Environmental Flows
Recommendations Report

Guadalupe, San Antonio, Mission, & Aransas Rivers and Mission, Copano, Aransas, & San Antonio Bays Basin and Bay Expert Science Team (GSA BBEST)

Sam Vaugh, PE
Norman Johns, PhD
Thom Hardy, PhD
Warren Pulich, PhD

March 2, 2011
Topics of Discussion

1) SB3 Environmental Flows Process
2) GSA BBEST Charge & Membership
3) Environmental Flow Regime Recommendations
4) Environmental Flow Analyses:
   a) Hydrology
   b) Instream
   c) Estuary
5) Application of Recommendations
SB3 Environmental Flows Process

- EFAG
- BBASC
- SAC
- BBEST

Other Needs

Recommended
Environmental Flow
Regimes

Recommendations on
Environmental Flow
Standards & Strategies

Science

Balance

Environmental Flow Standards

Texas Commission on Environmental Quality
**Basin & Bay Expert Science Team (BBEST)**

1) Comprised of technical experts with knowledge of the river basin and bay system and/or development of environmental flow regimes.

2) Charged to develop environmental flow analyses and recommended environmental flow regimes based on best available science through a consensus process.

3) Provide environmental flow regime recommendations by March 1, 2011.

4) Provide technical support to the GSA BBASC in its development of recommendations on environmental flow standards & strategies (next 6 months) and a work plan (thereafter).
### Basin & Bay Expert Science Team (BBEST)

<table>
<thead>
<tr>
<th>Member</th>
<th>Hydrology</th>
<th>Instream</th>
<th>Estuary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sam Vaugh, Chair</td>
<td>⭐️</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Norman Johns, Vice Chair</td>
<td>✓</td>
<td></td>
<td>⭐️</td>
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<tr>
<td>Thom Hardy</td>
<td>✓</td>
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<td>Warren Pulich</td>
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<tr>
<td>Tim Bonner</td>
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<td>Ed Buskey</td>
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<tr>
<td>Mike Gonzales</td>
<td></td>
<td>✓</td>
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<td>Scott Holt</td>
<td>✓</td>
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<td>Liz Smith</td>
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<tr>
<td>Gregg Eckhardt</td>
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<tr>
<td>Debbie Magin</td>
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SB3 Environmental Flows Process

- EFAG
- BBASC
- SAC
- BBEST

- Other Needs
- Science

- Recommendations on Environmental Flow Standards & Strategies
- Recommended Environmental Flow Regimes

Environmental Flow Standards

Balance

Texas Commission on Environmental Quality
GSA BBEST Recommendations Report

1) Preamble – Sound Ecological Environment
2) Overview of Watersheds & Bays
3) Instream Flow Analyses
4) Freshwater Inflow Analyses
5) Integration of Instream Flow & Estuary Inflow Regimes
6) Environmental Flow Regime Recommendations
7) Adaptive Management
8) References
Science Advisory Committee (SAC)

Technical Guidance:

a) Geographic Scope
b) Use of Hydrologic Data
c) Fluvial Sediment Transport (Geomorphology)
d) Freshwater Inflow Regime for Estuaries
e) Biological Overlays
f) Nutrient & Water Quality Overlay
g) Flow Regimes to Environmental Flow Standards
h) Lessons Learned
i) Work Plans for Adaptive Management
j) Flow Regimes & Water Supply Projects
k) Attainment Frequencies & Hydrologic Conditions
Environmental Flow Regime Recommendations

1) Instream Flows
   a) Hydrology-based Environmental Flow Regime (HEFR) Methodology
   b) Biology, Water Quality, Geomorphology, and Riparian Biological Overlays

2) Freshwater Inflows to Bays & Estuaries
   a) Salinity Zone Methodology Applied to Focal Species
   b) Nutrient, Sediment, and Other Focal Species Overlays
Flow Regime Components

1. High Pulse
2. Subsistence
3. Overbank
4. Base
Instream Flow Regime Recommendation

San Antonio River @ Goliad

<table>
<thead>
<tr>
<th>Overbank Flows</th>
<th>High Flow Pulses</th>
<th>Base Flows (cfs)</th>
<th>Subsistence Flows (cfs)</th>
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<tbody>
<tr>
<td>Qp: 1,520 cfs with Average Frequency 1 per season Regressed Volume is 12,830 Duration Bound is 19</td>
<td>Qp: 550 cfs with Average Frequency 2 per season Regressed Volume is 3,940 Duration Bound is 11</td>
<td>290</td>
<td>76 (100.0%)</td>
</tr>
<tr>
<td>Qp: 3,540 cfs with Average Frequency 1 per season Regressed Volume is 30,000 Duration Bound is 24</td>
<td>Qp: 1,570 cfs with Average Frequency 2 per season Regressed Volume is 11,300 Duration Bound is 16</td>
<td>280</td>
<td>60 (96.9%)</td>
</tr>
<tr>
<td>Qp: 1,640 cfs with Average Frequency 1 per season Regressed Volume is 11,200 Duration Bound is 16</td>
<td>Qp: 748 cfs with Average Frequency 2 per season Regressed Volume is 4,450 Duration Bound is 10</td>
<td>220</td>
<td>54 (94.5%)</td>
</tr>
<tr>
<td>Qp: 2,320 cfs with Average Frequency 1 per season Regressed Volume is 17,600 Duration Bound is 19</td>
<td>Qp: 775 cfs with Average Frequency 2 per season Regressed Volume is 5,070 Duration Bound is 11</td>
<td>270</td>
<td>66 (98.8%)</td>
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### Flow Levels

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<tr>
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<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
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<tr>
<td>High (75th %tile)</td>
<td>290</td>
<td>280</td>
<td>220</td>
<td>270</td>
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<tr>
<td>Medium (50th %tile)</td>
<td>200</td>
<td>180</td>
<td>150</td>
<td>200</td>
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<tr>
<td>Low (25th %tile)</td>
<td>140</td>
<td>130</td>
<td>120</td>
<td>130</td>
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</tbody>
</table>

Notes:
1. Period of Record used: 1/1/1940 to 12/31/1969.
2. Volumes are in acre-feet and durations are in days.
**Freshwater Inflow Regime Recommendation**

### Criteria Volumes

<table>
<thead>
<tr>
<th>Guadalupe Estuary Criteria - Volumes</th>
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<tbody>
<tr>
<td>Criteria level</td>
<td>Inflow Criteria Volumes, suite G1 for Rangia clams</td>
<td>Inflow Criteria Volumes, suite G2 for Eastern oysters</td>
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</tr>
<tr>
<td></td>
<td>Feb. (1000 ac-ft/mon)</td>
<td>Mar.-May (1000 ac-ft/3mon)</td>
<td>June (1000 ac-ft/mon)</td>
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<tr>
<td>G1-Aprime, G2-Aprime</td>
<td>n/a</td>
<td>550-925</td>
<td>n/a</td>
</tr>
<tr>
<td>G1-A, G2-A</td>
<td>n/a</td>
<td>375-550</td>
<td>n/a</td>
</tr>
<tr>
<td>G1-B, G2-B</td>
<td>n/a</td>
<td>275-375</td>
<td>n/a</td>
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<tr>
<td>G1-C, G2-C</td>
<td>≥75</td>
<td>150-275</td>
<td>≥40</td>
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<tr>
<td>G1-CC, G2-CC</td>
<td>0-75</td>
<td>150-275</td>
<td>0-40</td>
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<tr>
<td>G1-D, G2-D</td>
<td>n/a</td>
<td>0-150</td>
<td>n/a</td>
</tr>
<tr>
<td>G1-DD, G2-DD</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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### Attainment Recommendations

<table>
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<th>Guadalupe Estuary Criteria - Attainment Recommendations</th>
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</thead>
<tbody>
<tr>
<td>Criteria level</td>
<td>Specification</td>
<td>Inflow Criteria Attainment, G1 suite for Rangia clams</td>
<td>Inflow Criteria Attainment, G2 suite for Eastern oysters</td>
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<tr>
<td>G1-Aprime, G2-Aprime</td>
<td>Attainment, G - Aprime</td>
<td>G1-Aprime at least 12% of years</td>
<td>G2-Aprime at least 12% of years</td>
</tr>
<tr>
<td>G1-A, G2-A</td>
<td>Attainment, G - A</td>
<td>G1-A at least 12% of years</td>
<td>G2-A at least 17% of years</td>
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<tr>
<td>G1-A&amp;G1-B, G2-A&amp;G2-B</td>
<td>Attainment, G - A &amp; G - B combined</td>
<td>G1-A and G1-B combined at least 17% of years</td>
<td>G2-A and G2-B combined at least 30% of years</td>
</tr>
<tr>
<td>G1-C&amp;G1-CC, G2-C&amp;G2-CC</td>
<td>Attainment, G - C &amp; G - CC combined</td>
<td>G1-C and G1-CC equal to or greater than 19% of years. G1-CC no more than 2/3 of total</td>
<td>G2-C and G2-CC equal to or greater than 10% of years. G2-CC no more than 1/6 of total</td>
</tr>
<tr>
<td>G1-D</td>
<td>Attainment, G1 - D</td>
<td>no more than 9% of years</td>
<td>n/a</td>
</tr>
<tr>
<td>G2-DD</td>
<td>Attainment, G2 - DD</td>
<td>n/a</td>
<td>G2-D no more than 6% of years</td>
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<tr>
<td>G2-D&amp;G2-DD</td>
<td>Attainment, G2-D &amp; G2-DD combined</td>
<td>n/a</td>
<td>G2-D and G2-DD combined no more than 9% of years</td>
</tr>
</tbody>
</table>

### Mission-Aransas Estuary Criteria - Attainment Recommendations

<table>
<thead>
<tr>
<th>Mission-Aransas Estuary Criteria - Attainment Recommendations</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria level</td>
<td>Specification</td>
<td>Inflow Criteria Attainment, set MA1 for Rangia clams</td>
<td>Inflow Criteria Attainment, set MA2 for Eastern oysters</td>
</tr>
<tr>
<td>MA-Aprime</td>
<td>Attainment MA-Aprime</td>
<td>n/a</td>
<td>MA2-Aprime at least 2% of years</td>
</tr>
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</table>
1) Geographic Scope (Section 3.1)
2) Hydrology-Based Environmental Flow Regime (HEFR) Analyses (Section 3.2)
3) Freshwater Inflows to Estuaries (Section 4.2)
Blanco River @ Wimberley, TX
Plum Creek near Luling, TX
San Marcos River @ Luling, TX
Sandies Creek near Westhoff, TX
Guadalupe River @ Gonzales, TX
Guadalupe River @ Cuero, TX
Guadalupe River @ Victoria, TX
San Antonio River @ Goliad, TX
Mission River @ Refugio, TX
San Antonio River @ Elmendorf, TX
San Antonio River near Spring Branch, TX
Medina River @ Bandera, TX
Guadalupe River near Comfort, TX
Medina River @ San Antonio, TX
San Antonio River near Falls City, TX
Cibolo Creek near Falls City, TX
Guadalupe River @ Gonzales, TX
Hydrology-based Environmental Flow Regime (HEFR) Methodology

HEFR is used to provide an initial characterization of environmental systems with readily available data in the absence of definitive data relating flow alteration to ecological response.

Advantages:
1) Hydrology is a key variable for instream, and a good indicator for estuarine, environmental flows.
2) Consistent with TIFP and SAC guidance.
3) Lengthy records at multiple streamflow gage locations.
Instream Flow Analyses

1) Biology Overlay (Section 3.3)
2) Water Quality Overlay (Section 3.4)
3) Geomorphology Overlay (Section 3.5)
4) Riparian Biological Overlay (Section 3.6)
Biology Overlay

- Adhered to the Texas Instream Flow Program
  - Natural Flow Paradigm

Diagram:
- Flow Regime
  - Magnitude
  - Frequency
  - Duration
  - Timing
  - Rate of Change

- Water Quality
- Energy Sources
- Physical Habitat
- Biotic Interactions

Ecological Integrity
3.3.1.2 Quantification of Flow Regime Components
   - Based on the linkage between hydrology and physical habitat

3.3.2 Development of Habitat Guilds and Selection of Focal Species
   - Riffle
   - Deep Run
   - Shallow Run
   - Deep Pool
   - Shallow Pool
Published literature on fish distribution and status within the basins were reviewed as a starting point for selection of draft focal species and associated draft habitat guilds (Leavy and Bonner 2009).

The team also considered other target aquatic organisms such as mussels, macroinvertebrates
- concluded that protection of the habitats related to fish use would implicitly protect these other organisms.

The team also discussed other factors such as causative mechanisms for observed trends and their relative significance.

Other considerations included distribution, status, trophic position, reproductive strategies, sensitivity to flow regime changes and/or water quality, etc.

Selection of the draft focal species also considered their suitability for use in monitoring responses at the fish community level under an adaptive environmental monitoring and management program.
<table>
<thead>
<tr>
<th>Habitat Guild</th>
<th>Upper Guadalupe River</th>
<th>Lower Guadalupe River</th>
<th>San Antonio River</th>
<th>San Marcos River</th>
<th>Blanco River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool</td>
<td>bluegill, largemouth bass, river carpsucker</td>
<td>white crappie, blackstripe topminnow, largemouth bass, smallmouth buffalo, river carpsucker</td>
<td>white crappie, pugnose minnow, largemouth bass, smallmouth buffalo, river carpsucker</td>
<td>bluegill, largemouth bass, river carpsucker</td>
<td>bluegill, largemouth bass, river carpsucker</td>
</tr>
<tr>
<td>Shallow Run</td>
<td>roundnose minnow, Texas shiner, mimic shiner,</td>
<td>ghost shiner, mimic shiner</td>
<td>burrhead chub, central stoneroller, mimic shiner</td>
<td>roundnose minnow, Texas shiner, mimic shiner</td>
<td>Texas shiner, mimic shiner</td>
</tr>
<tr>
<td>Shallow Riffle</td>
<td>greenthroat darter, Texas logperch, Guadalupe bass</td>
<td>Guadalupe darter, Texas logperch, central stoneroller</td>
<td>Texas logperch, central stoneroller</td>
<td>Guadalupe darter, Texas logperch</td>
<td>orangethroat darter, central stoneroller</td>
</tr>
<tr>
<td>Deep Run</td>
<td>burrhead chub, gray redhorse, channel catfish, Guadalupe bass</td>
<td>burrhead chub, gray redhorse, channel catfish</td>
<td>burrhead chub, gray redhorse, channel catfish</td>
<td>burrhead chub, gray redhorse, channel catfish</td>
<td>burrhead chub, gray redhorse, channel catfish, Guadalupe bass</td>
</tr>
</tbody>
</table>
3.3.3.1 Habitat Suitability Criteria (HSC)

- Relied on habitat guild specific envelope curves
- Envelope curves were developed from species specific habitat suitability curves derived from Texas river and stream systems

In total, 1,338 fish abundance-habitat data points covering a broad range of systems, habitats, and flow conditions were used to develop species specific HSC.
Figure 3.3-2. Envelope and species-specific habitat suitability curves for Guadalupe-San Antonio fish in the Deep Pool habitat guild.
<table>
<thead>
<tr>
<th>Habitat Guild</th>
<th>Guild Focal Species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deep Pool</strong></td>
<td>largemouth bass</td>
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<tr>
<td></td>
<td>smallmouth buffalo</td>
</tr>
<tr>
<td></td>
<td>white crappie</td>
</tr>
<tr>
<td><strong>Shallow Pool</strong></td>
<td>blackstripe topminnow</td>
</tr>
<tr>
<td></td>
<td>bluegill</td>
</tr>
<tr>
<td></td>
<td>pugnose minnow</td>
</tr>
<tr>
<td></td>
<td>river carpsucker</td>
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<tr>
<td><strong>Shallow Run</strong></td>
<td>central stoneroller</td>
</tr>
<tr>
<td></td>
<td>ghost shiner</td>
</tr>
<tr>
<td></td>
<td>Guadalupe bass</td>
</tr>
<tr>
<td></td>
<td>mimic shiner</td>
</tr>
<tr>
<td></td>
<td>Texas shiner</td>
</tr>
<tr>
<td><strong>Riffle</strong></td>
<td>burrhead chub</td>
</tr>
<tr>
<td></td>
<td>Guadalupe darter</td>
</tr>
<tr>
<td></td>
<td>orangethroat darter</td>
</tr>
<tr>
<td></td>
<td>Texas logperch</td>
</tr>
<tr>
<td><strong>Deep Run</strong></td>
<td>channel catfish</td>
</tr>
<tr>
<td></td>
<td>gray redhorse</td>
</tr>
<tr>
<td></td>
<td>smallmouth buffalo</td>
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</tbody>
</table>
3.3.5 Estimating Habitat Guild Availability as a Function of Discharge Ranges

3.3.5.1 Physical Habitat Modeling
Figure 3.3-11. Percent of maximum habitat versus discharge for habitat guilds at San Antonio River at Elmendorf (Calaveras) (results provided by BIO-WEST, Inc.).

Table 3.3-6. Percent of maximum habitat versus discharge for habitat guilds at San Antonio River at Elmendorf (Calaveras) (results provided by BIO-WEST, Inc.).

<table>
<thead>
<tr>
<th>Discharge (cfs)</th>
<th>Moderate Pools</th>
<th>Deep Pools</th>
<th>Deep Run</th>
<th>Shallow Pool</th>
<th>Shallow Runs</th>
<th>Riffles</th>
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<tr>
<td>15</td>
<td>97.87</td>
<td>62.02</td>
<td>83.64</td>
<td>100.00</td>
<td>96.41</td>
<td>87.47</td>
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<tr>
<td>35</td>
<td>100.00</td>
<td>67.90</td>
<td>88.41</td>
<td>98.80</td>
<td>98.59</td>
<td>94.87</td>
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<td>66</td>
<td>98.98</td>
<td>73.96</td>
<td>92.36</td>
<td>94.52</td>
<td>100.00</td>
<td>100.00</td>
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<tr>
<td>131</td>
<td>94.87</td>
<td>85.22</td>
<td>98.72</td>
<td>91.90</td>
<td>99.79</td>
<td>97.21</td>
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<td>263</td>
<td>83.32</td>
<td>95.09</td>
<td>100.00</td>
<td>84.11</td>
<td>91.64</td>
<td>81.82</td>
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<td>346</td>
<td>76.86</td>
<td>97.49</td>
<td>97.44</td>
<td>77.61</td>
<td>85.24</td>
<td>71.02</td>
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<td>458</td>
<td>69.98</td>
<td>99.15</td>
<td>91.69</td>
<td>70.78</td>
<td>76.80</td>
<td>56.14</td>
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<td>650</td>
<td>59.01</td>
<td>100.00</td>
<td>77.81</td>
<td>58.39</td>
<td>64.36</td>
<td>40.77</td>
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<tr>
<td>1000</td>
<td>52.49</td>
<td>96.10</td>
<td>62.17</td>
<td>59.08</td>
<td>54.37</td>
<td>42.04</td>
</tr>
</tbody>
</table>
Data collected on water quality at or near the 16 elected streamflow gaging stations was assessed to determine how water quality may be used as an overlay for making appropriate instream flow recommendations.

The water quality parameters identified as being of interest were:

- Dissolved oxygen,
- pH,
- Conductivity,
- Temperature,
- Ammonia-nitrogen,
- Total phosphorus, and
- Total kjeldahl nitrogen.
The analysis included 4,217 sampling events between October of 1973 and August of 2010.

For each of the 30 sites and seven parameters, regression analysis was used to investigate the relationship between flow and constituent level.

A period-of-record analysis suggested that for these parameters, water quality is generally acceptable and not flow-related.

In addition to the period-of-record analysis, a similar analysis was conducted for the summertime June-August period, and for the lowest 10% of flow values at each site.

- No significant problems were found for any of the constituents.
Three locations were selected by the Guadalupe-San Antonio BBEST for sediment transport analysis in support of the Geomorphic Overlay. The locations were:

- San Antonio River at Goliad – USGS Gage Number 08188500, Goliad County
- Guadalupe River at Cuero – USGS Gage Number 8175800, De Witt County
- Guadalupe River above Comal River at New Braunfels – USGS Gage Number 08168500, Comal County
  - Guadalupe River above the Comal River at New Braunfels dropped – bedrock system
Geomorphology Overlay (Continued)

- Effective Discharge Approach
  - Frequency of Flow Analysis
    - The basic assumption of the effective discharge approach is that channel shape is a function of the flow in the channel.
  - Discharge Rating Curves
    - The existing channel should be analyzed to insure that it is reasonably stable and that it has adjusted to its existing hydrologic regime for the effective discharge calculation to be meaningful and provide guidance in how a future hydrologic regime might affect channel stability.
Geomorphologic Overlay (Continued)

- **Sediment Rating Curves**
  - Sediment rating curves estimate the amount of sediment moved by flows of various sizes

- **Hydrologic Time Series**
  - S flow duration curve developed from a time series of flow values is required in order to compute effective discharge
    - A total of 7 hydrologic flow series were evaluated
Stream channel shape (geometry or bathymetry) is determined by the movement of bed material (sediment) by flow. Substantial, long-term, changes in flow will change stream channel shape and consequently change existing habitat conditions for aquatic life.

Maintaining a flow regime in these reaches of approximately 80% of the average annual water yield that occurred during the hydrologic baseline time period maintains an average annual sediment yield of at least 90% of the baseline condition and maintains the effective discharge within +/- 10%.
Geomorphologic Overlay (Continued)

- The flow volume should occur so that daily, monthly and annual regime characteristics for the Baseline Period of Record are simultaneously maintained.

- Recommended environmental flow regimes considered adequate to provide for the biological considerations of the system (fish habitat, riparian maintenance, etc.) are not sufficient to maintain the stream channel shape (and therefore aquatic habitats) at the San Antonio River at Goliad and Guadalupe River at Cuero sites.
The resulting flow regime (recommended environmental flows for biological purposes plus additional flow for geomorphic purposes) should result in a similar effective discharge as the baseline condition for each site and an average annual sediment yield of at least 90% of the baseline condition (no more than a 10% decrease from baseline condition).

Computations show that maintaining an average annual yield of water equal to 80% of baseline average annual yield should maintain the required sediment balance.

Depending on the infrastructure (storage volume and diversion rate), current configuration of senior water rights in the basin, and environmental flow criteria; this study shows that options exist for future water projects that maintain channel stability in the basin.
Riparian Biological Overlay

- Evaluations of various physical (sediments flows), chemical (water quality), and biological overlays (instream fish and riparian vegetation communities) indicate that the GSAMA Basins and SACA Bays achieve the sound ecological environment definition.

- Three elements within the river basin systems that target floodplain function can be defined that will maintain the SEE conditions as well as provide benefits to the bay systems (Table 3.6-7).
### Riparian Biological Overlay (Continued)

Table 3.6-7. Key attributes of ecologically functioning floodplains (modified from Opperman et al. 2010).

<table>
<thead>
<tr>
<th>Elements</th>
<th>Functions</th>
<th>Flow Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) CONNECTIVITY: Hydrologic connectivity between river and floodplain</td>
<td>Provides mechanism of exchange of flow, sediment, nutrients, and organisms</td>
<td>Subsistence: groundwater recharge to stream &amp; estuary Base: groundwater recharge to stream &amp; estuary Pulse: groundwater recharge from stream Overbank: groundwater recharge from stream; surface water detention during flooding</td>
</tr>
<tr>
<td>2) FLOW REGIME: Variable hydrograph</td>
<td>Reflects seasonal precipitation patterns</td>
<td>Ensures timing of flow events with biological requirements</td>
</tr>
<tr>
<td></td>
<td>Retains a range of both high and low flow events</td>
<td>Supports important floodplain processes</td>
</tr>
<tr>
<td>3) SPATIAL SCALE: Sufficient spatial scale</td>
<td>Encompasses dynamic processes</td>
<td>Erosion and deposition of sediments along entire basin</td>
</tr>
<tr>
<td></td>
<td>Ensures meaningful floodplain benefits</td>
<td>Among terrestrial, floodplain, instream, and estuarine systems</td>
</tr>
</tbody>
</table>
Riparian Biological Overlay (Continued)

Environmental Flow Recommendations
Riparian Habitat

Over-Bank

1 per 5 Yrs
- Subsurface groundwater maximum recharge
- Maintain geomorphic dynamics
- Decrease flow velocity, temporarily store flood waters
- Transport maximum water, sediment, nutrients, leaf litter, woody debris to delta, estuary
- Maintain species diversity, regeneration, and multiple successional stages

1 per 2 Yrs
- Recharge groundwater to sustain higher baseflows
- Transport sediments, nutrients, leaf litter to delta & estuary
- Promote species diversity, growth & reproduction across floodplain
- Initiate channel meandering and other geomorphic processes

1 per Yr
- Recharge groundwater
- Increase baseflow
- Provide sediment redistribution
- Transport nutrients, litter, seeds, propagules
- Create new shoreline habitat for early succession species

High Flow Pulses

2 per Season
- Recharge groundwater
- Maintain riparian veg
- Limited growth & reproduction
- Limit veg encroachment

1 per Season
- Groundwater recharge to maintain or increase flow
- Max growth and reproductive
- Move sediment along stream bottom, along channel banks
- Limit vegetation encroachment into channel

Base Flows

DRY
AVG/MET

Groundwater recharge to stream, maintain connectivity and water quality; support growth of floodplain vegetation

Sub-sistence Flows

Groundwater recharge to stream, maintain connectivity along channel, water quality; maintain streamside vegetation to stabilize banks

Figure 3.6.14. Environmental functions of the riparian vegetation community that will be supported by the recommended environmental flow regimes for Guadalupe San Antonio and San Antonio Nueces Basins that will support a sound ecological environment within the basins and San Antonio and Aransas Bay systems.
Figure 3.6-15. Conceptual example of environmental flow recommendations applied to a flow duration curve for a specified location (in this case, Guadalupe River at Victoria).
**Freshwater Inflow Analyses**

1) Effects of Freshwater Inflow on Estuarine Ecosystems
2) Hydrology and Salinity
3) Key Bay Species/Habitat and Responses to Salinity
4) Analyses for Focal Species
5) Synthesis of Biology-Based Freshwater Inflow Regime Components
6) Integration of Instream Flow and Estuary Inflow Regimes
Freshwater Inflow Analyses

The Guadalupe and Mission-Aransas Estuaries. (map courtesy of Lynne Hamlin, TPWD).
Effects of Freshwater Inflow on Estuarine Ecosystems
Freshwater Inflow Analyses

Figure 4.2-7

Sept. 1989

Sept. 1993

Sept. 2001

Salinity Ranges

- 0-2
- 2-4
- 4-6
- 6-8
- 8-10
- 10-12
- 12-14
- 14-16
- 16-18
- 18-20
- 20-22
- 22-24
- 24-26
- 26-28
- 28-30
- 30-32
- 32-34
- 34+
Freshwater Inflow Analyses

Effects of Freshwater Inflow on Estuarine Ecosystems
Freshwater Inflow Analyses

Figure 4.3-18 The 5 selected fixed habitat areas used by the science team in the Guadalupe and Mission-Aransas Estuaries. (map courtesy of Lynne Hamlin, TPWD).
Estuarine Focal Species

Fixed Habitats vs. Motile Species and Responses to Salinity

*Rangia cuneata*

*Callinectes sapidus*
Adult

*Penaeus setiferus*
Adult

*Crassostrea virginica*
Adult

(from Goods 1884)
Mean(White Shrimp catch_per_hour) vs. month

White Shrimp Seasonality from TPWD Trawl samples
Figure 4.4.2. The salinity suitability curve for Eastern oysters utilized in the salinity zone analyses in the Guadalupe and Mission-Aransas Estuaries. An index of 1.0 indicates optimum salinity conditions and 0 indicates very bad conditions. This curve is from Cake (1985).
Freshwater Inflow Analyses

1) Effects of Freshwater Inflow on Estuarine Ecosystems
2) Hydrology and Salinity
3) Key Bay Species/Habitat and Responses to Salinity
4) Analyses for Focal Species
5) Synthesis of Biology-Based Freshwater Inflow Regime Components
6) Integration of Instream Flow and Estuary Inflow Regimes
7) Attainment Goals / Assessing
Table 4.5-1. The array of geographic, focal species, and calendar year coverage of the salinity zone analysis utilized for the Guadalupe and Mission-Aransas Estuaries.

<table>
<thead>
<tr>
<th>Estuary</th>
<th>Calendar year coverage</th>
<th>Focal species</th>
<th>basic salinity objectives</th>
<th>criteria reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guadalupe</td>
<td>Spring Feb-May</td>
<td>Rangia clams</td>
<td>2-10 ppt to support reproduction, at least 1 month Mar.-May</td>
<td>G1</td>
</tr>
<tr>
<td>Guadalupe</td>
<td>Summer June - Sept.</td>
<td>Eastern oysters</td>
<td>10-20 ppt best to control “dermo” parasite, 3 months Jul.-Sep.</td>
<td>G2</td>
</tr>
<tr>
<td>Mission-Aransas Bay</td>
<td>Summer June - Sept.</td>
<td>Eastern oysters</td>
<td>“</td>
<td>MA2</td>
</tr>
<tr>
<td>Mission-Aransas Bay</td>
<td>Spring Feb-May</td>
<td>Rangia clams</td>
<td>2-10 ppt to support reproduction, at least 1 month Mar.-May</td>
<td>MAC1</td>
</tr>
<tr>
<td>Mission-Aransas Copano Bay</td>
<td>Summer June - Sept.</td>
<td>Eastern oysters</td>
<td>10-20 ppt best to control “dermo” parasite, 3 months Jul.-Sep.</td>
<td>MAC2</td>
</tr>
</tbody>
</table>
Eastern Oyster Example of Focal Species Analyses

Figure 4.4.2. The salinity suitability curve for Eastern oysters utilized in the salinity zone analyses in the Guadalupe and Mission-Aransas Estuaries. An index of 1.0 indicates optimum salinity conditions and 0 indicates very bad conditions. This curve is from Cake (1985).
Finer detail in the Guadalupe Estuary oyster habitat
Gaudalupe Estuary, Salinity-Inflow: period-2005-6, moderate summers

- Average monthly salinity (ppt)
- Inflow (1000 ac-ft/mon.)

- Salinity, Guadalupe, Oyster area - nr. center
- Guadalupe Inflows
Criteria G2-A
275 – 450 k ac-ft/3 mon
Guadalupe Estuary, summer, oyster-based criteria

Inflow (1000 ac-ft/3 months)

G2-A
Criteria G2-C
75-170 k ac-ft/3 mon

Criteria G2-DD
0-50 k ac-ft/3 mon
Guadalupe Estuary, summer, oyster-based criteria

Inflow (1000 ac-ft/3 months)

- **G2-A & B**
  - Historical: 28yrs
  - Recommended: ≥21yrs

- **G2-A**
  - Historical: 16yrs
  - Recommended: ≥12yrs

- **G2-B**

- **G2-C**

- **G2-DD**

- **G2-D**

Months:
- Jan
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sep
- Oct
- Nov
- Dec
Table 4.5-2. A multi-tiered suite of inflow criteria covering the June-September period in the Guadalupe Estuary oyster area determined via the salinity zone approach.

<table>
<thead>
<tr>
<th>Criteria level</th>
<th>Inflow ranges (1000 ac-ft) [cfs equivalent]</th>
<th>Salinity and Weighted Useable Area objectives, Jul-Sep</th>
<th>Occurrence [/ Co-] of seasonal [and antecedent]</th>
</tr>
</thead>
<tbody>
<tr>
<td>G2-A</td>
<td>July-Sept. total inflows 275-450 [1507-2466]</td>
<td>100% WUA(^3) 11-18</td>
<td>16 / 23.2% '06,'05,'95</td>
</tr>
<tr>
<td>G2-B</td>
<td>170-275 [932-1507]</td>
<td>85-100% WUA(^2) 13-23</td>
<td>12 / 17.4% '08,'99,'96</td>
</tr>
<tr>
<td>G2-C</td>
<td>75-170 [411-932]</td>
<td>&gt;=50 65-100% WUA(^4) 16-27</td>
<td>6 / 8.7% '00,'82,'69</td>
</tr>
<tr>
<td>G2-CC</td>
<td>75-170 [411-932]</td>
<td>&lt;50 36-99% WUA(^4) 20-39</td>
<td>1 / 1.5% 1955</td>
</tr>
<tr>
<td>G2-D</td>
<td>50-75 - 39-73% WUA 25-&gt;40</td>
<td>2 / 2.9% '09,'89</td>
<td></td>
</tr>
<tr>
<td>G2-DD</td>
<td>0-50 - 0-43% WUA 31-&gt;40</td>
<td>4 / 5.8% '84,'63,'56</td>
<td></td>
</tr>
</tbody>
</table>

Criteria levels G2-A & G2-B, total historic occurrence 28 years (41%).

Recommended occurrence in future:
Criteria levels G2-A and G2-B total occurrence >= 21 years (30%); Criteria level G2-A occurrence >= 12 years (17%)\(^3\).

Criteria levels G2-C & G2-CC, total historic occurrence 7 years (10%).

Recommended occurrence in future:
Overall occurrence of Criteria level G2-C and G2-CC may increase beyond 7\(^5\) years (10%) if the constraints on other categories are met, and G2-CC comprises no more than 1/6 of total.

Criteria levels G2-D & G2-DD, total historic occurrence 6 years (9%)

Recommended occurrence in future:
Criteria level G3-D and G3-DD together should occur no more than a total of 6 (9%) years; Criteria level G3-DD should occur no more than 4 (6%) years.
Section 4.6 summary

Section 4.4, 4.5 details

Section 6 recommendations
Guadalupe Estuary, spring criteria (Rangia clams)

Inflow (1000 ac-ft / 3 months)

- G1-A
- G1-B
- G1-C
- G1-D
Guadalupe Estuary criteria: spring & summer

Inflow (1000 ac-ft/3 months)
Inflow (1000 ac-ft/3 months)

Integrating Instream & Estuary criteria

- Base Wet only
- Base Avg only
- Base Dry only
- Subsistence Flows only

G1-Aprime
G1-A
G1-B
G1-C
G1-D
G2-Aprime
G2-A
G2-B
G2-C
G2-D
G2-DD

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Integrating Instream & Estuary criteria

Inflow (1000 ac-ft/3 months)

- G1-Aprime
- G1-A
- G1-B
- G1-C
- G1-D
- G2-Aprime
- G2-A
- G2-B
- G2-C
- G2-D
- G2-DD

Legend:
- dark blue: base wet & 1/seas HFP
- blue: base avg & 1/seas HFP
- cyan: base dry & 1/seas HFP
Inflow (1000 ac-ft/3 months)

- **G1-Aprime**
- **G2-Aprime**
- **G1-A**
- **G2-A**
- **G1-B**
- **G2-B**
- **G1-C**
- **G2-C**
- **G1-D**
- **G2-D**
- **G2-DD**

**coincident (May) 1 per 2 year pulse**

<table>
<thead>
<tr>
<th>Months</th>
<th>G1-Aprime</th>
<th>G2-Aprime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb</td>
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<td></td>
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<td>Nov</td>
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</tr>
<tr>
<td>Dec</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sections 4.4, 4.5 details

Section 4.6 summary

Section 6.1.7 recommendations for assessing attainment of estuary criteria
Guadalupe Estuary, summer, oyster-based criteria

Inflow (1000 ac-ft / 3 months)

- **G2-A & B**
  - Historic: 28yrs
  - Recmd.: ≥21yrs

- **G2-A**
  - Historic: 16yrs
  - Recmd.: ≥12yrs

- **G2-B**
- **G2-C**
- **G2-DD**
- **G2-D**

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Evaluating attainment of estuary criteria

Texas Water Availability Models (WAMs) to predict inflow to estuaries.
Example Applications of Environmental Flow Regime Recommendations

1) Instream Flows below Example Run-of-River and Reservoir Projects
Example Application of Instream Flow Regime Recommendations

Reservoir Example, San Antonio R. @ Goliad - Flow Frequency Curves

Period of Record: 1/1/1934 to 12/31/1989

- Historical
- Region L Baseline
- Reservoir Example
- Minimum Flow Protected by Recommendation

Flow (cfs) vs. Percentage of Time Flows are Equaled or Exceeded

70
Flow Regime Components

Reservoir Example, San Antonio R. @ Goliad - Flow Frequency Curves

Period of Record: 1/1/1934 to 12/31/1989

- Historical
- Region L Baseline
- Reservoir Example
- Minimum Flow Protected by Recommendation

Flow (cfs)

Percentage of Time Flows are Equaled or Exceeded

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Pulses
Base
Subsistence
Ecological Significance - Subsistence

Water Quality

Aquatic Habitat
Ecological Significance - Base

Aquatic Habitat

San Antonio @ Goliad - LSAR Guild Results

Reservoir Example, San Antonio R. @ Goliad - Flow Frequency Curves

Period of Record: 1/1/1934 to 12/31/1989

Historical
Regional L Baseline
Reservoir Example
Minimum Flow Protected by Recommendation

Flow (cfs)

0 100 200 300 400 500 600 700 800 900 1000

Percentage of Time Flows are Equaled or Exceeded

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Percent of Maximum Habitat

Discharge (cfs)

0 100 200 300 400 500 600 700 800
Ecological Significance - Pulses

Geomorphology

Riparian Biology

Reservoir Example, San Antonio R. @ Goliad - Flow Frequency Curves

Period of Record: 1/1/1934 to 12/31/1989

- Historical
- Region 1 Baseline
- Reservoir Example
- Minimum Flow Protected by Recommendation

Flow (cfs)

Percentage of Time Flows are Equaled or Exceeded

0 100 200 300 400 500 600 700 800 900 1000

0 10 20 30 40 50 60 70 80 90 100

Geomorphology

- Constructed geomorphic processes
- Protect riparian vegetation
- Promote nutrient cycling
- Maintain stream health
- Support aquatic life

Riparian Biology

- Protect riparian vegetation
- Maintain connectivity along channel
- Support growth of aquatic vegetation
- Maintain stream health
Questions, Comments, & Discussion