# Colorado and Lavaca Rivers and Matagorda and Lavaca Bays Basin and Bay Area Stakeholder Committee

## Draft Work Plan

June 26, 2012

# Contents

## I. Purpose

This document sets out the work plan developed by the Colorado and Lavaca Basin and Bay Area Stakeholder Committee (BBASC) in conjunction with the Colorado and Lavaca Basin and Bay Area Expert Science Team (BBEST) pursuant to Section 11.02362 (p) of the Texas Water Code. The purpose of this work plan is to guide 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 directives for development and submission of the work plan are set out below.

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).*

## II. Work Plan Process

The following steps outline the organization and process to be followed in implementing the work plan:

1. Within six months of the approval of this work plan by the Environmental Flows Advisory Group, the BBASC will convene an initial meeting with the BBEST and appropriate staff of Texas Parks and Wildlife Department (TPWD), Texas Water Development Board (TWDB), Texas Commission on Environmental Quality (TCEQ), and other appropriate entities to initiate work plan activities. This meeting will identify specific steps to be taken, individuals responsible, funding sources, and deadlines.
    a. At the meeting, representatives of the BBASC, the BBEST, and the agencies, along with other participants, will identify potential sources for funding, monitoring, special studies, and research set out in this work plan. Individuals may be invited to describe local, state, and federal grant opportunities and other potential funding mechanisms. Invitations will be extended to organizations/individuals that are doing monitoring not included in the Coordinated Monitoring Schedule, e.g., 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 will be sought to adjust existing monitoring, particularly Clean Rivers Program work, to address multiple needs including those of the Senate Bill 3 Environmental Flows Process.
    b. At the meeting, or soon thereafter, the BBASC will establish three work groups (described below) that will be charged with undertaking specific activities under the oversight of the BBASC. A work group will normally include 9 to 11 formal members and will operate on a consensus basis to the maximum extent practicable. At the discretion of the BBASC, a work group may include members who are not members of the BBASC. The BBASC will appoint the chair and vice-chair of each work group. Each work group will make regular reports to the BBASC, normally at least semi-annually and not less often than once a year in accordance with the schedule established by the BBASC. Work group recommendations shall be approved by the BBASC prior to inclusion in the Work Plan Report.

i. The Work Plan Work Group will be responsible for:
    1. compiling information collected pursuant to the monitoring and assessment activities included in the work plan and other related information that bears on the interpretation of those activities,
    2. making arrangements for the analysis of the collected information and for the preparation of the draft work plan report for presentation to the BBASC by no later than December 31, 2020, and
    3. making recommendations for any needed work plan revisions.

ii. The Strategies Work Group will be responsible for:
    1. identifying potential strategies, giving special consideration to those listed in Section 8 of the Environmental Flows Recommendation Report, for evaluation to determine their viability for helping to meet the environmental flow standards;
    2. developing plans for the evaluation of specific, potential strategies that are identified and, to the extent possible given funding and other constraints, arrange for the completion of those evaluations;
    3. preparing recommendations for possible endorsement by the BBASC of strategies that should be pursued;
    4. developing, to the extent possible, recommendations for implementation of strategies endorsed by the BBASC;
    5. monitoring progress made by others in implementing strategies that benefit environmental flows; and
    6. preparing, by no later than December 31, 2020, a draft strategies section, which will include reports on any progress in the implementation of strategies for meeting environmental flow standards, for inclusion in the work plan report.

iii. The Baseline Work Group, which will be made up of technical experts, will be responsible for:
    1. recommending, for monitoring and assessment purposes, ecological baseline conditions that characterize a sound ecological environment for each site for which an environmental regime recommendation is included in the

BBEST report and East Matagorda Bay (recommendations for additional sites may also be included); and
2. recommending specific ecological components and values to be measured, along with a monitoring frequency for each component.

2. The BBASC will, by no later than December 31, 2020, finalize a process and schedule for describing work plan results and for developing any accompanying recommendations for inclusion in a formal BBASC Work Plan Report to be adopted and submitted to TCEQ and the Environmental Flows Advisory Group no later than September 1, 2021.

3. The BBASC will schedule semi- annual meetings, although the BBASC retains the discretion to meet more frequently or only to meet on an annual basis, to be informed of work plan progress, discuss needs and opportunities for funding and collaboration, consider reports on implementation of strategies and recommendations on the endorsement of strategies, and adjust the plan, as necessary.

4. Each basin has an annual Clean Rivers Coordinated Monitoring meeting to discuss monitoring needs for the upcoming monitoring year. At least one representative of the BBASC or BBEST will attend that meeting. The BBASC/BBEST representative, or representatives, will propose 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.

5. The BBASC has identified highest priority information needs from those listed in this work plan. The stakeholders will seek funding for the state agencies, and other appropriate entities, to accomplish the highest priority activities early in the work plan process, including through a request to the Environmental Flows Advisory Group for assistance with obtaining legislative support. In the event that adequate funding for work plan implementation has not been identified by the end of 2013, the BBASC will evaluate, in early 2014, the merits of establishing a funding work group, or two funding work groups organized by river basin, to assist in pursuing alternative funding sources.

6. In addition to the reservation by the BBASC of the option of adjusting this work plan in response to changed circumstances, the prioritization and review timeline

set out in this version of the work plan are subject to change by the BBASC based on the content of the final environmental flow standards adopted by TCEQ. Because this work plan has been developed without knowledge of what flow standards will actually be adopted, changes to this work plan may be needed to address discrepancies between the environmental flow standard recommendations developed by the BBASC and the standards adopted by TCEQ. To the extent that key components of the recommended flow regime are left unprotected by the flow standards, the BBASC may recommend additional studies to help understand the significance of that lack of protection, a change in prioritization of studies, and a change in the timeline for review of the recommendations and flow standards.

## III. Review Timeline and Continuing Role of BBEST

Based on the development of a reasonably comprehensive set of consensus recommendations, this work plan contemplates a ten-year review period for basin and bay environmental flow analyses and environmental flow regime recommendations and for environmental flow standards. That review period is intended to allow time for development of significant new information to inform the review process. The starting date for the initial review period is the date that TCEQ first adopts environmental flow standards for the Colorado and Lavaca basins. The work plan anticipates completion of studies, reports, and preliminary recommendations in time to inform the development of formal recommendations for potential revisions to environmental flow standards by no later than nine years after that starting date. For strategies to help meet environmental flow standards, the work plan contemplates an ongoing process of refinement and continued development, independent of the ten-year review period.

This work plan contemplates a continuing, and critically important, role for the BBEST in the development, interpretation, and, in some instances, implementation of studies. Unfortunately, we recognize that, at the time this work plan is being developed, funding has not been identified to support the continued operations of the BBEST. The BBASC strongly recommends that funding be provided to support the continued involvement of the BBEST in the work plan process. Similarly, successful implementation of the work plan will require substantial involvement by state agency staff, particularly staff of the Texas Parks and Wildlife Department, Texas Water Development Board, and Texas Commission on Environmental Quality, in ongoing monitoring and research activities related to environmental flow issues. Accordingly, the BBASC strongly recommends that funding for those monitoring and research activities, including funding for

installation and maintenance of stream flow gages, by the State of Texas be continued at least at existing levels and increased if possible.

## IV. Work Plan Product

A key product of work plan activities will be a BBASC Work Plan Report to the TCEQ and Environmental Flows Advisory Group to be delivered on or before September 1, 2021. In addition to that formal report, annual updates on work plan activities and a five-year interim report will be developed. The five-year interim report, to be submitted by the BBEST to the BBASC by June 20, 2017, will reflect data collections and analyses undertaken as of December 31, 2016 and will include, as appropriate, recommendations for revisions to work plan studies and monitoring and initial identification of aspects of the flow standards that should be considered for revision. As resources have allowed, the 2021 report will:

- summarize relevant monitoring, special studies, and research done;
- review the BBEST's environmental flows analyses and recommendations in light of any new data or information, including data or information developed through the work plan process;
- describe environmental flow regimes for sites not included in the original BBEST and BBASC recommendations as appropriate;
- review TCEQ's environmental flows standards and where appropriate, suggest refinements to those standards; and
- review effectiveness of strategies implemented to provide environmental flows and, where appropriate, recommend additional strategies or refinements to existing strategies.

The overall goal of the 2021 report will be to:

- summarize results of the studies and evaluations 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;
- document, as appropriate, revisions or additions to the environmental flow regime recommendations published by the BBEST on March 1, 2011;
- recommend, as appropriate, revisions or additions to environmental flow standards and strategies to meet the standards;

- propose revisions to the work plan to ensure future information adequately supports future refinement of environmental flow regimes and environmental flow standards; and
- document progress on the development and implementation of strategies to help meet environmental flow standards and provide recommendations to further those efforts.

This report will be published in 2021. This should be the first in what will be considered a long-term process. Subsequent reviews of the work plan implementation by the BBASC should be conducted at least once every five years. Reevaluation of the environmental flow regime recommendations, the environmental flow standards, and strategies to help meet environmental flow standards should occur at least once every 10 years.

## V. Baseline Identification

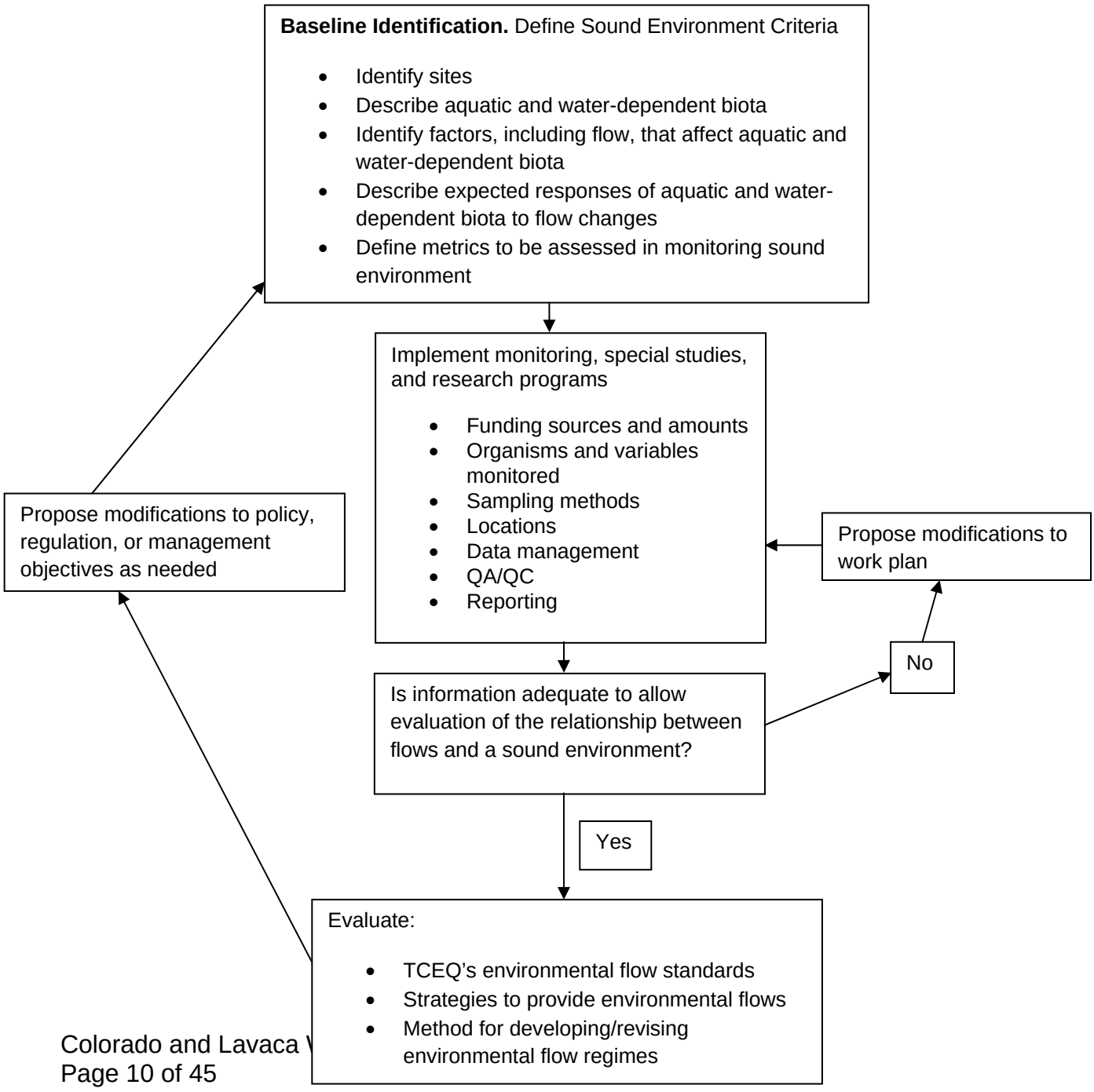
The Baseline Work Group, as appointed by the BBASC, may include local, state, and federal experts, university researchers, and others. Appropriate participation by individuals beyond the formally named members is encouraged. Measurable ecological components and their values which represent a sound environment will be described for each portion of a water body for which the BBEST developed a flow regime recommendation and including East Matagorda Bay.

Achievement of baseline values would be used to assess whether or not flow regimes are maintaining a sound environment. An ecological baseline condition would be a set of readily measurable parameters and their values which the work group identifies as indicative of an acceptably sound environment for each water body. Examples of ecological baseline conditions may include number of fish species, width of riparian plant zone, and dissolved oxygen levels. Other ecological components may include presence or absence of certain aquatic species (e.g., certain species of fish, some benthic macro invertebrates including mussels, and some types of aquatic and riparian vegetation), relative abundance of certain species, food web composition, reproductive behavior, area of water-dependent wetlands like marshes, habitat availability, etc.

The specification of sound environment baseline conditions for monitoring and assessment purposes for each site will be completed by December 31, 2015. The sound environment baseline condition 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



## VI. Information Needs and Proposed Work

Two tables of information needs, and work proposed to help meet those needs, as identified by the BBEST and the BBASC, are set out below. Table 1 provides a summary presentation of the highest priority study tasks, grouped by lead entity. That table also includes a rough estimate of anticipated costs for implementing those priority tasks. In some instances, additional information is necessary for use in developing even a rough estimate. In all instances, as additional information becomes available, cost estimates will be refined.

Table 2 provides a fuller description of all study tasks. Numbering and titles of tasks are consistent across both tables.

**TABLE 1**
## SUMMARY TABLE OF HIGH PRIORITY TASKS

| Task # From Full Table | Summary Task Description (fuller description appears in the "Description of Work Plan Tasks" table below) | Lead Entity | Rough Cost Range* |
|---|---|---|---|
| 1, sub 2 | Review best available science for determining environmental flow regimes for streams. | TPWD | $50,000 to $100,000 |
| 2, sub 3 | Describe relationships between physical habitat and flow. | TPWD | $100,000 to $150,000 |
| 10 | Develop a method for obtaining site-specific commercial fishing harvest data and for maintaining appropriate confidentiality of those data and develop an approach for incorporating reliable commercial fisheries harvest data into the analysis of the relationship between freshwater inflows and species productivity.** | TPWD | $100,000 to $200,000 |
| 12, sub 1 | Identify improvements made in methods for determining environmental flow regimes for estuaries. | TPWD | $50,000 to $150,000 |
| 12, sub 6 | Describe relationships between salinity and commercially important indicator species (e.g., white and brown shrimp, blue crab, and Gulf menhaden). | TPWD | $50,000 to $150,000 |
| 12, sub 8 | 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. | TPWD | $50,000 to $300,000 |
| 3 | Determine relationships between groundwater withdrawals from the Carrizo-Wilcox and the Gulf Coast aquifers and flows to rivers. | TWDB | $300,000 to $400,000 |
| 6 | Determine how groundwater development activities, as listed in the then current State and relevant Regional Water Plans, might influence river flows and the physical and hydrologic connections between surface and groundwater. | TWDB | $50,000 additional beyond Task 3 |

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| 7, sub 1 | 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. | TWDB | $250,000 plus $20,000/ yr |
| 9 | Evaluate decline in flows in the upper Colorado Basin with a particular emphasis on understanding the apparent change in relationship between rainfall and river flow. | TWDB | $30,000 for initial phase, 2nd phase unknown |
| 11 | Refine estimates of freshwater flow to the bays. | TWDB | $180,000 to $530,000 |
| 14 | Improve the existing hydrodynamic model or use other hydrodynamic models to model hydrology, circulation, and salinity patterns for Matagorda, East Matagorda, and Lavaca Bays. | TWDB | $300,000 to $584,000 |
| 16 | Quantify the effects of sediment transport on delta formation in Lavaca and Matagorda Bays. | TWDB | $300,000 |
| 8 | Evaluate and update the WAM, with particular emphasis on Run 3 and Run 8, for both the Colorado and Lavaca river basins, with a goal of the development of a daily time-step capability that could be employed for environmental flow assessment tasks. | TCEQ | $60,000 to $120,000 *** |
| 5 | Increase understanding of how different factors affect calculation of flow regime components and hydrologic conditions over time. | BBEST | $40,000 |
| 15 | Implement a program to review effectiveness of strategies that could be used in areas where there may be inadequate amounts of water to support an ecologically sound stream or estuary. | BBASC & BBEST | $100,000 |

*Additional information regarding cost estimates is included in Appendix B.

**There is uncertainty about whether those data could be kept confidential under current law.

***The cost of this task is expected to be covered in TCEQ's ongoing budget and contract for maintenance of WAMs unless unanticipated complications develop.

| Number | Priority | TABLE 2. Description of Work Plan Tasks<br>(Tasks, or subtasks, shaded in gray are identified as having high priority and funding initially will be sought, including through a request to the EFAG, to accomplish these tasks) |
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| | | **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.**<br><br>**Coordinating Agencies: Primarily TPWD with TWDB, and TCEQ**<br><br>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 early 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 2020. |
| Sub 1 | | • **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. |
| Sub 2 | Yes | • **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 refine or replace HEFR. These reviews should be summarized in reports prepared in 2016 and 2020 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**<br><br>**Coordinating agency: TPWD** |
| Sub 1 | | • **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 |

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| | | 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. |
| Sub 2* | | • **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.<br>o **Identify flow regime components and quantities necessary to sustain mussels and compare to flow regimes identified as being 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 or endangered 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 pursuant to the Endangered Species Act.<br>o **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. Consider significance, if any, of aquifer outflow for blue sucker.<br>o **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. |
| Sub 3 | Yes | • **Describe relationships between physical habitat and flow.** Special studies to measure water depth, velocity, and substrate |

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| Sub 4*<br><br><br><br><br><br><br><br>Sub 5* | | 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.<br>• **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 in developing its flow regime recommendations 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.<br>• **Identify ecological effects of overbank flows and flows that reach, or almost reach, flood stage elevation but do not overbank.** The BBASC recommended that pulse flows nearing 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.**<br><br>**Coordinating agency: TWDB**<br><br>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 |

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| Sub 1 | Yes | areas combined with inadequate information about runoff rates, plant uptake rates, and interception of runoff before it infiltrates the ground will complicate this analysis.<br>• **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 tributaries in addition to the main rivers or streams. Studies should be designed to help provide data suitable for use in both WAM and GAM modeling efforts, including efforts to understand historical and current relationships and to facilitate predictions of future relationships. |
| 4* | | **Describe relationships between water chemistry and flow regime components.**<br><br>**Coordinating agency: TCEQ**<br><br>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 at least 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 | Yes | **Increase understanding of how different factors affect calculation of flow regime components and hydrologic conditions over time.**<br><br>**Coordinating agency: Colorado-Lavaca BBEST**<br><br>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 analyses 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. |

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| | | 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 | Yes | **Determine how groundwater development activities, as listed in the then current State and relevant Regional Water Plan, might influence river flows and the physical and hydrologic connections between surface water and groundwater.**<br><br>**Coordinating agency: TWDB**<br><br>Review groundwater development possibilities identified in regional water plans and the state water plan. 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 groundwater development. As necessary, field studies would be conducted to provide needed information. Possible groundwater 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 groundwater development and the site where environmental flow standards have been set should be understood. |
| 7*<br><br>Sub 1 | Yes | **Research best methods to determine sediment transport and channel maintenance of streams for which environmental flow standards have been set.**<br><br>**Coordinating agency: TWDB**<br><br>Desk-top study of the best, currently available science on sediment transport and channel maintenance. It will evaluate applicability of the best available science for 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.<br><br>• **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. |

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| 8 | Yes | **Evaluate and update the WAM, with particular emphasis on Run 3 and Run 8 for both the Colorado and Lavaca river basins, with a goal of the development of a daily time-step capability that could be employed for environmental flow assessment tasks.**<br><br>**Coordinating agency: TCEQ**<br><br>TCEQ would manage revision of the WAM model. Desk-top studies would follow, evaluating how the revised version would affect estimates of available flow and the recommended flow regimes. It is recognized that the daily time-step function might not be employed by TCEQ in evaluating water availability. The preferred outcome would be to develop a model that could be easily switched between a monthly and a daily time-step function.<br>• |
| 9 | Yes | **Evaluate decline in flows in the upper Colorado Basin with a particular emphasis on understanding the apparent change in relationship between rainfall and river flow.**<br><br>**Coordinating agency: TWDB**<br><br>This task will initially involve evaluations of the relationship between rainfall and river and stream flow over time in order to gain a better understanding of how that relationship may have changed over the period for which records are available. Based on that improved understanding, the next phase is intended to help identify potential causes in that relationship.. It may be appropriate to involve regional experts with knowledge of flows and changes that have occurred over time in the area. . |
| **Bays** | | |
| 10 | Yes | **Develop a method for obtaining site-specific commercial fishing harvest data and for maintaining appropriate confidentiality of those data and develop an approach for incorporating reliable commercial fisheries harvest data into the analysis of the relationship between freshwater inflows and species productivity.**<br><br>**Coordinating agency: TPWD**<br><br>Commercial fishermen indicate that reliable site-specific harvest data exist which are not currently available in government databases. However, at least some of those fishermen are concerned about sharing those data with governmental entities because of a desire to maintain the confidentiality of those data. Because reliable commercial harvest data tied to specific locations could be highly useful in augmenting current databases used in evaluating the relationship between species productivity and freshwater inflows, there is a need to find a way to obtain, review, and, as appropriate, incorporate those data. That will require at least a two-step process. First, TPWD will need to identify and/or develop a way to maintain the confidentiality of commercial harvest data voluntarily provided in this manner. It is possible that can't be accomplished under current statutes. Second, TPWD will need to assess the reliability of the data and, if determined to be adequately reliable, develop a way to incorporate those data into analyses |

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| | | of the relationship between freshwater inflows and species productivity. |
| 11<br><br>Sub 1 | Yes | **Refine estimates of freshwater flow to the bays**.<br><br>**Coordinating agency: TWDB**<br><br>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.<br><br>• **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. |
| 12<br><br>Sub 1 | Yes | **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.**<br><br>**Coordinating agency: Primarily TPWD with support from TWDB, and TCEQ**<br><br>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, as appropriate, and freshwater inflow regimes will be prepared for East Matagorda and Tres Palacios bays, and Powderhorn Lake.<br>• **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 |

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| | | field of science. New techniques will be evaluated and applied to the Colorado-Lavaca estuaries as appropriate. |
| Sub 2 | | • **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. |
| Sub 3 | | • **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. |
| Sub 4 | | • **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. |
| Sub 5 | | • **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. |
| Sub 6 | Yes | • **Describe relationships between salinity and commercially important indicator species (e.g., 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. To the extent possible and appropriate, commercial harvest data obtained pursuant to Task 7, above, should also be considered. |
| Sub 7 | | **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. |
| Sub 8 | Yes | • **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 response to "exceptional", "average", or "low" suitability years? This analysis may be complicated if the freshwater inflows are |

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| Sub 9<br><br>Sub 10 | | substantially different than the MBHE regime.<br>• **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.<br>• **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. |
| 13 | | **Describe the relationships between subsidence and salinity regimes in East Matagorda Bay.**<br><br>**Coordinating agency: TWDB**<br><br>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. |
| 14 | Yes | **Improve the existing hydrodynamic model or use other hydrodynamic models to model hydrology, circulation, and salinity patterns for Matagorda, East Matagorda, and Lavaca Bays.**<br><br>**Coordinating agency: TWDB**<br><br>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. In particular, field studies may be required to get a better understanding of freshwater flows reaching the Intracoastal Waterway adjacent to East Matagorda Bay and of the amount of those flows, as well as flows from Caney Creek, that reach East Matagorda Bay. There also would be particular emphasis on the relationship between salinity in the marsh and adjacent open water in Matagorda and Lavaca bays. |
| **Basin-wide** | | |
| 15 | Yes | **Implement a program to review effectiveness of strategies that could be used in areas where there may be inadequate amounts of water for an ecologically sound stream or estuary.** |

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| | | **Coordinating organization: Colorado-Lavaca BBEST and Strategies Work Group**<br><br>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. |
| 16 | Yes | **Quantify the effects of sediment transport on delta formation in Lavaca and Matagorda Bays.**<br><br>**Coordinating organization: TWDB**<br><br>A key role of freshwater inflows is to replenish sediments reaching bay systems. That effect is most immediately reflected in the deltas formed adjacent to major inflow sources. Delta formation would be tracked over time, including through analysis, if possible, of historical responses between delta formation and freshwater inflows, reflecting changes in inflow patterns and the creation of upstream sediment traps. Future changes in delta formation would be measured and analyzed and, to the extent possible, tools for predicting changes in delta formation in response to future inflow changes and reductions in sediment load would be developed. |

* For these tasks or subtasks, the following prioritization mechanism for locations is recommended, except to the extent that a particular aspect of the task or subtask otherwise establishes location priorities.

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.

The following paragraphs describe the general types of information included in Table 2. Appendix A includes a detailed description of the ecological analysis of streams as an example of how tasks in this work plan may be conducted in a holistic fashion. The BBASC understands priorities can change for many reasons and will modify this work plan when appropriate.

### 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

In some instances, where the information was available, 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 2020 to allow review and revision of reports, and development of BBASC recommendations to the TCEQ. In 2021, the BBASC will provide the TCEQ and the Environmental Flows Advisory Group its formal 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 recommendations for 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 2021. 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, in addition to the BBASC and the BBEST, 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, and non-exclusive, 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

Availability of funding will limit implementation of the work plan. The primary approach to funding the work plan will be to seek funding from the legislature to support work by the state agencies, including through a BBASC request to the Environmental Flows Advisory Group for such funding support. This funding would allow the state agencies to conduct the highest priority tasks in the work plan early in the ten-year work plan cycle. Other approaches may be used to provide funding for tasks, including:

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 other sources of funding for tasks, including from private, local, state, and federal sources.
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 prioritization may be modified as necessary to improve access to existing funding sources. In addition, if funding for a particular task is available, the prioritization is not intended to suggest any limitation on the value or need to undertake the work plan task. 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. Even less funding is spent interpreting relationships between sound environment, flow, and other factors. Success of this work plan rests in large part on efforts of BBASC members and state agencies 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 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 of a span of time to completely understand these long-term patterns or to provide all of the information described in this document. Other complicating factors include:

- The relatively long life spans of some species that will be analyzed. For example, alligator gar may live for several decades and some mussel and riparian tree species may live over one hundred or more years.
- Ongoing changes in agricultural, industrial, and municipal use of surface and ground water.
- Ongoing changes in waste loading from municipal, agricultural, industrial, and nonpoint sources of pollution.
- Episodic events resulting in large-scale die-offs of fish and other aquatic species.
- Noxious species like toxic golden algae in the upper Colorado basin and red tides in Matagorda Bay that can cause massive die-offs 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 developing the work plan and ultimately responsible for guiding the accomplishment of the tasks described here. However, to be successful in this undertaking, the BBASC necessarily has to rely on TWDB, TPWD, and TCEQ 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, the participation of these agencies also is vital to the accomplishment of the other tasks identified in this work plan.

# Appendix A: Instream Flow Monitoring

## 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 may not be needed 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 preferable not 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 in understanding 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 (e.g., Texas Stream Team, Texas Master Naturalists, Colorado River Watch Network). TPWD's annual survey of wild rice in the San Marcos River 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)

# Appendix B: Background for Cost Estimates.

## 1. TWDB Input on Cost Estimates for Priority Tasks with TWDB as Lead Entity

**Cost Estimates of Colorado-Lavaca BBASC Work Plan Priority Studies Listing**
**Texas Water Development Board (TWDB) as the Coordinating Agency**

Estimates provided by TWDB staff,
Mark Wentzel Ph.D., P.E., Carla Guthrie, Ph.D., and Nolan Raphelt, Ph.D., P.E.

**3. <u>Determine relationships between groundwater and stream flow.</u>**

**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.*

***3A. 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 tributaries in addition to the main rivers or streams. Studies should be designed to help provide data suitable for use in both WAM and GAM modeling efforts, including efforts to understand historical and current relationships and to facilitate predictions of future relationships.*

A model relating groundwater withdrawals and river flows in Colorado, Wharton, and Matagorda counties was developed as part of the LCRA-SAWS studies. A link to that study can be found here:

http://www.lcra.org/library/media/public/docs/lswp/findings/URS_Mitigation_report_final.pdf

Development of a similar model for Fayette and Bastrop counties could cost as much as $500,000 or more. Such a model would have the capacity to predict surface water-groundwater interactions as conditions change in the basin.

As an alternative, an understanding of groundwater and surface water (at gage locations) could be developed at five to six locations within the basin for current conditions for significantly less. This would require about $200,000 for synoptic surface water measurements (cost for a similar study recently completed in the Brazos River basin). Data for surface water flows at stream gage locations is available at no additional costs (stream gaging costs are currently being paid by other programs). Groundwater

monitoring at existing wells could be carried out for approximately $5,000 for installation of equipment and $5,000 per year to monitor thereafter. If new monitoring wells were required, they could be completed for an approximate additional cost of $10,000 per well. A network of 6 wells (matched to 6 active stream gage locations within the basin) would therefore cost approximately $30,000 per year to monitor and from $30-90,000 for initial installation. Total cost to build relationships between groundwater conditions and streamflows for 6 locations in the basin would therefore be about **$300,000 to $400,000**.

**6. <u>Determine how groundwater development activities, as listed in the then current State and relevant Regional Water Plan, might influence river flows and the physical and hydrologic connections between surface water and groundwater.</u>**

**Coordinating agency: TWDB**

*Review groundwater development possibilities identified in regional water plans and the state water plan. 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 groundwater development. As necessary, field studies would be conducted to provide needed information. Possible groundwater 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 groundwater development and the site where environmental flow standards have been set should be understood.*

Once a model is developed for Task 3 above, it could be adapted to evaluate impacts of future groundwater development in the area of the model. An evaluation of future water management projects that may impact the basin (both surface water and groundwater) could be undertaken for approximately **$50,000**. Depending on the available outcomes of Task 3 (predictive models or simple descriptive relationships), these projects could be evaluated more or less qualitatively or quantitatively.

**7. <u>Research best methods to determine sediment transport and channel maintenance of streams for which environmental flow standards have been set.</u>**

**Coordinating agency: TWDB**

**7A. *Desk-top study of the best, currently available science on sediment transport and channel maintenance.***

*This study will evaluate applicability of the best available science for 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.*

This has already been completed by the SAC (with assistance from TWDB). Links to those methods are here:

http://www.tceq.texas.gov/assets/public/permitting/watersupply/water_rights/eflows/sac_2009_04_sedtransport.pdf

http://www.tceq.texas.gov/assets/public/permitting/watersupply/water_rights/eflows/sac_2011_08_sedtransportaddendum.pdf

For a relatively modest cost, a scientific peer review of these documents could be completed. A panel of scientists could review these guidance documents and suggest any improvements or refinements. This could be accomplished for a cost of from **$30,000 to $50,000** depending on the number of scientists selected.

***7, sub 1. 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.*

Several efforts could be undertaken here. First, an analysis of available aerial and satellite imagery could be undertaken to estimate rates of channel change in a broad sense (i.e. pre and post development of major water projects). A similar study on the Brazos River was recently completed at a cost of $40,000.

Second, sediment transport data could be collected at and near the six sites (two representative streams in each of the three basins). This would allow further refinement of desktop analysis and rough sediment budgeting for these reaches. A similar effort on the Brazos River is being accomplished for a cost of $90,000.

Third, historical data related to channel cross section and longitudinal profile dimensions are available for the main stem of the Colorado River and some tributaries such as the San Saba River. Similar contemporary data could be collected via GPS surveys, allowing analysis of changes. Such surveys at select sites in the basin could be accomplished for approximately $50,000.

Fourth, physical data collected by the USGS at stream gaging locations could be collected and analyzed for changes over time. A similar effort on the Brazos and Sabine Rivers was recently completed for a cost of approximately $45,000.

Finally, channel cross sections near the sites of interest could be monumented and resurveyed at regular intervals of time in order to monitor change. This activity could be accomplished at a cost of approximately $20,000 per year.

Total cost of these activities (7, sub 1) would be approximately **$250,000 for one time cost**, with an **additional cost of $20,000 per year** to continue to monitor channel change at monumented locations.

**9. <u>Evaluate decline in flows in upper Colorado Basin with particular emphasis on understanding the apparent change in relationship between rainfall and river flow.</u>**

**Coordinating agency: TWDB**

*This task will initially involve evaluations of the relationship between rainfall and river and stream flow over time in order to gain a better understanding of how that relationship may have changed over the period for which records are available. Based on that improved understanding, the next phase is intended to help identify potential causes in that relationship. It may be appropriate to involve regional experts with knowledge of flows and changes that have occurred over time in the area.*

The change in rainfall and river flow could be documented by a relatively quick study and analysis of weather and streamflow data. Such a study could be completed for approximately **$30,000**. After completion of that study, a second study related to identifying the causes of those changes could be undertaken. Approaches may include rainfall/runoff models to evaluate the influences of changes to land cover, downscaling of global climate models to identify impacts on local precipitation patterns, etc.

**11. <u>Refine estimates of freshwater flow to the bays</u>.**

**Coordinating agency: TWDB**

Recent TWDB estimates of surface inflow to Matagorda Bay show that approximately 30% of inflows (1.07 million acre-feet) are from ungaged watersheds, and approximately 70% of inflows (2.44 million acre-feet) are from gaged watersheds. Of the estimated ungaged inflows, diversions and returns account for approximately 1.2% of inflows (a net of 45,000 acre-feet). Similarly, recent estimates of surface inflow to East Matagorda Bay show that 100% of inflows (536,000 acre-feet) are from ungaged watersheds with approximately 2% of the flows accounted for by diversions and returns (a net of 10,000 acre-feet). Therefore, efforts to improve surface inflow estimates should include (1) calibration and validation of a rainfall-runoff model (*e.g.*, Texas Rainfall-Runoff (TxRR) model or Surface Water Assessment Tool (SWAT model)), (2) improved estimation of precipitation data across the watershed, and (3) improved records of irrigation return flows in the ungaged portions of the basin contributing to Matagorda and East Matagorda Bays.

- ***Validate estimates of gaged and ungaged flow.*** The cost estimate and timeline for this effort is similar to that provided for Project 9A (Garcitas Creek Inflows), where the desk-top analysis would cost approximately the same for both Matagorda Bay and East Matagorda Bay watersheds, but field data collection costs would scale up in accordance with the number of streams being monitored. **Total Cost $40,000** (desk-top analysis alone) **to $280,000** (for data collection (as described below for Garcitas Creek) in up to four contributing streams). Time-frame is 1 – 3 years.

- ***Information on diversions and return flows should also be validated.*** Agricultural irrigation return flows are an important component of this data set but historically have not been adequately recorded. A study effort to obtain improved and validated diversion and return flow data will need to focus on (1) obtaining accurate and complete historical records as well as (2) proposing methods for producing accurate and reported future irrigation return flow records. This effort may include reviewing all existing information and studies, such as those compiled as part of the LCRA-SAWS Water Project. A desk-top analysis of available data and known studies may be completed for as little as **$30,000**. Time-frame is 1 year.

- ***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.*** A special study of this nature could be used to validate TxRR or a SWAT model of the ungaged areas. See project 9A2 describing field data collection in Garcitas Creek. In addition, a desk-top study could be conducted to compare model calibration of ungaged watersheds to model performance in gaged watersheds, where stream flows are known. Total cost varies depending on whether the scope of work requires basic desk-top analysis and model calibration ($40,000) or additional field work to measure stream flows during and between rainfall events (up to $50,000 per site for one year of monitoring). Time-frame is 1 – 3 years.

- ***Develop estimates of groundwater flow to the bays.*** Quite little is known about groundwater inflows to the bays, both in terms of the volume and quality of inflow and in how to identify and assess source contributions. Initial efforts may require a literature survey to compile known

methods of assessment which can be applied to this bay system as well as the development of a study proposal and associated budget. **Cost Estimate $30,000**. Time-frame is 1 year.

- *Special studies will be necessary to identify locations where groundwater inflow is entering the bay, estimate quantities, and characterize factors that influence groundwater inflow.* See above bullet. In addition, TWDB funded a one-year special study in 2002 to assess "Submarine Groundwater Discharge and Associated Nutrient Fluxes to the Corpus Christi Bay System" (Breier *et al*. 2004, http://www.twdb.state.tx.us/RWPG/rpgm_rpts/2002483416.pdf). This study relied on a mathematical mixing model and concentrations of naturally occurring radium isotopes to estimate groundwater discharge to Nueces Bay. The study in 2002 was funded for $38,000. Time frame is 2 to 3 years.

*The objective of this task is to increase confidence in estimates of freshwater inflow to the bays.*

**9A. 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.*

**9A.1. Desk-Top Study of Garcitas Creek Flows** – This study may examine the existing daily USGS Stream Gage record (#08164600, Garcitas Creek near Inez, 1970 – present) alone or may include estimates of modeled flows in the ungaged portion of the watershed (TxRR estimates, 1978 – present) to determine changes in flows over time. To relate to changing agricultural practices or changing land-use patterns, information on agricultural practices and land-use patterns will need to be acquired and evaluated. TWDB recently contracted with Texas AgriLife Research to apply and assess the suitability of using a SWAT model to estimate freshwater inflows to Matagorda Bay. Using this project as a guide for estimating the cost to conduct a desk-top study of Garcitas Creek Flows, such a study could be completed for as little as $40,000.

**9A.1 Cost**: **$40,000**

**9A.1 Time-Frame:** 12 – 18 months from initiation.

**9A.2. Field Study of Garcitas Creek Flows** – TWDB's TxRR rainfall-runoff model has not been recalibrated in recent years. With changing land-use patterns, TWDB may need to recalibrate and verify the performance of TxRR in estimating stream flows in ungaged watersheds. Collecting stream flow (velocity and discharge) data would be beneficial for ensuring the accurate estimation

of flows entering Matagorda Bay via Garcitas Creek. This would require installing one or two acoustic Doppler current velocity meters to monitor flows for a period of time (3 months to one year) and developing rating curves to determine flow discharge.

**9A.2 Cost**: **$70,000** - **$110,000** (Assumes one year of service and purchase cost for instrumentation at two stations.)

*Note:* The U.S. Geological Survey charges about $30,000 to install a gage and another $20,000 - $25,000 to service the gage for one year. Most if not all creeks recommended for monitoring will be tidally influenced, hence requiring a higher level of servicing in order to accurately estimate stream flow. If the work were to be conducted by USGS, the total cost could be as high as $110,000 for two stations and one year of service.

**94A.2 Time-Frame**: 6 – 15 months from initiation. [[Costs could be significantly reduced *IF* this were conducted as part of routine TWDB business and if staffing and equipment were available at the time of study.]]

**14. <u>Improve the existing hydrodynamic model or use other hydrodynamic models to model hydrology, circulation, and salinity patterns for Matagorda, East Matagorda, and Lavaca Bays.</u>**

**Coordinating agency: TWDB**

*(14A) 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.*

**14A. – Desk-Top Study to Improve TxBLEND –** There are certain inflow conditions and geographic areas of Matagorda Bay and East Matagorda Bay that have proven difficult for TxBLEND to predict salinity accurately. Several areas of improvement have been identified, which if implemented, would improve TxBLEND model performance, including: (1) improving the model grid (*e.g.*, update bathymetry, increase grid resolution, move the freshwater boundary upstream, or improve spatial representation of inflow points); (2) improving estimates of hydrology and freshwater inflows entering the bays (including improved information about rainfall-runoff and diversion/return flows from ungaged areas); (3) improving spatial representation of precipitation falling on the bay (through use of NEXRAD data); (4) improving spatial representation of evaporation from the bay; (5) improving model coefficients, and (6) improving the availability of salinity data in upper estuarine portions of the bay (includes gathering only additional *existing* data). In most cases, these identified improvements would benefit implementation of other hydrodynamic and salinity-transport models in this bay system.

**14A. Cost**: **$50,000 - $84,000** [[Costs could be significantly reduced *IF* this were conducted as part of routine TWDB business and if staffing and equipment were available at the time of study.]]

**14A. Time-Frame**: 12 - 20 months from initiation. 6 - 10 months for model reassessment, including incorporation of any improved inflow estimates, modification of model grid, improved evaporation or precipitation techniques, and gathering additional existing inflow and salinity data for a longer period of record. 6-10 months to recalibrate and validate model. Not all above improvements may be possible in the time frame provided or at the cost provided. For example, upgrades to include NEXRAD rainfall data or to improve the rainfall-runoff model may require a separate study effort.

***Note:* This estimate and time-frame does *not* include any *new* field data collection efforts to collect additional salinity data in upper estuarine areas nor does it include the cost of improving the rainfall-runoff models which estimate flows in ungaged watersheds.**

*(14B) Additional field studies may be identified to support this effort. In particular, field studies may be required to get a better understanding of freshwater flows reaching the Intracoastal Waterway adjacent to East Matagorda Bay and of the amount of those flows, as well as flows from Caney Creek, that reach East Matagorda Bay.*

**14B. Field Study of Water Exchange to East Matagorda Bay** – Understanding water exchange to and from East Matagorda Bay requires understanding flow exchange as a result of tidal action with the Gulf of Mexico and as a result of freshwater inflows from inland creeks through the Intracoastal Waterway during both normal and wet periods. This can be accomplished by

installing fixed monitoring stations to record current direction and velocity at key interchange locations for a pre-determined period of time (few months to one year) and by conducting a 48 – 72 hour intensive survey of currents at the same key locations under both normal and wet conditions.

***Note:** This estimate and time-frame focuses only on understanding water exchange for East Matagorda Bay and does not include cost estimates for purchasing equipment. In 2000, TWDB conducted an intensive inflow study of the bay which would provide some baseline information on water exchange within the system; however, a second intensive survey still would be needed to understand water exchange during high inflow periods.**

**14B. Cost**: **$100,000** (Assumes *no cost for instrumentation*) - **$250,000** (Assumes purchase cost for all necessary instrumentation) [[All costs could be significantly reduced *IF* this were conducted as part of routine TWDB business, in cooperation with other state agencies, and if staffing and equipment were available at the time of study.]]

**14B. Time-Frame**: 12-18 months from initiation. 3-12 months for monitoring water velocity and currents at fixed locations. 3-12 months to conduct two intensive inflow studies. (This time-frame is dependent on receiving a suitable wet or high-inflow condition). 6 months to complete data analysis and report summary.

*(14C) Additional field studies may be identified to support this effort. … There also would be particular emphasis on the relationship between salinity in the marsh and adjacent open water in Matagorda and Lavaca bays.*

**14C. Field Study of Marsh-Open Water Salinity Study** – TWDB and TPWD are conducting separate but similar studies along the Texas coast to measure wetland salinity in relation to open bay salinity. TWDB has an ongoing study in the San Bernard Wildlife Refuge and Cedar Lakes Estuary; TPWD has an ongoing study near Rollover Pass in East Bay (Trinity-San Jacinto Estuary). Such a study requires numerous monitoring stations (10 – 15) for each wetland-bay complex being studied. Instrument costs alone require a capital input of $50,000 - $100,000. These studies then would require 1 – 2 years of monitoring at six-week service intervals, plus data processing and reporting. The cost for studying *one wetland-bay complex for one year* could be as high as **$250,000**, once instrumentation is factored in.

***Note:** This estimate and time-frame does not include any hydrodynamic and salinity transport modeling analysis.**

**14C. Cost**: $150,000 - $250,000 [[Costs could be significantly reduced *IF* this were conducted as part of routine TWDB business, in cooperation with other state agencies, and if staffing and equipment were available at the time of study.]]

**14C. Time-Frame**: 18-30 months from initiation. Three months to prepare equipment and conduct reconnaissance and installations; 12 – 24 months for monitoring wetland-bay salinity conditions and 3 – 6 months data analysis and report writing.

**16. <u>Quantify the effects of sediment transport on delta formation in Lavaca and Matagorda Bays.</u>**

**Coordinating organization: TWDB**

*A key role of freshwater inflows is to replenish sediments reaching bay systems. That effect is most immediately reflected in the deltas formed adjacent to major inflow sources. Delta formation would be tracked over time, including through analysis, if possible, of historical responses between delta formation and freshwater inflows, reflecting changes in inflow patterns and the creation of upstream sediment traps. Future changes in delta formation would be measured and analyzed and, to the extent possible, tools for predicting changes in delta formation in response to future inflow changes and reductions in sediment load would be developed.*

***16A. Collection and Review of Available Data and Literature*** – Cost $70,000; Time-Frame 1 year

***16B. Collection of Field Data*** – Cost $40,000 per year (Total $120,000); Time-Frame 2 – 3 years

***16C. Development of Simple Quantitative Model of Delta Sediment Patterns*** – Cost $100,000; Time-Frame 1 year

**16. Cost**: $300,000

**16. Time-Frame**: 36 - 42 months from initiation. Three months to prepare equipment and conduct reconnaissance and installations; 12 – 24 months for monitoring wetland-bay salinity conditions and 3 – 6 months data analysis and report writing.

2. TPWD Input on Cost Estimates for Priority Tasks with TPWD as Lead Entity

Task 1, sub 2:

We looked at several independent tasks to accomplish the goals including a literature review and creation/adaptation of HSIs. Some of the work identified in this task might be performed as part of Task 2. Since HEFR was developed as a method to develop environmental flow recommendations within the time and data constraints of SB3, there may not be a need to evaluate and update HEFR. Additional biological, ecological, geomorphological, and other information can be used to somewhat validate HEFR results. The estimated budget need is $50,000 to $120,000.

Task 2, sub 3:

Estimates are based on fielding a team to collect data and use PHABSM modeling to describe physical habitat and flow relationships at 5 sites. The estimated cost is $100,000 to $150,000.

Task 10:

There are concerns about TPWD's ability to perform this task due to FOIA requirements. The tentative cost estimate provided for this task assumes that no significant legal impediments are identified. If significant legal impediments are identified, there may be a way to modify TPWD sampling protocol to make it more useful for the work plan objectives.

Task 12, sub 1:

Depending on the level of evaluation of new techniques needed, the resource needs to accomplish Task 12, sub 1 could vary significantly. The estimated cost ranges from $50,000 to $150,000.

Task 12, sub 6:

Again, a broad range of potential cost ($50,000 to $150,000) is identified, depending on the amount of field work required and need to generate new habitat suitability information. Oysters are not included in this task, but are identified in a separate lower priority task. Oysters are a commercially and ecologically important species that merit consideration/inclusion on a priority basis.

Task 12, sub 6:

Developing a budget estimate for this task was difficult. There are a considerable number of variables that need to be considered in developing a plan to accomplish

this task. The timeline needs to be defined and suitable metrics identified. It will also be important to determine if additional monitoring is required, or if ongoing efforts by TPWD and LCRA will provide sufficient levels of robust and sensitive data to track ecological changes due to compliance/occurrence of MBHE inflows. A gross estimate of costs associated with this task ranges from $50,000 to $300,000.

3. Other Cost Input

Task 5:

Cost estimate of $40,000, provided by Dave Buzan. This task would be conducted about three-fourths of the way through the 10 year period. It would incorporate the most recent knowledge/understanding of HEFR (if HEFR is still being used) and important parts of the flow regime. It may look at different combinations of seasons, different pulse regimes (ex. a 2 per year pulse), use of median pulse volumes instead of mean pulse volumes, etc. It also might include consideration of alternative indicators of hydrological condition. The tasks would be expected to take about 6 months and be completed in time to apply the lessons learned in this effort to any calculation of revised flow regimes to protect sound environments.

Task 15:

Cost estimate of $100,000, provided by Dave Buzan. This cost depends on the number of strategies being considered and the complexity of individual strategies but is intended to allow $15,000 to $20,000 per strategy. This would pay for possible modeling, preliminary engineering design, biological sampling, literature review, data analysis, and preparation of recommendations about each strategy. Each set of recommendations would address the ability of the strategy to contribute to sound environmental health and would include advice as to how to implement the strategy to maximize ecological benefits. This would be primarily an ecological analysis and not a detailed design/engineering analysis. This task would be implemented for each strategy th the BBASC wishes to pursue. Four months should be allowed for this review for each strategy.