QUAL2K Dissolved Oxygen Modeling
Upper Pecos River (Segment 2311)
Evaluation of Best Management Practices

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& Nabin Basnet
TIAER

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Presentation Topics

• Pecos River Dissolved Oxygen Issue
• Model Verification (Calibration & Validation)
• Model Application to Evaluate BMPs
Pecos River Dissolved Oxygen Issue

Photo: May 4, 2010, US Hwy 67 Bridge, Abundant Attached Algae (Periphyton)
Upper Pecos River (Segment 2311)
Upper Pecos River (Segment 2311) & Lower Pecos River (Segment 2310)
Texas Surface Water Quality Standards

• Designated Aquatic Life Use: High
• Protective dissolved oxygen criteria
  24-hour Period Concentrations
  Average: 5.0 mg/L
  Minimum: 3.0 mg/L
• Dissolved oxygen concentrations at or above the criteria concentrations need to occur at least 90% of the time to be in support of designated use.
Upper Pecos River Showing Monitoring Stations
Station 13260
Pecos River at RR 1776

USGS 08437710 Pecos Rv at RR 1776 nr Grandfalls, TX

Dissolved oxygen, water, unfiltered, milligrams per liter


---- Provisional Data Subject to Revision ----
Station 13257
Pecos River at US Hwy 67

USGS 08446500 Pecos Rv nr Girvin, TX

Dissolved oxygen, water, unfiltered, milligrams per liter


---- Provisional Data Subject to Revision ----
Station 13249
Pecos River nr. Sheffield, TX

USGS 08447000 Pecos Rv nr Sheffield, TX

Dissolved oxygen, water, unfiltered, milligrams per liter


----- Provisional Data Subject to Revision -----

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### Pecos Water Quality

**Dissolved Oxygen Issue**

*Source: TCEQ 2012 303(d) List*

<table>
<thead>
<tr>
<th>SegID: 2311</th>
<th>Upper Pecos River</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From a point immediately upstream of the confluence of Independence Creek in Crockett/Terrell County to Red Bluff Dam in Loving/Reeves County</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter(s)</th>
<th>Category</th>
<th>Year Segment First Listed</th>
</tr>
</thead>
<tbody>
<tr>
<td>depressed dissolved oxygen</td>
<td>5c</td>
<td>2006</td>
</tr>
</tbody>
</table>

- **2311_03** From US Hwy 67 upstream to the Ward Two Irrigation Turnout
## 2010 Assessment – Dissolved Oxygen

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number Assessed</th>
<th>Number Exceed.</th>
<th>Mean Exceed.</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2311_04 FM 1776 upstream to US Hwy 80 (Bus 20)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>24-h DO Avg</td>
<td>12</td>
<td>1</td>
<td>4.9</td>
<td>5.0</td>
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<tr>
<td>24-h DO Min</td>
<td>12</td>
<td>7</td>
<td>1.6</td>
<td>3.0</td>
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<tr>
<td>2311_03 From US Hwy 67 up to FM 1776</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-h DO Avg</td>
<td>10</td>
<td>0</td>
<td>—</td>
<td>5.0</td>
</tr>
<tr>
<td>24-h DO Min</td>
<td>10</td>
<td>5</td>
<td>1.3</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Tool to Address Dissolved Oxygen – QUAL2K

• QUAL2K is a stream water quality model. It is one-dimensional* and operates under steady-state flow.

• All water quality variables are simulated on a diurnal (24-hour) time scale, including dissolved oxygen.

* One-dimensional means the model divides the Upper Pecos River into computation elements along the river’s length.
Stream Dissolved Oxygen (O₂) Factors

- Atmospheric oxygen (Source/sink)
- Streamflow O₂
- Ammonia (Sink)
- Organic matter (Sink)
- Aquatic vegetation (Source/sink)
- Sediment (Sink)
QUAL2K
Segmentation of Upper Pecos River
Model Verification

• Calibration Step – adjust input "kinetic" parameters and compare model predictions to observed data.

• Validation Step – hold "kinetic" parameters at calibration values and compare model predictions to observed data.
Typical DO Calibration – Warm Season


- DO (mgO2/L)
- DO (mgO2/L) data
- DO (mgO2/L) Min
- DO (mgO2/L) Max
- Minimum DO-data
- Maximum DO-data
- DO sat
BMP Evaluation Approach

• Use 12 scenarios from June 2006 – November 2009
• Run QUAL2K for 12 scenarios for baseline (existing) conditions and with selected BMPs
• Use Station 13260 as reference location (RR 1776)
• Modify historical 24-hr DO data at Station 13260 based on differences between baseline and BMP conditions
<table>
<thead>
<tr>
<th>Management Option</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Existing baseline conditions</td>
</tr>
<tr>
<td>1</td>
<td>Malaga Bend Project (decreased salinity in Red Bluff Reservoir releases)</td>
</tr>
<tr>
<td>2</td>
<td>BBEST 50&lt;sup&gt;th&lt;/sup&gt; percentile environmental flows applied April – October</td>
</tr>
<tr>
<td>3</td>
<td>BBEST 50&lt;sup&gt;th&lt;/sup&gt; &amp; 75&lt;sup&gt;th&lt;/sup&gt; percentile flow selectively applied April – October</td>
</tr>
<tr>
<td>4</td>
<td>Decrease algal biomass 25% in summer in zone of impairment</td>
</tr>
<tr>
<td>5</td>
<td>Decreased sediment-water fluxes by 25%</td>
</tr>
<tr>
<td>6</td>
<td>Decreased Red Bluff Reservoir nutrients 50%</td>
</tr>
<tr>
<td>7</td>
<td>Added riffle 1.5 km (1 mile) above FM 1776 crossing of Pecos River</td>
</tr>
<tr>
<td>8</td>
<td>Combination of Management Options 3, 4 &amp; 6</td>
</tr>
<tr>
<td>9</td>
<td>Combination of Management Options 3, 4, 5 &amp; 6</td>
</tr>
</tbody>
</table>
Option 1: Malaga Bend Project

- Control of brine intrusion above Red Bluff Reservoir.
- Assumed decreased salinity of 1.6 ppt in Red Bluff Reservoir releases (Miyamoto et al., 2007).
- Benefit – lower salinities slightly increase saturation level of DO in water.
Option 2: Increased Streamflow

- Increased streamflow in zone of impairment during April - October.
- Increased flow based on 50th percentile flows of local basin and bay expert science team (BBEST). Reports (BBEST, 2012a & 2012b)
- Used recommended flows for Grandfalls and Girvin.
- Issue: Does not consider where water would come from.
BBEST recommended 50\textsuperscript{th} percentile base flows in warm months (all flows in cfs; blue font values are the flows implemented in QUAL2K)

Girvin flows used as minimum flows from RR 1776/Ward 2 Turnout continuing downstream.

<table>
<thead>
<tr>
<th>Location</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>Sept.</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orla</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Pecos</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Girvin</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>
Option 3: Increased Streamflow

- Increased streamflow in zone of impairment during April - October.
- Increased flow based on 50th and 75th percentile flows of local BBEST. Reports (BBEST, 2012a & 2012b)
- Used recommended flows for Grandfalls and Girvin.
- Issue: Does not consider where water would come from.
Recommended 50th percentile base flows (cfs) (Blue Text) and 75th percentile base flows (cfs) (Red text) in warm months from BBEST Report

Girvin flows used as minimum flows from RR 1776 /Ward 2 Turnout continuing downstream.

<table>
<thead>
<tr>
<th>Location</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>Sept.</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orla</td>
<td>15</td>
<td>15</td>
<td>44</td>
<td>69</td>
<td>69</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Pecos</td>
<td>16</td>
<td>16</td>
<td>78</td>
<td>104</td>
<td>104</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Girvin</td>
<td>19</td>
<td>19</td>
<td>25</td>
<td>27</td>
<td>27</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>
Option 4: Decrease Periphyton 25%

- Implemented in QUAL2K by increasing die-off rate of bottom algae until biomass decreased by 25%.
- In practice accomplished by chemical or biological means.
- Issue: Could cause environmental concerns and consequences.
Option 5: Decrease Sediment-Water Fluxes 25%

• Implemented in QUAL2K by reducing prescribed sediment oxygen demand and nutrient fluxes from sediments by 25%.
• In practice land management practices and scouring pulses of water could bring this change.
• Issues: Source of water for pulses & unknown efficacy of land management practices in arid region.
Option 6: Decrease Nutrients in Red Bluff Reservoir 50%

• This option results from a desire for better water quality in the water delivered to Texas.
• Could be implemented through a mechanism similar to Pecos River Compact.
• Issue: No ongoing action to bring this about at this time.
Option 7: Add Riffle Area Above RR 1776 Crossing of Pecos River

• Implemented in QUAL2K by adding a 3-foot high broad crested weir 1 mile above the crossing.
• To be effective for entire depressed zone would require a series riffles/dams.
• Issue: Gradual gradient along Pecos River may limit number of units and increase spacing & length of Pecos being improved is limited.
Option 8: Combine Options 3, 4 & 6

- 50\textsuperscript{th} and 75\textsuperscript{th} percentile BBEST flows.
- 25\% decrease in bottom algae biomass.
- 50\% reduction in nutrients in releases from Red Bluff Reservoir
Option 9: Combine Options 3, 4, 5 & 6

• $50^{\text{th}}$ and $75^{\text{th}}$ percentile BBEST flows.
• 25% decrease in bottom algae biomass.
• 50% decrease in sediment-water fluxes.
• 50% reduction in nutrients in releases from Red Bluff Reservoir
Not Considered: Saltcedar Control

• Difficulty in quantifying water quantity benefits.
• Scientists suggest that long-term benefits decrease as native riparian vegetation matures in size.
<table>
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<tr>
<th>Management Option</th>
<th>Brief Description</th>
<th>Percent time 24-hr minimum DO ≥ 3.0 mg/L on Pecos at FM 1776</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Existing baseline conditions</td>
<td>79.0</td>
</tr>
<tr>
<td>1</td>
<td>Malaga Bend Project (decreased salinity in Red Bluff Reservoir releases)</td>
<td>79.0</td>
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<td>2</td>
<td>BBEST 50th percentile environmental flows applied April – October</td>
<td>83.6</td>
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<td>BBEST 50th &amp; 75th percentile flow selectively applied April – October</td>
<td>84.4</td>
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<td>4</td>
<td>Decrease algal biomass 25% in summer in zone of impairment</td>
<td>85.2</td>
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<td>5</td>
<td>Decreased sediment-water fluxes by 25%</td>
<td>85.0</td>
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<td>6</td>
<td>Decreased Red Bluff Reservoir nutrients 50%</td>
<td>79.0</td>
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<td>7</td>
<td>Added riffle 1.5 km (1 mile) above FM 1776 crossing of Pecos River</td>
<td>87.7</td>
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<td>Combination of Management Options 3, 4 &amp; 6</td>
<td>87.2</td>
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<tr>
<td>9</td>
<td>Combination of Management Options 3, 4, 5 &amp; 6</td>
<td>96.0</td>
</tr>
</tbody>
</table>
### Upper Pecos River (7/23/2008)

[Above FM 1053 upstream to Below Hwy US 80 nr. Pecos, TX]

<table>
<thead>
<tr>
<th>DO (mgO2/L) Min</th>
<th>DO (mgO2/L) Max</th>
<th>DO sat</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>12</td>
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</tr>
<tr>
<td>4</td>
<td>10</td>
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<td>12</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

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![Graph showing water quality data for Upper Pecos River on 7/23/2008](#)
Option 8
(Example DO Exceedance Curve)
Conclusions

• Challenges will be faced to restore DO in the Upper Pecos River.
• No single management option will likely bring about restoration.
• Finding viable management options is another serious constraint.
Thank You

Questions??

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