# ENVIRONMENTAL FLOWS REGIME AND ANALYSIS RECOMMENDATION REPORT

## TABLE OF CONTENTS


1 Introduction ..... 1
1.1 Cypress Flow Project and SB 3 ..... 1
1.2 Sound Ecological Environment ..... 6
1.3 Geographic Scope ..... 6
2 Development of Scientifically Based Environmental Flow Regime and Analysis ..... 9
2.1 Development of Building Blocks (Environmental Flow Regimes) ..... 9
2.1.1 Literature Review and Summary Report (Reasonably Available Science) ..... 9
2.1.2 Flows Workshops and Building Blocks (Preliminary Flow Regime Matrices) ..... 27
2.2 Environmental Flow Analysis (Overlays) ..... 33
2.2.1 Biology ..... 34
2.2.2 Geomorphology ..... 49
2.2.3 Water Quality ..... 50
2.2.4 Connectivity ..... 52
2.3 Environmental Flow Regime Recommendation ..... 56
3 Conclusions ..... 59
References ..... 60
List of Available Appendices ..... 63


## TABLES


Table 1 Cypress Basin watershed areas. ..... 9
Table 2 Geomorphic surfaces in the Big Cypress drainage basin (USACOE, 1994) ..... 16
Table 3 Stream power of a 2-year recurrence interval flow before and after dam construction. ..... 18
Table 4 Critical shear stresses required to entrain sediments ranging from medium sand to clay. ..... 19
Table 5 Average depths required to have sufficient shear stresses to entrain sediments ranging from medium sand to clay. ..... 20
Table 6 Required discharges to entrain sediments ranging from medium sand to clay. ..... 21
Table 7 Impairments in the Cypress Basin. ..... 23
Table 8 Indicator species with flow dependencies. ..... 35
Table 9 Habitat guilds for Cypress and Twelve-mile Creek fishes, based on preferred velocities (horizontal axis and spawning substrate (vertical axis). Evaluation species are indicated in red bold. (USACE 1994). ..... 36
Table 10 Trends in reproductive guilds in terms of relative abundances. (Pelagophils: Obligate riverine species, broadcast-pawn buoyant eggs within current, Lithophils: Includes most Centrarchidae, spawn elliptical egg envelopes over rock or gravel nests.) ..... 38
Table 11 Segment, reach, and transect-scale geomorphic and stream habitat measures ..... 41
Table 12 Summary of biotic responses to altered flow regimes in relation to flow-induced changes in habitat (principle 1). (Bunn and Arthington 2002). ..... 43
Table 13 Summary of life history responses to altered flow regimes (principle 2). (Bunn and Arthington 2002). ..... 43
Table 14 Summary of biotic responses to loss of longitudinal or lateral connectivity (principle 3). (Bunn and Arthington 2002). ..... 44

# ENVIRONMENTAL FLOWS RECOMMENDATION REPORT

*Final Submission to the Sabine and Neches Rivers and Sabine Lake Bay Basin and Bay Area Stakeholder Committee, Environmental Flows Advisory Group, and Texas Commission on Environmental Quality*

## TABLE OF CONTENTS


**EXECUTIVE SUMMARY** ..... **VII**

**1 PREAMBLE** ..... **1**

1.1 SENATE BILL 3 ..... 1

1.2 SABINE-NECHES BBEST ..... 3

*1.2.1 Primary Charge* ..... *6*

*1.2.2 Accomplishment of Primary Charge and Decision Tree* ..... *6*

*1.2.3 Recommendation Report Evolution* ..... *6*

*1.2.4 Sound Ecological Environment* ..... *9*

*1.2.5 Goal* ..... *9*

*1.2.6 Objectives* ..... *9*

*1.2.7 Instream Flow Regime Components* ..... *10*

**2 SUMMARY OF RECOMMENDATIONS, RECOGNITIONS, AND RATIONALE** ..... **13**

2.1 RECOMMENDATIONS ..... 13

*2.1.1 Recommendation 1: Definition of a Sound Ecological Environment* ..... *13*

*2.1.2 Recommendation 2: The Current Conditions of the Sabine and Neches Rivers and the Sabine-Neches Estuary are Sound* ..... *14*

*2.1.3 Recommendation 3: Acknowledge That Flows in the Sabine and Neches Rivers and Inflows to The Sabine-Neches Estuary will Change Over Time* ..... *14*

*2.1.4 Recommendation 4: Future Study, Data Gathering, and Adaptive Management are Necessary to Determine Whether or Not Changes in Environmental Flows will Maintain a Sound Ecological Environment* ..... *15*

*2.1.5 Recommendation 5: Applicable hydrologic conditions for the entire season are defined on the basis of an assessment of hydrologic conditions of storage in selected reservoirs at the beginning of the first day of the season thereby recognizing both drought persistence and practical operations* ..... *15*

*2.1.6 Recommendation 6: Subsistence Flows* ..... *15*

*2.1.7 Recommendation 7: Base Flows* ..... *16*

*2.1.8 Recommendation 8: High Flow Pulses* ..... *17*

*2.1.9 Recommendation 9: Fluvial Matrices Inflow Recommendations are Adequate to Maintain a Sound Ecological Environment in the Sabine-Neches Estuary* ..... *18*

2.2 RECOGNITIONS ..... 19

*2.2.1 Recognition 1: Overbank Flows Have Recognized Ecological Benefits but are not Recommended* ..... *19*
*2.2.2 Recognition 2: Toledo Bend Reservoir FERC Relicensing* ..... *20*
*2.2.3 Recognition 3: Sabine River Compact* ..... *20*
*2.2.4 Recognition 4: Cutoff Bayou* ..... *20*

**3 BASINS AND BAY DESCRIPTIONS AND CURRENT CONDITIONS ..... 22**

3.1 SABINE RIVER BASIN ..... 23
3.2 NECHES RIVER BASIN ..... 23
3.3 SABINE-NECHES ESTUARY (SABINE LAKE) ..... 26
*3.3.1 Estuary Description* ..... *27*
*3.3.2 Estuary History* ..... *30*
3.4 REGIONAL WATER PLANNING ..... 32
*3.4.1 2007 State Water Plan* ..... *32*
*3.4.2 Unique Stream Segments* ..... *33*
*3.4.3 Unique Reservoir Sites* ..... *35*
3.5 SABINE-NECHES STUDY AREA UNIQUE ISSUES ..... 36
*3.5.1 Texas Louisiana* ..... *36*
*3.5.2 Texas State Water Quality Flows (7Q2)* ..... *36*
*3.5.3 Senate Bill 2: Lower Sabine River Priority Instream Flow Study* ..... *36*
*3.5.4 Toledo Bend Project Joint Operations* ..... *37*
*3.5.5 Sabine River Compact* ..... *37*
*3.5.6 Lower Neches River Saltwater Barrier* ..... *38*
*3.5.7 Cutoff Bayou: Lower Sabine River* ..... *38*
*3.5.8 USACE Sabine-Neches Waterway Feasibility Study* ..... *39*

**4 SCIENCE ADVISORY COMMITTEE ..... 40**

4.1 BACKGROUND ..... 41
4.2 GUIDANCE ..... 41
*4.2.1 Geographic Scope* ..... *41*
*4.2.2 Use of Hydrologic Data* ..... *41*
*4.2.3 Fluvial Sediment Transport (Geomorphology)* ..... *42*
*4.2.4 Freshwater Inflow Regime* ..... *42*
*4.2.5 Water Quality* ..... *42*
*4.2.6 Biology* ..... *42*

**5 DISCIPLINE REPORTS ..... 43**

5.1 HYDROLOGY ..... 43
*5.1.1 Gage Selection and Geographic Coverage* ..... *43*
*5.1.2 HEFR Analysis for Sabine-Neches BBEST* ..... *44*
*5.1.3 WAM Analysis for Sabine-Neches BBEST* ..... *44*
*5.1.4 Instream Flow Regime Components* ..... *45*
*5.1.5 Hydrologic Data* ..... *46*
*5.1.6 Advantages and Disadvantages Common to All Hydrologic Methods* ..... *46*
*5.1.7 Available Methods* ..... *47*

*5.1.8 HEFR Basics* ..... *48*
*5.1.9 Approach* ..... *49*
*5.1.10 Sabine-Neches BBEST Hydrology* ..... *49*
*5.1.11 Use of 7Q2 and Other Alternate Low Flow Statistics* ..... *55*
*5.1.12 Sabine-Neches Estuary Flow Matrix* ..... *58*
5.2 BIOLOGY (ECOLOGICAL REVIEW) ..... 62
*5.2.1 Fluvial Ecosystem Realm* ..... *62*
*5.2.2 SAC Recommended Procedure for Biological Overlays* ..... *62*
*5.2.3 Estuarine Ecosystem Realm* ..... *72*
*5.2.4 Adaptive Management* ..... *81*
*5.2.5 BIO-WEST Ecological Review* ..... *82*
*5.2.6 National Wildlife Federation* ..... *85*
5.3 GEOMORPHOLOGY (SEDIMENT TRANSPORT) ..... 86
*5.3.1 Recent Senate Bill 2 Studies* ..... *86*
*5.3.2 Science Advisory Committee Recommendations* ..... *89*
*5.3.3 SAM Application* ..... *90*
*5.3.4 Conclusions* ..... *92*
5.4 APPLICATION OF WATER QUALITY IN ENVIRONMENTAL FLOWS ..... 93
*5.4.1 Regulatory Perspectives in Water Quality* ..... *93*
*5.4.2 Available Water Quality Data* ..... *94*
*5.4.3 Flow and Water Quality Relationships* ..... *95*
*5.4.4 Selection of Water Quality Parameters for Environmental Flow Recommendations* ..... *98*
*5.4.5 Integrating Water Quality into Environmental Flow Recommendations* ..... *98*

**6 DEVELOPMENT OF ENVIRONMENTAL FLOWS RECOMMENDATIONS/ RECOGNITIONS/ UNRESOLVED ISSUES ..... 100**

6.1 INSTREAM FLOW REGIME APPLICATION ..... 102
*6.1.1 Introduction* ..... *102*
*6.1.2 Elements of a Recommended Flow Regime* ..... *102*
*6.1.3 Definition of Hydrologic Condition (Wet/Average/Dry)* ..... *105*
*6.1.4 Example Application of a Flow Regime* ..... *105*
*6.1.5 Attainment Frequencies in Flow Regime Application* ..... *109*
*6.1.6 Geographic Interpolation* ..... *116*
6.2 HEFR OUTPUT MATRICES FOR SELECTED STREAM FLOW GAGING STATIONS IN THE SABINE AND NECHES RIVER BASINS ..... 117
*6.2.1 Sabine Basin* ..... *117*
*6.2.2 Neches Basin* ..... *129*
*6.2.3 Sabine-Neches Estuary (Sabine Lake)* ..... *141*

**7 GLOSSARY OF TERMS AND ACRONYMS ..... 148**

**8 ANNOTATED BIBLIOGRAPHY ..... 154**

**9 APPENDICES ..... 170**

9.1 SAC GUIDANCE ..... 171

*9.1.1 Appendix I: Essential Steps for Biological Overlays in Developing Senate Bill 3 Instream Flow Recommendations* ..... *171*
*9.1.2 Appendix II: Fluvial Sediment Transport as an Overlay to Instream Flow Recommendations for the Environmental Flows Allocation Process* ..... *171*
*9.1.3 Appendix III: Geographic Scope of Instream Flow Recommendations* ..... *171*
*9.1.4 Appendix IV: Methodologies for Establishing a Freshwater Inflow Regime for Texas Estuaries Within the Context of the Senate Bill 3 Environmental Flows Process* *171*
*9.1.5 Appendix V: Nutrient and Water Quality Overlay on Hydrology-Based Instream Flow Recommendations* ..... *171*
*9.1.6 Appendix VI: Use of Hydrologic Data in the Development of Instream Flow Recommendations for the Environmental Flows Allocation Process and the Hydrology-Based Environmental Flow Regime (HEFR) Methodology* ..... *171*
9.2 CONTRACT WORK ..... 171
*9.2.1 Biology (Ecological Review): BIO-WEST, Inc.* ..... *171*
*9.2.2 Hydrologic Analyses: Freese and Nichols, Inc.* ..... *171*
9.3 DISCIPLINE REPORTS ..... 172
*9.3.1 Appendix XII: Sabine-Neches BBEST Water Quality Overlay Appendices* ..... *172*
*9.3.2 Appendix XIII: Sabine-Neches BBEST Biological Overlay Discipline Report* ... *172*
*9.3.3 Appendix XIV: Sabine-Neches BBEST Geomorphology Overlay Discipline Report* ..... *172*
9.4 CONTRIBUTIONS ..... 172
*9.4.1 Texas Instream Flow Program* ..... *172*
*9.4.2 National Wildlife Federation* ..... *172*
*9.4.3 National Wildlife Federation & Greater Edwards Aquifer Alliance* ..... *172*
9.5 SABINE-NECHES BBEST REVIEW ..... 172
*9.5.1 Sabine-Neches BBEST Comments on Draft Report* ..... *172*

# TABLES

TABLE 1. SABINE-NECHES BBEST MEMBERSHIP ..... 4
TABLE 2. INSTREAM FLOW REGIME COMPONENTS DEFINITIONS ..... 11
TABLE 3. PRELIMINARY SELECTION OF STREAM FLOW GAGES FOR EVALUATION ..... 51
TABLE 4. SELECTED STREAMFLOW GAGES FOR EVALUATION ..... 52
TABLE 5. PUBLISHED 7Q2 VALUES ..... 56
TABLE 6. COMPARISON OF PUBLISHED 7Q2 TO DFLOW 7Q2 AND 7Q10 FOR HYDROPOWER INFLUENCED GAGES ..... 57
TABLE 7. COMPARISON OF HEFR ANNUAL VOLUMES TO STATE METHODOLOGY FOR THE SABINE-NECHES ESTUARY ..... 60
TABLE 8. SABINE/NECHES FISH SPECIES WITH SPAWNING SYNCHRONIZED TO FLOW PULSES DURING LATE WINTER-SPRING (FEBRUARY-JUNE) WITHIN-CHANNEL, WATER-COLUMN SPAWNERS (N= 26) ..... 69
TABLE 9. FOCAL RIVERINE/FLOODPLAIN SPECIES IDENTIFIED TO SUPPORT INSTREAM FLOW RECOMMENDATIONS OF THE SABINE-NECHES BBEST ..... 84

# Environmental Flows Recommendation Report

*Final Submission to the Trinity and San Jacinto Rivers and Galveston Bay Basin and Bay Area Stakeholder Committee, Environmental Flows Advisory Group, and Texas Commission on Environmental Quality*

## TABLE OF CONTENTS


1. Preamble ..... 1
   1.1. Senate Bill 3 ..... 1
   1.2. Trinity-San Jacinto BBEST ..... 2
      1.2.1. Legislative Mandate ..... 3
   1.3. Sound Ecological Environment ..... 4
   1.4. Overview of Trinity, San Jacinto, and Galveston Bay Watersheds ..... 5
      1.4.1. Galveston Bay ..... 5
      1.4.2. San Jacinto River Watershed ..... 7
      1.4.3. Coastal Bayous and Watersheds ..... 10
      1.4.4. Trinity River Watershed ..... 10
   1.5. Recommendation Report Evolution ..... 12
      1.5.1. Alternative Instream Flow Approaches ..... 12
         1.5.1.1. Science Based Conditional Phased Approach ..... 12
         1.5.1.2. Science Based Environmental Flow Regime for the Trinity River, San Jacinto River, and Galveston Bay ..... 15
      1.5.2. Freshwater Inflow Process ..... 17
2. Instream Flows ..... 18
   2.1. Science Based Conditional Phased Approach ..... 18
      2.1.1. Introduction ..... 19
      2.1.2. Best Available Science for Support of Recommendations ..... 22
      2.1.3. Approach ..... 25
      2.1.4. Recommended Flows ..... 26
         2.1.4.1. Trinity River Basin ..... 26
         2.1.4.2. San Jacinto River Basin ..... 30
      2.1.5. Conditional Flows (Not Recommended until Further Science is Developed) ..... 32
         2.1.5.1. Adaptive Management ..... 32
         2.1.5.2. Candidate Flows ..... 35
   2.2. Science Based Environmental Flow Regime for the Trinity River, San Jacinto River, and Galveston Bay ..... 39
      2.2.1. Executive Summary ..... 40
      2.2.2. Legislative Mandate ..... 46
      2.2.3. Best Available Science ..... 48
      2.2.4. Biological/Ecological Justification for Instream Environmental Flow Regimes ..... 53

2.2.5. The Trinity and San Jacinto River Ecosystems – Current Conditions and Responses of Species to Flow Components ..... 55
2.2.5.1. Focal Species and Species Guilds ..... 60
2.2.5.2. Subsistence Flows ..... 68
2.2.5.3. Base Flows ..... 70
2.2.5.4. High Flow Pulses ..... 73
2.2.5.5. Overbanking Flows ..... 75
2.2.6. Use of Hydrologic Data in the Development of Instream Flow Recommendations ..... 77
2.2.7. SAC identified decision points encountered when using hydrologic data to help define environmental flow recommendations ..... 83
2.2.7.1. Number of Instream Flow Regime Components ..... 83
2.2.7.2. Geographic Scope of Instream Flow Recommendations and Spatial Extent of Individual Instream Flow Recommendations ..... 84
2.2.7.3. Hydrologic Period of Record ..... 86
2.2.7.4. Hydrologic/Climatic Condition ..... 88
2.2.7.5. Assignment Period ..... 88
2.2.7.6. Memory ..... 89
2.2.7.7. 7. Delineation of High Flow Pulse and Overbank Flow Components ..... 89
2.2.7.8. Subsistence Flows Less Than 7Q2 ..... 90
2.2.7.9. Number and Location of Control Points ..... 91
2.2.7.10. Flow Recommendations For Waters not Specifically Included in These Environmental Flow Recommendations ..... 92
2.2.7.11. Daily Average versus Instantaneous Flow Data ..... 93
2.2.7.12. Overbank Recommendations ..... 93
2.2.8. Decision points required in HEFR ..... 95
2.2.8.1. Hydrographic Separation ..... 95
2.2.8.2. Seasonality ..... 98
2.2.8.3. Percentiles ..... 98
2.2.8.4. Episodic Events Calculations ..... 99
2.2.8.5. Subsistence Percentile ..... 99
2.2.8.6. Multipeaks_Multiplier ..... 100
2.2.9. Flow recommendations ..... 100
2.2.9.1. Subsistence and Base Flow Attainment Frequencies ..... 100
2.2.9.2. Flow Regime Recommendations ..... 109
2.2.10. Application ..... 121
2.2.11. Knowledge Gaps, Research priorities and Adaptive Management ..... 121
3. Freshwater Inflow Recommendations for Galveston Bay ..... 128
3.1. Trinity River Flow Recommendations ..... 141
3.2. San Jacinto River Flow Recommendations ..... 146
3.3. Coastal Streams Flow Recommendations ..... 150