Colorado-Lavaca Basins and Bays
Environmental Flows Stakeholders' Work Plan

1. Purpose

The Colorado-Lavaca Basins and Bays Environmental Flows stakeholders worked closely with the BBEST to produce this work plan guiding future changes in environmental flows analysis, environmental flows standards, and strategies to provide environmental flows. The work plan is designed, and will be implemented with awareness of the ecological complexity linking groundwater and surface water with the physical, chemical, and biological characteristics of sound environments.

The legislative charge below specifies the goals of the work plan.

Senate Bill 3 states:

> *Section 11.02362 (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.*
>
> *Section 11.1471 (f) An environmental flow standard or environmental flow set-aside adopted under Subsection (a) may be altered by the commission in a rulemaking process undertaken in accordance with a schedule established by the commission. In establishing a schedule, the commission shall consider the applicable work plan approved by the advisory group under Section 11.02362 (p).*

2. Work Plan Process

An organization and process is needed to implement the work plan. The following steps outline the organization and process:

1. The BBASC will convene a meeting with the BBEST, and staff of Texas Parks and Wildlife Department (TPWD), Texas Water Development Board (TWDB), and Texas Commission on Environmental Quality (TCEQ) to initiate the work plan. This meeting will identify steps to be taken, individuals responsible, funding sources, and deadlines.
    a. BBASC, the BBEST, and agency representatives will identify potential sources for funding, monitoring, special studies, and research. Individuals may be invited to describe local, state, and federal grant opportunities. Invitations would be extended to organizations/individuals that are doing monitoring not included in the Coordinated Monitoring Schedule, i.e. industries or municipalities required to monitor, LCRA's Colorado River Watch Network, Texas Stream Team volunteer monitors, Texas Mussel Watch volunteers, Texas Master Naturalists, etc. Opportunities would be sought to adjust existing monitoring, particularly Clean Rivers Program work, to address multiple needs including those of the BBASC.
    b. The BBASC will convene a work group that would:
        i. Identify baseline sound environment conditions
        ii. Compile information collected for the work plan
        iii. Analyze information and prepare the work plan report for the BBASC in 2021.
    c. The BBASC would finalize a process and schedule for describing work plan results by 2021.
    d. The BBASC would schedule annual meetings to be informed of work plan progress, discuss needs and opportunities for funding and collaboration, and modify the plan as necessary.
2. Each basin has an annual Clean Rivers Coordinated Monitoring meeting to discuss monitoring needs for the upcoming monitoring year. A member of the BBASC or BBEST would attend that meeting. The BBASC/BBEST representative would discuss inclusion of work plan monitoring in the basin's Coordinated Monitoring Schedule with the goal of incorporating as much of the work plan monitoring as reasonable.

3. The stakeholders have identified highest priority information needs from those listed in this work plan. The stakeholders will request the Environmental Flows Advisory Group provide funding to the state agencies to accomplish these highest priority information needs.

3. Work Plan Product

The product of the work plan will be a report to the TCEQ and Environmental Flows Advisory Group on or before the 10th anniversary of TCEQ's adoption of environmental flow standards for the Colorado and Lavaca basins. As resources have allowed, the report will:

- Summarize relevant monitoring, special studies, and research done,
- Validate the BBEST's environmental flows analyses and recommendations,
- Describe environmental flow regimes for sites not included in the original BBEST and BBASC recommendations as appropriate;
- Validate TCEQ's environmental flows standards and where appropriate, suggest refinements to those standards; and
- Validate strategies implemented to provide environmental flows and where appropriate, propose new strategies or refinements to existing strategies.

The overall goal of this report will be to:

- Summarize results of the studies recommended in this work plan with particular emphasis on the inclusion/analysis of information collected after March 1, 2011 when the BBEST's environmental flow recommendations were published.
- Revise as appropriate, environmental flow regime recommendations published by the BBEST on March 1, 2011.
- Revise the work plan to ensure future information adequately supports development of environmental flow regimes and environmental flow standards.

This report will be published in 2021. This should be the first in what will be considered a long term process with reviews of the work plan implementation being conducted at least once every five years and reevaluation of environmental flow regime recommendations at least once every 10 years until 2081.

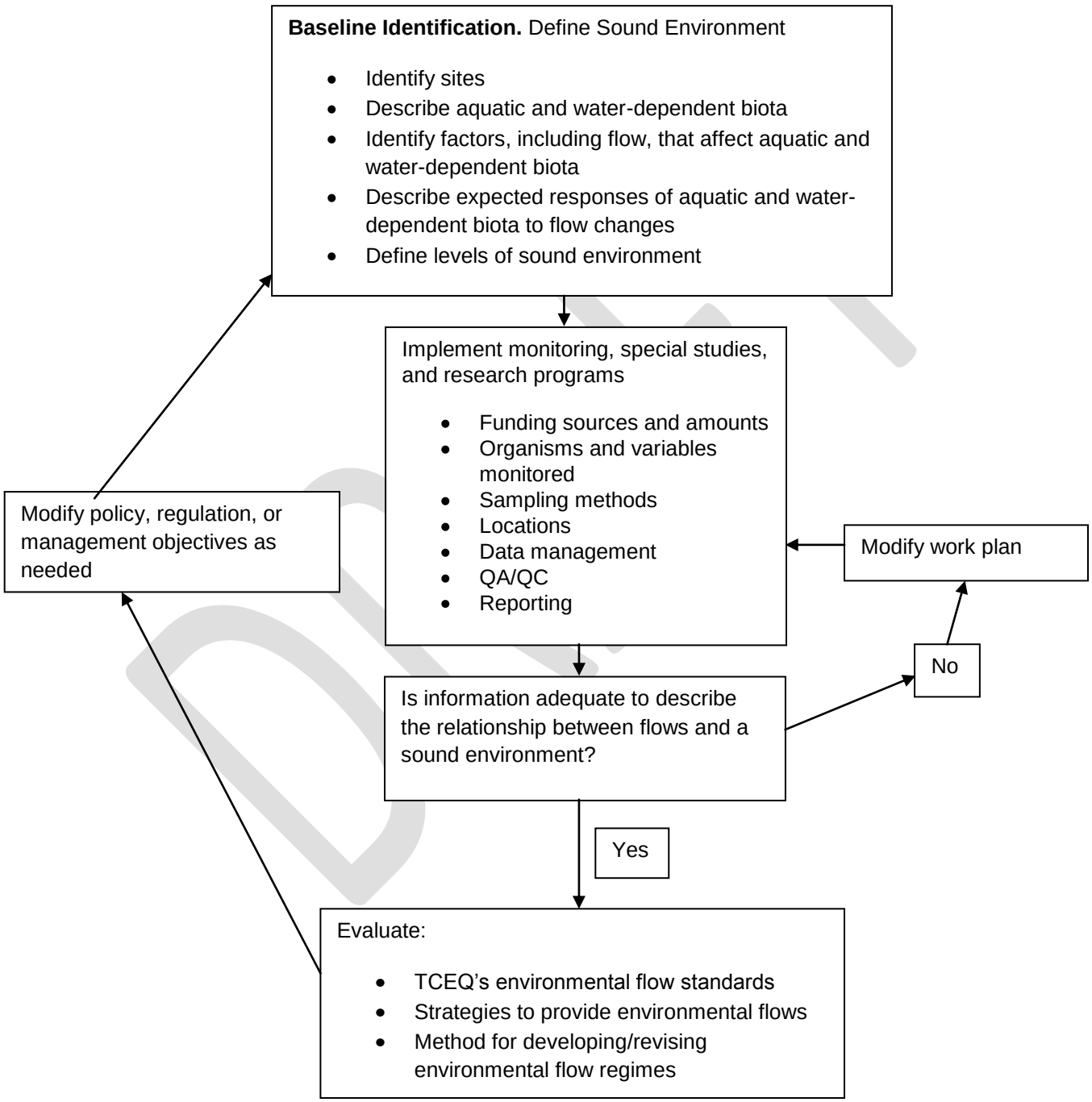
4. Baseline Identification

The BBASC, in cooperation with the state agencies and the BBEST, will create a work group to describe ecological baseline conditions that represent a sound environment for each site included in the BBEST's environmental regime report and for sites added later. The group could also include local, state, and federal experts, university researchers, and others. Measurable ecological components and their values which represent a sound environment will be described for each water body.

Achievement of baseline values would be used to assess whether or not flow regimes are maintaining a sound environment. Ecological components may include lists of aquatic species (fish, benthic macroinvertebrates including mussels, aquatic and riparian vegetation), expected relative abundance, food web composition, reproductive behavior, area of water-dependent wetlands like marshes, habitat availability, etc.

The sound environment baselines for each water body will be completed by 2015. The sound environment descriptions will be dynamic and modified as more information is obtained. The diagram below illustrates this process and is based on the U. S. Environmental Protection Agency report (2005), "Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards: Tiered Aquatic Life Uses."

Adaptive Management Plan Flow Chart



5. Information Needs

A table of information needs identified by the BBEST and the BBASC concludes this report. The following paragraphs describe the general sections of the table. Appendix A includes a detailed description of the prioritization of streams and their ecological analysis as an example of how tasks in this work plan may be conducted in a holistic fashion.

Number

This column assigns a number to each information need for ease of identification and future reference.

Priority

Priority (whether high, medium, or low) refers to the importance of the information needed as decided by the BBASC at the time this work plan is produced. The BBASC understands priorities can change for many reasons and will modify this work plan when appropriate.

Information Need

This column identifies the question that needs to be answered to achieve the work plan's purpose.

Monitoring, Special Study, Research or Modeling

Some work may require monitoring which usually involves collecting the same types of data at a site over several seasons and years. Other questions may be addressed with a special study involving one or a few sampling trips to some sites to answer a specific question. Research may involve literature review, data compilation, and analysis to answer a question without additional field data collection. Modeling is the specialized analysis of relationships, usually with the use of sophisticated computer models of parts of the ecosystem. There are not always clear distinctions between special studies, research, and modeling. In many cases, these approaches will be combined to answer work plan questions.

Schedule

The year is shown in which completion of the analysis and final report to answer each question is expected. This schedule may change based on availability of resources and revised needs for information. Most projects are scheduled to be completed by 2021 to allow review and revision of reports, and development of BBASC recommendations to

the TCEQ. In 2022, the BBASC will provide the TCEQ and the Environmental Flows Advisory Group its final report, summarizing:

1. Validation and 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, and
2. Suggestions for future monitoring, studies, and activities.

In a few cases, the schedule identifies activities expected to continue past 2022. Those activities have a start date of 2021.

A long-term work plan schedule compatible with Senate Bill 1, regional water planning effort's 5-year schedule is desirable. The work plan schedule should be merged with Senate Bill 1's schedule after 2022. Every effort should be made to stay informed of and coordinate with the Senate Bill 1 process in the interim.

Organizations Involved

Organizations expected to contribute to the work described here include the state agencies: principally TWDB, TCEQ, and TPWD with possible support by the Texas General Land Office, Texas State Soil and Water Conservation Board, and the Texas Department of State Health Services, particularly its Seafood Safety Division. Federal agencies include the U.S. Geological Survey, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, Natural Resource Conservation Service, National Oceanic and Atmospheric Administration, and the U.S. Army Corps of Engineers. River authorities and water providers will be involved as necessary. Some nonprofit organizations including Texas Stream Watch and the Colorado River Watch Network conduct water monitoring. Others that may collect data relating flow to environmental health include the Nature Conservancy, a variety of land trusts, local chapters of the Audubon Society, local chapters of Texas Master Naturalists, and others. Colleges and universities across the state are engaged in research and monitoring that may produce the types of information sought in this work plan. This is a preliminary list of organizations that may be involved and will be updated as responsibilities, key personnel, and funding priorities of different organizations change with time.

Funding

Funding will limit implementation of the work plan. The primary approach to fund the work plan will be to request funding from the legislature to the state agencies, through a BBASC request to the Environmental Flows Advisory Group. This funding will allow the

state agencies to conduct the highest priority tasks in the work plan. Three other approaches may be used to provide funding for tasks:

1. Seek ways to collaboratively incorporate work plan tasks into existing, funded, monitoring programs with related objectives. Several BBASC members represent organizations conducting monitoring and they should take leadership roles in guiding this merger of monitoring efforts.
2. Seek new sources of funding for tasks
3. Modify tasks if possible and appropriate to access existing funding sources not necessarily intended to support the Senate Bill 3 process. Although work plan tasks are prioritized, the order of implementation may be modified as necessary to improve access to existing funding sources. Additionally, many tasks have closely related objectives. If necessary, objectives can be partially modified to obtain existing funding.

The BBASC will focus on identification of funding sources as it initiates this work plan. University researchers are aware of different funding sources, particularly research grants, which may facilitate work to address work plan tasks. Considerable local, state, and federal funding is currently allocated to monitoring flow and water chemistry. Comparatively little funding is spent collecting biological data. Less funding is spent interpreting relationships between sound environment, flow, and other factors. Many members of the BBASC belong to organizations that conduct monitoring. Success of this work plan rests in large part on efforts of BBASC members to integrate information needs described below with existing monitoring and analysis programs.

Complicating Factors

Complicating factors include conditions which could obscure a sound understanding of the relationship between flow and stream and by ecological health. One universal complicating factor is the long-term variability in climate. We continue to learn more about the effects of conditions in the equatorial Pacific Ocean on wetter and dryer than normal seasons and years in Texas. Recent analysis of tree rings suggests that “megadroughts” lasting 20 to 30 years may have occurred in the past. Long-term variability means some monitoring and special studies may collect data over too short a span of time to completely understand these long term patterns or to provide all the information described in this document. Other complicating factors include:

- The relatively long life spans of some species that will be analyzed. Alligator gar may live for several decades and some mussel and riparian tree species may live over one hundred or more years.

- Changes in agricultural, industrial, and municipal use of surface and ground water.
- Changes in waste loading from municipal, agricultural, industrial, and nonpoint sources of pollution.
- Noxious species like toxic golden algae in the upper Colorado basin and red tides in Matagorda Bay that can cause massive dieoffs of fish and mussels. Expansion of giant reed or salt cedars along river courses, or brush replacing grasses that affect uptake of water by plants. And,
- Changes in land cover/land use by cities, industries, or agricultural which modify drainage and aquifer recharge patterns.

Identification of complicating factors relevant to specific tasks will be critical prior to initiating any monitoring, special studies, or research for the work plan.

Responsible Party

The BBASC is responsible for the work plan and ultimately responsible for guiding the accomplishment of the tasks described here. The TWDB, TPWD, and TCEQ, are expected to complete the high priority tasks identified in this work plan with funding provided by the state legislature. Because of their prominent roles in managing Texas water, these agencies are also expected to participate in the accomplishment of the other tasks identified in this work plan.

Number	Priority	Description of Work Plan Tasks (Tasks shaded in gray are considered highest priority and funding will be sought from the legislature for the state agencies to accomplish these tasks)
		Rivers and Streams
1		**Describe relationships between flow, and physical, chemical, and biological structure and function of the streams and how these relationships support ecological health.** **Coordinating Agencies: Primarily TPWD with TWDB, and TCEQ** Describe role of flow in ecological health of the stream. This is an overarching goal that should be accomplished by combining information collected from 2011 through 2020 with earlier data. The 2021 work plan report should summarize the results of the monitoring and studies conducted in the basins for this adaptive management process and obtained from other sources. The focus of the report should be on the relationships between flows and ecological health in a minimum of two representative streams in each of the Lavaca-Navidad, upper Colorado, and lower Colorado River basins. Revised environmental flow regime recommendations will be developed for sites identified by the BBEST. Completed 2021. • **Identify stream locations and estuaries not included in the BBEST environmental flow regime report that should be analyzed for relationships between flow and environmental health.** Desk-top study based in part on review of expected water demands and availability identified by the regional water planning process. Identify water bodies that may have future applications for diversions. Identification of additional locations for environmental flow analysis will be summarized in reports done in 2013 and 2018. • **Review best available science for determining environmental flow regimes for streams**. Literature review and discussion with experts in relevant fields of study. Appropriate enhancements will be applied to the determination of new environmental flow regimes and modification of existing environmental flow regimes. This effort will include evaluation of HEFR and possible approaches to replace HEFR. These reviews should be summarized in reports prepared in 2016 and 2021 which conclude with recommendations for approaches to use in determining future environmental flow recommendations or for verifying existing environmental flow recommendations.
2		**Describe key biological features of environmental flow regimes** **Coordinating agency: TPWD** • **Describe ecological services provided by perennial pools**. Special study on at least two streams in the upper Colorado River

		basin and at least one stream in each of the Lavaca-Navidad and lower Colorado River basins. Some monitoring programs do not collect information from perennial pools when there is no flow. In some cases there will be difficulty accessing streams when there is no flow and the perennial pool is not near the established monitoring site. Existing monitoring programs should continue monitoring physical, chemical, and biological conditions when streams form perennial pools. • **Describe relationships between aquatic biota (including riparian and floodplain species) and flow.** Although this is a broad category of endeavor, it is important to identify plant or animal species, guilds, or communities considered representative of environmental health and begin literature review, focused sampling, and analysis to understand flow regimes which sustain them. Identify two aquatic and two riparian plant and/or animal species, guilds, or communities in each of the upper Colorado, Lavaca-Navidad, and lower Colorado basins on which to focus study. Study will include literature review and focused sampling whether by special study, monitoring, or a combination of the two. This work will continue by identifying two more aquatic and two more riparian species, guilds, or communities in each of the basins on which to focus work for the next ten years (2021 through 2030). These studies may be focused if necessary on a minimum of two streams in each basin. The length of time it takes for some riparian plants like trees and aquatic organisms like mussels to respond to environmental changes may complicate data collection and interpretation. ○ **Identify flow regime components and quantities necessary to sustain mussels and compare to flow regimes identified necessary to sustain fish communities**. Focus on distribution of mussels, their life stages, life cycles, and relationships to flow with greater emphasis initially on threatened species. There may be more funding for this work, particularly through the US Fish and Wildlife Service's State Wildlife Grant program than for other monitoring described here since the US Fish and Wildlife Service is considering listing some mussel species. ○ **Describe relationships between Guadalupe bass and flow and blue suckers and flow.** Site and species specific studies of habitat use, age structure, community structure, distribution of different life stages, stimulation of spawning, food web interactions, and relationships between those features and flows. This work should be conducted on at least two streams in the upper Colorado basin which have self-sustaining populations of Guadalupe Bass, the state fish of Texas and a state-listed threatened species. Blue suckers should be studied in the lower Colorado River. ○ **Determine if there are relationships between toxic golden algae blooms and flow in the upper Colorado basin.** The upper Colorado River, Beals Creek, and the lower reaches of the Concho River and Elm Creek have experienced substantial mortality of fish in the past from toxic golden algal blooms. An organization representing the upper Colorado basin should participate on the TPWD's Golden Alga Task Force. This organization should collaborate, whenever possible, in helping evaluate the life history of golden alga in basin and encourage adequate consideration of the relationship between flow and toxic blooms. Routine golden alga monitoring should be added to a minimum of two streams in the upper Colorado basin, including the Colorado River upstream of Lake Ivie. These sites preferably should be sites with water chemistry and flow monitoring. The episodic nature of toxic blooms complicates this task since years may pass without a bloom occurring.

		• **Describe relationships between physical habitat and flow.** Special studies to measure water depth, velocity, and substrate types of key riverine habitats (riffles, runs, pools, glides, backwaters, oxbows) for representative sections of two streams in the upper Colorado basin, two streams in the Lavaca-Navidad basin, and one stream in the lower Colorado basin. These data will be linked to information about changes in habitat quality and availability when flows change through hydrologic modeling. Studies will be repeated every five years to track changes in physical habitat possibly resulting from changes in flow regime. Factors possibly complicating this analysis include human alterations to physical habitat like channel clearing and shaping for flood control, invasion of noxious plants (giant cane, salt cedar) or animals that alter physical habitat. • **Describe upstream-downstream connectivity and lateral connectivity of streams with the floodplain and aquatic features like wetlands, backwaters, sloughs, and oxbows under different flow conditions.** Special study acquiring and reviewing aerial photography for each stream under different flow conditions. Information collected would include location of dams and places where perennial pools form under low flow conditions. It would also include locations where streams flood into important aquatic features outside the channel. This process should be applied initially to streams analyzed by the BBEST and any other streams the BBASC believes are important to analyze. Analysis should be repeated every 10 years on a subset of the initial streams studied. These analyses should be conducted as much as possible in partnership with analysis of aerial photography for other purposes. • **Identify ecological effects of overbank flows and flows that reach flood stage elevation but do not overbank should be identified.** The BBASC recommended flows attaining flood stage elevation should be allowed to occur at their historical frequency. Physical, chemical, and biological monitoring associated with floods should be conducted. These data should be used to evaluate the relation between ecological effects and environmental health of the streams. Because these events occur relatively infrequently, monitoring should be implemented whenever possible on streams in both basins. The infrequent nature of these events will support the need for extensive literature review of the ecological effects of these types of events. Obstacles to completion of this task will be their relatively infrequent nature, and logistic challenges in safely sampling episodic, short-lived events during potentially hazardous conditions. The frequency of overbank flows and floods that reach the flood stage elevation over the period from 2010 – 2019 should be compared to the BBEST's overbank and the BBASC's flood stage elevation flow recommendations.
3		**Describe relationships between groundwater and stream flow.** **Coordinating agency: TWDB** This may require creation of long-term groundwater monitoring locations combined with special studies analyzing relationships between groundwater levels, stream flows, groundwater withdrawals, land cover/use patterns, and meteorological conditions for specific streams. Monitoring should be designed to last preferably until at least 2071. Special studies analyzing relationships between groundwater levels, stream flows, and groundwater withdrawals, combined with a review of monitoring data should be conducted

		every 10 years. These studies should be conducted on a minimum of two representative watersheds in each of the upper Colorado and Lavaca-Navidad river basins and on at least one watershed in the lower Colorado basin. Lack of rainfall monitoring in specific areas combined with inadequate information about runoff rates, plant uptake rates, and interception of runoff before it infiltrates the ground will complicate this analysis. • **Determine relationships between groundwater withdrawals from the Carrizo-Wilcox and the Gulf Coast aquifers, and flows to rivers.** These studies would start as desk-top analysis but additional field work should be conducted if more data are needed. These studies should be conducted on tributariesin addition to the main rivers or streams.
4		**Describe relationships between water chemistry and flow regime components.** **Coordinating agency: TCEQ** Considerable water chemistry monitoring is currently done and some data are analyzed on a regular basis for the Clean Rivers Program and the federally-required biennial water quality inventory. Current analysis focuses on possible point and nonpoint sources of contaminants. When data indicate the presence of harmful levels of certain parameters, the current analysis should be expanded to determine the role flow regimes play in determining those levels. Existing monitoring programs should be encouraged to collect water chemistry data over a wider range of flow conditions than may normally be done. For example, water chemistry should be measured when flow stops and as long as perennial pools persist and when streams have higher than normal flow or are flooding. Analysis of relationships with flow should focus on a minimum of the following parameters: temperature, pH, specific conductance, dissolved oxygen, nitrate + nitrate, total phosphorus, and chlorides. Two obstacles associated with this task involve ensuring safe sampling under high flow and flood conditions and obtaining access to perennial pools that may form at different locations than currently used monitoring locations when a stream stops flowing.
5		**Increase understanding of how different factors affect calculation of flow regime components and hydrologic conditions over time.** **Coordinating agency: Colorado-Lavaca BBEST** This desk-top study of flows and climate should evaluate different periods-of-record data sets, parameterizations of HEFR, hydrologic conditions, and hydrologic condition triggers. The BBEST did some evaluation of different periods of record and HEFR parameterizations. Those analyzes however were necessarily limited because of the relatively short time the BBEST had in which to produce flow regimes. Apply to a minimum of two sites in each of the upper Colorado, lower Colorado, and Lavaca-Navidad basins. Consideration will be given to how well the hydrologic condition represents the actual flow regime, the ability of the hydrologic condition and triggers to represent the natural variability of flows, and the ease with which the hydrologic triggers can be used by the regulated community.

		This will also include review of flow data collected principally by the USGS. Preliminary flow data review will be conducted every three years and recommendations will be issued regarding the continuation of monitoring at gages and the addition of flow monitoring at new sites. Natural flow patterns may be relatively long and may be influenced by several different global climate drivers, ex. Southern Pacific Oscillation, North Atlantic Oscillation, etc.
6		**Identify water development activities planned for the future, and how they might influence groundwater, river flows, and physical and hydrologic connections between the two.** **Coordinating agency: TWDB** Review water development possibilities identified in regional water plans and from other sources. These studies would start as desk-top studies involving prioritization of possible water development activities to evaluate. These desk-top studies would compile and review available information about groundwater, stream flow, and possible links between the two in the area of the planned water development. As necessary, field studies would be conducted to provide needed information. Possible water development activities are likely to occur distant from sites for which environmental flow regimes have been identified. Groundwater/surface water linkages between the location of the possible water development and the site where environmental flow standards have been set should be understood.
7		**Identify how variation in flow associated with hydropower operation affects environmental health of the lower Colorado River.** **Coordinating agency: LCRA** This might be done with desk-top analysis of existing data. If not, a special study should be conducted to collect data necessary to address this question. Factors like daily changes in treated wastewater return flow, changes in downstream diversions, and increasing distance from hydropower operation will complicate this analysis.
8		**Research best methods to determine sediment transport and channel maintenance of streams for which environmental flow standards have been set.** **Coordinating agency: TWDB** Desk-top study of the best, currently available science on sediment transport and channel maintenance. It will evaluate applicability of the best available science to the types of streams in the Colorado and Lavaca-Navidad basins. This effort will guide future analysis of flow regimes needed to maintain the existing, dynamic channel morphology.

		• **Describe changes in geomorphology, i.e. trends in channel elevation, longitudinal profile, width, floodplain width, stream form, bed sediment size, and the role the flow regime contributes to those changes.** Utilize available data and aerial photography for at least two representative streams in each of the three basins. Review of available literature will guide identification of additional field data and/or aerial photography to be collected. Indicators of change in channel morphology and levels useful in identifying ecologically harmful changes in channel morphology will be identified. The cumulative impacts of multiple, relatively small, diversions on channel morphology should be evaluated in this analysis. Limited availability and resolution of Lidar data that measures ground surface elevation along with the dynamic nature of stable channels could complicate this analysis.
9		**Refine estimates of freshwater flow to the bays**. **Coordinating agency: TWDB** Validate estimates of gaged and ungaged flow. Develop estimates of groundwater flow to the bays. Special studies may be necessary to collect rainfall runoff information from ungaged watersheds and particularly to measure how it changes with season and land cover. Special studies will be necessary to identify locations where groundwater inflow is entering the bay, estimate quantities, and characterize factors that influence groundwater inflow. Information on diversions and return flows should also be validated. The objective of this task is to increase confidence in estimates of freshwater inflow to the bays. • **Describe flows into Garcitas Creek and their sources with particular emphasis on the reach downstream of the USGS gage.** Evaluate how the flow regime in Garcitas Creek is changing because of changing agricultural practices. Identify how flow patterns in the past compare to existing flows and they are expected to change in the future. Recalculate the amount of freshwater Garcitas Creek is delivering to Lavaca Bay. This is primarily a desk-top study of existing flow and agricultural data (information on irrigation practices and changes in acreage in production). Field studies evaluating ungaged flow into Garcitas Creek downstream of the gage may be needed.
10		**Evaluate and update the WAM Run 3 for the Colorado River basin.** **Coordinating agency: TCEQ** TCEQ would manage revision of the WAM Run 3 model. Desk-top studies would follow, evaluating how the revised version would affect estimates of available flow and the recommended flow regimes. • **Explain why recent historical flows at some sites, particularly in the upper Colorado basin are less than WAM Run 3 flows**

		(based on the 2011 WAM Run 3 model for the Colorado Basin). This will initially consist of a desk-top study describing differences between recent historical flows and those predicted by WAM Run 3. It may require meetings of regional experts with knowledge of flows in the area and factors affecting flows in order to help understand flow patterns in this area. Additional field studies may be necessary to understand the relationship between flows and the WAM Run 3 model. This information may set the stage for updating the WAM Run 3 model for the Colorado basin.
Bays		
11		**Describe relationships between freshwater inflow to bays, and physical, chemical, and biological structure and function of the estuaries and how these relationships support ecological health.** **Coordinating agency: Primarily TPWD with support from TWDB, and TCEQ** This is an overarching goal that should be accomplished by combining information collected from 2011 through 2020 with earlier data. The 2021 work plan report should summarize the results of the monitoring and studies conducted for this adaptive management process and obtained from other sources. The report should focus on relationships between inflow and ecological health in Lavaca Bay, Matagorda Bay, and East Matagorda Bay. Work should also be conducted in Tres Palacios Bay and Powderhorn Lake. Planning should begin for freshwater inflow recommendations for Carancahua, Keller, Cox, Chocolate, and Turtle bays. Revised freshwater inflow regimes will be prepared for Lavaca and Matagorda bays, and new freshwater inflow regimes will be prepared for East Matagorada and Tres Palacios bays, and Powderhorn Lake. • **Identify improvements made in methods for determining environmental flow regimes for estuaries.** Intensive literature review combined with expert meetings and consultation will be conducted to stay abreast of latest developments in this field of science. New techniques will be evaluated and applied to the Colorado-Lavaca estuaries as appropriate. • **Describe relationships between freshwater inflow, marsh, and the threatened diamond-back terrapin populations.** A special study would be conducted in upper Lavaca Bay to understand the relationship between this state-listed threatened species, its habitat, and freshwater inflows. • **Describe the relationship between freshwater inflow and *Rangia* clam abundance in upper Lavaca Bay.** Anecdotal information suggests *Rangia* clams were very abundant in upper Lavaca Bay at one time. Field studies would be conducted to identify *Rangia* clam distribution, abundance, spawning, and life history patterns and relationships to freshwater inflows. • **Describe the relationship between freshwater inflow, location and size of oyster reefs, and health of oysters in Lavaca Bay and Matagorda Bay.** Oysters would be mapped with side-scan sonar (this may be done by TPWD since it has acquired side-scan sonar capability). Dermo monitoring by the Oyster Sentinel program would be expanded to include more reefs over a broader range of salinities. Water quality monitoring (temperature, salinity, oxygen, and pH) would be conducted using continuously recording meters placed on the reefs in locations where Oyster Sentinel samples would be collected. Monitoring of commercial oyster harvest would be expanded to account for harvest effects on oyster reefs. TWDB, with its

		coast-wide salinity monitoring program, and TPWD, with its role in assisting the TWDB with salinity monitoring and its responsibility in measuring oyster populations and tracking harvest, will be key partners in this effort. • **Evaluate relationships between freshwater inflow and the distribution, health, and abundance of seagrass in East Matagorda Bay and Matagorda Bay.** Field studies would map seagrass in both bay systems. Monitoring should be initiated in key seagrass beds in both bay systems using protocols identified by the interagency Seagrass Monitoring Workgroup. Additional sampling as appropriate would be identified to explain relationships between seagrass and freshwater inflow. This work may be complicated by the relatively turbid condition of the bays compared to other areas with seagrass which have more transparent water and where it is easier to see the seagrass and capture it in aerial photography. • **Describe relationships between salinity and commercially important indicator species (white and brown shrimp, blue crab, and Gulf menhaden).** This study would be a desk-top review of existing inflow, salinity (TWDB), and abundance (TPWD) data. Field work may be identified and conducted as appropriate. This field work may include monitoring of larval life stages or habitats not typically sampled in existing monitoring programs. This effort may be complicated by difficulty in obtaining commercial harvest data and by factors, i.e. changing market demand, fuel prices, that affect harvest effort. • **Identify marsh changes occurring in the Lavaca River and the Matagorda River deltas and relationship of those changes to freshwater inflow.** Conduct field studies including aerial photography designed to describe these changes. Placement of water quality and sedimentation monitoring equipment in key marsh locations may be necessary. • **Evaluate achievement of the BBEST freshwater inflow recommendations in Matagorda Bay (based on the Matagorda Bay Health Evaluation recommendations) and ecological response to those freshwater inflow quantities and distribution.** Determine if ecological structure and functions identified as likely to be protected by the Matagorda Bay Health Evaluation, are responding as predicted with the salinity-based approach of MBHE? Are the abundance and recruitment of key species as predicted by MBHE criteria occurring? Are metrics of abundance and recruitment being reflected in "exceptional", "average", or "low" suitability years? This analysis may be complicated if the freshwater inflows are substantially different than the MBHE regime. • **Describe the relationship between freshwater inflow and sound environment in the coastal drainages of East Matagorda Bay.** The area of focus would be north of the Intracoastal Waterway and east of the Colorado River to Caney Creek. Field studies would be conducted with expected focus on the marsh communities in this area. Complicating factors for this task include absence of gaged stream flows in these watersheds and changing agricultural practices that may change amounts of irrigation return flow to the area. • **Identify methods to lower salinities in East Matagorda Bay without degrading the environmental condition of the bay.** This would be a desk-top study to identify techniques to lower salinity in the bay. Meetings with technical experts and stakeholders would be essential. Proposed alternatives may need to be addressed in an environmental impact statement under the National Environmental Protection Act. Additional monitoring or field studies may be identified.
12		**Describe the relationships between subsidence and salinity regimes in East Matagorda Bay.**

		Coordinating agency: TWDB Subsidence may be occurring in the East Matagorda Bay area. Field studies would be conducted to determine if subsidence was occurring and if so, its rate. If subsidence was substantial, field studies would be conducted to evaluate the effects of subsidence on freshwater inflow, salinity and ecological health.
13		**Improve the existing hydrodynamic model or use other hydrodynamic models to model hydrology, circulation, and salinity patterns Matagorda and Lavaca Bays.** **Coordinating agency: TWDB** This would be a desk-top study to validate and refine prediction of salinity and other environmental factors at different inflows. Focus would be on ranges of inflows and areas of the bays (i.e. near shore) where modeling capability is weaker. This work would be limited by the cost associated with enhancing existing models or using new models. Additional field studies may be identified to support this effort. There would be particular emphasis on the relationship between salinity in the marsh and adjacent open water in Matagorda and Lavaca bays.
Basin-wide		
14		**Implement a program to review effectiveness of strategies used in areas where there may be inadequate amounts of water for an environmentally sound stream or estuary.** **Coordinating organization: Colorado-Lavaca BBEST** Part of this program would involve the design of desk-top or field studies needed to determine strategy effectiveness in: 1) restoring or providing ecological structure and function provided by a sound flow regime, or 2) restoring environmentally sound flow regimes.
15		**Quantify the affects of sediment transport on existing water supply reservoirs and delta formation in Lavaca and Matagorda Bays.** **Coordinating organization:**

Appendix A: Instream Flows

a. Locations:

Tier 1 - Lavaca River, Tres Palacios Creek, Garcitas Creek;

Tier 2 - Navidad River, Sandy Creek, West Mustang Creek, East Mustang Creek;

Tier 3 - Onion Creek, Pedernales River, Llano River, San Saba River, Concho River, Pecan Bayou, South Concho River;

Tier 4 - Colorado River at Bastrop, Colorado River at Columbus, Colorado River at Wharton; Colorado at San Saba, and

Tier 5 - Colorado River at Ballinger, Colorado River at Silver, Elm Creek at Ballinger

As resources are available to conduct this work, those resources should be applied to Tier 1 streams decreasing in priority to Tier 5 streams. If resources become available for a particular stream, those resources should be applied to that stream regardless of which tier it is assigned to.

This prioritization is based on several factors. Tier 1 streams are shown by water availability modeling to have the most water potentially available for future appropriations. Tier 4 sites have already had intensive analysis of relationships between flow and ecology and have limited amounts of water potentially available for future appropriations. Tier 5 streams have such small amounts of water available for future appropriation that work in those streams should be minimized until higher tier streams are adequately studied. The BBASC is interested in ensuring all streams have environmentally sound flows regardless of their priority for analysis.

b. Instream Flow: Relationships between flow regime components and physical, chemical, and biological ecosystem components

This section describes a holistic approach to sampling instream sites which should help understand relationships between flows and sound environment in streams and rivers.

1. Sampling Period

Annual monitoring should be conducted during the late summer or early fall at each site. The goal is to minimize variation due to flows during the sampling period, maximize sampling gear efficiencies, and permit comparative evaluations of the aquatic, riparian, water quality, and physical conditions. It is suggested that intensive Texas Instream Flow Program (Senate Bill 2-style) studies not be initiated at this time. We believe that it would be more practical to implement intensive surveys based on the 5 year monitoring results if monitoring results show that alternative flow regimes may be warranted or the status of the system is trending toward an unsound ecological environment.

2. Establishment of Monitoring Reaches

At each site, a monitoring reach should be established of sufficient length (~150 mean active channel widths) provided site access and logistics allow, near enough to the USGS flow gage to allow an accurate understanding of flows and flow changes.

3. Data Collected

a. Flows

The work plan should track plans to maintain flow gaging at all sites of interest in order to ensure flow continues to be monitored by USGS at all necessary sites. At each site, it is recommended that the daily gage data be analyzed in terms of attainment frequencies of the various environmental flow regime components such as:

- percent of time flows were observed in each of the base flow levels;
- number, timing, and duration of pulse flow events
- number, timing, and duration of overbank flow events
- amount and timing of all diversions

As much attention as possible should be placed on quantifying flows contributed by groundwater, whether from springs, alluvial aquifers, or bank storage. Some of these flows derived from groundwater which contribute to stream flow are typically referred to as "base flow". This should be done for main-stem river channels as well as tributaries in areas where groundwater outflows to surface waters are anticipated. Quantification of groundwater flows and how they are changing should be focused in areas where groundwater withdrawals have affected stream flow or where they may affect stream flows in the future. One example is the Carrizo-Wilcox aquifer in the vicinity of the Colorado River below Austin. A second example is along the Concho River downstream of San Angelo where there has been a substantial increase in the number of groundwater wells.

b. Water Quality and Temperature

Available data from all existing water quality monitoring activities should be assimilated and analyzed for trends and potential limiting values for target aquatic biota. It is recommended that during the initial 5 year monitoring activities that meters be placed within the monitoring reach to accumulate daily oxygen and temperature data that would permit calibration of a water quality model such as QualTx.

With the exception of the sites on the lower Colorado River where the equivalent of SB2 full studies were conducted, the existing BBEST/BBASC recommendations are based on an evaluation of historical water quality data. Modeling oxygen levels and temperature with flow will permit an evaluation of subsistence flows and water quality conditions that may impact the aquatic biota.

c. Aquatic Biota Monitoring

Sampling should be conducted using a variety of gear types (i.e., electrofishing, seining, hoop nets, etc) in three replicates of all available mesohabitat types within each established monitoring reach. Examples of different mesohabitats are shallow pools or deep pools, riffles, and shallow or deep runs. This sampling will permit assessment of the community structure and distribution by habitat types. All fish should be identified to species, total lengths and wet weights measured, and qualitative data on overall condition such as emaciation, external parasites, etc, recorded. It is not prudent to focus on only a few indicator species given how little quantitative data exists on community structure and population

dynamics. Selection of indicator species should be evaluated at year 5 based on the analysis of the holistic sampling results.

It is also recommended that 3 replicate samples of both invertebrate drift and benthic invertebrates be collected from a randomly selected riffle habitat at the monitoring site. All available mesohabitats should be surveyed for mussels within each monitoring reach to assess their distribution and abundance within the monitoring reach. Data should be collected on spawning condition. These data should be analyzed in terms of species composition, relative abundance, and relation to flow, etc.

d. Habitat Monitoring

Mesohabitat mapping should be conducted with the aquatic biota sampling. This mapping should delineate the area of each mesohabitat and its characteristics like maximum depth, current velocity, substrate, and cover for fish (i.e., vegetation, woody debris). Mesohabitat maps will relate aquatic biota to habitats at each monitoring site. Linking habitat availability with biological community composition and relative abundance will help understand how changes in habitat availability with flow can impact species distributions and abundance. These data will also be valuable in assessing potential trends in habitat availability over time.

e. Channel Geometry and Riparian Community

The shape of the cross-sections across the river should be measured from where the riparian vegetation meets the upland vegetation from one side of the river to the other side where the riparian and upland vegetation meet. The shape of cross-sections across the river should be measured at approximately 20 points along the channel on an annual basis. Riparian plants, their ages, and locations should be measured along each of these cross sections. These data should be analyzed to examine changes in native and non-native plants and their recruitment into the riparian zone. At each cross section, Wolman Pebble counts (a technique for measuring the size of particles on the river bottom) should be conducted to describe the sizes of particles on the river bottom. These data will show if large changes in bottom sediment movement are affecting river channel characteristics.

f. Land Use/Land Cover

Changes in land use and land cover should be examined every 5 years within the contributing watershed and used to assess trends that can affect flow regimes and changes in water quality. The contributing watershed is the portion of the watershed where rainfall runoff will enter into a stream and flow through the watershed. Non-contributing areas are the portions of the watershed where rainfall will not runoff into a stream. This should identify for example changes in impervious layer area, changes in native and non-native vegetation, agricultural crop patterns, etc.

g. Monitoring Organizations

Tier 1 and Tier 2 streams. The Lavaca-Navidad River Authority and the US Geological Survey already conduct monitoring at most of these streams.

Tier 3, 4, and 5 streams. The Lower Colorado River Authority (LCRA), the Texas Commission on Environmental Quality (TCEQ), the City of Austin, Hays County, the Upper Colorado River Authority (UCRA), and the USGS sample these streams.

It is possible that Texas Parks and Wildlife Department (TPWD) and Texas Water Development Board (TWDB) staff may be able to help conduct this intensive monitoring. Volunteers may be recruited from local colleges, universities, and interested organizations (ex. Texas Stream Team, Texas Master Naturalists, Colorado River Watch Network). TPWD's annual survey of wild rice in July of each year is an example of professional biologists and volunteers working together to collect meaningful information.

Universities which are located in these basins and/or which have conducted work in these basins include:

- Angelo State University (San Angelo)
- Texas Tech University (Lubbock)
- Howard Payne University (Brownwood)
- University of Texas at Austin
- Texas State University (San Marcos)

- Texas A & M University (College Station)
- University of Texas Marine Science Institute (Port Aransas)
- Texas A & M University (Galveston)
- Harte Research Institute (Corpus Christi)

h. Funding Sources

Funding by the U. S. Environmental Protection Agency (EPA) supports monitoring by TCEQ while Clean Rivers funding supports water monitoring by the river authorities. Different private, state (ex. State Wildlife Grants), and federal grant programs occasionally make funding available for this type of data collection and analysis. A work group of BBASC and BBEST members should be established in each basin by 2012 for the purpose of pursuing alternative funding sources.

i. Potential Confounding Variables

Relationships between flow regime and environmental health may be confounded by:

- Episodes (fish die-offs and spills) that negatively impact biota and affect biological monitoring results,
- Point and nonpoint source pollutants,
- Invasive species
- Urban development in the watershed that increases impervious cover
- Changes in land use and/or land cover
- Changes in ground water use

j. Schedule and Reports

Data collected and analyzed should be reviewed by 2016 and a report should be produced that summarizes information collected, identifies changes that need to be made in monitoring, and identifies potential aspects of environmental flow regime that may need to be modified in the future.

A summary report should be produced by 2022, summarizing data collected from present into 2021 and making recommendations for environmental flow regime components. This report will also identify water bodies that should be studied in the future.