# Sample Instream Flow Matrix

| Overbank Flows          | 4,000-10,000 cfs for 2-3 days  
                          | Once every 3-5 years  
                          | Channel maintenance  
                          | Floodplain connectivity, Seed dispersal |
|-------------------------|-------------------------------------------------|
| High Flow Pulses        | 700-1500 cfs for 2-3 days  
                          | 2-3 X per year every year  
                          | Sediment transport  
                          | Lateral connectivity  
                          | Fish spawning  
                          | 1800 cfs for 2 days  
                          | 1 X per yr every other year  
                          | “Big River fish” spawning  
                          | between Jul 15 - Aug 15 |
| Base Flows              | 300-450 cfs  
                          | Maintain biodiversity and longitudinal connectivity  
                          | 100-150 cfs  
                          | Fish habitat  
                          | 150-300 cfs  
                          | Spring spawning  
                          | 40-50 cfs  
                          | Fish habitat  
                          | 90-100 cfs  
                          | Fish habitat  
| Subsistence Flows       | 35 - 55 cfs  
                          | Maintain water quality (35 cfs) and key habitats in May (55 cfs)  
| **JAN** **FEB** **MAR** **APR** **MAY** **JUN** **JUL** **AUG** **SEP** **OCT** **NOV** **DEC** |
Upper Brazos River (confluence of Salt Fork and Double Mountain Fork to Possum Kingdom Lake): High fish assemblage integrity: dominated by a few, fluvial specialist taxa that are adapted to the variable and sometime extreme conditions of this region.
Upper Brazos River (confluence of Salt Fork and Double Mountain Fork to Possum Kingdom Lake): High fish assemblage integrity: dominated by a few, fluvial specialist taxa that are adapted to the variable and sometime extreme conditions of this region.

Photos from Chad Thomas. Texas State Univ.

This book lists dozens of methods – their intended uses and potential abuses.
For its evaluations and analyses, the Brazos BBEST used:

1. **Indicators of Hydrologic Alteration Method** – provides ecologists and hydrologists with a tool to characterize and compare complex hydrologic regimes in ecologically meaningful terms.
2. **Target Fish Community Assessment** – describes a model fish community that serves as a target for river restoration, rehabilitation, or enhancement and as an endpoint for evaluating program success.
3. **Biological Response to Flow Correlation Method** – identifies correlations between biological response or habitat condition and flow-related variables.
4. **Floodplain Inundation Method** – determines flows to protect aquatic, riparian, wetland, and floodplain resources or compare alternative flow regimes.

   - No study results were available from *IFIM, PHabSim or MesoHabSim* methods.

The BBEST also evaluated:

5. **Water quality in relation to discharge**
6. **Sediment transport in relation to flow regimes** (Flushing flow: empirical, sediment transport modeling, and ‘desktop’ hydrologic methods)
7. **Estuarine inflows, salinity, and potential responses of coastal marine organisms** (indicator taxa)
Research findings specifically useful for evaluation of Upper Brazos River near Seymour


| Overbank Events | Qp: 16,800 cfs with Average Frequency 1 per 2 years  
Regressed Volume is 125,000  
Duration Bound is 35 |
|----------------|------------------------------------------------------------------|
|                | Qp: 10,400 cfs with Average Frequency 1 per year  
Regressed Volume is 74,100  
Duration Bound is 29 |
| Qp: 250 cfs with Average Frequency 1 per season  
Regressed Volume is 1,560  
Duration Bound is 10 |
| Qp: 4,730 cfs with Average Frequency 1 per season  
Regressed Volume is 30,500  
Duration Bound is 20 |
| Qp: 4,570 cfs with Average Frequency 1 per season  
Regressed Volume is 28,600  
Duration Bound is 21 |
| Qp: 97 cfs with Average Frequency 2 per season  
Regressed Volume is 490  
Duration Bound is 6 |
| Qp: 2,000 cfs with Average Frequency 2 per season  
Regressed Volume is 12,000  
Duration Bound is 15 |
| Qp: 1,560 cfs with Average Frequency 2 per season  
Regressed Volume is 8,910  
Duration Bound is 14 |
| Qp: 1,040 cfs with Average Frequency 3 per season  
Regressed Volume is 5,870  
Duration Bound is 12 |
| Qp: 800 cfs with Average Frequency 3 per season  
Regressed Volume is 4,290  
Duration Bound is 11 |
| Qp: 560 cfs with Average Frequency 4 per season  
Regressed Volume is 2,960  
Duration Bound is 10 |
| Qp: 370 cfs with Average Frequency 4 per season  
Regressed Volume is 1,870  
Duration Bound is 8 |
| Base Flows (cfs) | 46  
25  
10  
1 |
| Subsistence Flows (cfs) | 35  
19  
7  
1 |
| Base Flow Levels | High (75th %ile)  
Medium (50th %ile)  
Low (25th %ile) |

Pulse volumes are in units of acre-feet and durations are in days. Period of record used: 1/1/1924 to 12/31/2010. Episodic events are terminated when the volume or duration criteria are met, or when the flow drops below 42 cfs, or when the flow is below 152 cfs and the flow drops from one day to the next by less than 5%.
Figure 7.7. Flow duration curves for the Brazos River at Seymour.
<table>
<thead>
<tr>
<th>Hydrologic Scenarios</th>
<th>Average Annual Yield</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water Acre-Feet (% of Baseline)</td>
<td>Sediment Tons per Year (% of Baseline)</td>
<td></td>
</tr>
<tr>
<td>BRAZOS RIVER AT SEYMOUR</td>
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<tr>
<td>Historical Flows</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1940-1997 Gaged Flows</td>
<td>246,000 (102%)</td>
<td>296,000 (103%)</td>
<td></td>
</tr>
<tr>
<td>Simulated Flows</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAM 8 Flows (Baseline)</td>
<td>242,000 (100%)</td>
<td>288,000 (100%)</td>
<td></td>
</tr>
<tr>
<td>G WAM</td>
<td>233,000 (96%)</td>
<td>262,000 (91%)</td>
<td></td>
</tr>
<tr>
<td>G WAM with Project</td>
<td>223,000 (92%)</td>
<td>233,000 (81%)</td>
<td></td>
</tr>
<tr>
<td>E Flow Only</td>
<td>93,400 (39%)</td>
<td>56,600 (20%)</td>
<td></td>
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</tbody>
</table>
Brazos River Basin BBEST
Selected Locations where Flow Recommendations will be Developed

BBEST Selected USGS Gages
1 - DMF Brazos Rv nr Aspermont, TX
2 - Salt Fk Brazos Rv nr Aspermont, TX
3 - Brazos Rv at Seymour, TX
4 - Clear Fk Brazos Rv at Nugert, TX
5 - Clear Fk Brazos Rv at Ft Griffin, TX
6 - Brazos Rv nr South Bend, TX
7 - Brazos Rv nr Palo Pinto, TX
8 - Brazos Rv nr Glen Rose, TX
9 - N Bosque Rv nr Clifton, TX
10 - Brazos Rv at Waco, TX
11 - Leon Rv at Gatesville, TX
12 - Lampasas Rv nr Kempner, TX
13 - Little Rv nr Little River, TX
14 - Little Rv nr Cameron, TX
15 - Brazos Rv at Sh ! 21 nr Bryan, TX
16 - Navasota Rv nr Eastery, TX
17 - Brazos Rv nr Hempstead, TX
19 - Brazos Rv at Richmond, TX
20 - Brazos Rv nr Rosharon, TX
21 - San Bernard Rv nr Boling, TX

Other USGS Gages Evaluated

- Brazos River Basin
- Brazos Basin Study Divisions
- San Bernard Basin
- San Jacinto Brazos Coastal Basin
Moehlman’s Slough, oxbow in Burleson co.
<table>
<thead>
<tr>
<th>Oxbow</th>
<th>Flow to Connect (cfs)</th>
<th>Number of Connections 1984-1994</th>
<th>Number of Connections 1994-2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hog Island</td>
<td>3,625</td>
<td>61</td>
<td>68</td>
</tr>
<tr>
<td>Big Bend</td>
<td>20,000</td>
<td>32</td>
<td>41</td>
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<tr>
<td>Korthauer Bottom</td>
<td>20,500</td>
<td>32</td>
<td>50</td>
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<tr>
<td>Moehlman Slough</td>
<td>45,000</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Cutoff Lake</td>
<td>76,200</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Horseshoe Lake</td>
<td>99,000</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Structure of river channel and oxbow lake fish assemblages

CA using seine CPUE data for fishes
During floods there is exchange of fishes between river and oxbows

CA using seine CPUE data for fishes
Lower Brazos River (reach below the mouth of the Bosque River to the coast): Moderate fish assemblage integrity; the majority of the fish community remains intact. Loss of at least one fluvial specialist (smalleye shiner, *Notropis buccula*) and declines in populations of several other fluvial specialists and increases in abundance of habitat generalists, such as bluegill sunfish (*Lepomis macrochirus*), suggest community changes associated with flow modifications.
Research findings specifically useful for evaluation of Lower Brazos River near Richmond


| Overbank Events | Qp: 68,100 cfs with Average Frequency 1 per 2 years  
Regressed Volume is 1,487,000  
Duration Bound is 41 |
|-----------------|--------------------------------------------------------------------------------|
| High Flow Pulses | Qp: 51,600 cfs with Average Frequency 1 per year  
Regressed Volume is 1,019,000  
Duration Bound is 35 |
| Qp: 24,600 cfs with Average Frequency 1 per season  
Regressed Volume is 383,000  
Duration Bound is 23 | Qp: 35,000 cfs with Average Frequency 1 per season  
Regressed Volume is 617,000  
Duration Bound is 29 |
| Qp: 12,400 cfs with Average Frequency 2 per season  
Regressed Volume is 150,000  
Duration Bound is 16 | Qp: 16,300 cfs with Average Frequency 2 per season  
Regressed Volume is 215,000  
Duration Bound is 19 |
| Qp: 6,410 cfs with Average Frequency 3 per season  
Regressed Volume is 60,600  
Duration Bound is 11 | Qp: 8,930 cfs with Average Frequency 3 per season  
Regressed Volume is 94,000  
Duration Bound is 13 |
| Qp: 12,900 cfs with Average Frequency 1 per season  
Regressed Volume is 144,000  
Duration Bound is 15 | Qp: 5,430 cfs with Average Frequency 2 per season  
Regressed Volume is 46,300  
Duration Bound is 10 |

<table>
<thead>
<tr>
<th>Base Flows (cfs)</th>
<th>3,310</th>
<th>3,980</th>
<th>2,190</th>
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<tbody>
<tr>
<td></td>
<td>1,650</td>
<td>2,140</td>
<td>1,330</td>
</tr>
<tr>
<td></td>
<td>990</td>
<td>1,190</td>
<td>930</td>
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</table>

<table>
<thead>
<tr>
<th>Subsistence Flows (cfs)</th>
<th>550</th>
<th>550</th>
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<tr>
<th>Nov</th>
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<td>Winter</td>
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</tbody>
</table>

Base Flow Levels
- High (75th %ile)
- Medium (50th %ile)
- Low (25th %ile)

Pulse volumes are in units of acre-feet and durations are in days.
Period of record used: 1/1/1923 to 12/31/2010.
Episodic events are terminated when the volume or duration criteria are met, or when the flow drops below 1260 cfs, or when the flow is below 8430 cfs and the flow drops from one day to the next by less than 5%.
Figure 7.13. Flow threshold for lateral connection between the Brazos River channel and Hog Island oxbow in relation to the flow duration curve at the Richmond gage under five flow scenarios.
<table>
<thead>
<tr>
<th>Hydrologic Scenarios</th>
<th>Average Annual Yield</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>Sediment</td>
</tr>
<tr>
<td></td>
<td>Acre-Feet (% of Baseline)</td>
<td>Tons per Year (% of Baseline)</td>
</tr>
<tr>
<td><strong>BRAZOS RIVER AT RICHMOND</strong></td>
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<tr>
<td><strong>Historical Flows</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1940-1997 Gaged Flows</td>
<td>5,480,000 (107%)</td>
<td>3,010,000 (85%)</td>
</tr>
<tr>
<td><strong>Simulated Flows</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAM 8 Flows (Baseline)</td>
<td>5,130,000 (100%)</td>
<td>3,530,000 (100%)</td>
</tr>
<tr>
<td>G WAM</td>
<td>4,780,000 (93%)</td>
<td>3,190,000 (90%)</td>
</tr>
<tr>
<td>G WAM with Projects</td>
<td>4,580,000 (89%)</td>
<td>2,930,000 (83%)</td>
</tr>
<tr>
<td>E Flow Only</td>
<td>2,340,000 (46%)</td>
<td>797,000 (23%)</td>
</tr>
</tbody>
</table>
Geomorphology and Sediment Transport Analysis

- Historical data indicates both locations experiencing modest geomorphic change (*channel widening*) *(correction: channel incision)*
- Transport formulas all significantly underestimate transport at the larger discharges
- Channels at both sites have not reached dynamic equilibrium
- Cannot determine if a new project subject to flow alterations would move channel towards stability or increase instability
- E-flow only regimes, as recommended, provide approximately 80% *(correction: 20 – 23%)* of the annual average sediment yield compared to baseline conditions
Hydrologic Scenarios

• Gaged – daily flows from 1940 – 1997
• WAM – monthly flows intended to represent current conditions with respect to water rights, considering full utilization of all rights
  – WAM 8 – actual, current diversion rates
  – G WAM – WAM model adjusted to represent conditions expected to be in place in 2060
• With Projects – conditions expected in the future if various water supply projects are completed
• E-flow Only – environmental flow recommendations only
With Projects

• Seymour
  – Double Mountain Fork-West Reservoir
• Richmond
  – Double Mountain Fork-West Reservoir
  – Millican Panther Creek Reservoir
• Used estimated daily project outflows based on daily inflows and projected reservoir capacity
E-Flows Only Scenario

• Supposes “infinite infrastructure”
  – Capacity to divert or impound all water in excess of the e-flow recommendations
  – In reality, projects have limits on diversion rates or total volume impounded

• Does not consider downstream water rights
  – Some water that could physically be diverted via a new project is already legally obligated downstream
Figure 1. Uncertainty decreases as some function of increasing scientific knowledge. The statistical thresholds that define Type I errors (the likelihood of incorrectly inferring a relationship between variables when none exists) and Type II errors (the likelihood of incorrectly concluding no relationship when in fact one exists) are generally well established. The location of the “good enough” threshold is more nebulous, and shifts toward the right as the costs of making a mistake become greater.
Example of E-flows derived from habitat availability models – Nueces BBEST

**Laguna – % Max WUA, 0.5 Threshold**

How much is “enough”? – we used 75% for base flows, 20% for subsistence