Qp:100 Volume 540 Duration 6
		Average	20cfs				
		Wet	52cfs				
Spring	1cfs	**Dry**	10cfs		Pulse(s) 1 Qp:340 Volume 1.910 Duration 10	Pulse(s) 3 Qp:340 Volume 1,910 Duration 10	Pulse(s) 2 Qp:630 Volume 4,050 Duration 13
		Average	24cfs				
		Wet	54cfs				
Summer	1cfs	**Dry**	4cfs		Pulse(s) 1 Qp:58 Volume 220 Duration 4	Pulse(s) 3 Qp:58 Volume 220 Duration 4	Pulse(s) 2 Qp:140 Volume 600 Duration 6
		Average	12cfs				
		Wet	27cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second   Volume is in ac/ft   Duration is in Days

Gage Number 12- USGS Gage 8103800 Lampasas River near Kempner

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	10cfs	**Dry**	18cfs		Pulse(s) 1 Qp:78 Volume 430 Duration 8	Pulse(s) 3 Qp:78 Volume 430 Duration 8	Pulse(s) 2 Qp:190 Volume 1,150 Duration 11
		Average	27cfs				
		Wet	39cfs				
Spring	10cfs	**Dry**	21cfs		Pulse(s) 1 Qp:780 Volume 4,020 Duration 13	Pulse(s) 3 Qp:780 Volume 4,020 Duration 13	Pulse(s) 2 Qp:1,310 Volume 6,860 Duration 16
		Average	29cfs				
		Wet	43cfs				
Summer	10cfs	**Dry**	16cfs		Pulse(s) 1 Qp:77 Volume 270 Duration 4	Pulse(s) 3 Qp:77 Volume 270 Duration 4	Pulse(s) 2 Qp:190 Volume 680 Duration 6
		Average	23cfs				
		Wet	32cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 13- USGS Gage 8104500 Little River at Little River

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	55cfs	**Dry**	82cfs		Pulse(s) 1 Qp:520 Volume 2,350 Duration 5	Pulse(s) 3 Qp:520 Volume 2,350 Duration 5	Pulse(s) 2 Qp:1,600 Volume 11,800 Duration 11
		Average	110cfs				
		Wet	190cfs				
Spring	55cfs	**Dry**	95cfs		Pulse(s) 1 Qp:1,420 Volume 9,760 Duration 10	Pulse(s) 3 Qp:1,420 Volume 9,760 Duration 10	Pulse(s) 2 Qp:3,290 Volume 32,200 Duration 17
		Average	150cfs				
		Wet	340cfs				
Summer	55cfs	**Dry**	84cfs		Pulse(s) 1 Qp:430 Volume 1,560 Duration 4	Pulse(s) 3 Qp:430 Volume 1,560 Duration 4	Pulse(s) 2 Qp:1,060 Volume 5,890 Duration 8
		Average	120cfs				
		Wet	200cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 14- USGS Gage 8106500 Little River near Cameron

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	32cfs	**Dry**	110cfs		Pulse(s) 1 Qp:1,080 Volume 6,680 Duration 8	Pulse(s) 3 Qp:1,080 Volume 6,680 Duration 8	Pulse(s) 2 Qp:2,140 Volume 14,900 Duration 10
		Average	190cfs				
		Wet	460cfs				
Spring	32cfs	**Dry**	140cfs		Pulse(s) 1 Qp:3,200 Volume 23,900 Duration 12	Pulse(s) 3 Qp:3,200 Volume 23,900 Duration 12	Pulse(s) 2 Qp:4,790 Volume 38,400 Duration 14
		Average	310cfs				
		Wet	760cfs				
Summer	32cfs	**Dry**	97cfs		Pulse(s) 1 Qp:560 Volume 2,860 Duration 6	Pulse(s) 3 Qp:560 Volume 2,860 Duration 6	Pulse(s) 2 Qp:990 Volume 5,550 Duration 8
		Average	160cfs				
		Wet	330cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 15- USGS Gage 8108700 Brazos River at SH 21 near Bryan

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	300cfs	**Dry**	540cfs		Pulse(s) 1 Qp:3,230 Volume 21,100 Duration 7	Pulse(s) 3 Qp:3,230 Volume 21,100 Duration 7	Pulse(s) 2 Qp:5,570 Volume 41,900 Duration 10
		Average	860cfs				
		Wet	1,760cfs				
Spring	300cfs	**Dry**	710cfs		Pulse(s) 1 Qp:6,050 Volume 49,000 Duration 11	Pulse(s) 3 Qp:6,050 Volume 49,000 Duration 11	Pulse(s) 2 Qp:10,400 Volume 97,000 Duration 14
		Average	1,260cfs				
		Wet	2,460cfs				
Summer	300cfs	**Dry**	630cfs		Pulse(s) 1 Qp:2,060 Volume 12,700 Duration 7	Pulse(s) 3 Qp:2,060 Volume 12,700 Duration 7	Pulse(s) 2 Qp:2,990 Volume 20,100 Duration 8
		Average	920cfs				
		Wet	1,470cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 16- USGS Gage 8110500 Navasota River near Easterly

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	1cfs	**Dry**	9cfs		Pulse(s) 1 Qp:260 Volume 1,610 Duration 9	Pulse(s) 3 Qp:260 Volume 1,610 Duration 9	Pulse(s) 2 Qp:800 Volume 5,440 Duration 12
		Average	14cfs				
		Wet	23cfs				
Spring	1cfs	**Dry**	10cfs		Pulse(s) 1 Qp:720 Volume 4,590 Duration 11	Pulse(s) 3 Qp:720 Volume 4,590 Duration 11	Pulse(s) 2 Qp:1,340 Volume 8,990 Duration 13
		Average	19cfs				
		Wet	29cfs				
Summer	1cfs	**Dry**	3cfs		Not Recommended	Not Recommended	Pulse(s) 2 Qp:49 Volume 220 Duration 5
		Average	8cfs				
		Wet	16cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 17- USGS Gage 8111500 Brazos River near Hempstead

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	510cfs	**Dry**	920cfs		Pulse(s) 1 Qp:5,720 Volume 49,800 Duration 10	Pulse(s) 3 Qp:5,720 Volume 49,800 Duration 10	Pulse(s) 2 Qp:11,200 Volume 125,000 Duration 15
		Average	1,440cfs				
		Wet	2,890cfs				
Spring	510cfs	**Dry**	1,130cfs		Pulse(s) 1 Qp:8,530 Volume 85,000 Duration 13	Pulse(s) 3 Qp:8,530 Volume 85,000 Duration 13	Pulse(s) 2 Qp:16,800 Volume 219,000 Duration 19
		Average	1,900cfs				
		Wet	3,440cfs				
Summer	510cfs	**Dry**	950cfs		Pulse(s) 1 Qp:2,620 Volume 17,000 Duration 7	Pulse(s) 3 Qp:2,620 Volume 17,000 Duration 7	Pulse(s) 2 Qp:5,090 Volume 40,900 Duration 9
		Average	1,330cfs				
		Wet	2,050cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 18- USGS Gage 8114000 Brazos River at Richmond

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	550cfs	**Dry**	990cfs		Pulse(s) 1 Qp: 6.410 Volume 60,600 Duration 11	Pulse(s) 3 Qp:6,410 Volume 60,600 Duration 11	Pulse(s) 2 Qp:12,400 Volume 150,000 Duration 16
		Average	1,650cfs				
		Wet	3,310cfs				
Spring	550cfs	**Dry**	1,190cfs		Pulse(s) 1 Qp:8,930 Volume 94,000 Duration 13	Pulse(s) 3 Qp:8,930 Volume 94,000 Duration 13	Pulse(s) 2 Qp:16,300 Volume 215,000 Duration 19
		Average	2,140cfs				
		Wet	3,980cfs				
Summer	550cfs	**Dry**	930cfs		Pulse(s) 1 Qp:2,460 Volume 16,400 Duration 6	Pulse(s) 3 Qp:2,460 Volume 16,400 Duration 6	Pulse(s) 2 Qp:5,430 Volume 46,300 Duration 10
		Average	1,330cfs				
		Wet	2,190cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 19- USGS Gage 8116650 Brazos River near Rosharon

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	430cfs	**Dry**	1,140cfs		Pulse(s) 1 Qp:9,090 Volume 94,700 Duration 12	Pulse(s) 3 Qp:9,090 Volume 94,700 Duration 12	Pulse(s) 2 Qp:13,600 Volume 168,000 Duration 16
		Average	2,090cfs				
		Wet	4.700cfs				
Spring	430cfs	**Dry**	1,250cfs		Pulse(s) 1 Qp:6,580 Volume 58,500 Duration 10	Pulse(s)3 Qp:6,580 Volume 58,500 Duration 10	Pulse(s) 2 Qp:14,200 Volume 184,000 Duration 18
		Average	2,570cfs				
		Wet	4,740cfs				
Summer	430cfs	**Dry**	930cfs		Pulse(s) 1 Qp:2,490 Volume 14,900 Duration 6	Pulse(s) 3 Qp:2,490 Volume 14,900 Duration 6	Pulse(s) 2 Qp:4,980 Volume 39,100 Duration9
		Average	1,420cfs				
		Wet	2,630cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

Gage Number 20- USGS Gage 8117500 San Bernard River near Boiling

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	11cfs	Dry	23cfs		Pulse(s) 1 Qp:510 Volume 3,710 Duration 8	Pulse(s) 3 Qp:510 Volume 3,710 Duration 8	Pulse(s) 2 Qp:1,060 Volume 9,370 Duration 12
		Average	43cfs				
		Wet	73cfs				
Spring	11cfs	Dry	32cfs		Pulse(s) 1 Qp:350 Volume 2,360 Duration 7	Pulse(s) 3 Qp:350 Volume 2,360 Duration7	Pulse(s) 2 Qp:680 Volume 5,300 Duration 10
		Average	53cfs				
		Wet	85cfs				
Summer	11cfs	Dry	64cfs		Pulse(s) 1 Qp:300 Volume 2,480 Duration 9	Pulse(s) 3 Qp:300 Volume 2,480 Duration 9	Pulse(s) 2 Qp:470 Volume 4,050 Duration 10
		Average	98cfs				
		Wet	140cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

APPENDIX C Invited Presentations

February 25, 2011 - Brazos BBASC meeting

Overview of Environmental Issues within the Basin Brazos River Authority (BRA)

Brazos River Authority staff presented an overview of the Brazos River Authority and its water supply system throughout the basin.

April 26, 2011 - Brazos BBASC meeting

Environmental Flows 101 – TPWD

Dan Opdyke with TPWD presented a PowerPoint slideshow giving an overview of environmental flows (presentation on BBASC website). He defined environmental flows and listed some of the major ecosystem services they provide. He talked about the economic impact that fish and wildlife recreation can have in Texas.

Kevin Mayes with TPWD gave a PowerPoint presentation entitled “A Primer on Fish and Wildlife Issues in the Brazos River Basin.” He further elaborated on the primary disciplines involved with instream flow quantification and gave example considerations of each discipline. Kevin then discussed issues such as threatened and endangered species for specific Brazos River Basin fish, invertebrates, and reptiles. He also talked about golden algae and the impact that it can have in the basin. (Presentation on BBASC website)

Texas Instream Flow Program Update – TCEQ

Dakus Geeslin with TCEQ gave an update on the activities of the Texas Instream Flow Program (TIFP) in the middle and lower Brazos River (presentation on website). He provided background on the TIFP and its purpose to determine flow regimes necessary to support a sound ecological environment in Texas rivers and streams.

June 28, 2011 - Brazos BBASC meeting

Basin and Bay Expert Science Team (BBEST) update – Tom Gooch

BBEST chair Tom Gooch gave an update of the science team’s activities (handout and presentation posted to BBASC website).

Presentation on Consensus-Building Suzanne Schwartz

Suzanne Schwartz, Environmental Program Director at the Center for Public Policy Dispute Resolution. She provided a handout (posted to the website) which reviewed the definition of consensus, principles of consensus, and a flowchart for consensus decision-making contained in the BBASC meeting rules.

August 23, 2011 - Brazos BBASC meeting

Brazos River Authority Drought Update Brad Brunett (BRA)
BBASC alternate Brad Brunett provided an update to the group on the status of the BRA reservoir system in the midst of the ongoing drought.

Basin and Bay Expert Science Team (BBEST) update Phil Price (BRA)
BBEST member Phil Price gave the BBASC an update on the activities of the expert science team.

Corps of Engineers Reservoir Operations Presentation Paul Rodman (USACE)
Paul Rodman with the Corps of Engineers gave a PowerPoint presentation on Corps-operated reservoirs in the Brazos Basin (Presentation on BBASC website).

Industrial Water Demand in the Brazos Basin Presentation Genά Leathers
BBASC member Genά Leathers gave a PowerPoint presentation entitled "Industrial Water Rights Holders Overview" (Presentation on BBASC website)

October 25, 2011 - Brazos BBASC meeting

Basin and Bay Expert Science Team (BBEST) update Tiffany Morgan
BBEST member Tiffany Morgan gave an update of the science team's activities via a PowerPoint presentation (Presentation on BBASC website)

Presentation: Flow Regime Application Tool (FRAT) – Kirk Kennedy
Kirk Kennedy with Kennedy Resource Company gave a PowerPoint presentation regarding the Flow Regime Application Tool (FRAT). (Presentation on BBASC website)

January 24, 2012 - Brazos BBASC meeting

BBEST presentation: Flow Regime Development Considerations Tim Bonner
BBEST member Dr. Tim Bonner gave a PowerPoint presentation to the BBASC covering the many considerations of the BBEST in developing their flow recommendations (Presentation on BBASC website)

February 28, 2012 - Brazos BBASC meeting

BBEST Presentation: Flow Regime Recommendations and Testing Tiffany Morgan
BBEST member Tiffany Morgan gave a PowerPoint presentation to the BBASC covering the BBEST flow regime recommendations, their suggested implementation rules, and scenario testing (Presentation on BBASC website)

BBASC presentation: Why Rivers Are Important Steve Nelle
Steve Nelle, retired from NRCS, discussed the values and benefits of healthy creeks and riparian areas, especially in the context of the severe water challenges that Texas is facing. (Presentation on BBASC website)

March 27, 2012 - Brazos BBASC meeting

Refresher on BBASC Charge Bob Huston – SAC Chairman

The Texas Environmental Flows Science Advisory Committee (SAC) chairman, Bob Huston, reviewed the important aspects of the BBASC charge as stated in the Senate Bill 3 legislation.

Discussion of BBEST Report - BBEST Members

BBEST vice-chair, Kirk Winemiller, gave a presentation and answered questions of the BBASC.
(Presentation on BBASC website)

April 24, 2012 - Brazos BBASC meeting

Discussion of BBEST report -Tom Gooch/David Dunn

David Dunn of the BBEST made a presentation focusing on Chapter 7 of the BBEST report. (Presentation on BBASC website)

Discussion of recent TCEQ SB 3 rulemaking, and of surface water rights in Texas Todd Chenoweth and Kathy Alexander

Todd Chenoweth and Kathy Alexander of TCEQ, and Colette Barron Bradsby of TPWD briefed the BBASC about (1) TCEQ's recent SB 3 rulemaking in other basins that have made recommendations for environmental flow standards (EFS), (2) the legal structure of water rights administration in Texas, and (3) water availability in the Brazos Basin.

BRA System Operation application in comparison to SB 3 Brad Brunett, BRA

Brad Brunett with BRA presented an overview of the System Operation Permit application. The slide presentation is posted to the BBASC web page.

May 30-31, 2012 - Brazos BBASC meeting

Discussion of steps for developing consensus Suzanne Schwartz

Facilitator Suzanne Schwartz gave a PowerPoint presentation on building consensus. The presentation has been posted to the BBASC web page.

Report on the analysis of Double Mountain Fork and Allens Creek projects Brad Brunett

Brad Brunett of Brazos River Authority and Cindy Loeffler of Texas Parks and Wildlife Department (TPWD) presented the results of their analysis. (Slides of this presentation are available on the BBASC web page). The analysis provides a comparison of the reservoirs operating under both the Lyons method for imposing environmental flows (the current TCEQ default criteria) and with the BBEST EFR imposed.

Cedar Ridge Reservoir Cory Shockley

Cory Shockley with HDR Engineering presented information about a permit above Possum Kingdom reservoir to construct the Cedar Ridge reservoir. He spoke of the impacts of the EFR (Cory's presentation is available on the BBASC web page).

Consider uses of Brazos River for other water needs: presentations from Regions G and H; discussion

Jason D. Afinowicz of Freese & Nichols presented information on Region H water needs; Cory Shockley of HDR presented information on Regions O and G water needs from the Brazos River Basin. (Slides for these presentations are available online).

Base and subsistence flow Phil Price

BBEST member Phil Price provided information to the BBASC about different elements of the BBEST environmental flow regime recommendation, focusing primarily on base and subsistence flows. (Slides for this presentation are available on the BBASC web page.)

Education and discussion on how to develop strategies to meeting environmental flow standards Caroline Runge

Caroline Runge of the Menard Underground Water District, briefed the group about strategy development for the Colorado-Lavaca BBASC, and presented an overview of the strategies that BBASC developed. (Slides for this presentation are available on the BBASC web page).

June 27-28, 2012 - Brazos BBASC meeting

Report on the analysis of Double Mountain Fork and Allens Creek projects by Technical Work Group

Phil Price (BRA and Brazos BBEST member), Brad Brunett (BRA) and Kevin Mayes (TPWD), representing the technical work group, provided analyses of the impacts on the yields of Double Mountain Fork and Allens Creek hypothetical projects if an environmental flow regime similar to the TCEQ proposed environmental flow standards for the Colorado basin were imposed on the projects. Environmental flow attainment frequency results for the projects under various environmental flow standards were also presented. (Slides of this presentation are available on the BBASC web page).

Cedar Ridge Reservoir Cory Shockley

Cory Shockley of HDR, a consultant for City of Abilene, provided information to the BBASC about the impacts of various environmental flow standard recommendations on the City of Abilene's Cedar Ridge permit application, including the BBEST EFR, TCEQ adopted rules for the Sabine-Neches and Trinity-San Jacinto, and TCEQ proposed rules for the Colorado-Lavaca (Slides of this presentation are available on the BBASC web page.)

BBEST/ BBASC exchange of information on BBEST report and requested BBEST input

Tom Gooch noted that the BBEST has answered all questions submitted by the BBASC. (Answers are available on the BBASC web page.)

Consider use of Brazos River for other water needs: information related to the Turkey Peak project Scott Blasor

Scott Blasor of Palo Pinto County Municipal Water District (MWD) No. 1 provided a presentation to the BBASC about the proposed Turkey Peak project. (Slides of this presentation are available on the BBASC web page.)

Develop environmental flow standard components Tom Gooch
Tom Gooch of the BBEST provided a presentation regarding base and subsistence flows. (Slides of this presentation are available on the BBASC web page.)

Presentations on pulse flows Tom Gooch
Tom Gooch presented information on the BBEST recommendations for pulse and overbank flows. (Slides of this presentation are available on the BBASC web page.)

Cedar Ridge presentations Cory Shockley
Cory Shockley of HDR, a consultant for City of Abilene, provided information to the BBASC regarding the impact pulse flows have on the City's proposed Cedar Ridge reservoir project. (Slides of this presentation are available on the BBASC web page.)

Ed Oborny with Bio-West (consultant for City of Abilene) gave a presentation regarding site-specific studies for the Cedar Ridge reservoir project. (Slides of the presentation are available on the BBASC web page)

July 17, 2012 - Brazos BBASC meeting

Technical reports, including: (1) project yields under possible environmental flow standards; and (2) biological impact of changing pulse flows Kevin Mays
Kevin Mayes from TPWD coordinated with Dr. Wilde from Texas Tech University, at the request of the BBASC, to determine the impact on the smalleye shiner of reduced magnitude and frequency of high flow pulses based on the Cedar Ridge Reservoir template using HDR's WAM/FRAT output for the Double Mountain West Reservoir simulation at the Double Mountain Fork at Aspermont gage. Kevin presented his analysis (PowerPoint slides available on the BBASC webpage)

Cory Shockley of HDR Engineering, at the request of the BBASC, provided information on impacts to the yield of the Double Mountain Fork and Little River Reservoir (on-channel) if additional pulse flows were required above those in the Cedar Ridge Reservoir (CRR) template, which the BBASC adopted for gages 4, 5 and 6 at its June 28 meeting. (Power point slides available on the BBASC website)

July 30-31, 2012 - Brazos BBASC meeting

Matt Nelson of the TWDB provided a summary of recommended and alternative reservoir projects in the Brazos BBASC geographic area that have been identified by Regions O, G and H. The handout is available on the BBASC website.

Cindy Loeffler and Kevin Mayes (TPWD) gave a presentation requested by the BBASC summarizing selected biological issues in the upper, middle and lower parts for the Brazos Basin. For example, five species of mussels that are currently on the State's list of threatened species occur in the middle and lower Brazos Basin. These species are also candidate species for Federal listing. Ms. Loeffler also presented information comparing on-channel to off-channel reservoirs. The presentation is available on the BBASC website.

At the request of several BBASC members, Joe Trungale of Trungale Engineering & Science, made a presentation on a possible way to increase the number and amount of pulse flows over the previously proposed Cedar Ridge Reservoir template (also called "Balancing template" and identified in these notes as the CR/B template) while enhancing the yield of potential future projects more than under the BBEST EFR. This would be accomplished by imposing lower pulse-flow requirements during times reservoirs hold less water in storage, but by releasing BBEST-levels of inflows when the reservoir has a higher storage volume. (Power point slides available on the BBASC webpage).

Kevin Mayes from TPWD coordinated with Dr. Wilde from Texas Tech University, at the request of the BBASC, to present additional information relating to the impact on the smalleye shiner of reduced magnitude and frequencies of high flow pulses based on the CR/B template using Brazos G WAM, 2060, provided by Brazos River Authority (Brazos River at Seymour modeled flows with DMF West Reservoir in place). Mr. Mayes presented an analysis of reach lengths, flow changes, and simulated population responses to different environmental flow regime scenarios (power point slides available on the BBASC webpage).

August 15-16, 2012 - Brazos BBASC meeting

Cory Shockley of HDR Engineering provided information requested by the BBASC relating to modeling conducted for the following two issues. PowerPoint slides are available at the BBASC website:

Water Availability Evaluation to determine if a modified BBEST EFR at Palo Pinto and Glen Rose would negatively impact the potential Cedar Ridge project. Mr. Shockley concluded that a different environmental flow regime could be imposed on the middle basin (gage 7 – Palo Pinto and gage 8 – Glen Rose) without negatively impacting the potential Cedar Ridge project in the upper basin; and
Evaluation of "Local projects" impact on middle basin gages [or upper basin gages?] (similar to Little River or DMF) from the BBEST EFR or slight variations to pulses). Mr. Shockley used the hypothetical Bee Mountain project, using the FRAT analysis, and found similar results for previously analyzed projects.

Tom Gooch, chair of the Brazos BBASC (with Freese&Nichols, Inc.), made a presentation explaining the BBEST proposed implementation rules. PowerPoint slides are available at the BBASC website.

George Guillen, member of the BBEST and with University of Houston, Clear Lake City, made a presentation explaining how the BBEST made its recommendation regarding estuarine inflows.

APPENDIX D Identified Issues

Golden Algae **Ecological, Economical, and Recreational Impacts**
"Over the past three decades, the naturally occurring golden alga (Prymnesium parvum) has bloomed in water bodies across the United States and Texas, including reservoirs within the Brazos River basin. Golden alga is tolerant of large variations in temperature and salinity. Under certain environmental conditions, golden alga can produce toxins that can cause massive fish and bivalve kills. In Texas, golden alga blooms are winter phenomena that develop under conditions sub-optimal for their reproductive growth but conducive for toxicity generation (Roelke et. al. 2010 a, 2010b, 2010c; Brooks et. al. 2011). During these stressful times, the production of toxins suppresses the golden alga's competitors and deters it predators (Graneli et.al. in press). The toxins also immobilize bacterial prey during this period when the alga enters into a heterotrophic mode of growth (P. parvum is a mixtroph, an organism that both performs photosynthesis and consumes other organisms to obtain energy), which allows it to feed on bacteria more efficiently and maintain higher densities in the water column (Brooks et. al. 2011).

"Golden alga blooms are complex and involve changing water flow, salinity, nutrient concentration, light intensity, and temperature, various combinations of which may increase or decrease a golden alga bloom (Brooks et. al. 2011). While increased water flow may cause hydraulic disruption of the organism's ecology of dilute salinities to level that do not support a bloom, in the Brazos River Basin the location of the precipitation event may be important because western portions of the Brazos Basin have naturally high salinity. Runoff can wash more nutrients and suspended sediments into the water body, which may increase or diminish the golden alga blooms depending on the time of year and other environmental factors. Currently, the precise combination of factors that initiate or terminate a toxic bloom is not fully understood. Recent research in Texas has addressed alternative approaches for managing impacts of golden alga blooms when they occur (Barkoh et. al. 2005; Sager et.al. 2007; Roelke et. al. 2010c, 2011; Brooks et. al. 2011)."

Zebra Mussels - Ecological, Economical, and Recreational Impacts
This highly invasive aquatic species multiplies rapidly and can cause tremendous environmental and economic damage. One adult zebra mussel can filter up to one liter of water per day. This filtering and feeding activity reduces the abundance of plankton, the microscopic organisms that form the bottom of the aquatic food chain. This can lead to reduced populations of gizzard shad and other organisms that eat plankton. In Texas reservoirs, declines in those populations could mean a shortage of food for sport fish such as striped bass, which feed on shad. Zebra mussels pose a real threat to native mussels by competing for food and attaching to their shells. A zebra mussel colony can eventually smother a native mussel colony.

Each year millions of dollars are spent in controlling, cleaning and monitoring zebra mussels in other states. They can disrupt an entire water supply system by colonizing the insides of pipelines and restricting the flow of water.

On the fishing and recreational front, zebra mussels are responsible for fouling boat hulls and plugging water systems used in motors, air conditioners and heads.

The Texas Parks and Wildlife Department has developed a public awareness campaign, "Hello Zebra Mussels, Goodbye Texas Lakes: Clean, Drain and Dry" to make boaters and other water recreation users more aware of the potentially devastating effects that zebra mussels pose to our state's aquatic ecosystems, private property and water-related infrastructure such as water supply systems. This campaign is made possible by a coalition of partners, including:

- North Texas Municipal Water District
- Tarrant Regional Water District;
- Trinity River Authority
- City of Dallas Water Utilities Department
- Sabine River Authority
- Canadian River Municipal Water Authority
- San Jacinto River Authority
- Lady Bird Johnson Wildflower Center
- Angelina and Neches River Authority
- Brazos River Authority

Sharpnose Shiner and Smalleye Shiner

The Smalleye Shiner and the Sharpnose Shiner are candidate species for the Federal Endangered Species list.

The Smalleye Shiner is found only in Texas and now only in the Upper Brazos River, although there have been attempts to introduce this fish into the lower Brazos River and into the Colorado River.

The Sharpnose Shiner is found in the Upper Brazos River and in the Red River. It has been identified in the Colorado Rivers, but may have been an introduced specimen. Both the Sharpnose and the Smalleye Shiners are only found in the United Staes.

Historically, the range of these fish included most of the Brazos River, but interruptions in the river continuum (reservoirs) have isolated these species within the river upstream of the Possum Kingdom reservoir.

These fish have two-three year lifespans and are dependent on river flows at the “base” and “pulse” levels for survival and spawning. Two to three year droughts or low flows (no pulses) have a compounding impact on the reproduction of these shiners.

These shiners primarily consume invertebrates (insects) but have shown the ability to eat detritus (plant parts in the riverbed) during periods of drought when the fish are limited to unconnected pools of water.

APPENDIX E Minority Report for Recommendations for Gages 1-3

Introduction

The Brazos River and associated bay and estuary system Basin and Bay Area Stakeholder Committee (Brazos BBASC) is charged with finding an appropriate balance between the water needs of the environment and other human water supply needs, and accordingly, recommending environmental flow standards for gages throughout the basin. On August 16, 2012, the Brazos BBASC adopted, by a non-consensus vote of 19-4, environmental flow recommendations for pulse flows for the three upper-most gages within the Brazos River basin: the Double Mountain Fork of the Brazos near Aspermont (gage 1); the Salt Fork of the Brazos near Aspermont (gage 2); and the Brazos River at Seymour (gage 3).

The three headwaters stream segments where these gages occur have unique ecological considerations. The BBASC stakeholders who voted against the pulse flow recommendations for the three upper-most gages (minority) undertook considerable effort to put forward reasonable proposals to find a middle ground between these considerations and those stated by other stakeholders. When attempts to reach a compromise failed, the majority of stakeholders voted to adopt pulse flow recommendations that, in the opinion of the minority, fail to adequately address these specific ecological concerns. As a result, we, the minority, are ultimately unable to support the majority pulse flow recommendation at these three gages.

The purpose of this report is to document why the majority recommendation is insufficient in fulfilling the balancing charge of the committee and to set out our compromise proposal that strikes an appropriate balance between environmental protection and human water supply needs for these three gage locations.

Ecological Setting

The Brazos Bay and Basin Expert Science Team (Brazos BBEST) evaluated stream reaches of the Brazos watershed to determine if they met the Texas Environmental Flows Science Advisory Committee's (SAC) definition of a Sound Ecological Environment:

- Sustains the full complement of native species in perpetuity;
- Sustains key habitat features required by these species
- Retains key features of the natural flow regime required by these species to complete their life cycles; and
- Sustains key ecosystem processes and services, such as elemental cycling and the productivity of important plant and animal populations.[1]

The Brazos BBEST determined that only three stream reaches in the Brazos watershed fully support the SAC definition of a sound ecological environment: the Double Mountain Fork of the Brazos; the Salt Fork of the Brazos; and the Upper Brazos. Gages 1, 2 and 3 occur in these stream reaches respectively. In denoting these reaches as having "high integrity", the Brazos BBEST noted that these reaches have high fish assemblage integrity dominated by fish species that require variable flow regimes including frequent pulse flows, referred to as fluvial

[1] Page 1-3, Brazos River BBEST Environmental Flow Regime Recommendations Report

specialists.[2] Two of the fluvial specialists found in these three reaches are the Sharpnose Shiner and Smalleye Shiner, both Federal candidate species currently under review for listing as either threatened or endangered under the Endangered Species Act.

The current range of the Sharpnose and Smalleye Shiner is limited to the upper Brazos River drainages above Possum Kingdom Reservoir. According to the U.S. Fish and Wildlife Service, the "*current threats to the shiners include future water development projects (new reservoirs, reservoir enhancement, chloride control, etc.), irrigation and water diversion, wastewater and agricultural discharges, drought, and excessive sedimentation and erosion resulting from surrounding land use and the invasion of salt cedar.*" [3] Additional research indicates that pulse flows are necessary to provide spawning cues for the species as well as larval distribution.[4]

<u>Development of Majority Recommendation</u>
During the June 28th, 2012 Brazos BBASC meeting, Ed Oborny, a consultant with BIO-WEST hired by the City of Abilene, presented a site-specific study of environmental flow findings for the Clear Fork of the Brazos near Abilene's proposed Cedar Ridge Reservoir (between gages 4 and 5, a stream reach designated as having "low biotic integrity" by the Brazos BBEST).[5] This BIO-WEST study has been relied upon as the basis for the "Cedar Ridge template" which the majority also relied upon for its recommendations on gages 1, 2, and 3.

During his presentation, Mr. Oborny, who is also a member of the SAC, explained his belief that an environmental flow regime less protective than that recommended by the Brazos BBEST could be justified for the Clear Fork of the Brazos because of:

- the presence of a naturally armored channel that prevents significant changes in channel morphology;
- the lack of significant riparian vegetation; and
- the lack of fluvial specialists present in these reaches.

Based on this site-specific information, and in the spirit of compromise, the Brazos BBASC adopted, by consensus, an environmental flow regime significantly less protective than the Brazos BBEST recommendation, referred to as the Cedar Ridge template, for gages 4, 5, and 6. A comparison between the Brazos BBEST recommendation and the Cedar Ridge template is discussed in the next section.

Despite the explicit site-specific caveats underlying the scientific justification for adopting the Cedar Ridge template for the Clear Fork of the Brazos, the majority of the Brazos BBASC members chose to also adopt this template for gages 1, 2, and 3. There is neither an adequate

[2] Page 1-4, 1-5, ibid.
[3] U.S. Fish and Wildlife Service, Smalleye Shiner and Sharpnose Shiner Fact Sheet, available at: http://www.fws.gov/R2ESArlington/pdf/Shiner_Factsheet.pdf
[4] Durham, B.W. and G.R. Wilde, 2009, Population dynamics of the smalleye shiner, an imperiled cyprinid fish endemic to the Brazos River, Texas. *Transactions of the American Fisheries Society* 138:666-674
[5] Clear Fork Brazos River- Site Specific Studies, from June 27-28, 2012 meeting presentations on Brazos BBASC website available at:
http://www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/eflows/20120627_28brazosbbasc_cfbr%20site%20specific%20studies.pdf

scientific nor water supply justification for doing so. We have well-founded concerns that a water supply project subject to a level of environmental flow protection as low as that of the Cedar Ridge template at gages 1, 2, and 3 would severely harm and, quite likely, extirpate the two Candidate Shiner Species found in these river reaches.

The Brazos BBEST report notes that fluvial specialist species—those with life histories that require variable flow regimes to complete their life cycles—were a particular focus for making recommendations for high flow pulse requirements for fish spawning and recruitment. The report references Durham and Wilde (2009a) and notes that "*their study determined that recruitment of both species* [of shiner] *was related to streamflow in two principal ways. First, the greatest proportion of young-of-year produced during the reproductive season was associated with high pulse flows. Second, no young-of-year were successfully produced during periods of reduced flow when stream pools became isolated. Their results suggest that, in addition to providing proper conditions for spawning, flows must be maintained for survival of eggs and larvae.*" [6] No scientific justification has been produced to show that the Cedar Ridge template provides adequate protection for the high flow pulses determined by the Brazos BBEST to be necessary to maintain fish spawning and recruitment for those shiner species and, indeed, such low levels of protection would reduce the overall health of the system by reducing or eliminating critical ecological function.

<u>Comparison of Brazos BBEST recommendation to Majority BBASC recommendation</u>
The BBEST recommendation for gages in the upper Brazos included flow targets for a full range of flows including

- subsistence flows,
- three levels of base flows (based on hydrologic condition)
- four levels of seasonal high flow pulses and
- three levels of annual high flow pulses

In the BBEST recommendation, all high flow pulse targets are active at all times, irrespective of hydrologic condition. The complete BBEST recommendation for the Double Mountain Fork Brazos River near Aspermont is provided in Figure 1. The values on the right show the frequency of the seasonal high flow pulses that are recommended under the given hydrologic conditions. They have been added to this figure solely to make it more directly comparable with some of the figures that follow.

[6] Page 4-9, ibid

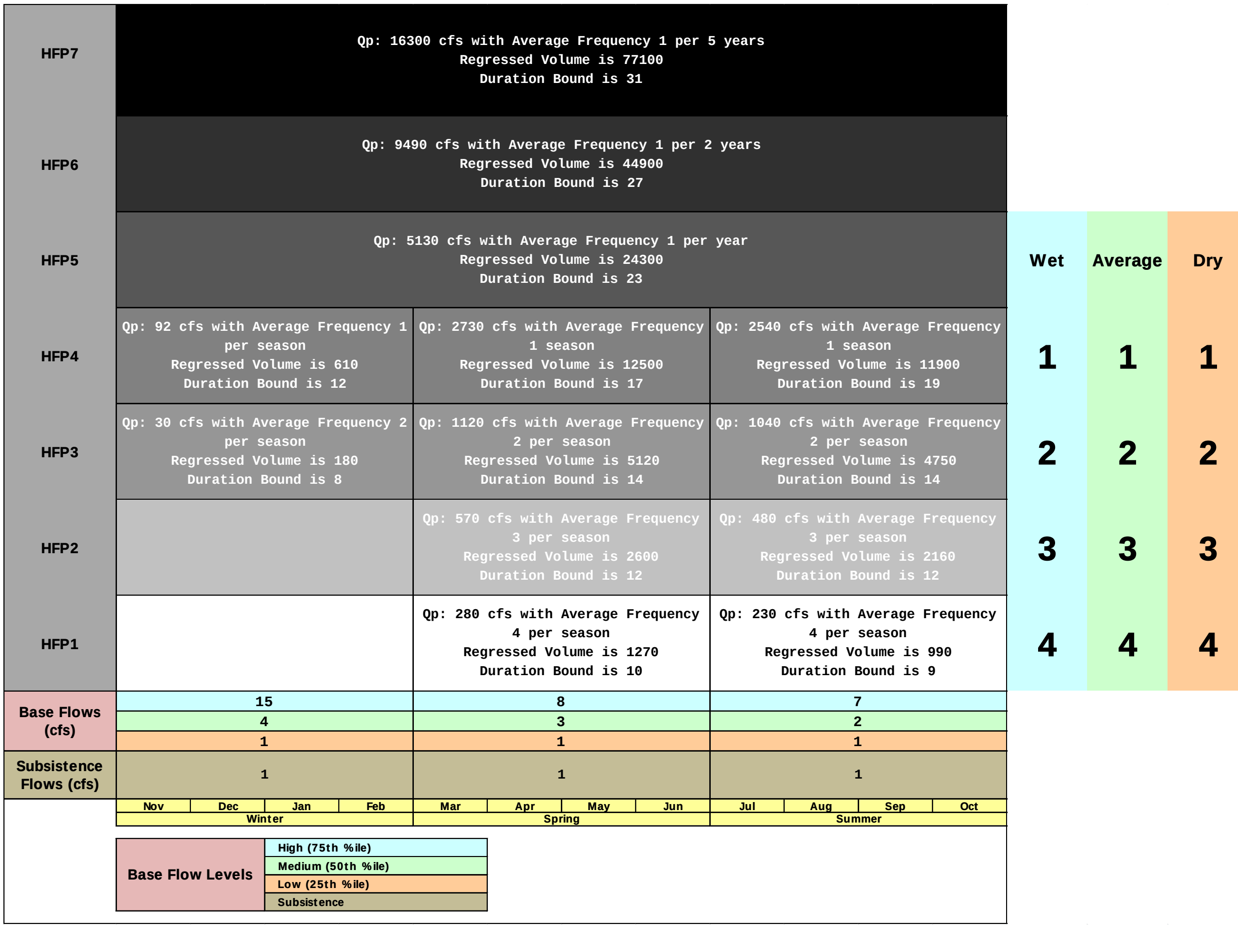


Figure 1 Brazos BBEST Instream Flow Recommendation for the Double Mountain Fork Brazos River near Aspermont

The majority of the Brazos BBASC recommended the Cedar Ridge template discussed above which eliminates most of the pulse flow components recommended by the Brazos BBEST and reduces the frequency at which the various pulse flow recommendations would be active under the different hydrologic conditions. The Cedar Ridge Template (which was later renamed "the Balancing Template") also uses the shorthand 1,2,1 to designate the number of pulses that are active during the different hydrologic conditions.

Wet – one (1) HFP2 in a season (the second lowest magnitude pulse recommended by the BBEST, which historically occurred three times per season on average)
Average – two (2) HFP1 in a season (the lowest magnitude pulse recommended by the BBEST, which historically occurred four times per season on average)
Dry – one (1) HFP1 in a season (the lowest magnitude pulse recommended by the BBEST, which historically occurred four times per season on average)

The majority BBASC recommendation is shown in Figure 2. Note that because the BBEST did not include anything in the boxes labeled HFP1 or HFP2 in the winter for these gages and instead relied on the HFP3 and HFP4 pulses, this recommendation does not include any pulse flow recommendations in the winter. At most, this recommendation would protect just four pulses per year under average conditions and would only protect two pulses all year during wet and dry conditions.

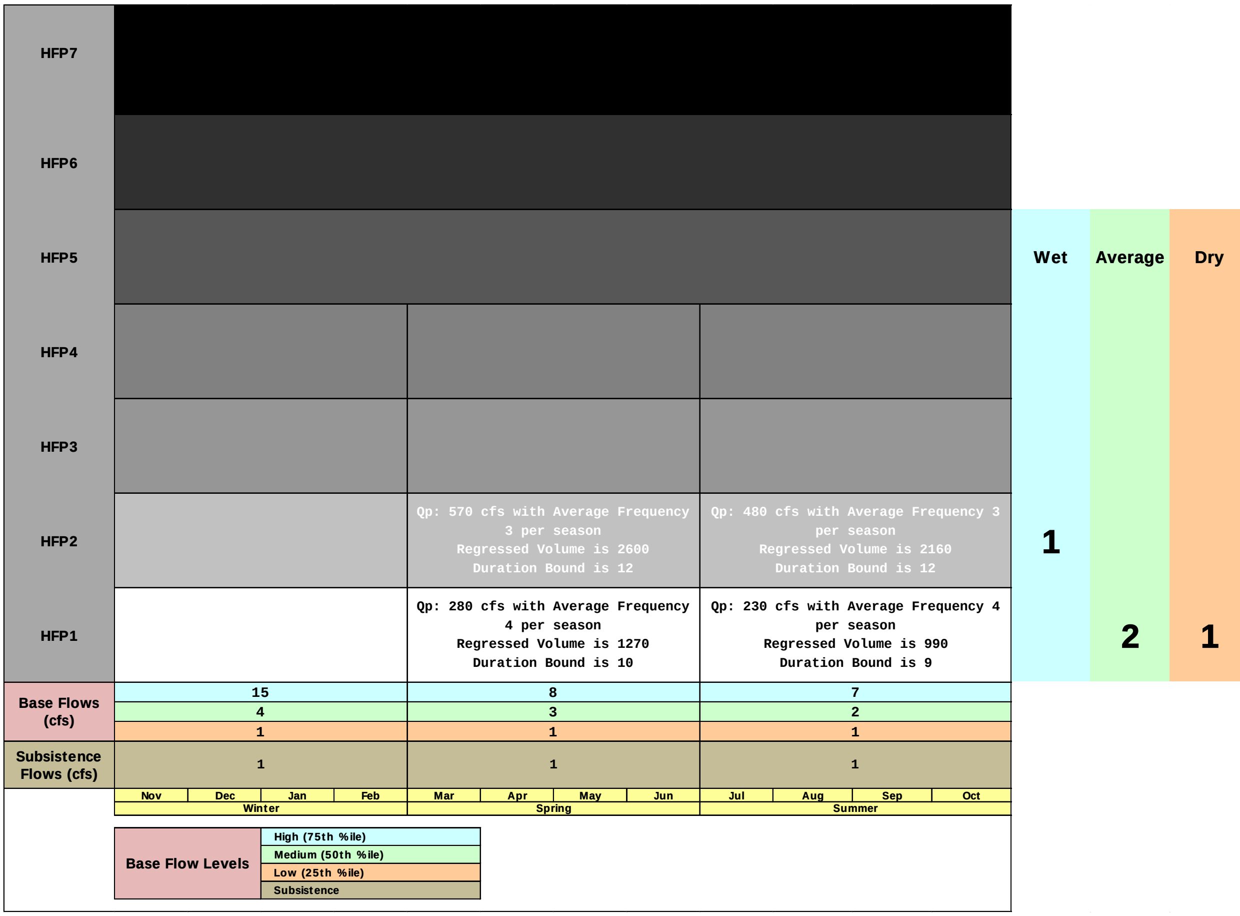


Figure 2 Majority Brazos BBASC Instream Flow Recommendation for the Double Mountain Fork Brazos River near Aspermont

<u>Realistic Modeling Assumptions</u>

One of the arguments which was put forth in support of adopting this 1,2,1 recommendation was that when a hypothetical reservoir project on the Double Mountain Fork was simulated in a computer model, the model results indicated that many pulse events would continue to occur even though most of the pulses are not explicitly protected in the recommendations. Figures similar to Figure 3 were shown to the BBASC to demonstrate this.

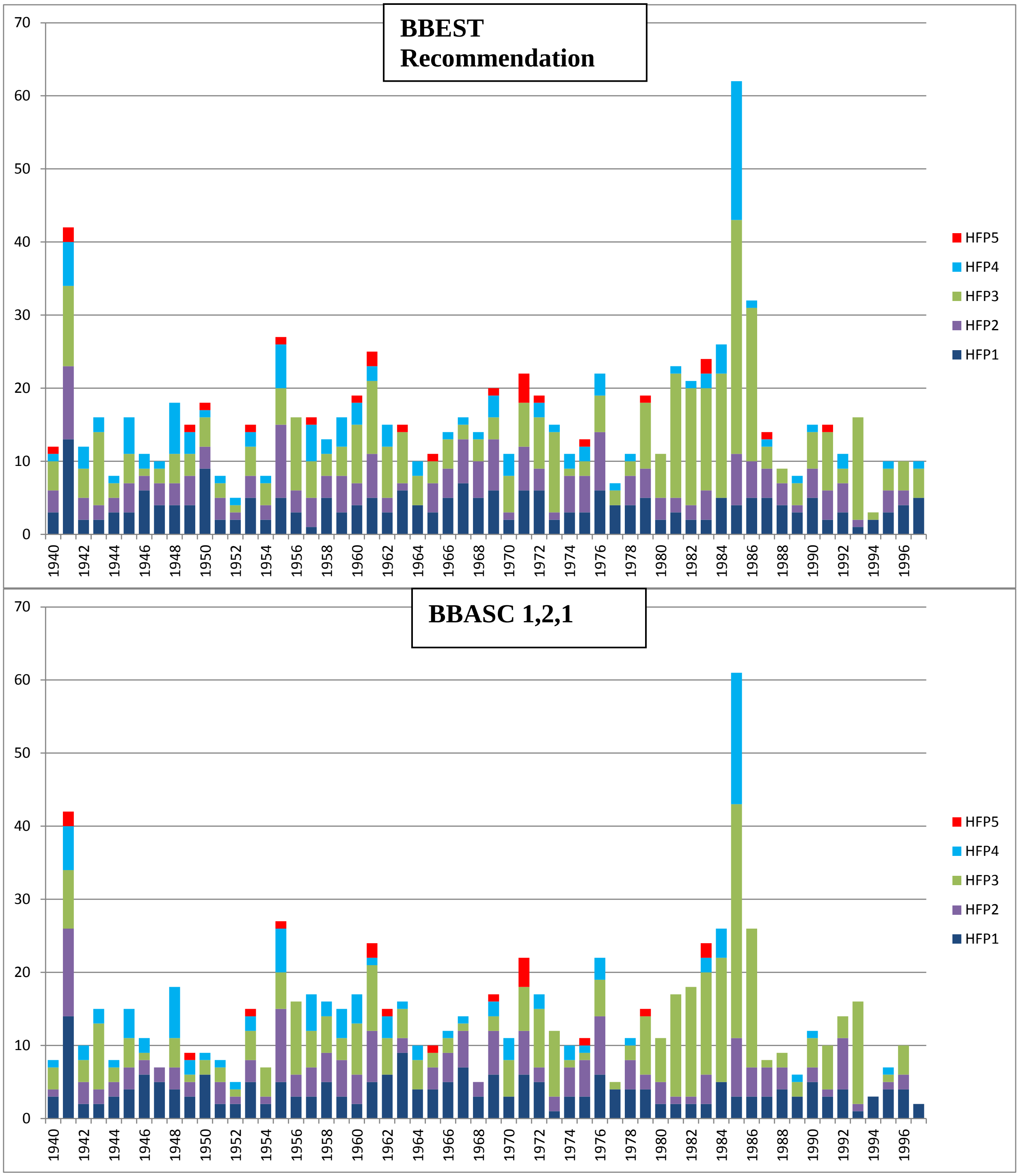


Figure 3 Comparison of pulses assuming application of the BBEST Recommendation and the BBASC 1,2,1 Recommendation without subordination

The reason that the BBASC 1,2,1 implementation shows many pulses being passed is that significant quantities of water are assumed to be required to be passed at this site to satisfy the demands of senior downstream water users, regardless of the environmental flow recommendations. Water rights permitting in Texas is predicated on the doctrine of prior appropriation, "first in time, first in right." This concept is incorporated into the state's Water Availability Model (WAM), which was used in the BBASC process to determine how much water is available for diversion and how much remains in the stream. In the case of the hypothetical Double Mountain Fork project that the BBASC chose to evaluate, this assumption effectively means that whenever Possum Kingdom Reservoir (the large senior water right downstream) is not full and spilling, any water reaching the proposed Double Mountain Fork site must be passed to fill Possum Kingdom, since that water right is senior to Double Mountain Fork. Based on results similar to the above bar charts, the majority of the stakeholder group determined that the difference in the number of pulse events under the two recommendations was not significant enough to justify the yield impact of incorporating the full BBEST recommendation. These results are the primary basis of support for the conclusion of the majority of the stakeholder committee that implementation of this 1,2,1 approach would be protective of a sound ecological environment.

The key problem with this conclusion is that while the application of the prior appropriation doctrine in this analysis is consistent with TCEQ rules for granting water rights permits in the absence of subordination agreements, it fails to account for realities specific to water rights development in this area of Texas. As noted by members of the BBASC familiar with the water rights situation in the area, subordination agreements are anticipated as a prerequisite to reservoir development. Thus, it is very unlikely that any new reservoir project in this part of the state would be routinely called upon to pass flows to meet downstream senior water rights. In order to avoid the effects of the priority system and be able to produce sufficient yield to make a project feasible, any new water right upstream of Possum Kingdom would likely need to secure a subordination agreement with the Brazos River Authority. This fact is evident when one reviews the description of the Double Mountain Fork project in the regional water plan.[7]

Although the Double Mountain Fork yield under the 1,2,1 scenario was reported to the BBASC as approximately 14,000 ACFT per year, the regional water plan reports a safe yield[8] of 34,775 ACFT per year, or more than double the reported yield considered by the BBASC. The primary reason for this discrepancy is the effect of an assumed subordination agreement in the regional water plan analysis but not in the BBASC analysis. Smaller amounts of discrepancy might be explained by the fact that the regional plan assumes the consensus criteria flow targets and that the water availability analysis done by the regional planning group used a WAM which included return flows and 2060 expected demand levels rather than full use of existing water rights. These effects, however, are minor compared to the effect of the subordination agreement.

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[7] It is important to reiterate here that the Double Mountain Fork project is not a recommended water supply project in the State Water Plan and is not needed for any identified water needs. However, it was determined by the consultant hired by the City of Abilene, HDR, who was presenting the majority of the technical analysis to the BBASC, that this project provides a good test project for evaluating the impacts to yield when various levels of environmental flow protection are applied.

[8] Safe yield estimate in fact underestimates the firm yield that would be expected using the regional planning group scenario because safe yield uses reduced annual diversion availability, as compared to a firm yield analysis, in order to maintain a full year of supply in storage at the end of the historical drought of record. An apples to apples comparison of firm yields would result in an even greater discrepancy. Firm yield for this project, with subordination, would be greater than the 34,775 safe yield reported in the regional plan.

If a subordination agreement is incorporated into the analysis of the Double Mountain Fork project, as would almost certainly be required to make this a feasible project, then the conclusion arrived at by the BBASC, namely that the 1,2,1 approach produces a significant number of pulse flow events, would no longer be a valid one. Most of these pulses would not be passed but instead would be captured by the new reservoir.

Figure 4 shows significant reductions in pulse flows under the BBASC 1,2,1 scenario that would be expected should the requirement to pass flows for senior water rights be subordinated. In this application, downstream pulses only occur when explicitly protected under the 1,2,1 recommendation or when the reservoir is spilling. Unlike analyses that have been performed for other basins under SB3, specifically the so-called "infinite infrastructure" application, which was investigated in the much wetter Sabine basin, this analysis, shows that in drier west Texas a finite, very realistically sized, project can effectively capture most of the flow in the river. This would have devastating effect on the ecological function that these flows provide to maintain the health of this system.

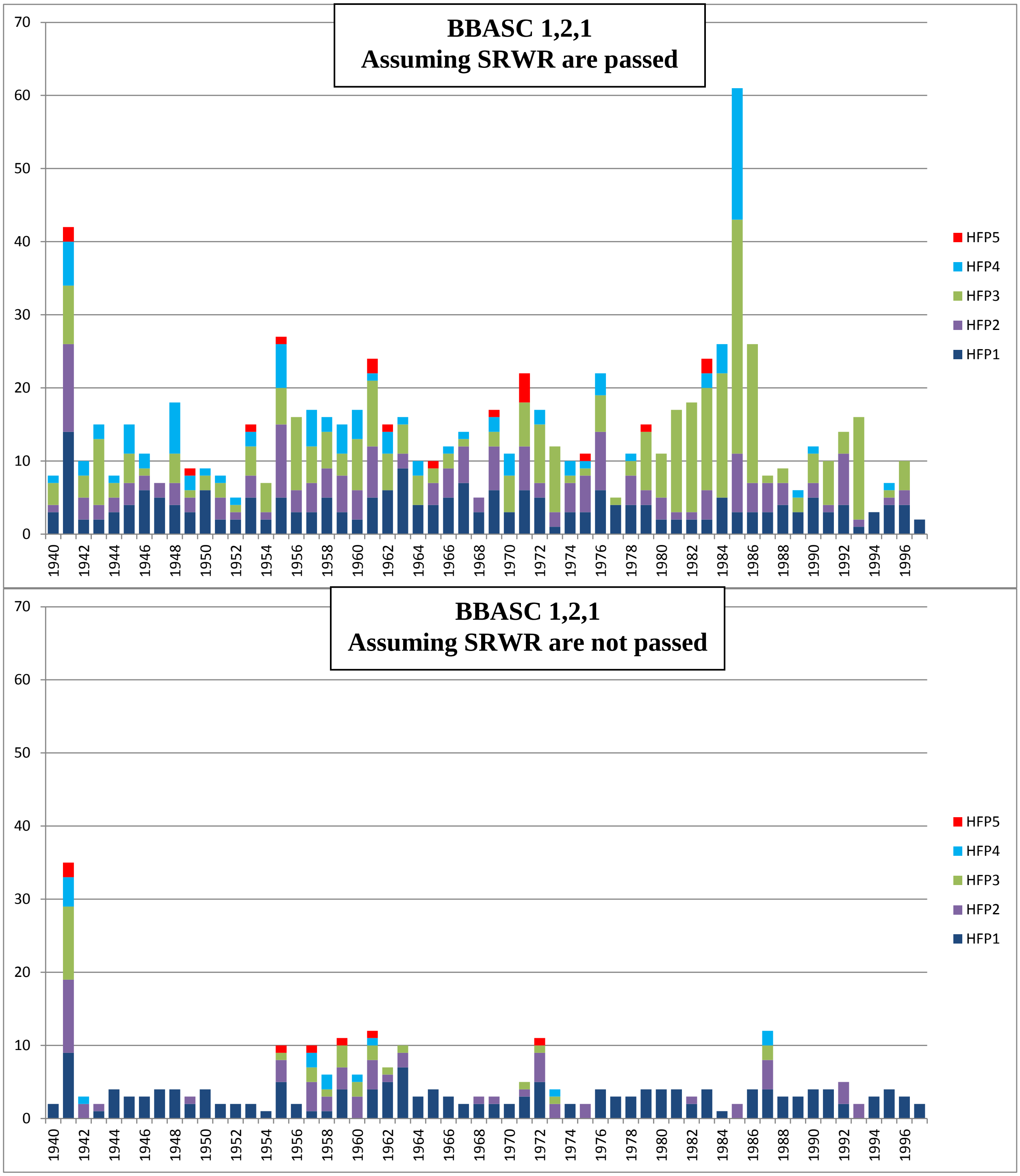

Figure 4 Number of Pulse Events with the implementation of the Cedar Ridge Template 1,2,1 at Double Mountain Fork West, with and without subordination

Figure 5 below shows the number of pulses modeled assuming an application of the BBEST recommendations. The upper panel in Figure 5 shows the pulse events for a flow regime, assuming passage of water for senior water rights holders (i.e. no subordination). The flows that produced these results are comparable to those reviewed by the BBEST (although they did not review them in the precise format presented here) and upon which they arrived at the following conclusion:

> "*While the BBEST's e-flows recommendations will not restore the full complement of native species to every reach of the Brazos basin, the BBEST is confident that the recommended e-flows are a starting point that will maintain the fish species and current level of ecological soundness in the instream environments, preventing any future degradation caused solely by alteration of instream flows*."

The lower panel in Figure 5 shows the pulses that would be expected under the application of the full BBEST recommendation but without flows being passed to honor senior water rights (i.e., with subordination). It is true that in many years, fewer total pulses would occur with the BBEST recommendations and subordination than under the scenario that assumes BBEST recommendations and no subordination. However, even for the scenario with subordination, the pulse recommendations are achieved at almost the same attainment frequencies as recommended by the BBEST (see Table 1 below). What is different is that there are many pulse events that would occur with the requirement to pass water for senior water rights holders that would not occur under a more realistic no call, or with subordination, scenario. For example, in 1985 the figure in the upper panel shows that HFP3 events occur more than 20 times, even though the BBEST recommendations only call for these events 6 times per year (2 per season) which is about the number of events that are shown in in the figure on the bottom. Without the need to pass this water for downstream senior rights, most of these extra pulses would be captured at the reservoir. A key point here is the critical importance of evaluating flow recommendations considering a realistic scenario that includes subordination agreements.

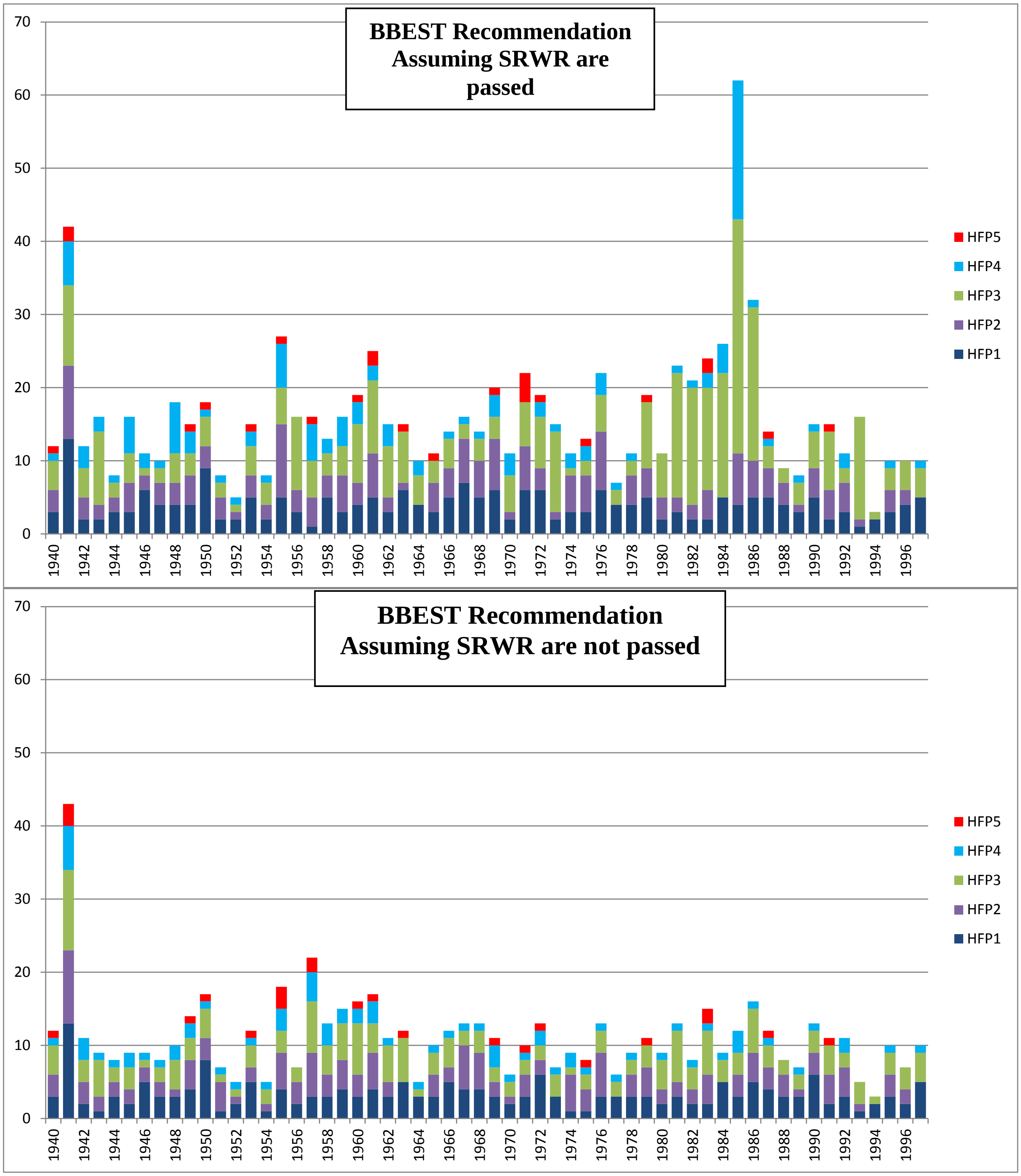

Figure 5 Number of Pulse Events with the implementation of the full BBEST recommendations at Double Mountain Fork West, with and without subordination

Compromise Proposal

As evaluated for the BBASC, application of the full BBEST recommendations results in a reduction in firm yield of the Double Mountain Fork project, when evaluated without subordination, of about 6,400 ACFT per year (about a 42% reduction) when compared to having no instream flow requirements. This compares to a reduction of only about 1,200 ACFT per year (about a 8% reduction) with the application of the BBASC 1,2,1 recommendation. In the interest of trying to reach a compromise, the minority group offered an alternative that would protect more of the pulse requirements than the 1,2,1 recommendation, but, in order to provide a higher project yield, would eliminate some of the higher pulses recommended by the BBEST and reduce the frequency for some of the smaller pulses and base those smaller pulses on hydrologic condition. As shown in Figure 6, this alternative would remove protection for all of the annual pulses and protect all of the BBEST-recommended seasonal pulses only during wet hydrologic conditions. During average hydrologic conditions, the highest tier of seasonal pulse would not be protected and during dry hydrologic conditions, the highest two tiers of seasonal pulses would not be protected and the frequency of the remaining pulse tiers would each be decreased by 1.

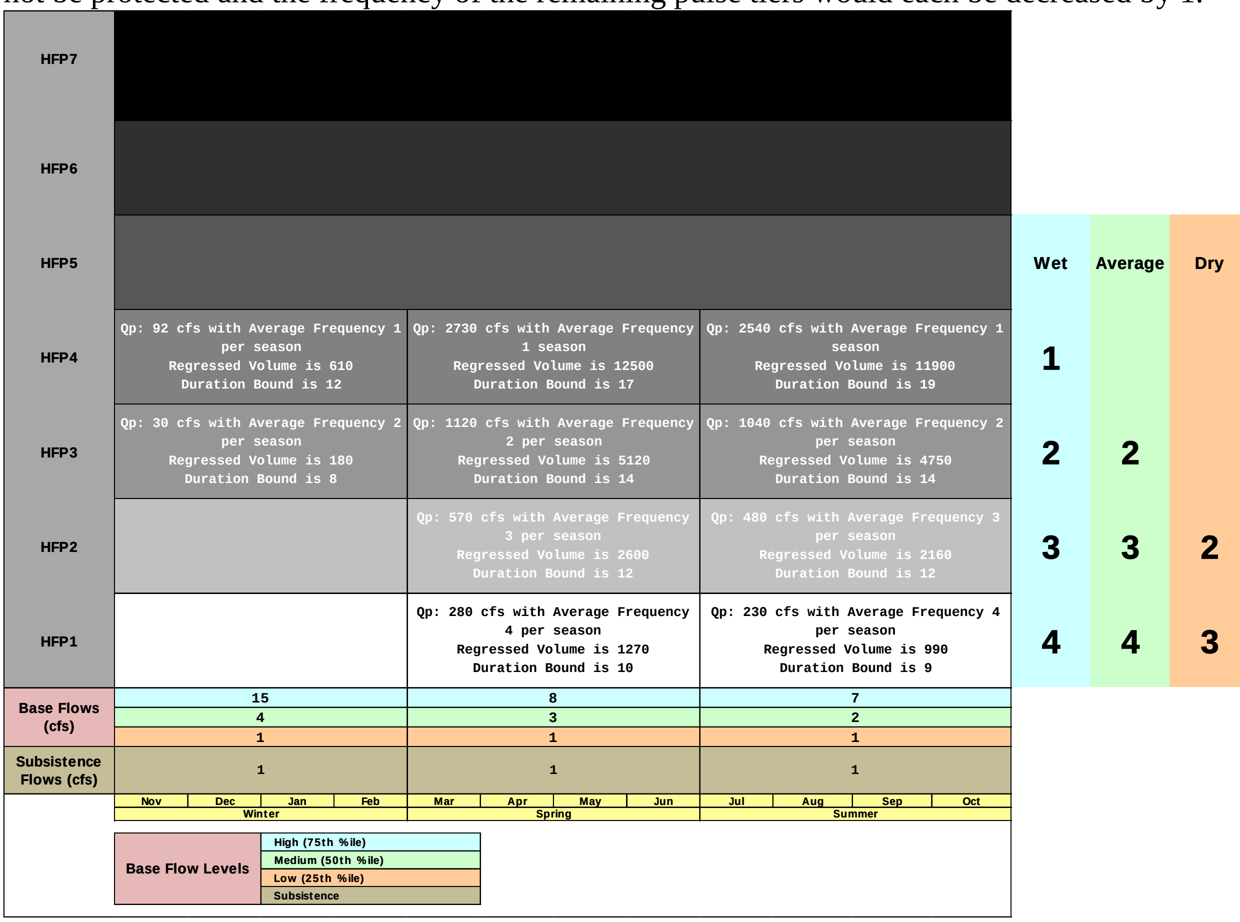

Figure 6 Minority Brazos BBASC Compromise Instream Flow Recommendation for the Double Mountain Fork Brazos River near Aspermont

For the sake of completeness, Figure 7 shows results, similar to those provided for the previous two alternatives, for the application of the minority compromise application with and without passage of flows for downstream seniors (i.e., with and without subordination).

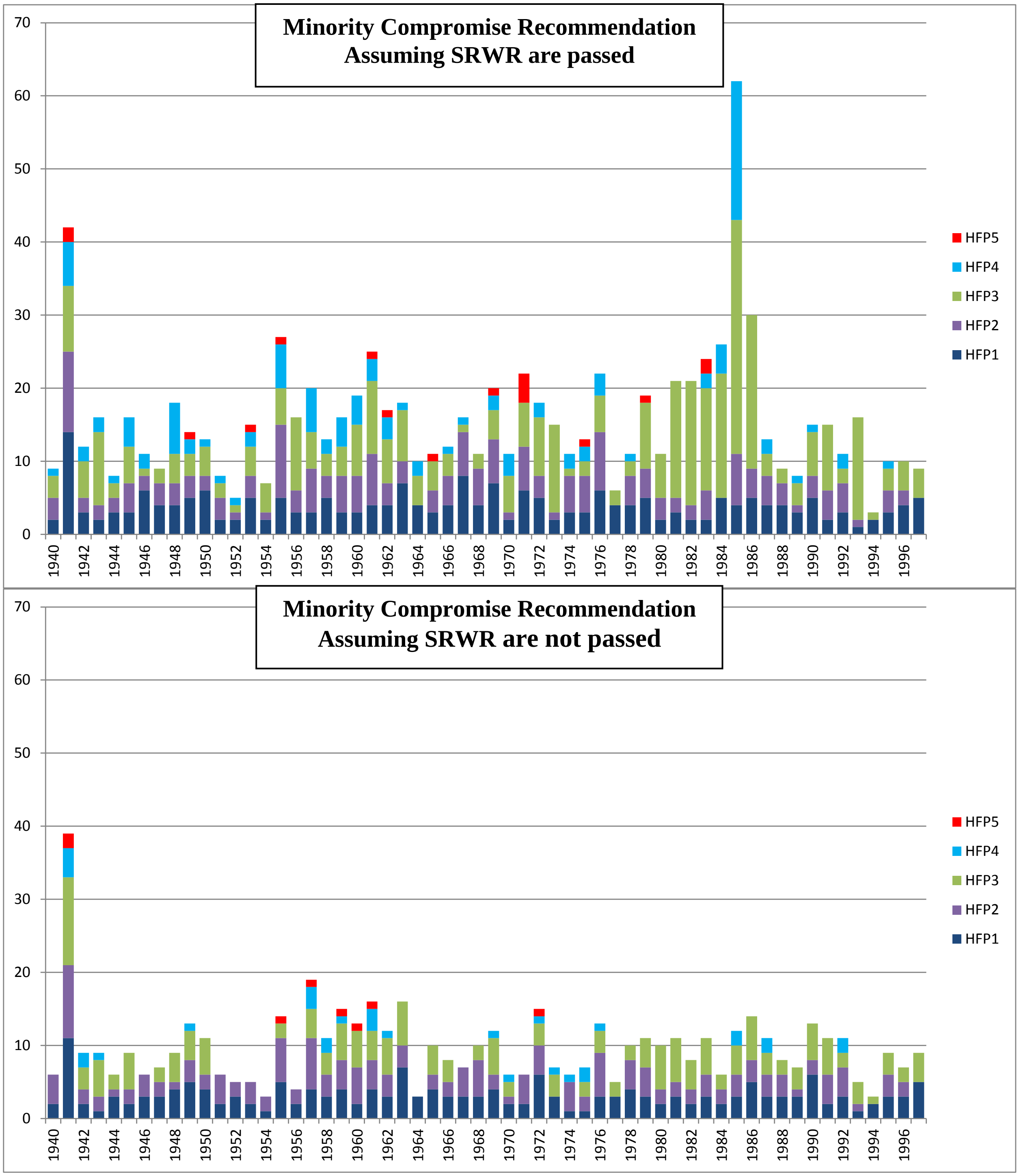

Figure 7 Number of Pulse Events with the implementation of the Minority Compromise recommendations at Double Mountain Fork West, with and without subordination

The minority position continues to be that as much of the BBEST recommendation should be preserved as possible in order to maintain a sound ecological environment in the upper Brazos. To help evaluate how much of the original BBEST recommendation is maintained under the various scenarios, attainment frequencies of the BBEST pulse recommendations are presented in Table 1.

The results for the application of the BBEST targets both with and without the requirement to pass water for senior water rights show the same level of attainment frequencies[9]. Since these results are representative of the flow recommendations that BBEST considered appropriate to protect a sound ecological environment, these levels should be viewed as the target frequencies. Generally, this analysis suggests that the target should be to meet most of the pulse flow targets about 50% of the years, with some of the higher targets met only about 40% of the time and some of the lower pulses met closer to 75% of the time. The results under the Cedar Ridge Template (CRT 121) heading show the attainment frequencies of the standard proposed by the majority of the BBASC. Even with passage of senior water rights (i.e., without subordination), these result show declines in attainment of greater than 10 percentage points in most cases (shown in yellow) for most of the pulses. It might be reasonable to assume that many of these deviations are minor, especially in light of the level of data available for this analysis. If the highly reasonable assumption of a subordination agreement is considered, the situation becomes significantly more dire. Pulses that should occur about 60-70% of the time would be expected to occur as little as 10% of the time. The compromise offered by the minority group, restores, although only to a limited extent, some of the protections recommended by the BBEST. Under the assumption that senior water rights would be passed, the compromise alternative closely mimics the attainment levels that would be provided with the application of the full BBEST recommendations. Assuming subordination, or no calls for downstream senior water rights, the discrepancies become larger though not nearly as dire as they would be under the 1,2,1 recommendation.

[9] Minor differences are due to the effect of passing senior water rights which in some cases satisfy the pulse volume requirement in a single day and thus reset the pulse counter in the model.

Table 1: Attainment Frequencies

Assuming SRWR pass through

HFP1 - 4 per season

Season #	BBEST	CRT121	Comp
1	n/a	n/a	n/a
2	65%	46%	63%
3	73%	66%	73%

HFP2 - 3 per season

Season #	BBEST	CRT121	Comp
1	n/a	n/a	n/a
2	60%	39%	57%
3	67%	55%	67%

HFP3 - 2 per season

Season #	BBEST	CRT121	Comp
1	74%	59%	67%
2	51%	31%	51%
3	54%	45%	49%

HFP4 - 1 per season

Season #	BBEST	CRT121	Comp
1	60%	41%	48%
2	51%	29%	41%
3	50%	45%	47%

HFP5 - 1 per year

BBEST	CRT121	Comp
47%	31%	31%

HFP6 - 1 per 2 year

BBEST	CRT121	Comp
38%	28%	28%

HFP7 - 1 per 5 years

BBEST	CRT121	Comp
43%	34%	34%

Assuming No SRWR pass through

HFP1 - 4 per season

Season #	BBEST	CRT121	Comp
1	n/a	n/a	n/a
2	62%	12%	45%
3	73%	16%	62%

HFP2 - 3 per season

Season #	BBEST	CRT121	Comp
1	n/a	n/a	n/a
2	60%	8%	42%
3	65%	10%	50%

HFP3 - 2 per season

Season #	BBEST	CRT121	Comp
1	74%	5%	55%
2	48%	5%	37%
3	53%	10%	39%

HFP4 - 1 per season

Season #	BBEST	CRT121	Comp
1	60%	7%	26%
2	50%	5%	18%
3	50%	10%	23%

HFP5 - 1 per year

BBEST	CRT121	Comp
47%	12%	12%

HFP6 - 1 per 2 year

BBEST	CRT121	Comp
38%	14%	14%

HFP7 - 1 per 5 years

BBEST	CRT121	Comp
43%	34%	34%

Consensus

At the May 30th, 2012 meeting of the Brazos BBASC, stakeholders agreed that "Consensus is reached when all member participating in a meeting at which there is a quorum agree that their major interests have been taken into consideration and addressed in a satisfactory manner so they can support the decision of the group". The stakeholders also agreed that the idea behind consensus was to generate options and packages that would provide for contingency agreements amongst stakeholders. At the end of the day, the signatories to this minority position compromised in order to achieve consensus at each of the gage locations other than 1-3. We also offered a serious compromise proposal for gages 1-3 significantly below the level of flow protections recommended by the BBEST. However, because the majority of the BBASC was unwilling to move off of the position of the Cedar Ridge 1,2,1 recommendation, regardless of the unique ecological considerations and water supply development realities, it was not possible to reach consensus on pulse flow recommendations at gages 1, 2, and 3.

Conclusion

The majority of the BBASC appears to have reached the conclusion that the 1,2,1 alternative would be protective of many pulses in the upper basin. "They are going to happen anyway" was a frequent refrain during stakeholder committee meetings. This conclusion was based on an unrealistic set of assumptions about how future water projects will be developed in this part of the state. The assumption that these projects would be called upon to make releases to honor downstream senior water rights is simply unrealistic as is readily apparent in the regional water plan. If water is not passed for senior water rights, the pulses are not going to happen anyway, they are going to be captured if upstream reservoirs are built. The danger in moving forward with a recommendation based on these assumptions is that when it comes time for TCEQ to grant a permit there is no opportunity to insert into the process that these standards would be adequate only if the protected pulses are going to happen anyway. By adopting the Cedar Ridge 1,2,1 pulse flow recommendations at gages 1, 2, and 3 instead of a more protective flow regime, the Brazos BBASC majority has rejected taking a proactive approach to reduce the likelihood of the listing of species under the Endangered Species Act and the costs associated with such action. Furthermore, the choice to not work to reach a consensus recommendation on these gages increases the likelihood of future conflict over water supply projects that might be pursued in this area.

The Brazos BBASC majority did not make a sufficient effort to find a reasonable compromise recommendation on pulses for gages 1-3 that all parties could live with. Instead, the least protective regime option was adopted at these locations even though the bases underlying that regime are not valid for these locations. That regime is neither adequate to protect a sound ecological environment nor necessitated by water supply considerations. Therefore, we are unable to support the majority pulse flow recommendation for gages 1-3. Instead, we recommend the compromise proposal put forward herein as the basis for setting environmental flow standards for gages 1, 2, and 3.

This Minority Report is respectfully submitted by:

- Cindy Bartos, Brazos BBASC Recreational Water Users Representative
- Matt Phillips, Brazos BBASC Environmental Interests Representative
- Jennifer Ellis, alternate for Ed Lowe, Brazos BBASC Environmental Interests Representative
- Tyson Broad, alternate for Patrick Riley, Brazos BBASC Commercial Fishing Interests Representative

APPENDIX F Supporters of the BBASC Process

These entities enabled the BBASC process to be completed through significant support in in-kind services and/or financial contributions. We thank you for your investment in Texas water.

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BRAZORIA CO FARM BUREAU

BRAZOS ELECTRIC CO-OP

BRAZOS RIVER AUTHORITY

BURNET CO FARM BUREAU

CITY OF ABILENE

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CITY OF COPPERAS COVE

CITY OF GALVESTON

CITY OF SUGAR LAND

CITY OF TEMPLE

CITY OF WACO

COMANCHE CO FARM BUREAU

CORYELL CO FARM BUREAU

DOW CHEMICAL CO

FORT BEND CO WCID #2

FRIENDS OF BRAZOS RIVER

FT BEND SUBSIDENCE DISTRICT

GULF COAST WATER AUTHORITY

HAMILTON CO FARM BUREAU

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Photo credits:
Front page – The Brazos River downstream from Possum Kingdom; Phil Ford, Brazos River Authority
Last page – The Brazos River at Seymour; Phil Ford, Brazos River Authority